

https://dspace.org/

Skills development and employment creation through small public buildings in South Africa

Fitchett, Anne Susan

2009-09-09T08:09:18Z
http://hdl.handle.net/10539/7217

Downloaded from a DSpace repository. https://dspace.org/

SKILLS DEVELOPMENT AND EMPLOYMENT CREATION THROUGH SMALL PUBLIC BUILDINGS IN SOUTH AFRICA

Anne Susan Fitchett

A thesis submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfillment of the requirements for the degree of Doctor of Philosophy.

March 2009

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the Degree of Doctor of Philosophy to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

……..

……. day of …… year …….

ABSTRACT

Poverty and unemployment are extremely high in South Africa, especially in rural areas where there are low levels of infrastructure. The government has begun to address this in the field of civil engineering; however this has not extended into the field of building, which is assumed to be inherently employment-intensive.

This thesis challenges the perception that expenditure on building will automatically generate substantial employment. Because labour ratios are not known, targets are merely guesswork. The research question is therefore posed:

> What are the parameters within which a significant increase in employment can be generated through the design and construction of small public buildings?

The focus is on small public buildings because government should serve as exemplar to the private sector; absorb the risk of innovation; is instigator and end user of public buildings; and can adopt a programme approach. Training, small business development and environmental best practice can be integrated. Schools are specifically considered, as they require skills that participants can use in subsequent projects.

Employment-intensive principles are derived from civil engineering. Examples of schools that use different methods and materials are analysed to answer the question: ‘How labour-intensive is building?’ This shows the range of labour-intensity of different activities and defines the components that would lead to a significant increase in employment.

The structural-spatial envelope of the building is the subject of a technical study of thin shell vaults of stabilized earth tiles manufactured on site to achieve a high proportion of the project cost within the target community without compromising cost or performance.

Supply Chain management is explored as a way of ensuring productivity where low levels of formal skills and education prevail. This is proposed for nurturing small contractors, manufacturers and suppliers, themselves creators of jobs for the less skilled.

The most significant conclusion is that there is considerable potential for building to create employment, providing it is based on comprehensive data relating to all activities. The proposed framework for the integration of management; design, detailing and specification; construction and manufacturing processes forms the basis for future research to broaden the field of application.

ACKNOWLEDGEMENTS

My thanks go firstly to my supervisor, Professor Robert McCutcheon, who has unstintingly shared his knowledge and insights throughout the duration of this thesis.

Professor Mitchell Gohnert, Head of the School of Civil and Environmental Engineering has provided extensive logistical support, a wealth of knowledge on vault building, and recently has appointed me to his staff. The entire staff of his School has shown generosity and interest in my work, but special mention must go to Mr Norman Alexander for teaching me the principles and techniques of soil testing. Four final year Civil Engineering students played a significant role in the technical studies: Effort Mokoena and Ntsako Malepfane set up the computer aided finite element model, while Adil Saloojee and Shaahid Hansa investigated new possibilities with soil stabilization to produce improved tiles.

Wim van Steenderen assisted with soil evaluation and foundation design for the pilot structure, built with kind permission of Dr Maureen Coetzee, Dr Richard Hunt and their daughter, Tamsin. Their support is testament to their dedication to research, even where this extends far from their own discipline.

Students from the School of Architecture and Planning helped with the building of this structure, as well as a demonstration timbrel vaulted structure, with Franz Prinsloo deserving special mention. He was also involved with the construction of the Visitors Centre at Mapungubwe, a project by Peter Rich Architects that has allowed me to test out the manufacture and application of tiled vault construction. Peter Rich has served as inspiration (dating back to 1978), with his rare talent for drawing together the finest minds to achieve important social objectives. In relation to this thesis, he has brought me in contact with Dr Michael Ramage from Cambridge, UK, John Ochsendorf and Matthew Hodge of MIT, James Bellamy as specialist contractor for the Mapungubwe project. Heinrich Kammeŷer has shared his lifelong interest in traditional methods of construction.

Christos Daskalakos provided the information about the Alexandra Far East project; the staff of the Limpopo Public Works, in particular Faisal Goode, gave access to drawings and costing information on their school projects; the staff of Everite and Vela Construction assisted with information on the Lightweight Steel Frame system. Filip Taylor Parkins and the staff of LITE included me in their team for the additions to their offices, accommodation and training school at Mohlaletse in Limpopo Province and gave me access to the extensive costing information and management processes used for these buildings.

Lastly, I would like to thank my daughters, Jen and Meg, for their encouragement, complete dedication and selflessness.

CONTENTS

DECLARATION ii
ABSTRACT iii
ACKNOWLEDGEMENTS v
LIST OF FIGURES x
LIST OF TABLES xiii
LIST OF ACRONYMS xv
1 INTRODUCTION 1
1.1 BACKGROUND 1
1.1.1 Unemployment and Poverty 1
1.2 RESEARCH QUESTION 2
1.2.1 Hypothesis 3
1.2.2 Objectives 3
1.2.3 Inclusions and Exclusions 4
1.3 PUBLIC BUILDING PROGRAMMES 5
1.3.1 Government Policy 5
1.3.2 The Need for Public Facilities 6
1.3.3 Public Building as the Initiator 7
1.3.4 Public Buildings in Rural Areas 9
1.3.5 Optimizing Rural Resources 11
1.4 CONSTRUCTION AND EMPLOYMENT 12
1.4.1 The Current State of the Construction Industry 14
1.4.2 Training for Employment-Intensive Construction 15
1.4.3 Skills and Productivity 17
1.5 DESIGN FOR EMPLOYMENT-INTENSIVE CONSTRUCTION 18
1.5.1 Vaulted Earth Roofs 19
1.6 FORMAT OF THIS STUDY 20
2 FOCUS OF THE STUDY 23
2.1 MOVING AWAY FROM MASS HOUSING 24
2.1.1 Meaningful Jobs 25
2.1.2 Innovation and Risk 26
2.1.3 Decline in Construction Skills 26
2.1.4 Government as Exemplar 27
2.2 IS BUILDING ALWAYS EMPLOYMENT-INTENSIVE? 29
2.3 RE-ENGINEERING CONSTRUCTION 31
2.3.1 Credibility of the Construction Industry 32
2.3.2 Three steps towards re-engineering 33
2.4 CONCLUSIONS 34
3 LITERATURE REVIEW 36
3.1 INTRODUCTION 36
3.1.1 Poverty and unemployment 38
3.1.2 Productivity and skills for sustainable employment 41
3.1.3 The South African context 46
3.1.4 Characteristics of the construction sector 53
3.1.5 Construction and development 56
3.2 CONSTRUCTION MATERIALS 66

3.2.1 International literature....67
3.2.2 Decentralized manufacture....70
3.2.3 South African adaptation and innovation in materials....72
3.3 LOW-COST HOUSING....74
3.3.1 Self-help housing....75
3.3.2 The Cuban 'brigades'....76
3.3.3 Hassan Fathy and his followers....77
3.3.4 Low-cost housing as employment generator....79
3.3.5 Public building as precursor to housing....79
3.4 'LABOUR-INTENSIVE' CIVIL CONSTRUCTION....80
3.5 NEW DIRECTIONS....86
3.5.1 Innovative public buildings....86
3.5.2 Innovative structural systems....87
3.5.3 New approaches to management....91
3.6 CONCLUSIONS....95
4 PRINCIPLES OF EMPLOYMENT-INTENSIVE CONSTRUCTION....99
4.1 OVERVIEW....99
4.1.1 Definition....99
4.1.2 Background....101
4.2 PRINCIPLES....104
4.3 METHODS FOR EMPLOYMENT-INTENSIVE CONSTRUCTION....105
4.3.1 Materials and specification....105
4.3.2 Choice of Technique Analysis....110
4.3.3 Task-based organization and team balancing....112
4.4 ACHIEVEMENTS IN ROAD BUILDING....114
4.4.1 A new organizational structure: The Kenyan Programme....115
4.4.2 Botswana....119
4.4.3 Lesotho....120
4.4.4 Malawi....121
4.4.5 High-standard roads....123
4.5 CHARACTERISTICS OF SUCCESSFUL PROGRAMMES....127
4.6 THE EXPANDED PUBLIC WORKS PROGRAMME....129
4.7 APPLICATION OF PRINCIPLES TO BUILDING....132
5 PROJECT REVIEW....135
5.1 PRELIMINARY INVESTIGATION: ALEXANDRA FAR EAST BANK137
5.2 PROTOTYPICAL SOUTH AFRICAN PRIMARY SCHOOL....142
5.2.1 Cost and Labour Analysis - DPW school....144
5.3 GIRLS SCHOOL: NEW GOURNA....148
5.3.1 The Girls' School....150
5.3.2 Cost and Labour Analysis – New Gourna....153
5.3.3 Fathy's approach to training....154
5.4 LITE OFFICES AND STAFF ACCOMMODATION....156
5.4.1 Cost and Labour Analysis – LITE offices....158
5.5 LIGHTWEIGHT STEEL SYSTEMS BUILDING....161
5.5.1 Cost and Labour Analysis – Lightweight Steel Frame System....163

5.6 CONCLUSIONS 165
6 TECHNICAL INVESTIGATION: STABILIZED EARTH 168
6.1 OBJECTIVES OF THE TECHNICAL STUDY 169
6.1.1 Increasing the local content 172
6.1.2 Stabilized earth blocks and tiles 173
6.1.3 Public building as training facilitator 177
6.1.4 Climatic and environmental considerations 178
6.2 SMALL PUBLIC BUILDINGS 179
6.2.1 Small business development 180
6.2.2 Choice of prototype 181
6.2.3 Focus on the envelope 185
6.3 PHYSICAL MODELLING 187
6.3.1 Barrel vaulting 189
6.3.2 Timbrel Vaulting 194
6.3.3 Groin vaulting: Historical examples 198
6.4 CATENARY GROIN VAULT 201
6.4.1 Technical evaluation: physical model 204
6.4.2 Technical evaluation: computer model 210
6.4.3 Classical analysis 215
6.4.4 Employment Calculations 220
6.5 CONCLUSION 221
7 THE MODEL 224
7.1 OVERVIEW 224
7.2 PROGRAMME INCEPTION 226
7.2.1 Programme objectives 229
7.2.2 Research and Development 230
7.2.3 Management structure 232
7.2.4 Initiating the training programme 236
7.3 THE PILOT PROJECT 242
7.3.1 The Supply Chain model 243
7.3.2 Evaluation of Resources 255
7.3.3 Materials and component manufacture 257
7.3.4 Design and specification 257
7.4 SITE IMPLEMENTATION 262
7.4.1 Design as process 262
7.4.2 Integration of manufacture and construction 263
7.4.3 Site management for efficiency and productivity 263
7.4.4 The site supervisor 263
7.4.5 Quality management 264
7.5 CLOSE-OUT OF EACH BUILDING CONTRACT 265
7.6 GEOGRAPHICAL EXPANSION 266
7.7 EXPANSION TO OTHER BUILDING TYPES 268
7.8 DECISION TREE FOR EMPLOYMENT-INTENSIVE CONSTRUCTION 269
7.8.1 Reverse Substitution 270
7.8.2 Material Substitution 270

7.8.3 Adaptation of Conventional Materials and Methods 271
7.8.4 New Materials....272
7.8.5 Re-engineering Design and Construction....272
8 CONCLUSIONS AND RECOMMENDATIONS....275
8.1 REVISITING THE RESEARCH QUESTION 277
8.1.1 A Programme Approach....278
8.1.2 An Integrated Training Programme 279
8.1.3 Materials and Components....280
8.1.4 Design and Detailing 281
8.1.5 Exemplary Management....282
8.1.6 An Ethos of Continual Improvement....283
8.2 THE OBJECTIVES....284
8.3 AREAS FOR FUTURE RESEARCH....286
8.3.1 New materials....287
8.3.2 Services....288
8.3.3 Training 289
8.4 CONCLUSIONS....290
9 REFERENCES....294
APPENDIX 1: TRAINING....314
A1.1 OVERVIEW OF SKILLS TRAINING IN THE BUILDING INDUSTRY ..314
A1.2 TRADITIONAL METHODS OF TRAINING 320
A1.2.1 The apprenticeship system....321
A1.2.2 Advantages of apprenticeship 322
A1.2.3 The collapse of the apprenticeship system....323
A1.3 SOUTH AFRICA UNDER APARTHEID 325
A1.4 POST-APARTHEID SOUTH AFRICA....328
A1.5 THE MODEL AS A VEHICLE FOR TRAINING....332
A1.5.1 Artisan training 333
A1.5.2 Management training....337
APPENDIX 2: STABILIZED EARTH TILE MANUFACTURE....339
A2.1 STRATEGIC MANAGEMENT 339
A2.2 SUPERVISOR TASKS 340
A2.3 TILE-MAKER TASKS 342
A2.4 THE ASSISTANT 342
A2.6 CONCLUSIONS 343
APPENDIX 3: DETAILED COST ANALYSIS OF CASE STUDIES344
A3.1 DPW SCHOOL DETAILED COST BREAKDOWN 344
A3.2 NEW GOURNA SCHOOL DETAILED COST BREAKDOWN 348
A3.3 LITE HOUSE DETAILED COST BREAKDOWN 354
A3.4 LIGHTWEIGHT STEEL SYSTEM DETAILED COST BREAKDOWN..360

LIST OF FIGURES

FIg 1-1: Location of Highveld, South Africa (www.routes.co.za)……...4

Fig 4-1: Organizational structure for employment-intensive construction (McCutcheon and Marshall 1998: 95)…….117

Fig 4-2: Ratio of direct costs to overheads in the Kenyan Rural Access Roads Programme…..118

Fig 4-3: GoM/EU PWP Organizational Structure (Courtesy: Africon 2005)……122

Fig 4-4: GoM/EU PWP Cost ratio for road rehabilitation (Courtesy: Africon 2005)……122

Fig 5-1: Alexandra Far East Bank House Type B (Michael Hart Christos Daskalakos Architects, 2002)……..139

Fig 5-2: Typical block of four classrooms – Department of Public Works……...144

Fig 5-3: Assumed configuration of typical toilet block……144

Fig 5-4: Boys' school and house courtyard, New Gourna (Aga Khan Trust for Culture)…….…..148

Fig 5-5: Brickmaking at New Gourna (Aga Khan Trust for Culture)……..149

Fig 5-6: Plan of Girls School, New Gourna (Fathy 1973)……...151

Fig 5-7: Section through Girls School, New Gourna. (Egypt Architecture online)..……...152

Fig 5-8: Courtyard of Girls School, New Gourna. (Egypt Architecture online)…..…….152

Fig 5-9: Market, New Gourna (Aga Khan Trust for Culture)……..152

Fig 5-10: Ablutions, New Gourna (Aga Khan Trust for Culture)……152

Fig 5-11: School at Fares (Aga Khan Trust for Culture)……153

Fig 5-12: School at Fares (Aga Khan Trust for Culture)……153

Fig 5-13: LITE offices……158

Fig 5-14: LWSF design on CAD/CAM (Group5 2007)……162

Fig 5-15: LWSF profiling machine (Group5 2007)……..162

Fig 5-16: Completed framework (Group5 2007)……..163

Fig 5-17: Flexible conduit (Group5 2007)……..163

Fig 5-18: Interior (Group5 2007)……163

Fig 5-19: Completed building (Group5 2007)……...163

Fig 6-1: Hydraform diesel block press and standard profiled block (www.hydraform.com).....174

Fig 6-2: Hand press by Hydraform (www.hydraform.com).....175

Fig 6-3: Work cycle for two teams of tile makers……175

Fig 6-4: Process of construction for skills development……180

Fig 6-5: Prototype for Sekhukhuneland……182

Fig 6-6: Prototype for Northern Limpopo……182

Fig 6-7: Ndebele homestead (http://www.primaleyecreations.com/)……183

Fig 6-8: Venda homestead (Frescura)……183

Fig 6-9: Model of groin vault, scale 1:10……188

Fig 6-10: Pilot structure, Stables at Hunts End……190

Fig 6-11: Model of barrel vault, scale 1:20……191

Fig 6-12: Buttress collapse, Hunts End……193

Fig 6-13: Thermal expansion in a timbrel vault (M Ramage)……196

Fig 6-14: Boston Public Library (http://www.cslib.org/) and Guastavino Club, Boston (uweb.ucsb.edu/)……196

Fig 6-15: Timbrel vault, scale 1:4……196

Fig 6-16: Pines Calyx Ecological Centre, UK (architecture.mit.edu and www.arct.cam.ac.uk)……197

Fig 6-17: Mapungubwe World Heritage Site Visitors Centre (Lerotholi Rich Architects)……197

Fig 6-18: Gothic vaulting (Mark 1993:161)……199

Fig 6-19: Thrust-Network Analysis of groin vault (Block and Ochsendorf 2008) ……200

Fig 6-20: 1:20 Models of groin vaults……202

Fig 6-21: 1:10 Catenary groin vault under construction……205

Fig 6-22: Catenary groin vault loading method……206

Fig 6-23: Buckling of catenary groin vault……206

Fig 6-24: Damage and repair to edge of vault……207

Fig 6-25: Catenary groin vault - first sequence of testing……208

Fig 6-26: Video stills at 212 N when removing load……208

Fig 6-27: Catenary groin vault - final sequence of testing……210

Fig 6-28: Position of concentrated and wind load (Mokoena and Malepfane 2007:23 & 73)……211

Fig 6-29: Contour plot of Von Mises stress invariant for distributed dead and live loads (Mokoena and Malepfane 2007:32)……212

Fig 6-30: Diagram of square-plan groined vault (Billington 1965:266)……215

Fig 7-1: CETA Career Map (http://www.ceta.org.za/).....225

Fig 7-2: Japan Pavilion, Expo 2000, Hanover (http://www.shigerubanarchitects.com/).....260

Fig 7-3: Zulu beehive dwelling (Coetzee 1982:27).....260

Fig A1-1: Rural Access Roads Programme, Kenya. (RT McCutcheon)……318

Fig A1-2: Quarry, Rural Access Roads Programme, Kenya. (RT McCutcheon)……318

Fig A1-3: CETA Career Map. (CETA 2004)……329

Fig A1-4: Road Camp/primary school showing sequencing for different skills levels……...335

Fig A2-1: Reduced productivity through excessive number of workers (F Prinsloo)……...341

Fig A2-2: Optimal cycle for tile manufacture……341

Fig A3-1: Raft foundation dimensions, Lightweight Steel System school……360

LIST OF TABLES

Table 1-1: Trends towards casualization of employment. (StatsSA 2002; interpretation of data: H Quainoo 2003)……13

Table 1-2: Climate chart - Polokwane, Limpopo Province, South Africa (Climate-Charts.com)…19

Table 4-1: National Economic Forum estimates (1994) of potential for spending on targeted labour as a percentage of direct construction costs. (Adapted by Phillips 1995; cited in McCutcheon and Taylor Parkins 2003:76)……101

Table 4-2: Field implementation of waterbound macadam (McCutcheon and Taylor Parkins 2003:67)……107

Table 4-3: Soweto Small Contractor Programme (Mkhize 1994:88-89)……126

Table 5-1: Ratio of trade to project cost, Alexandra Far East Bank……139

Table 5-2: Labour as percentage of trade, Alexandra Far East Bank……140

Table 5-3: Cost ratios of labour, materials and plant/overheads by trade, Alexandra……141

Table 5-4: Limpopo DPW School - Bill of Quantities summary (DPW 2003)……145

Table 5-5: Human resources – Department of Public Works school (DPW 2003)……146

Table 5-6: Breakdown of costs by trade, Department of Public Works school……147

Table 5-7: Ratio of materials and labour to trade price, DPW School……147

Table 5-8: Cost summary, New Gourna……153

Table 5-9: Training programme, New Gourna. (Fathy 1973)……156

Table 5-10: Cost analysis with unadjusted labour rate, LITE offices……159

Table 5-11: Adjusted wage rates and labour cost for brick-making, LITE offices……159

Table 5-12: Labour days by grade, per activity, LITE offices……160

Table 5-13: Cost analysis using adjusted labour rates, LITE offices……161

Table 5-14: Lightweight Steel System cost breakdown by activity……164

Table 5-15: Lightweight Steel System, Labour and activities as percentages of direct construction costs……165

Table 5-16: Summary of labour ratios……165

Table 6-1: Catenary groin vault - first sequence of testing and position of dial gauges……207

Table 6-2: Catenary groin vault - final sequence of testing……209

Table 6-3: Classical analysis of groin vault (Gohnert 2009)……219

Table 6-4: Cost and labour analysis for groined vault classroom block……221

Table 6-5: Summary of labour ratios including tiled vault……...…222

Table 7-1: Evaluation of labour content for different materials and method……...…274

Table A1-1: NQF Framework. (SAQA 2004:6)……..……330

Table A3-1: Bill of Quantities, trade summaries (DPW Limpopo)……..……344

Table A3-2: Materials from building supplier, VAT included (DPW Limpopo)……..……346

Table A3-3: Labour quantities and rates (DPW Limpopo)……..……...…346

Table A3-4: Materials direct from quarry/manufacturer (MBA 2003)……..……347

Table A3-5: Cost breakdown, separating general carpentry from roof carpentry……..……..…347

Table A3-6: New Gourna School quantities for masonry work……..……348

Table A3-7: Detailed labour and material cost breakdown, New Gourna School, with equivalent South African costs (2003 values)……..……353

Table A3-8: Concrete and mortar cost per m^3, LITE house (LITE 2003)……..……...…354

Table A3-9: Stabilized earth brick cost (material only), LITE house (LITE 2003)……..……..…355

Table A3-10: Material costs, LITE house (LITE 2003).....……...357

Table A3-11: Direct labour costs, LITE house (LITE 2003)……..……358

Table A3-12: Site management costs, LITE house (LITE 2003)……..……358

Table A3-13: Equipment costs, LITE house (LITE 2003)……...……359

Table A3-14: Bill of Quantities, LITE house (LITE 2003)……360

Table A3-15: Vela quotation for Lightweight Steel System school (Vela 2007)……..…361

Table A3-16: Summary Bill of Quantities, Lightweight Steel System school (2007 SA Rands)……..……..361

LIST OF ACRONYMS

Where possible, acronyms are written in full at the beginning of each section in which they are found. All organisations are South African unless otherwise specified.

ANC	African National Congress
BIFSA	Building Industries Federation of South Africa
BSRIA	Building Services Research and Information Association
CAD/CAM	Computer Aided Design and Manufacture
CETA	Construction (Sector) Education and Training Authority
COSATU	Congress of South African Trade Unions
COTA	Choice of Technique Analysis
CSIR	Council for Scientific and Industrial Research
DBSA	Development Bank of Southern Africa
DORA	Division of Revenue Act
DPW	Department of Public Works
EBT	Emulsion treated base courses
ELHUS	Excavate, Load, Haul, Unload, Spread
EPWP	Expanded Public Works Programme
GDP	Gross Domestic Product
GEAR	Growth, Employment and Redistribution
GMP	Guaranteed Maximum Price
GoM/EU	Government of Malawi and European Union
IBRD	International Bank for Reconstruction and Development
ILO	International Labour Office
ITDG	Intermediate Technology Development Group
LITE	Labour Intensive Training and Engineering
LWSF	Lightweight Steel Frame
MBSA	Master Builders South Africa (formerly BIFSA)
MIT	Massachusetts Institute of Technology
NEF	National Economic Forum
NORAD	Norwegian Agency for Development Cooperation
NPWP	National Public Works Programme
NQF	National Qualifications Framework
OJT	On-the-job training
RDP	Reconstruction and Development Programme
SAQA	South African Qualifications Authority
SETA	Sector Education and Training Authority
UNDP	United Nations Development Programme

1 INTRODUCTION

1.1 BACKGROUND

1.1.1 Unemployment and Poverty

The need to address the problem of widespread poverty is regarded as one of the most urgent challenges presently facing South Africa. The socio-economic structure of this country is one of great contrasts, with the rich being well served in relation to public facilities while the poorest experience little or no basic physical or social infrastructure. This is reflected spatially in that areas of greatest poverty coincide with the lowest provision of public services and the highest unemployment. While the debate on the most effective method of addressing poverty is acknowledged, the present study is underpinned by the argument that employment provides a sustainable method of improving livelihoods, while alleviating other social ills (Stiglitz 2002:9).

Structural unemployment is extremely high in some parts of the country,[1] significantly in rural areas where controls over land ownership through apartheid policy eroded the potential for subsistence farming (Illife1987:124). Several interrelated factors characterize the lot of the rural poor, including educational disadvantage in both quantity and quality; lack of financial and natural resources; isolation through lack of access to affordable transport; and societal imbalances as a result of colonial and apartheid policy. Poverty is entrenched through the sheer weight of numbers of unemployed in these areas.

This has shaped an important aspect of government policy since 1994, where job creation is used as one of the primary measures to address poverty (ANC 1994). Linked to this is the understanding that longer term employment objectives must be coupled with training initiatives that aim at generating marketable skills. At the

[1] Hirsch et al (2002) define structural unemployment as: “Relatively long-lasting unemployment resulting from long-term shifts in economies and markets rather than short-term savings in economic conditions.”

same time, the South African government is committed to redressing backlogs of all forms of infrastructure, a result of inequitable allocation of resources in the apartheid era. Construction can be used to link these objectives in that it offers an avenue for mass employment, both through building and civil engineering. Much of the literature on building as a means of job creation has focused on housing, especially publicly driven mass housing. However, it is argued here that the innovation needed for a fully employment-intensive approach is better implemented through the State's own buildings before being disseminated into the private sector or State funded mass housing.

The goal of this research is to develop methods of employment-intensive construction that match conventional building practice in terms of time, cost and quality, thereby making these methods financially competitive. The creation of jobs emanates from a change in focus and choice of technology that does not compromise the more conventional objectives.

1.2 RESEARCH QUESTION

The role of building construction as an employment generator has been acknowledged by the post-apartheid government, but lack of research has prevented its full-scale adoption in the provision of much needed public buildings. To date, the extent of the contribution of building construction to job creation has been assumed to be *pro rata*, where the number of jobs is considered to increase in direct proportion to the expenditure on building projects (see note 2 below).

Backlogs in the construction of new schools, clinics, hospitals, police stations and other social infrastructure are mentioned in policy documents relating to poverty reduction and employment creation initiatives (DPW 2004a), but these objectives have not been implemented with the rigour found in some sectors of civil engineering. For this reason, the following research question is posed:

What are the parameters within which a significant increase in employment can be generated through the design and construction of small public buildings?

1.2.1 Hypothesis

Because the construction of buildings by conventional methods is generally assumed to be labour-intensive, no analytical technique or body of knowledge has been developed from which to test this premise rigorously. For this reason, the potential for the building process to generate a significant increase[2] in the employment of relatively low-skilled labour has not been comprehensively explored.

This thesis proposes that, through adapting the principles of employment-intensive construction used in certain civil engineering programmes, the opportunities for job creation through building works could be more substantial. To achieve this, a change in emphasis and methodology would be required at all stages of the process, through design, specification and the management of the implementation on site. For employment to be sustainable, evidence points to the importance of technical and organisational training at all levels. Moreover, for employment-intensive methods to have credibility and meet the requirements of public accountability, they must be quantifiable, measurable and replicable.

1.2.2 Objectives

The specific objectives of this study are threefold, namely:

1. To develop an approach to building that can be used as a vehicle for skills enhancement and employment creation.

2. To create a replicable programme for skills and managerial capacity enhancement through the medium of construction.

3. To establish a framework within which to generate a body of knowledge of 'best practice' in employment-intensive, affordable building.

---

[2] McCutcheon defines 'significant' in this context as a 300 to 700 percent increase in the ratio of the direct construction cost allocated to targeted labour (McCutcheon and Taylor Parkins 2003:21).

Through pursuing these objectives towards the goal stated above, a clearer understanding of the meaning of 'employment-intensive' in the domain of building can be attained, leading to an informed programme of action. This would give far greater credibility to the inclusion of building projects into the sphere of larger employment initiatives already in operation in South Africa, and potentially in other regions.

1.2.3 Inclusions and Exclusions

The model developed in this study is intended to be directly applicable only to the Highveld region of South Africa (see Fig 1-1 and 1.5.1). However, the research leading up to its development draws from a far wider field including other regions in the world that enjoy a warm to hot climate with relatively low rainfall. The results that emerge from the study should facilitate fairly easy adaptation to other circumstances, but only broad guidelines are proposed in this regard, as each step geographically and culturally away from the study area will generally require more comprehensive research and analysis of local conditions. The general model can be adapted easily to meet climatic and social variables outside of the present geographical boundaries to allow it to be replicated in differing circumstances.

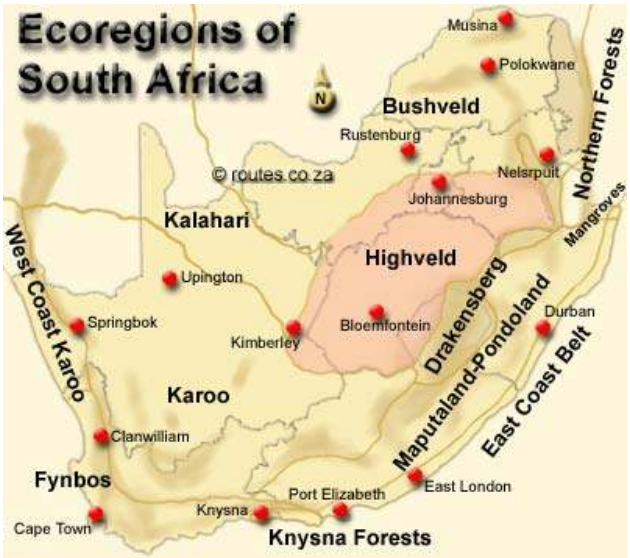


FIg 1-1: Location of Highveld, South Africa (www.routes.co.za)

Monitoring and evaluation form a fundamental component of the model. As current initiatives in social restitution, education, skills development and economic improvement mature, this model will need revision and modification to meet the needs of a society in transition.

1.3 PUBLIC BUILDING PROGRAMMES

In South Africa, the discrepancies in wealth and opportunity shift the focus of employment creation and poverty relief towards the redistribution of resources, acknowledged at the highest level of government. In the context of construction, the most direct method of achieving this objective is through retaining the majority of the project cost within a target community rather than allowing money to filter back to major manufacturers, suppliers and large-scale contracting companies. Moreover, a characteristic of the sector is in the downstream and sideways linkages of employment creation through skills development. “One job in construction gives rise to two further jobs elsewhere in the construction sector and other sectors of the economy,” (Van Wyk 2003:13).

1.3.1 Government Policy

The present democratic government in South Africa, elected in 1994, inherited a country sharply divided in wealth and opportunity. Legislation had forced the majority into rural ‘homelands’ devoid of infrastructure, public amenities and economic opportunities. One of the most important policy documents produced by the South African Government after the first democratic elections was the *Reconstruction and Development Programme* (ANC 1994), which outlined an integrated approach to restructuring an economy characterized by vast discrepancies in wealth and opportunity. The elements of relevance to the present study are:

a) Reduction of poverty through employment creation;
b) Improving employability and productivity through skills development in a new education and training framework;

c) Reducing the backlogs in infrastructure, public building and housing.[3]

The South African government has placed considerable emphasis on job creation, and has made numerous statements on the role of building in this regard, but strategies to increase the number of jobs in the building industry have had disappointing results, exacerbated by a decline in formal employment in the sector (BIFSA 2002). This can be attributed in part to the lack of data on labour in the industry, compounded by competitive tendering processes where labour is not disaggregated from item prices (Wells 1986:74). The extensive research, pilot studies and implementation of labour-intensive practices over the last 30 years in civil engineering programmes have not had a parallel in the construction of buildings. Without this information and experience, employment creation in the building field cannot be accurately determined.

1.3.2 The Need for Public Facilities

The *Reconstruction and Development Programme* (ANC 1994) makes reference to the lack of public amenities in rural and impoverished urban areas, and in the first ten years enacted several pieces of legislation to redress the backlogs in this respect. Much attention was paid to mass housing, but in the White Paper on housing, the need for fully developed facilities is acknowledged, although the provision of public buildings has invariably lagged behind these new housing developments.

This is addressed in the President's "State of the Nation" speech to parliament in 2003:

> Further improvement in the quality of the lives of our people also requires that we take new measures to increase the volume and quality of our investment in the social infrastructure. This includes such areas as housing and municipal infrastructure, hospitals and clinics, schools, roads,

[3] Three of the five major policy programmes contained in the RDP are: meeting basic needs; developing our human resources; and building the economy (ANC 1994:1.1.3).

> water, electricity and government facilities. In all these areas, we must improve our performance relative to the previous year (Mbeki 2003:11).

This speech was also the forum for the launch of the Expanded Public Works Programme, initially to provide certain designated categories of infrastructure using labour-intensive methods, but with the intention of expanding the scope to other types of construction when sufficient information was made available to ensure public accountability. It is specifically in this context that the present research is located.

1.3.3 Public Building as the Initiator

Construction offers one avenue for mass employment. Much of the discussion on building as a means of job creation has considered mass housing to be the obvious vehicle for this because of the high number of units and degree of replication. While housing may offer valid opportunities for employment generation, a few caveats must be noted, including the vulnerability of the beneficiaries to inadequate quality control, and their resistance to unfamiliar design, materials and methods (Mathéy 1992). Housing financed through the government Capital Subsidy Scheme has been substantially carried out by formal sector developers, although in many cases there have been conditions of contract requiring the use of local labour and emerging sub-contractors. A multiplicity of problems have arisen from these arrangements, resulting in the recent policy shift to the “Peoples Housing Process”, a variant on self-help provision, that undermines the creation of permanent quality jobs in construction. The tendency towards the use of informal and unregulated operatives can be expected to increase through this move to owner-build.

Government programmes for public buildings, by contrast, provide the opportunity to control design and procurement in order to meet social objectives while ensuring the provision of quality facilities. This research aims to develop methods of employment-intensive construction that match conventional building in terms of time, cost and quality, thereby making the new methods competitive.

This objective is important in ensuring the long-term viability of this approach as the socio-economic benefits do not need to be factored into the feasibility of the programme (Phillips 1994).

In comparison with many poverty relief projects, employment-intensive programmes for public building and infrastructure such as roads, sewerage systems, dams and water supply, provide necessary services in a structured mode of delivery (McCutcheon and Taylor Parkins 2003:1). This is particularly significant in South Africa, where imbalances in the provision of public facilities, brought about under apartheid, need redressing (Mbeki 2003). Experience in the use of employment-intensive delivery for infrastructure already planned and budgeted for by government (in contrast to 'make work' projects) has shown how a change in technology, if properly implemented, can give a product of equal quality, at the same cost and within the same timeframe as conventional and machine intensive methods. The same communities that suffer the most extreme unemployment are those where the backlogs of public facilities are the most severe (ANC 1994). For any employment initiative to be successful for any duration, provision of adequate roads, education facilities, water supply and sewerage reticulation are essential to support the establishment and growth of business ventures.

In the building sector, the focus has been on the building product, with labour considerations being relegated to a minor role. The predominant measure of success of a building project is the building alone, and not the means by which it is produced. By contrast, this thesis investigates the potential role of building specifically from the point of view of sustainable job creation and skills enhancement, in both the construction process and the production and supply of materials. Linked to this is the consequences of architectural decision making (design, detailing, specification and procurement) on the proportion of project value that is disbursed to the labour force at all stages, rather than to machinery or imported materials. Projects in other parts of the world that have used labour-

intensive methods in comparison with conventional practice provide important information for determining the effectiveness of employment generating initiatives.

The potential for small-scale building work to make a significant contribution to employment creation is explored through evaluation of existing design, construction and management practice to determine areas for intervention. Various levels of intervention are investigated, from simple substitution of materials through to radical reconsideration of design and specification, and rigorous evaluation of management processes.

Research and field application in civil engineering programmes for the provision of infrastructure have shown that for a programme to be fully employment-intensive, it is not enough merely to substitute labour for machines in some, or even all construction activities. The programme has to be reconsidered, from initial research and feasibility studies, through design and specification, in the determination of procurement and management structures, and through training of all participants in employment-intensive practices (McCutcheon 1998). This study proposes a model that parallels the conceptual shift that has taken place in civil engineering in order to facilitate the application of fully employment-intensive practice in building works.

1.3.4 Public Buildings in Rural Areas

In this study, the focus is on public buildings, specifically small-scale facilities built to serve the functions of government departments at a local level. Through the construction of these buildings, it is hoped that greater confidence in employment- intensive principles and methods can be nurtured, in that government will be seen to be taking the initial technical and financial risks that will be necessary. Moreover, the scale of these structures can be readily associated with domestic and commercial buildings in rural areas.

Through the construction of small public buildings, skills development can take place as a means to creating quality jobs – jobs which themselves generate employment opportunities for those who have not been exposed to vocational training. The public sector has the means to develop long-term programmes, both for training and for building works as the medium for this training, without the volatility that characterizes operations in the private sector. The need for public buildings and other forms of infrastructure in areas of poverty and high unemployment can provide a guaranteed flow of work that can be linked to on-going skills development and entrepreneur support initiatives. Moreover, the public sector is more capable of carrying the risks of innovation and low productivity in the initial stages of the kind of programme recommended by this study. Public buildings can act as exemplars in the use of employment-intensive practices, environmentally appropriate design and locally manufactured materials.

In summary, the motivation for concentrating on public facilities is manifold, namely that:

- There is an ongoing programme of construction of these building types from public money already committed to meet departmental needs;
- The buildings can demonstrate government policy objectives, and not just produce a physical product;
- Projects can be used to test new methods of construction and materials which relieves the burden of risk on individual households or private commercial ventures;
- Government departments are more capable of absorbing the cost of research, experimental design and initial training;
- Government can demonstrate its commitment to employment-intensive practices, and thereby give the private sector confidence in their application;
- A co-ordinated series of small buildings can facilitate a programme approach to training; and

- As these buildings are ‘in the public eye’ they can shape aspirations and promote innovation.

1.3.5 Optimizing Rural Resources

In decentralized areas suffering from high levels of unemployment, an important objective is to retain as much of a building project’s cost as is feasible within the target community. This requires design and specification that maximizes the use of local materials, locally manufactured components, local suppliers and transport, local energy sources, as well as local labour at all levels of expertise. Imports of any of these should be considered only when no equivalent is feasible within the project locality, or where a small quantity of imported material makes a significant difference in terms of performance.

Research into raw materials and decentralized manufacturing places a burden on an isolated project, which is another justification for using the construction of public facilities to spearhead an employment initiative. Moreover, the flow of work that can be created through the co-ordination of public works can sustain local businesses and contracting companies in areas where endemic poverty results in low demand from the private sector. In this regard, locally manufactured components should be versatile and popular enough to have a ready market in the private sector.

History has shown the advances that can be made when labour is regarded as a resource that adds value to land and materials (Clark 1992). An approach to employment-intensive construction that merely substitutes labour for machines misses out on the opportunity of creating products for which the high labour content gives additional value as is found in well crafted products. This concept is easily visualized in high cost building, especially where artworks and handcrafted components are used, but less familiar when related to more modest structures. This study seeks to investigate the versatility of small-scale manufacture as an

important element of the process of re-engineering for employment-intensive construction.

This study proposes that training programmes be decentralized, with the more formal 'classroom' components taking place close to the building sites. This would help in establishing credibility for the programme within the community, but it also facilitates the development of methods and use of materials suited to local climate, building traditions and cultural practices. This should not exclude training in methods suited to other parts of the country to allow for labour mobility and thereby more long-term job opportunities.

1.4 CONSTRUCTION AND EMPLOYMENT

The construction sector is particularly important in employment creation for several reasons, including that:

- The construction side of the sector accounted for 220 000 jobs in 2003[4] and studies suggest that directed labour-intensive methods can substantially increase employment;
- Construction of housing and infrastructure (both civil works and public facilities) forms an important element of the national development strategy which could lead to a significant increase in employment;
- By transferring assets effectively to poor households and communities, a basis for more equitable and sustainable growth can be established.

One of the factors that jeopardize large-scale employment generation in the sector is the perception expressed by the Building Industry Federation of South Africa that: "It is common knowledge that the construction industry is labour intensive…" (BIFSA 2003:12). The lack of critical analysis evident in this statement suggests that no substantial effort is being made across the sector to adopt latest principles and practice in labour-intensive methods, either in the production of materials or in the process of construction.

[4] Since the inception of the Expanded Public Works Programme, this figure grew to 468 000 by March 2008, however it is not clear how many of these workers had previously been in the informal part of the industry (MBSA 2008:16; Table 1-2; and note 5 below).

Over the past thirty years, the construction sector has shown a substantial decline in employment, significantly with regard to artisans and middle management. While the total number of jobs lost in the sector is a subject of debate because of the increasing growth of informal and unregulated operatives, the loss of quality jobs in the formal sector is undeniable (ILO 2001).

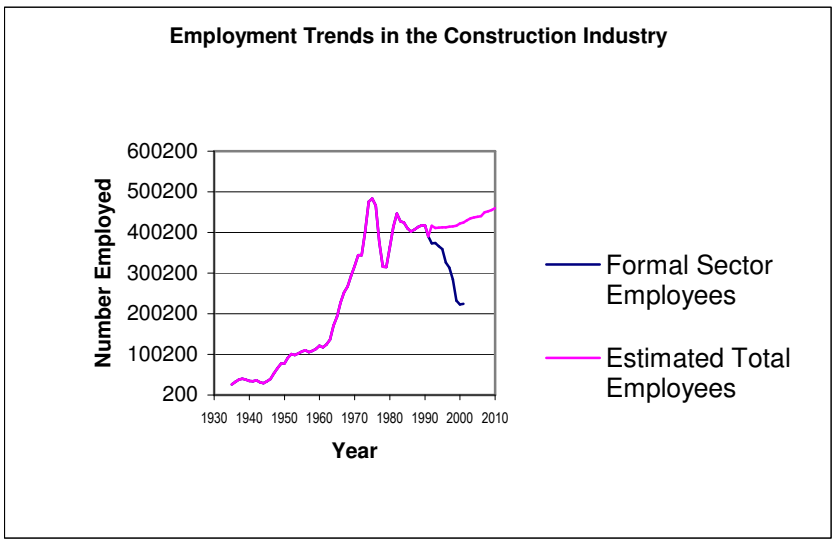


Table 1-1: Trends towards casualization of employment. (StatsSA 2002; interpretation of data: H Quainoo 2003)[5]

Factors blamed for the lack of growth of the industry in South Africa include:

- the economic slowdown after 1997;
- high interest rates after 1996;[6]
- substantial real decline in government budgets for infrastructure after 1997;
- new labour laws that some employers (contractors) claim discourage employment- intensive technologies; and

[5] While formal employment in the construction sector in South Africa dropped from 255 000 in 1990 to less than 160 000 in 2002, the 2001 census figures for those 'employed within the construction sector' were 520 486 (Van Wyk 2003:1). BIFSA (2002) anticipated that the informal sector would account for 50% of the workforce in construction by 2003. These figures highlight the difficulties in determining employment statistics where a large proportion of those actively engaged in the industry are in less formal modes of employment.

[6] One measure of this is that residential mortgages dropped from R40 billion in 1996 to R32 billion in 1998, and revived only to R38 billion by 1998 (BIFSA 2002).

- the internal structure and ownership patterns of the sector (McCutcheon et al 2004).

However, the fundamental problem in this country lies in the stratification of employment on racial lines that had been entrenched through apartheid policy and legislation (Feinstein 2005:11). Thus formal means of entry into a sector that has provided employment for less skilled people has been closed to a substantial section of the population, and has given rise to a substantial informal and unregulated component. (Table 1-1)

1.4.1 The Current State of the Construction Industry

Statistics in the building industry have shown a decline in numbers of formally employed people especially since 1999 (BIFSA 2002). While this is counteracted to some extent by the growth of an unregulated informal building sector, a number of negative elements result when a sector has less than half of its participants operating within formal frameworks. Of importance to the wider public is the lack of protection and recourse to normative mechanisms when the work of unregulated operators is defective.

There is a tendency for the informal sector of the construction industry to evade all forms of regulation, in the fear that they will be traced by other regulatory bodies and forced into compliances that are unaffordable within their precarious financial circumstances. This may include registration with trade bodies; compliance with building regulations; payment of taxes; contributions to medical, unemployment and pension schemes; and in South Africa, payment of a skills levy (Fitchett 2001: 20-21; 70).

Significant to this study is the lack of involvement by the informal sub-sector in supporting training of their employees in trade skills and managerial expertise. These two factors alone lead to bad health and safety records, low productivity and inadequate workmanship, thereby eroding the image of building industry as a sector offering high quality career opportunities (ILO 2001).

1.4.2 Training for Employment-Intensive Construction

The experience of successful programmes of employment-intensive construction in civil engineering works has shown the necessity of integrating comprehensive training programmes. Where labour is the primary mode of delivery, training is the method by which quality and productivity are ensured. Design, specification and materials manufacture all need to be considered in relation to how training is facilitated. In the conventional building process, many of the most complex and intellectually demanding activities take place at the beginning of the project, such as measuring and ordering materials, surveying the site and setting out the buildings. Often the more challenging components of an activity precede the simpler, for example, taking up brick corners before filling in the straight walling. If a building design were to be programmed entirely by the sequence of tasks demanded by the training programme it would not be feasible, which is one of the reasons for the proposed model's use of an ongoing programme[7] of buildings as a vehicle for teaching. However, even within a single building project, greater awareness of the skills scenario with a re-structuring of activities that progress from simple to demanding would aid the teaching of technical and managerial skills.

This thesis argues that a more sustainable route to employment creation lies in focusing on the development of higher technical and managerial skills in the building industry. Several interrelated benefits emerge from this strategy, namely:

- People who have been through an artisan training programme will have skills which are more marketable, and thereby more sustainable;
- Skilled workers generate jobs for less skilled people – for every artisan or manager, several unskilled and semi-skilled workers are required to form an efficient team;
- Higher productivity and workmanship give greater credibility to the industry

[7] This is in contrast to the piecemeal approach where each individual building or localized project is considered in isolation. This is another persuasive reason for using small public buildings as the catalyst for employment-intensive practice, where the Department of Public Works can drive the process and insist on the programme objectives and methods.

and reduce maintenance, thereby improving the lifecycle value of the building;

- Greater skill allows for flexibility in the choice of detailing and specification thereby permitting higher labour content in these areas;
- Development of small contractors and specialised artisan companies is facilitated as one strand that emerges from the skills programme.

Evidence from labour-intensive construction in the civil engineering sector has shown that only where there has been a consistent approach to job creation in a long-term programme environment has there been any evidence of substantial new employment or skills development. Fundamental to the success of programmes such as the Rural Access Roads Programme in Kenya, is a well structured skills training framework which moves from the lowest skills levels through the creation of technical capacity to supervisory, management and professional competence. Theoretical work and field experience in this sector provide valuable insights into the dynamics of employment-intensive construction that meets all the targets of conventional contracts in terms of scope, cost, time and quality.

The South African government's commitment to innovation in education, with its attendant appreciation of how this relates to long-term employability of its citizens, gives this study particular significance. Its timing is important in feeding the results of research into education initiatives through highlighting successful practice in vocational training, and identifying problems and misconceptions both locally and internationally. This aspect of the research is covered in detail in Appendix 1, in which training for construction is considered in the global context as well as in relation to the unique situation of South Africa, where apartheid policies undermined the natural growth of artisan skills. In this section, new South African education and training initiatives are analysed, leading to a proposed integration with the employment strategies that emanate from the present study, especially with regard to the significance of productivity in employment-intensive construction.

1.4.3 Skills and Productivity

Of all the problems facing the building industry, the one most central to the present study is the lack of skills development, a phenomenon identified in an International Labour Office report (ILO 2001) as being of global concern. This applies to all levels of the industry, for example, where traditional artisan skills have been eroded as a result of the shift to mechanisation. The trend towards 'flexible' labour arrangements, including direct 'labour only' contracts and sub-contracting exacerbates the lack of formal skills development. Casual workers are generally employed only when required for production: their employers have little incentive to train them, given the flexibility of the labour relationship, and the workers themselves have survival as their priority when they are not actively engaged in building.

In contrast with large-scale civil engineering projects that are characterised by a substantial amount of repetitive work, building requires considerable diversity within each trade, and the integration of activities is complex. Training programmes presently being implemented in South Africa tend to be of short duration, whether as a component of a building programme or in the upliftment of a community or target group. The result is often a saturation of low level skills in any geographic area, thereby being neither sustainable in themselves nor leading to future entrepreneurial opportunities, employment possibilities, or the generation of work for less skilled people not involved in the training process.

In projects where emerging small contractors have been targeted, managerial and business skills training have been used to assist participants in the preparation of tenders and day-to-day running of site works. Frequently, these contractors have no previous experience in construction, and rely on their employees to supply the necessary trade skills. The traditional transition from artisan to foreman and then to construction manager is evaluated in the present study along with innovative approaches to skills programmes as discussed in Chapter 5 in relation to the work of Hassan Fathy.

The cyclic and volatile character of the construction industry, experienced internationally, creates vulnerability for all workers in the sector, but especially for those whose training is in a narrowly defined skills band. Building is inherently diverse, especially at the level of artisan, where knowledge and experience in any one trade can be adapted to another with the addition of a modest range of new techniques, thus facilitating job diversification. The experience of well structured training programmes linked to labour-intensive road building has proved the value of a long term commitment to skills development in which individuals can progress to higher levels of technical and managerial expertise within the system (Mkhize 1994).

1.5 DESIGN FOR EMPLOYMENT-INTENSIVE CONSTRUCTION

Designers such as Hassan Fathy in Egypt (Fathy 1976) and Eladio Dieste in Uruguay (Pedreschi 2000) share a number of objectives that relate to employment creation, especially for workers with low skills levels at the outset of the building work. These include:

- facilitation of a training programme, at least to artisan or site management level;
- promotion of employment-intensive materials manufacture and construction methods;
- high quality architectural and engineering design;
- environmental responsiveness and responsibility; and
- nurturing of social and cultural values, with a respect for the recipients' aspirations.

In designing for the most effective use of labour, Fathy and Dieste have shown the advantages of using small components, exploiting the versatility that results from this choice to create buildings of exceptional quality. Both of these designers have acknowledged the importance of the integration of product and process during both the design and construction phases. Fathy, in particular, writes extensively on the importance of training, and adapting the building design to the capacity of the workforce. In contrast to many of the buildings that purport

to have had job creation as an objective, Fathy's work has received one of the highest architectural accolades, the Aga Khan Award (Steele 1989), thereby being an important precedent for the present research.

1.5.1 Vaulted Earth Roofs

The emphasis on local resources and climatic responsiveness means that each area in which building takes place will have specific parameters. However, within the geographical area of this study, certain generalizations can be made with respect to both raw materials and to macro-climatic conditions. The South African Highveld experiences seasonal summer rainfall, with high daytime temperatures and fairly high diurnal variation.[8] (Table 1-2)

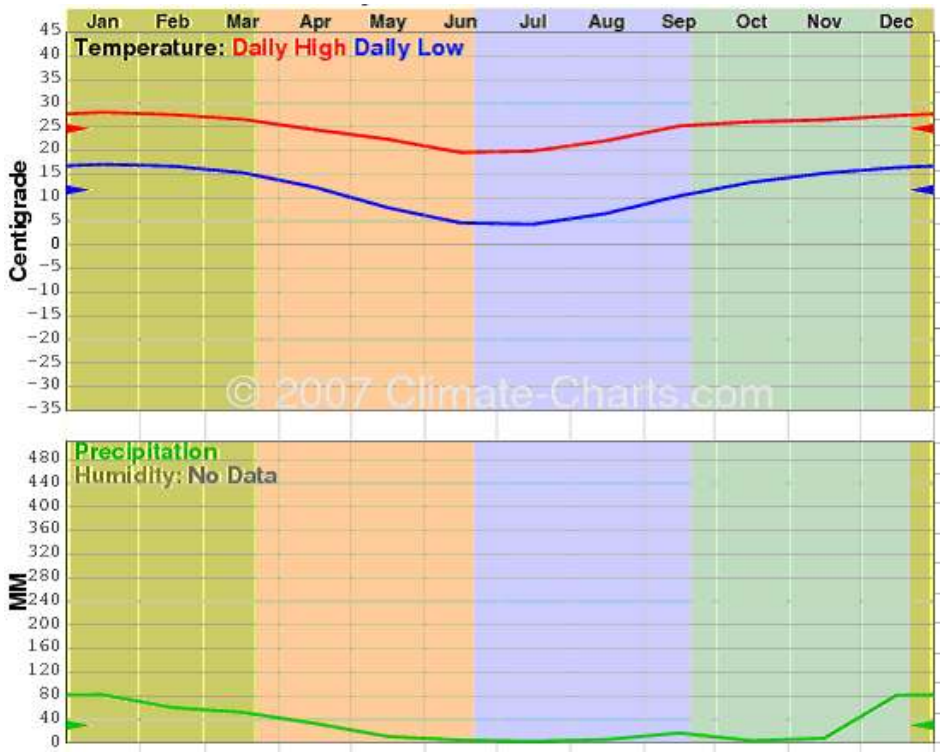


Table 1-2: Climate chart - Polokwane, Limpopo Province, South Africa (Climate-Charts.com)

Pioneering work by Koenigsberger et al (1974) shows that the use of materials with high thermal capacity, such as stabilized earth, is one of the most cost-effective solutions in this climate. It can be assumed that suitable building soil

[8] The northern and western zones of this region tends to have higher temperatures and lower rainfall than average for the Highveld as a whole (Richards 1952).

would be available relatively close to each building site, although research and testing would have to be carried out at each location for optimising raw materials.

Various methods of building with stabilised earth are investigated here, which are the subject of ongoing research in the Department of Civil Engineering, University of the Witwatersrand. Significant to the adoption of a particular method of manufacture and format of the masonry elements is the method of building and structural type chosen. Physical modelling has been the primary method of research, using various techniques to simulate the structural forms, and to give insight into the buildability of different methods.

This area of research should be seen primarily as a demonstration of the kind of processes that need to be undertaken to work towards a fully employment-intensive method of building rather than a definitive solution. For the purpose of presenting a complete building for analysis, assumptions have been made about other materials and components, the validity of which should be the subject of future research.

1.6 FORMAT OF THIS STUDY

Following this introductory chapter, the research question and hypotheses that underpin it are expanded in Chapter 2, where the focus of the study is outlined and discussed.

A review of the literature pertaining to employment-intensive construction is presented in Chapter 3. The magnitude of publication on the broad topic has indicated concentrating on three areas of greatest significance to this study, namely; theory and practice of employment-intensive construction in civil engineering infrastructure; local and on-site materials manufacture by small businesses; and architectural design and specification for employment generation. Other avenues of enquiry in this study, such as training methods, are generally integrated in the literature falling under the above three categories. The

extensive literature on employment-intensive construction of civil engineering works provides the basis for development and evaluation of the present study. Much of this writing is in the form of unpublished research, project reports and manuals that are analysed and reviewed in Chapter 4, from which principles for employment-intensive construction are drawn.

Of central importance to the objectives of this thesis is the analysis of conventional and employment-intensive public building projects. This is necessary to gain an understanding of the extent to which building is a generator of jobs, and the degree to which labour content may be productively increased. As far as the available information permits, the project review in Chapter 5 analyses each work holistically in terms of: design: specification of building techniques and materials; project costs and wage ratios; and skills development. The review concentrates on rural schools, as a building type from which an understanding of the implications for other small public buildings can be relatively easily extrapolated. The choice of a single functional type for review facilitates comparison between different levels of employment-intensiveness for each of the parameters analysed. The presentation of material from this chapter is intended to become part of a wider study presently being undertaken which facilitates decision making for a wide range of publicly funded initiatives where employment-intensive construction is contemplated.

The methods and results of the technical studies into stabilised earth vaulting are presented in Chapter 6 as demonstration of the research that would be required for innovation in design, specification and the use of local materials. The choice of earth-brick roofs is prompted by the expense and scarcity of other resources in the study area, as well as an analysis of the wage ratios of metal roofing typically used in small buildings. Sophisticated engineering principles form the background to the investigation of the structural characteristics of the roof forms.

The investigations in the previous chapters are synthesized in Chapter 7 through the development of a model that integrates management, design, specification,

materials and component manufacture, and a training programme. Results of analysis and evaluation of this model are presented in this chapter, with recommendations on how the model may be developed in future.
The research question and the objectives of this study are revisited in the conclusions in Chapter 8, followed by proposals for further research. References to works consulted, projects investigated and internet site details complete the main body of the study.

Appendix 1 presents the recently developed South African approach to education and training in terms of its appropriateness as a vehicle for skills development in an employment-intensive construction environment. This is compared with successful training programmes for construction of rural roads and for urban infrastructure upgrading. It provides the background to the discussion on training throughout the body of the thesis. A method study for the employment-intensive production of stabilized earth tiles is given in Appendix 2, as an example of the site management processes that need to be considered to maximize productivity and ensure quality. Appendix 3 provides detailed data from which cost ratios have been derived in the Project Review (Chapter 5).

2 FOCUS OF THE STUDY

In section 1.3.4 of the Introduction, a number of reasons were given for the public sector taking the lead in employment-intensive building, and specifically through public facilities. In this way, it is anticipated that employment-intensive principles and practices in building construction can be established that can emulate those developed for civil engineering infrastructure. The methodology proposed here can be expanded into other types of building such as government subsidised housing and structures in the private sector, both domestic and commercial.

At the outset, it must be stressed that the focus is not on housing, for reasons enumerated below, despite the apparent connection to employment in many people's minds. In brief, employment-intensive construction of housing should *follow* the lead provided by government through its own buildings. The State should be taking the risk of innovation, the cost of initial training and re-engineering of the industry. These initial costs firstly can be offset against the social benefits of the employment created and the strengthening of a strategic industry. Secondly, the government has the capacity to use a long-term programme approach, in which these preliminary overheads can be amortized over the life of the programme. As can be appreciated, these are considerable burdens on even a large housing project, except where delivery is through highly paternalistic 'State owned and State delivered' housing schemes, which have been discredited globally. (Turner 1972; Mathéy 1992)

Therefore, if government is to take the initiative in developing an employment-intensive approach to the construction of its own buildings, it needs certain guarantees to ensure public accountability. In civil engineering works that have a primary objective of job creation, it has been shown that a body of knowledge has had to be developed, encompassing materials and techniques, management systems and training methods. These are founded on two branches of understanding, data on conventional methods and research into innovative ones, to allow for accurate comparison between conventional construction and

employment-intensive in terms of cost, time and quality. The cost of the social benefit of the created employment can only be established when this relationship has been determined. This thesis contends that employment-intensive methods can match conventional construction on all the parameters of time, cost and quality, providing that certain decisions and guidelines are followed from the inception and that a long-term programme approach is followed.

The focus of this study is therefore on determining the labour content of a range of small buildings to provide base-line data. From this, alternatives are investigated, leading to a set of recommendations that can be used by government to instigate and manage a long-term programme of employment-intensive construction. This then has the potential for revitalizing the industry, through technical and managerial training and through the establishment of small contracting, manufacturing and supply businesses as the basis for long-term employment creation.

2.1 MOVING AWAY FROM MASS HOUSING

Much of the literature on employment creation through building dwells exclusively on mass housing for the poor. While the provision of housing is of indisputable concern in the developing world, it is a contested field, clouded by the competing objectives of providing sufficient housing stock of adequate quality within the limited budgets allocated by governments of the developing world. At the one extreme 'complete' houses are constructed in response to basic rights to hygiene, safety and privacy, but in most instances these are not affordable for lower income households, resulting in 'downward raiding'.[9] At the other end of the scale, self-help and core-house approaches are used, but these are justifiably criticised for materials and construction inefficiency, degradation of habitat, and placing unreasonable burdens on the poor (Fitchett 2001:12 and 51).

[9] Downward raiding is a term used to describe the phenomenon that arises when target households cannot afford the rental, lease repayment or service levies on their property, forcing them to give up their house to a higher income family and return to lower grade accommodation such as slums or squatter dwellings (Bond and Tait 1997).

The so-called ‘employment’ generated through self-help and community built housing is questioned here. Apart from the lack of quality, productivity and efficiency that characterises this mode of construction, the work is seldom done at market rates of pay, and there are few opportunities for continuing the employment after the project is completed.

The two objectives of space and cost have been given far greater emphasis than employment creation. Because of the extensive analysis of housing in the Third World, evidence has been used from this sector, but the primary focus is on the broader building environment, and specifically those structures built for service components of government: schools, clinics, police stations and the like.

The preconception of housing as an employment generator has allowed other government departments that commission buildings to sidestep the issue. In South Africa, the Department of Housing policy documents acknowledge society’s expectations in relation to creating jobs, and it has responded to this part of its mandate in various ways, ranging from contractual provisions in formal sector delivery to self-help housing modes.

2.1.1 Meaningful Jobs

Aside from these international debates around modes of mass housing provision, several other factors have determined the focus of this study away from public housing. Of central importance is that very few of the so-called jobs created through housing provision are sustained beyond the duration of the project in any one community; thus there is not enough time to develop marketable skills, resulting in a saturation of low level abilities in any one area. This has particular significance in very poor rural communities where the cost of transport inhibits the phenomenon of the ‘jobbing artisan’ found in cities. Moreover, in self-help projects, no wages are paid – employment is in the form of ‘sweat equity’ at best, where one person’s specialization is traded for that of another in the community. While the validity of this approach can be debated in general, it is untenable in

communities that suffer extremely high levels of unemployment, in a society where some form of cash income is a necessity.

2.1.2 Innovation and Risk

Low-cost housing in South Africa has tended towards miniaturized versions of middle-class dwellings, prompted in part by designers' perceptions of the expectations of the end users. Where there has been innovation in materials and methods, these have been constrained by attempts to replicate this standardized image of brick walling with pitched roof. While this may be an accurate assessment of user aspirations, justified by its appearance amongst the wealthier in rural areas, one has to question whether this is through lack of awareness of alternatives. Linked to this is the inability of poorer households to absorb the risk of innovation, even when this would lead to lower cost of construction, better climatic performance and lower costs of services and maintenance. This thesis argues that public bodies need to take on the real risks of innovation in materials, structural systems and construction processes, while serving as exemplars that can later be absorbed into the private sector as their familiarity becomes entrenched.

2.1.3 Decline in Construction Skills

A third factor that suggests a shift in focus away from mass housing is the global decline in artisan training, exacerbated in South Africa by apartheid legislation that prevented the majority from entering the building trades. Many construction workers have therefore learned their skills on site, without the benefit of more formal training. This has had inevitable adverse consequences on quality of workmanship and productivity. Certain fundamental techniques, often as basic as the bonding of brickwork or the geometrical setting out of the works, are not understood or observed. (Doku 2007)

People with several years of site experience find it difficult to re-learn techniques in the context of conventional building. By contrast, in a visibly innovative structure, correct methods can be more easily introduced as a lead-in to overall

skills upgrading. Similarly, management techniques that differ significantly from the conventional provide a more congenial environment for introducing the mechanisms for improvements in quality and output, especially if these are introduced in a context where design, management and construction are integrated, in contrast to the adversarial scenario of conventional practice.

Training has important cost implications, to the trainee, her or his employer and to the client. While the South African government has instituted various mechanisms to facilitate training (see Appendix 1), other factors stand in the way of re-skilling the industry. These include:

- disruption and delay to production;
- the cyclic and volatile nature of the industry, where specific skills needs are unpredictable;
- the fear that trained staff will be poached by competitors; and
- the high numbers of informal operatives, who need to spend down time engaged in other forms of income generation.

In the context of housing, individual householders have little influence over the quality of workmanship where this meets the industry norms, however low these may be. The cost of poor quality and low productivity is, however, less than the perceived cost of training to an individual or to a contractor in a small, isolated project.

By contrast, in a long-term programme of public works, the cost and time implications of training can be spread over a number of projects, and can be structured to maximise the benefit to both the trainees and to the client body.

2.1.4 Government as Exemplar

There is little evidence of government departments other than the Department of Housing engaging with employment creation as a central aspect of policy. They could make a significant difference to employment creation in building works because of their greater potential to control three of the key factors which impact

on employment, namely; design, materials specification and management both on and off site.

The building requirements of service providing departments differ from the Department of Housing, in that they tend to be both the end-users as well as the initiators of the buildings. This presupposes a greater commitment to the long-term value and maintenance of their individual buildings and complexes, more control over the design and construction process, and at the same time they tend to have very limited options for 'self-help' through unpaid community participation.[10]

A striking example of how political attitudes have not changed in favour of employment-intensive methods is the new Constitutional Court complex presently under construction in Johannesburg, budgeted at R700 million. This project has been widely publicised as having employment creation as a fundamental objective, yet even a superficial inspection of the construction site shows a highly machine-intensive operation, with considerable off-site fabrication (Tariq Ali 2003). The design shows no evidence of any effort towards creating a substantial number of jobs or developing construction skills in an employment-intensive framework, despite the highly publicised promises. From the limited information that has been gleaned[11] the construction phase of the building work is highly mechanised, and one can only assume that the labour figures will be met through non-construction components of the project.

While high profile projects are a clear indicator of the initiating Departments' lack of concern for employment creation, politicians, bureaucrats and professionals generally respond to criticism through assuming that quality control, contractual

[10] For example, while parent bodies of schools are encouraged to play an active part with regard to facilities, this is generally in the form of maintenance and small-scale refurbishment of furniture, fittings and outdoor elements, rather than major structural work.

[11] Research by MSc and B Arch students has shown the difficulty in accessing the main contractor's information on numbers of people employed, their rates of pay, and thus the ratio of project cost routed to the various skills classes of workers. It is quite clear from the design drawings that not even the most cursory investigation into increasing the labour content has been undertaken (Tariq Ali 2003).

predictability and image would be compromised. An employment-intensive route is considered to be high risk, an attitude that can be justified to some extent through experience in other sectors such as housing.[12] Policy makers commissioning public buildings are therefore unlikely to change their attitude on labour orientated methods in large-scale complex projects in the near future, but there is scope for familiarising operatives in these departments in employment-intensive practice, and developing guidelines through the numerous more modest buildings commissioned by departments of health, safety and security, education, and other branches of government.

It is the contention of this research that the criticisms levelled at employment intensive construction and the concerns about increased risk can be attributed largely to the lack of research and development. In this regard, it is heartening to see the positive role that is being assumed by the government in the United Kingdom in using the construction of its own buildings as a means for revitalizing their construction sector. This initiative forms an important input to the proposals found in Chapter 7 of the present work.

2.2 IS BUILDING ALWAYS EMPLOYMENT-INTENSIVE?

One of the barriers to the establishment of employment-intensive building is the perception that inherently the construction of new buildings will generate a substantial number of jobs. While this is certainly the case in some instances, the assumption needs to be challenged from the following perspectives:

- How many jobs are actually created per unit of expenditure?
- Are there other ways of building, or other materials and components, which generate more jobs?
- Is the objective of employment creation dominant, or is it low on the list of competing factors?

[12] The reasons for failure to meet quality levels can be attributed to the lack of an adequate skills development programme and some questionable management strategies and policy decisions. This goes to the heart of the thesis (Fitchett 2001: 34).

- Are the jobs created through the building project directed at the people most in need of them, giving targeted individuals a foothold in the major wage earning economy?
- Will the job opportunities last beyond the duration of the individual project?

It is the contention of this thesis that none of the above questions has been adequately or consistently answered, even in projects that purport to hold this central policy objective.

Employment creation through building has become something of a slogan, used to indicate social concern. Its application is, at best, in a piecemeal fashion, unsurprising given the lack of data readily available to designers and other decision-makers. Another important factor militating against a consistent approach to job creation is the fixation among professionals and client representatives with the building *product*. Conventional procurement methods leave the *process* of construction entirely to the contractor. Where there have been efforts to raise the employment figures through conditions of contract, these have been difficult to enforce because of this entrenched divide between design and implementation.

In the building sector, there has been a lack of independent and objective research and development orientated at employment-intensive construction. New products and processes have tended to be commercially driven, generally with an acceptance of the low levels of skill prevailing. This has resulted in the certification of various levels of ‘systems build’ that are orientated towards manufacture of components in factories located in the larger centres. This siphons yet more of the project cost away from the rural communities that are the focus of the present study, and prevents any marketable skills from being developed. In general, buildings using these industrialised systems are locked into them for future additions and alterations, thereby excluding one of the traditional mainstays of the small contractor. By contrast, where employment

creation has been a central concern, one sees small inputs of high cost materials, skills and energy that add correspondingly high value to the product, leaving the bulk of the project outlay for local wages, locally manufactured components, and materials sourced from the vicinity of the building site.

2.3 RE-ENGINEERING CONSTRUCTION

Two major reasons for building lagging behind civil engineering infrastructure in terms of research, knowledge and practice of *fully* employment intensive construction are that:

1. It is taken for granted that building is inherently labour intensive; and
2. As a consequence of this attitude, there has been scant investigation, analysis and presentation of data on just how employment intensive building really is, and which trades, activities, designs, details, specifications and management systems enhance or diminish the labour content of projects.

For this data to be effective in evaluating projects from pre-feasibility studies to post-completion, the following need to be analysed:

- the percentage of project cost given over to labour; plant and machinery; materials; overheads and profit;
- the percentage of labour cost directed to less skilled workers;
- the project cost retained within impoverished local communities.

Through this evidence, employment intensive construction could, in many instances, become the preferred method, in that where it can match other methods in terms of cost and time, it can lead to work of higher quality while simultaneously conferring social benefits. This study is directed towards creating a preliminary understanding of what fully employment intensive building means, and to establish a framework within which further theoretical and project-specific research can be based.

2.3.1 Credibility of the Construction Industry

This study is framed in the context of an industry that is the subject of concern at both a global and local level. While governments and commentators are agreed on the importance of construction in the economy, its poor performance has prompted numerous studies and proposals over the last forty years, culminating in the United Kingdom's "Building Down Barriers" initiative, and in the ILO's report entitled "The Construction Industry in the Twenty-first Century: Its image, employment prospects and skills requirements" (ILO 2001) that focuses on the developing world.

Rich and poor countries share a number of sectoral issues, especially the decline in vocational skills and consequential lowering of productivity and quality. However, the British approach is driven by a concern for efficiency, value for money, environmental and energy considerations, and life cycle costs-in-use. Those who commission buildings as well as the building users are the primary concern of the British initiatives, consistent with a Total Quality Management approach. The ILO's perspective is more institutionally focused, with the most important trends being identified as the increase in 'flexible labour practices' and migration to the informal sector with the resultant lowering of skills and expertise.

Any effort to improve the employment capacity of the industry must either address or acknowledge and accept these failings. The following aspects will form the focus of the present study:

- Lack of technical skill and the resultant low quality of product;
- Inefficiency as a result of lack of management expertise;
- The risks attendant on the informalisation and deregulation of the industry;
- The lack of appeal of the industry as a career or vocation;
- Client and user dissatisfaction in terms of initial objectives, prioritisation and performance-in-use of their buildings;
- Unsatisfactory cumulative consequences of poor decision-making and implementation, especially on the economy and the environment.

While each of these areas warrants dedicated research, one of the failings in the industry has been the lack of rigour in defining and addressing all of its key parameters. The vast choice open to decision-makers, clients and especially professionals, has resulted in a 'shopping list' of issues, in contrast with a set of measurable objectives that characterises best practice in project management and engineering.

2.3.2 Three steps towards re-engineering

Authorities in the field of employment-intensive construction have shown that if this mode of delivery is relegated to the margins of peripheral expenditure, it can never be expected to make a significant impact on poverty alleviation or unemployment. For this to happen, it needs to become part of the mainstream economy as one of the preferred techniques on its own merits, and not through government incentives or enforcement. A fully-fledged employment-intensive construction sector can come about only when the following steps have been taken:

1. Understand the current environment, establish existing labour values, determine project cost retained in targeted community; determine materials and activities technically suitable and financially significant for re-engineering.[13]
2. Research and develop methods of increasing labour content, from reverse substitution to development of mew materials and techniques; institute pilot studies to determine labour efficiency;
3. 'Re-tool' construction and its inputs of materials and component production; establish training and orientation programmes.

These steps presuppose that there is political, strategic and financial commitment to a long-term programme of employment-intensive construction so that the cost of re-engineering can be spread over a number of years and

[13] In the initial stages, the cost of research and development for any one material, component or activity is significant. For this reason, it is important to determine those that form a large part of the cost of the project, and at the same time have clear potential for raising the labour ratio.

projects, and that they can be shared by government as the client and the industry as a whole.

Employment-intensive specialists in the civil engineering field have noted the need for re-engineering their component of the construction sector to be able to make a significant contribution to poverty alleviation and job creation. If the building industry and its supporting materials suppliers and component manufacturers were to join this initiative, the cumulative effect of the whole sector moving in the same direction would be to mutual benefit that extends beyond the obvious areas, such as where they use the same resources and inputs.

The most obvious of these benefits relates to economy of scale, especially in the initial phase where research, training and pilot studies are needed. Less apparent is the result of mainstreaming employment-intensive practices: if this is effective, there would no longer be a need for government inducements or enforcement, which recent experience in South Africa has shown to have mixed results. Thirdly, and of direct importance to the objectives of this study, the importance of reshaping all three components of the sector (civil engineering, building and materials) is that each reinforces the other two, especially with regard to retaining money in decentralized and other targeted communities and allowing emerging contractors and entrepreneurs to have a more constant flow of work.

2.4 CONCLUSIONS

Broader scale analysis of labour content is beyond the scope of this research. Here it is acknowledged that jobs could be lost by changing methods of working, in the choice of materials and through their method of procurement, but the general principles that underpin the present study are that:

a) Until employment intensive construction takes over a substantial proportion of the market, the influence of local manufacture will have a negligible effect on either the mainstream industries or their supply chains;

b) As South Africa becomes globalized, new markets are opening, resulting in less negative effect on technology shifts, and generally leading to globalized pricing policies;[14]
c) Much of the project cost is sunk into imported machinery, fuel and the salaries of highly skilled technical and managerial staff when machine intensive methods and materials are chosen;
d) The poorest communities also have the highest unemployment levels, in the urban centres as a result of in-migration from rural areas where there is little chance of making a living, and in rural areas where infrastructure and public facilities are most lacking.

Thus the research is directed at understanding where the project money goes, in general terms, and how changes in design, specification and management can make a significant difference in terms of money directed to the workforce and the number of jobs generated, especially for those at the lower levels of skill. Improving the industry's ability to deliver projects that can compete with conventional and machine intensive construction in all respects is central to the long-term adoption of employment intensive practices.

[14] An example of this is the dramatic rise in the steel price in 2002 and 2003 (McCutcheon et al 2004:49).

3 LITERATURE REVIEW

3.1 INTRODUCTION

The literature on poverty, employment and construction is extensive; therefore this review is necessarily extremely selective. There are few works that tie all these themes together explicitly, nevertheless there are significant debates, valuable case studies, field reports and principles from which such links can be forged. A central concern of the present study is that any attempt to address poverty through employment creation must be formulated within the broader socio-economic and environmental context, especially as the geographical focus of the present study is on rural communities.

Most of the authors on economics in the developing world agree that employment creation is essential to poverty alleviation, as well as being a cornerstone of healthy decentralized communities. There is not an exact correlation between poverty and unemployment, as has been demonstrated empirically by World Bank and International Labour Office studies which particularly highlight the problem of the 'working poor'.[15] However, the link between unemployment and poverty is inescapable in areas of high levels of unemployment, particularly in countries that cannot afford extensive social services. In South Africa, problems found throughout the Third World have been exacerbated by apartheid which produced areas of extreme unemployment, low levels of education and a lack of basic physical infrastructure. This is especially a problem in rural areas where subsistence farming was undermined through the apartheid 'Homelands policy' which saw the majority of the population being forced into a tiny proportion of the land, invariably the least agriculturally productive. In such communities, any effort at developing a healthy economy is compromised by an almost complete lack of surplus, except of labour.

[15] The International labour Office use the term 'under employed' in that they earn less than a living wage, set as a $2 per day equivalent (ILO 2005:23).

The present chapter focuses on the literature that analyses the broad socio-economic issues surrounding poverty and unemployment in the developing world, with particular attention to the sub-Saharan region and specifically South Africa. Following this is an investigation into the history of labour-intensive construction in sub-Saharan Africa through the provision of civil engineering infrastructure. This is explored from the perspective of technological and managerial developments, and the central role given to training.

Much work has been done on adapting building materials and construction techniques for Third World contexts, under the banner of ‘appropriate technology’, ‘intermediate technology’ and other similar labels. A selected sample of these is analysed, with particular emphasis on techniques adapted for climates similar to that of the present study region. A brief overview of the contribution of low-cost housing to the debate on labour-intensive building follows, because this association is so firmly entrenched.

Section 3.5 examines four areas of particular relevance to the current study that show an integration of some of the elements that would contribute to a lasting response to employment creation through building. These are all new developments: in architectural design; structural engineering; environmentally sensitive building materials; and new management approaches to construction and maintenance of buildings.

The conclusions drawn from this Review indicate the locus of attention for this research, as well as highlighting gaps and inconsistencies. The review concentrates on published sources, with unpublished work consulted only where no published material is available on the topic. These unpublished works are generally referenced in the notes rather than being the subject of analytical critique to make the discussion more accessible to a broad readership.

3.1.1 Poverty and unemployment

Economists and social historians have shown that, while there is no inevitable link between unemployment and poverty, these two conditions are often to be found in conjunction, especially in areas of structural unemployment (UNDP 2004). An important distinction that is made in the literature on poverty is between the unemployed poor and the 'working poor'; those who earn less than the Poverty Datum Line for their region. Despite typically working long hours, they and their families remain destitute because of extremely low wages. Allied to the concept of 'working poor' is that of underemployment, a term which includes the working poor as people who could be employed more effectively to command a higher wage. Generally, 'underemployed' is used to denote those who work at very low levels of productivity; work for few hours in the day and/or share a job; or work in non-wage earning jobs, for example, household tasks, family business, volunteer community work or self-help projects. In all cases the term indicates inefficient use of labour on the part of the employer, and little or no income to the worker.

Since its inception in 1919, the International Labour Office has been as concerned with the unemployed, underemployed and working poor as it has with those in formal modes of employment.[16] Its extensive global data bank provides a consistent record of the shifting patterns of labour structures, income and poverty levels at regional and individual country levels. Several of the ILO's annual and other reports have a bearing on the present research, which will be addressed in various places in this Review.

The annual reports of the United Nations Development Programme, especially the country reports, provide both an overview of statistics and changes in key indicators, as well as giving analysis and recommendations which, in some instances, have had important consequences on the country's policy and

[16] While its mandate lies predominantly with improving conditions of those who are employed, there is an acknowledgement that high levels of unemployment undermine the ability of those who work to promote their needs and status relative to employers and governments.

implementation. This review focuses on the *South Africa Human Development Report 2003*, the most recent at the time of writing, and specifically on "Chapter 7: Creating jobs".

Consistent with recent reports from the ILO, this chapter is prefaced by an explicit position on the quality of jobs, and not just a 'numbers game':

> Access to jobs that are appropriately remunerated and provide decent work is not only a means of improving living standards; it is also a means of exercising skills, creativity, making a productive contribution to society and enjoying self-respect, dignity and empowerment. (UNDP 2004:144)

This theme is developed in the section entitled "Underemployment" which the authors define as:

> …jobs characterized by low wages, lack of training and promotion opportunities, exposure to excessive occupational health and safety risks, lack of job security and lack of worker representation and collective bargaining at the workplace. (UNDP 2004:147)

They note that such jobs are more frequently found in rural areas of South Africa, and disproportionately held by African and Coloured women. They also note the prevalence of these characteristics with casual and temporary work.[17]

Looking more specifically at unemployment, the authors draw attention to the statistics, which show that: "Since 1994, the evolution of the economy has continued to generate increasing unemployment," (UNDP 2004:150). They attribute this to the post 1994 government's:

> …restructuring the economy through export-promotion in an increasingly liberalized environment. In doing so, it has used a host of incentives that have continued to foster the capital intensity of production at the expense of encouraging employment potential. (UNDP 2004:151)

[17] This is of particular significance in the construction sector (McCutcheon et al 2004; ILO 2001).

This is compared with the apartheid era incentives that they identify as promoting capital-intensive methods of production, namely: “tax incentives, depreciation allowances, tariff rebates, debt financing, subsidized interest rates, the provision of utilities and infrastructure and the legacy of import substitution,” (UNDP 2004:151) factors analysed in more detail by Feinstein (2005) as discussed below. These measures can be compared with the post-apartheid ‘supply-side policies’ to increase international competitiveness, cited here as: “tax holidays, technology upgrading schemes, … and accelerated depreciation allowances”, leading in part to the real growth rate of investment in machinery during the 1990s and 50.7% of total investment in 2002 (UNDP 2004:152). The authors see these and the regulatory bias towards large-scale enterprises as barriers to more inclusive and more labour intensive modes of production (UNDP 2004:153).

Despite an extensive section on skills and human resource development, directives are not clearly articulated, only caveats such as:

> Thus even a combination of rapid growth and a related high response of job creation does not guarantee a rapid rise in the employment of the unemployed poor. If the new opportunities are such that the capabilities they demand do not match the capabilities of the poor, then non-poor workers will either seize those opportunities or the opportunities may be lost altogether. (UNDP 2004:154)

The chapter concludes with policy recommendations, included in which are: increasing the labour intensity of production; enhancing the economy’s capacity to utilize more labour; promoting programmes with a high employment multiplier; promoting education, training and human resource development; and micro-enterprises (UNDP 2004:162-165).

The UNDP’s internal review of this report rates it highly in terms of the organization’s terms of reference. However, while argued from a predominantly ‘pro-poor’ stance, much of the analysis, and most of the recommendations, are highly generalized. The case study on tourism (UNDP 2004:163) gives some

insight, but conflicting concepts and strategies that government well understands, are swept away by the rhetoric. The review suffers from a similar over-simplification, eg: "…the ability to achieve and sustain high growth rates that simultaneously reduce unemployment, poverty, and income and wealth inequality, while improving environmental sustainability and macroeconomic balances," (UNDP NHDR Reviews 2006:11).

3.1.2 Productivity and skills for sustainable employment

The *"World Employment Report of 2004-2005"*, published by the International Labour Office, is significantly entitled "Employment, Productivity and Poverty Reduction" (ILO 2005). In their own words:

> This topic was chosen based on the strong conviction and empirical evidence that creating decent employment opportunities is the best way to take people out of poverty. In addition there is a strong link between productivity and decent work… (ILO 2005:23)

The report acknowledges the controversy around productivity and unemployment: "…jobs can be lost as a result of improvements in productivity" (ILO 2005:5), but counters this with the arguments for productivity equating to increase in value and volume, not just unit output. Thus, the simple inverse relationship of productivity to quantity of labour only works in a closed system and in the short term. The second theme of the report is a concern for the 'working poor', those who live on less than $2 per day (based on purchasing power parities) who accounted for 76.4% of the population of sub-Saharan Africa in 2003 (ILO 2005:23). The report argues that: "…concentrating on unemployment runs the further risk of excluding from the analysis the less privileged population who simply cannot afford to be unemployed," (ILO 2005:26). The link between productivity and adequately remunerated employment is introduced:

> …differences in labour productivity levels have essentially nothing to do with differences in how hard workers work – on the contrary they often indicate differences in working conditions. A poor worker in a developing

> economy can work long hours, strenuously, under bad physical conditions, but yet have low labour productivity and therefore receive a low income because he or she lacks access to technology, education, or other factors needed to raise productivity. (ILO 2005:28)

The relationship of the 'working poor' to the global economy is alluded to: "…if the jobs created are not decent and productive, providing an insufficient income for the employees, and making it impossible for them to have an impact on the demand side of the economy," (ILO 2005:30). This concern for 'demand' becomes a pillar of the ILO's argument:

> …GDP growth will occur only in the presence of increases in productivity and decent employment creation. Only with productive jobs where workers can use their potential, and only with decent employment opportunities, will people permanently stay out of poverty. In short, workers need to be in a position to stimulate demand through their consumption and invest in themselves and the future of their children. (ILO 2005:32)

While the authors acknowledge that the link between poverty reduction and productivity is empirical, they present global data over a significant time-frame to give credibility to their hypothesis.

They develop this argument for poorer regions by proposing:

> …a two-pronged strategy of improving the productivity of workers in dynamic *niche* industries and, at the same time, focusing on those sectors of the economy where the majority of labour is concentrated. This focus would give them the tools to move from low- to high-productivity activities. (ILO 2005:78)

Their presentation of "theoretical benefits of productivity growth" is, however, modeled on the premise that poorer economies would (and would want to) follow the pattern of highly industrialized nations, specifically in declining product prices, increased wages and investment, overall improvement in employment, and innovation in products and processes (ILO 2005:81). Later in the report, there is

some acknowledgement of how these 'benefits' might be subverted in developing countries because of inherited wealth and skills inequalities and the importation of capital-intensive technologies to improve global competitiveness driven by Structural Adjustment Programmes (ILO 2005:97).

With reference to the ILO's decades of experience in employment-intensive infrastructure projects, the report examines the opportunities and conditions for more equitable distribution of a developing country's GDP, and the retention of the economic benefits within such country: "The reason for the higher GDP impact in the labour-based methodology is that a higher proportion of income and consumption remains in the local economy," (ILO 2005:104) The authors sum up this element of their argument as follows:

> …the statement that countries should focus on employment at any cost, irrespective of productivity, is misguided. Were a country to do so it would be a prescription for widening inequality between it and wealthier countries, where the main source of economic growth and growth in standards of living is through productivity increases. Rather, policy focus needs to be on both employment and productivity growth. (ILO 2005:104)

This is followed by a prescript that urges policy makers "…to focus attention on employment and productivity growth on the sectors and areas where they can have the greatest impact on poverty," (ILO 2005:105), and reiterated in: "…it is paramount to ensure that workers can be provided with skills and training for labour absorption in … growing areas of the economy, a strategy that requires increasing the productivity of workers in labour abundant industries," (ILO 2005:110).

Of central importance to the present study is the attestation that this strategy:

> …would have the largest impact on workers' lives not only in the short and medium run, but also in the long term. In the short and medium term it will provide workers with decent employment opportunities, defined by security, opportunities, basic workers' rights and representation; in the

> long term, workers will be equipped with the necessary skills and training to compete for job opportunities in a dynamic economy. (ILO 2005:110)

It is not surprising that the ILO promotes the construction of certain types of infrastructure by means of employment-intensive construction, given its successes dating from the 1970s. However, the following is typical of its very broad conclusions:

> For developing economies, this[18] entails investing in strategic growth sectors by acquiring and internalizing the knowledge developed elsewhere if they are to 'catch up', while at the same time improving worker productivity in traditionally low-productivity sectors, such as the informal economy. (ILO 2005:121)

Underpinning these recommendations is the assumption of significant increases in demand for goods and services at all levels of income. What can be extrapolated from this is a strategy that focuses on increasing productivity at the lower end of the economic spectrum, with attention being given to the manufacture and beneficiation of 'low-income' goods and services to retain the benefits of this strategy in localized poor communities. The implications of this are not fully explored in the ILO report and cannot withstand rigorous examination, especially in the context of their own phrase "catch up"…

Based on the ILO's empirical evidence, this organization's *World Employment Report* of 2004-2005 is significant in challenging the commonly held assumption that employment and productivity are inversely related. However, its use is limited by the data being presented in aggregated form, with trends being analysed at regional level. The basis for their 'theoretical' propositions is not made explicit, for example, that productivity drives an increase in demand for goods and services, a shortcoming that is acknowledged to some extent within the report itself. It could be argued that it is unsubstantiated 'theoretical

[18] They propose a policy of increasing productivity and employment through a dual strategy of investing in dynamically growing sectors of the economy while also building capacity in sectors where the majority of labour is employed.

principles' from international bodies that have been the central *cause* of parts of the world becoming increasingly poor, and deeper in debt.[19] Within the report, these limitations are alluded to, in the tabulation of causes of poverty and the attention given to the 'working poor'.

In contrast to these 'principles' certain limitations of the report in relation to this study need to be identified, namely:

a) That there is a saturation of 'cheap labour' in South America and Asia that would result in a barrier to Africa's development, especially with regard to the expansion of markets into the international arena;[20]
b) That there is an underlying assumption that all countries and regions want to mimic the route and results of advanced capitalism;
c) That the focus is on poor individuals and households that underplays the dire poverty of whole communities, resulting in a lack of immediate markets, inadequate access to transport and trade networks, and inadequate skills, education and basic infrastructure;
d) The collapse of subsistence agriculture in these communities and the lack of even a rudimentary cash economy;
e) Over-optimistic expectations of the informal sector, ignoring the negative characteristics of this sector, especially the exploitation of employees through which the 'not-so-poor' benefit at the expense of the poorest and most vulnerable (despite being addressed in the ILO report of 2001, as discussed below);
f) The neo-liberal (or its 'pro-poor' liberal variant) assumption of a limited role for the State, essentially restricted to policy formulation and not as a catalyst to growth, and the commitment to free market principles and methods.

[19] Stiglitz (2002) discusses the results of these principles being implemented in Structural Adjustment Programmes imposed on heavily indebted nations.
[20] This is countered, to some extent, in the construction sector through the immobility of its products (see ILO 2001, discussed in 3.1.4 below).

In the context of the present study, it is significant that infrastructure is not disaggregated from manufacturing, so the effects of globalization on these fixed assets is not analysed in the report. While these could be expected to be far less, there have been instances in South Africa's past where substantial numbers of construction workers have come from other countries.[21]

Specifically with regard to Southern Africa, no indication is given of what the "*niche* industries" might be, especially as the report glosses over the legacy of decades of inadequate education and skills training for the majority of the region's population, a direct result of colonial rule and its dismantling.

3.1.3 The South African context

With the advent of democracy in South Africa, extremely high levels of unemployment and poverty in parts of the country have been the subject of intense concern as a barrier to a truly democratic society. However, since 2006, the South African government has tended to publish statistics based on a narrow definition of unemployment, capturing data of only those who have actively sought work in the previous four weeks (Perold and Jooste 2006:12). The focus of the present study is on those rural regions where unemployment is so endemic that expectations of formal work opportunities are minimal. The following two sources provide a framework for understanding the causes of poverty and unemployment that are unique to South Africa (Ilife 1987; Feinstein 2005).

Iliffe's *"The African Poor: A History"* (1987) traces concepts of poverty on the African continent, with particular reference to Ethiopia, Nigeria and South Africa. He draws an important distinction between poverty in pre-colonial Africa and in other parts of the pre-industrial world; that of the role of the extended family as a means of support to the poor: in the form of supplying jobs for the landless; work for landowners who are incapacitated; and in the form of direct aid. To some extent, he sees this phenomenon having been used by colonial powers to

[21] One of the most recent of these influxes was in the 1970s, when artisans and contractors from Mozambique and Angola emigrated as a result of civil war and set up business in South Africa.

abdicate State responsibility, especially in the case of South Africa, both under colonial and apartheid rule.[22]

In his two chapters specifically on South Africa, Iliffe highlights the differences between the rural areas of this country and other parts of colonial Africa in the early Twentieth Century, with specific reference to the Land Act of 1913. In discussing the incremental dispossession of land, he concludes that: "…limited land available to Africans was precipitating the reserves into endemic under-nutrition…" (Iliffe 1987:124).[23] However, he notes that in South Africa the broader economy has had the capacity to prevent death by famine, in contrast to other African countries. He attributes this to the income from migrant mineworkers from the 1880s to the 1980s, and more recently supplemented by pensions. This was despite the pension for blacks in 1982 being R49 per month, while the Household Subsistence Level was rated at R242 (Iliffe 1987:272).

A central theme of Iliffe's work is the relationship between agriculture and poverty, with agricultural surplus as the primary means of generating other modes of income through specialization. In South Africa, the dual economy exacerbated the destruction of this pattern:

> South Africa exemplified Dr Hill's claim that towns have impoverished the African countryside during the twentieth century by absorbing all occupations except agriculture. Moreover, rural poverty was self-reinforcing. The reserves were too poor to support prosperous local traders or craftsmen. (Iliffe 1987:124)

He attributes this, in part, to the erosion of non-agricultural rural activities such as traditional crafts and the gathering of firewood as the towns became electrified.

---

[22] To a large extent, Iliffe ignores indigenous market forms in existence in the inland parts of Southern Africa in the 19th and early 20th century (see Austen 1987:155-188 and Bundy 1988).

[23] The Land Act and subsequent legislation under Apartheid was not only directed at quantity of land, with a mere 13% allocated to over 80% of the population (van Zyl et al 1996), but in most instances this land was of low quality, often unsuitable for farming. This can be seen in the 1980s maps of South Africa that demarcate the 'homelands' as fragmented patches that retained productive lands for white farmers.

Iliffe identifies a critical change taking place from the 1970s, with the rise of a new category of poor rural households, characterized by:

> …those willing and able to work but continuously excluded from employment by an absolute shortage of jobs and land. Not only did the proportion of South Africa's labour force unemployed or underemployed increase between 1970 and 1980 from 12 to 21 per cent, but for the first time in South African history the cyclical upswing of 1978-81 did not reduce unemployment levels. (Iliffe 1987:273-4)

He ascribes this predominantly to the "relatively high-wage urban economy … and an attempt to divide urban workers from the rural poor," (Iliffe 1987:267) thus correlating higher wages to structural unemployment.

While Iliffe's work gives insight into the social dynamics of the poorest parts of South Africa, it is presented more as a narrative than from an analytical perspective. The value of his approach in writing a history of 'the poor' is in providing a balance with the more conventional histories of the rich and powerful. However, his chapters dedicated to South Africa tend to present his subjects as pawns to the powerful, which should be read in contrast to the works of, for example, Delius (1996) and Rich (1991), both of whom have stressed the ability of rural communities (specifically the Pedi in Limpopo Province) to retain their dignity and identity through political defiance and the maturation of new and sophisticated cultural practices in the face of serfdom and racism.

Feinstein's *"An Economic History of South Africa"* (2005) supplements the works of Iliffe in providing greater depth and focus on this country. Arguing from a predominantly liberal viewpoint, the author gives valuable historical background on the social, economic and political conditions that he attributes to the collapse of the South African economy in the last years of apartheid. This provides the context for the current excessively high levels of unemployment and the dearth of marketable and productive skills. Feinstein seldom refers specifically to construction as an economic sector, nor does he focus on its products in the form

of equitable provision of educational and other infrastructure. The main substance of his argument is based on an analysis of agriculture, mining and the manufacturing industries, consistent with his emphasis on free market economics.

He poses the following questions:

> Why did South Africa grow more slowly than other countries in the boom years from 1948 to 1973, even though its own performance improved? What explains the transition to negative growth in the last quarter of the twentieth century, and how does this relate to the policies of apartheid? What were the reasons for the exceptionally high degree of inequality between black and white South Africans? (Feinstein 2005:13)

In relation to this last question, he further notes the “huge disparity in average income of African households between those in large urban centres with one or more members in employment, and those in rural areas,” (Feinstein 2005:11). The title to his Chapter 3, “Making the labour force: coercion and discrimination”, encapsulates the principal theme of the book; that of forcing blacks into the position of a subservient labour pool. He shows this process occurring through the dispossession of agricultural land, and by taxation that compelled at least some members of each homestead into the westernized cash economy. The land question dates back to the earliest years of the Dutch colony, despite the policy of the Dutch East India Company (VOC) that the Cape of Good Hope should be merely a refreshment station to their fleet (Leibbrandt 1897:1-12).

More significantly, in Feinstein’s analysis, was the response to the need for cheap labour for the mining industry, dating from the last decades of the nineteenth century. Pressure in the form of taxation pre-dated large-scale mining:

> …mainly in the form of hut or poll taxes which could be levied on all residents of a district irrespective of their income. … In some instances, a … motive for such taxes was to raise revenue, but these had the same

> effect as taxes explicitly adopted to increase the supply of labour. When this was clearly the objective, the tax was deliberately set at a level that would force young men to leave their rural areas in order to earn enough to pay the amounts due for themselves and other members of their family. (Feinstein 2005:55)

He expands on this by identifying legislation dating from the mid-nineteenth century that restricted movement of blacks into urban areas unless they had proof of a job with a white employer.

Feinstein continues:

> Trade was also an effective form of pressure … the authorities encouraged Africans in the Cape to develop new wants by including goods such as coffee, sugar, and tobacco as part of the payment made to those employed on public works projects. They were steadily drawn into a cash nexus, their self-contained subsistence economy was broken down, and their traditional crafts of iron smelting and pottery making were destroyed. (Feinstein 2005:59)

The importance of the collapse of these elements of rural economy is pertinent to this study in relation to the World Bank and International Monetary Fund model for the restoration of economic development in poor rural areas.

Of central importance to the present study is Feinstein's discussion of job reservation and the mechanisms that were put in place to debar blacks from any skilled positions. As early as 1904, largely through pressure from white mineworkers, a schedule of occupations reserved "for European workers" was put into effect[24]. Included in the list were the following construction trades: "blacksmith; bricklayer; brickmaker; carpenter; electrician; joiner; mason; painter; plasterer; plumber; and stonecutter".

[24] This was put into legislation in 1911 by the Union government in the Mines and Works Act.

> In other industries a similar policy was implemented by measures that effectively prevented Africans from acquiring the formal qualifications necessary for performance of skilled work. (Feinstein 2005:76-77)

Feinstein provides a synopsis of the increasingly discriminatory legislation that was enacted from 1911 to the 1950s, which sought to exclude blacks from any but the most menial and low paid work. These included:

> …the 1922 Apprenticeship Act (which) had effectively prevented them from entering a wide range of skilled jobs in other industries (than mining). … In 1951 the Native Building Workers Act prohibited Africans from undertaking skilled building work outside their own areas… (Feinstein 2005:157)

This was followed in 1953 by the Native Labour (Settlement of Disputes) Act which redefined the term 'employee' to exclude Africans, a measure to prevent industrial action by blacks. In the same year, the Bantu Education Act was promulgated, in which the responsibility for education of blacks was transferred to the Department of Native Affairs. This mechanism allowed vast inequity between blacks and whites in education funding. Teaching in indigenous languages was enforced, despite the lack of textbooks for technical subjects, significantly science and mathematics, thereby debarring blacks from pursuing tertiary education in science, engineering and related fields.[25]

Feinstein identifies the 1970s as the period of decline from which South Africa was not to recover, ultimately leading to the collapse of apartheid. He sees the period after World War II as one of inefficient development of manufacturing, largely import substitution, for which low productivity and high wage differentials between whites and blacks were propped up by global demand for gold. He mentions the shift to capital-intensive production, citing the scarcity of skilled

[25] The inadequacy of education in Maths and Science in the majority of high schools is reflected in the low number of Black matriculants whose teachers are equipped to teach them at higher grade, a minimum requirement for admission into Engineering (Doku 2007).

workers as the primary motivation (Feinstein 2005:222).[26] Despite the shift to machinery, the total factor productivity fell consistently in all industries between 1965 and 1994. The 1970s saw the massive rise in structural unemployment, reaching six million in the broad definition (Feinstein 2005:148). Coupled with the increase in wages that "far exceeded the improvement in output per worker, and was thus responsible for a substantial rise in labour costs per unit of output," (Feinstein 2005:232) was a rapid rise in consumer prices, which meant that the position of this large unemployed group was exacerbated.

Feinstein concludes with commentary on "the fallacy of 'cheap' labour", drawing attention to the relationship between poverty and productivity, and criticizing the "flawed economic analysis" of both apartheid ideologues and Marxists, the former through racial prejudice, and the latter through the premise of "a zero-sum game in which higher productivity is allowed to play no part," (Feinstein 2005:248). This part of his work parallels the *ILO Annual Report* (2005) discussed above.

In summary, Feinstein gives a clear account of the social, economic and political factors relating to: poverty, including land dispossession and coercion into a cash economy; unemployment and the rise of capital-intensive modes of production; education and training, including the problem of skills and job reservation; and the summation of these factors in low productivity as a barrier to economic growth. By contrast, very little is discussed relating to government expenditure on infrastructure (either as a 'consumer' or as stimulator of economic growth). Consistent with his liberalist stance, government is analysed primarily as legislator and as borrower of international funds.

Of particular significance in the work of Iliffe and Feinstein is that they demonstrate that employment for a cash wage must be the focus of attention.

[26] See, by contrast, the range of factors identified in the UNDP South Africa Human Development Report 2003, discussed below. McCutcheon (1995:333) cites Ligthelm and Kritzinger-van Niekerk on the shift of the entire South African economy to capital intensive production, and Steyn on the negative effect that this has had on employment in the late 1980s.

Even the poorest in this society need to have some formal income. Subsistence farming, self-help and volunteerism can be valid only for a small percentage of any community or as a short-term measure. These modes of creating infrastructure and other facilities cannot be justified as employment creation in the South African context.

3.1.4 Characteristics of the construction sector

The International Labour Office's report of 2001 entitled *"The Construction Sector in the twenty-first century"* highlights a number of factors that differentiate this sector from other industries, all of which have an impact on the current discussion. In general, the sector consists of the building industry, the civil engineering industry and construction materials production. Internationally, 60 to 70% of the funding for civil engineering comes from the public sector (in South Africa during the 1990s it exceeded 75%), while the proportions are reversed for building, with two thirds being privately funded.

Within the materials production industry, the industrial environment varies from forestry and timber production, through quarrying of aggregate, the heavy industrial production of steel, aluminium, cement, brick, bitumen, plastic, paint and glass, to the light manufacturing of components such as window-frames, doors, and light fittings. This results in a highly complex labour environment with diverse needs in terms of training and different capacity to absorb unskilled labour. Construction in developing countries tends to rely to a large extent on locally produced and fabricated materials, and in this way the growth of the sector plays a significant role in stimulating the economy as a whole from what is often termed 'backward linkages'.

An important aspect of the construction sector is that it has traditionally been one of the industries within which people who have neither skills nor land for the production of food, have been able to earn a living, however precarious. This has been termed the ability to "absorb the excluded" (de Sousa 2000, cited in ILO

2001).[27] This attribute of construction is extremely important as a component of the social characteristics of the sector, and is one of the reasons why governments often use it as a vehicle for job creation schemes and poverty alleviation.

Moreover, as an industry that can provide jobs for people with a wide range of skills and formal learning, down to very low levels of both, important 'sideways linkages' are formed to the immediate community of the employee and to the rest of the country. Workers at the lower end of the wage scale will tend to purchase predominantly local goods and services from markets in their immediate vicinity because of financial constraints and lack of mobility. The 'forward linkages' which are created through the products of construction; roads, clean water and sanitation, electricity, houses and public facilities all contribute to increased productivity, improved performance of learners who will become the next generation of workers, and to emerging businesses.

This ILO document provided the global overview for a report prepared by McCutcheon et al (2004) entitled "*An Overview of the South African Construction Sector in 2003"* commissioned by organized labour for the national Job Summit of 2004. Other sources consulted for this work included the Building Industry Federation of South Africa Annual Reports 2001-2003; official statistics, legislation and government policy documents; reports of the South African Federation of Civil Engineering Contractors; Black Construction Industry publications; and sources from the major construction materials manufacturing organizations.

Six principal characteristics of the construction sector in South Africa were identified in this report, namely:

a) ownership patterns distorted through colonialism and apartheid;

[27] Kirmani (1988:34) argues that "Employment in construction is often a stepping stone to work in manufacturing."

b) the role of small and micro-enterprises, especially small contractors;
c) the shift to informal labour practices, including 'labour only' contracts;
d) the cyclic, and especially the volatile, nature of the sector;
e) the lack of entry-level skills and skills training of site workers, with associated problems of low productivity, health and safety; and
f) the globalization of the larger and more experienced participants in the sector.

The report observed that despite initiatives to overcome the marginalization of the majority of the population through the dysfunctional economy resulting from Apartheid policies, positive results were slow and uneven (McCutcheon et al 2004:17).

The decline in artisan training is attributed to the move to more flexible labour practices, brought about through the volatility of the industry. The report identifies the trend of formal sector companies to subcontract the actual building activities, while becoming construction management specialists. The present South African government has responded to this phenomenon through the establishment of new forms of artisan training, but this has been met with some scepticism (McCutcheon et al 2004:19 & 23). Similar hesitation can be seen in relation to the government's emphasis on small contractor development as its principal measure to redress distorted patterns of ownership, while simultaneously encouraging more labour-intensive delivery. Despite mentorship programmes, small contractors have an increasingly high attrition rate, and contribute a small fraction of the output of the industry (McCutcheon et al 2004:20).

The phenomenon of high structural unemployment is identified as a central theme, with its direct consequences on workers' job security and ability to engage in wage negotiations. Moreover, in the construction sector, the increasing casualization of the workforce through subcontracting and 'labour only' arrangements leads to precarious conditions at a broad level in terms of lack of social security and benefits, but more directly in relation to health and safety

issues. This was noted as being of particular concern as the most vulnerable in the sector are forced to absorb much of the risk, whether as labourers or as small contractors, as the established businesses shelve the physical construction in favour of management functions (McCutcheon et al 2004:55).

In the context of being a briefing document for organized labour to address the disturbing unemployment trends in the country, the report concludes:

> Two interrelated issues emerge as the central findings of the research on which this report is based, namely the changing role of labour in the construction sector, and the importance of informed and properly structured employment intensive programmes. The initiatives to date on the latter through the Special Public Works programmes indicate awareness and the political will to use the creation and maintenance of infrastructure and public facilities as vehicles for job creation. Now the challenge lies in adapting local and international experience to make these programmes viable in achieving their objectives. (McCutcheon et al 2004: 54-55)

While this report is useful in presenting trends and statistics, and in giving directives for policy formulation, it is somewhat generalized in methods of implementation. In the field of civil engineering, especially those types of construction identified for employment-intensive construction in the South African Expanded Public Works Programme, implementation is well established, even to the extent that at the time of writing, all the necessary legislation, guidelines and provisions of contract had been put in place (Department of Labour 1997, 2002 and 2007; DPW 2003, 2004a, 2004b and 2005). As regards building, no similar process of development has yet been undertaken in the region, so the directives must necessarily be provisional and expressed in broad outline.

3.1.5 Construction and development

The history of technological transfer has been dominated by the strategies of the World Bank and other international funding agencies. It is instructive to note the

considerable changes in policy that have characterized the provision of aid for development over the last century, especially in the context of the high failure rate[28] of World Bank and other internationally sponsored projects and programmes.[29]

From the mid 1960s, the intellectual underpinning of development aid and its implementation has been the subject of criticism from academics, researchers and field workers. One of these approaches was dubbed 'alternative technology' by its proponents, inspired by the work of Schumacher. Under various labels such as 'appropriate technology', 'intermediate technology' and similar appellations, a wealth of literature has been produced, including: discussions on ethics; economic and social analyses; dissemination of case studies; and detailed manuals.

Stewart's *Technology and Underdevelopment* (1977) provides an intellectual rationale for this approach to development with a critique of technological transfer modes. Despite being published 30 years ago, her analysis is still pertinent, both to the introduction of new technology and in relation to the dysfunctional environment to which new initiatives have to respond. Fundamental to her study is the observation of the gap between what she terms the F-sector (foreign/imported) and the L-sector (local) in terms of technology, economy and techniques of management. She identifies four problem areas relating to the F-sector, namely:

---

[28] Heeks (2003) gives the following statistics for World Bank sponsored "e-government" projects, aggregated from data, polls of government personnel and individual project data:

Classification	Percentage
Success	15%-
Partial Failure	60%+
Total Failure	25%+

While no data on other sectors has been identified, criticism of World Bank projects suggests that these figures could apply more generally. The World Bank itself alludes to failures (World Bank 1994), although it attributes lack of sustainability to the recipient countries.

[29] Other responses to the poor track record of projects that followed the World Bank guidelines were reforms emanating from the Bank itself, including Structural Adjustment Programmes and a greater focus on private sector involvement (IBRD 1990; IBRD 1994).

1. That the "historical evolution of technology has conditioned the characteristics of the technological choice facing under-developed countries," (Stewart 1977: 29);
2. That "technology is a package, and the efficiency or otherwise of a particular technique depends not only on its own performance, and that of its immediate substitutes, but also on the surrounding technology," (Stewart 1977:21);
3. That technologies which might be efficient in less developed economies have become obsolete, often with these countries not having the capacity to make the necessary equipment (Stewart 1977:20); and
4. That the level of technology generally demands equivalent management expertise, thereby ruling out the nurturing of local entrepreneurial ability (Stewart 1977:65).

She questions the relevance of mainstream economic concepts, such as 'economy of scale', showing that these phenomena are equally the products of the history of technological development that have favoured particular organizational forms and large-scale techniques (Stewart 1977:65).

Of central importance to the present study, she provides an evaluation of the problems of importing advanced-country techniques, unmodified, to poorer countries:

> …in effect what happens is that all the investment resources have to be concentrated in the sector receiving the advanced-country technology… The heavy investment demands imposed by advanced-country technology thus concentrates countries' savings resources in that sector to the neglect of the rest of the economy. (Stewart 1977:72-73)[30]

[30] An example of this in recent South African economic policy is the Growth, Employment and Redistribution Strategy (GEAR), intended to speed up economic growth in order to provide additional finance for social development. The result was a period of jobless growth which has received extensive criticism for undermining other important government objectives (Dept of Finance 1995).

In pursuing this line of thought, she attributes the 'employment problem' to the big gap in labour productivity and wages per worker between the sector using imported technology and the local technology sector.

> Open unemployment results as workers attempt to secure the few jobs and high rewards of the F-sector, while underemployment, which is normally defined as relatively low productivity and incomes, stems from poor technology and underinvestment in the L-sector… (Stewart 1977:74)

The imported technology, moreover, requires specific skills often met only through importing people from the country originating the technology, thereby increasing the skills and wage differentials, with immigrants generally demanding higher salaries than they would in their home country (Stewart 1977:76). The elite that is created from this phenomenon provides "a market for the inappropriate products and so appear(s) to justify the technology. But this is because the technology is self-justifying, creating its own demand," (Stewart 1977:81).[31]

Her discussion moves to the role of government, firstly in terms of "standards and product specifications, protection and employment," derived from the developed world and thus enhancing the F-sector at the expense of the L-sector "since they increase the cost of any resources that they acquire from the F-sector, and make it more difficult for them to establish markets," (Stewart 1977:91). She links this tendency of governments to the belief that 'high' technology is the only way to escape underdevelopment. In relation to specification, she identifies the prevalence of using first world products and methods as *parameters* in cost/benefit analyses, and in this way building bias into choice of technique with the assumption that "choice is restricted to existing technologies," (Stewart 1977:95).

[31] This has particular significance in relation to building, where materials such as profiled steel (corrugated iron) and steel window frames are regarded throughout sub-Saharan Africa as the only 'proper' solution, despite the high cost and climatic inappropriateness.

This leads into a discussion of 'appropriate technology', focused on rural areas to target the greatest numbers in underdeveloped countries. While stressing simplicity, both of machinery and products, she notes that simplicity in one aspect is not necessarily associated with simplicity in others (Stewart 1977:104). Linked to this is the advantage of focus on local inputs, including the production of machines. She shows that, despite the fact that more investment-intensive technologies were developed more recently, "this does not invariably mean that the earlier techniques involve lower levels of output … as many empirical examples have shown," (Stewart 1977:107).

In summary, she provides important guidelines for choice of technique, namely:

a) that factors beyond the 'neoclassical' ones of labour and investment should be considered: size of firms, size of markets, product requirements, types of available labour and fuel costs;
b) that the whole chain of production should be considered, from the raw materials, and include transport methods;
c) that the product need should be precisely defined, and that products that 'overfill' this should not be classed as being of higher value.

And finally, in stressing the importance of decision makers, she concludes:

> To secure technical innovation appropriate to the third world requires much more than a formal structure of local scientific institutions … It also requires that decision makers use this sort of technology, which means that the selection mechanisms have to be right. But this requires economic changes which are only likely to occur after an alternative technology has been successfully adopted, and are unlikely to precede it. (Stewart 1977:278, her emphasis)

This 'chicken and egg' scenario posed by Stewart is countered to some extent by the work of the Intermediate Technology Group. Through wide dissemination of technological inventions and developments, these proponents of a 'third way' attempt to reduce the risk of innovation, although in most cases local adaptation

is required. The intellectual underpinning of this group is presented in Jequier's *Appropriate Technology: problems and promises*, published in 1976. This movement grew out of the acknowledgement that First World technology was, in many instances, inappropriate to the needs and budgets of developing countries. However, their aim has been to avoid the reactionary approach of those attempting to revive traditional methods, expressed thus:

> …the concern of most practitioners in appropriate technology today is not to repeat the experiences of the past and turn back the technological clock but to develop alternative technological and social solutions to problems which for the time being, given the lack of resources and the particular nature of local conditions, cannot be met successfully through large-scale modern technology. (Jequier 1976:30)

This is driven by awareness that, for appropriate technology to succeed, it "…must not only be competitive today, economically, technically and culturally, with existing technologies: it must also have what might be called an evolutionary capacity," (Jequier 1976:97). For this reason, reversion to the traditional is seldom an option, not least because of low productivity, although in several instances, older methods serve as inspiration and existing technologies and skills form the basis for the new. This more flexible attitude to tradition is taken up by Hoda in the same work, where he proposes four strategies for intermediate technology, namely:

- the reviving of an old technology;
- adapting a current one;
- inventing a new one; and
- improving the traditional indigenous technology (Hoda, in Jequier 1976:150).

This has clear parallels with the work of McCutcheon and others in employment-intensive civil construction, as presented by McCutcheon and Taylor Parkins (2003:62-63), discussed in Chapter 4 below.

The first part of this book has a somewhat neo-liberal bias, where governments' policies in supporting small industry are criticized for blocking the transition to 'higher' technology (Jequier 1976:46). The authors call on governments to take a passive role "…by helping to create a more favourable climate for the development of entrepreneurship," (Jequier 1976:89). This view is tempered by acknowledgement that the risk of innovation cannot be taken by the poor of these countries, and should therefore be taken up by government, universities and research institutes (Jequier 1976:108-109). This aside, it is clear that the movement is driven by non-government organizations, with significant input from field workers engaging in actual projects.

However, this pragmatism is balanced by the links to progressive academic institutions, especially with regard to environmental and social concerns. This is expressed in the criteria of appropriateness of a technology, as outlined in the chapter from Brace Institute, Canada:

- compatibility with local cultural and economic conditions;
- tools and processes maintained by and under the operational control of the target population;
- use of locally available resources;
- community control of imported technologies and resources;
- use of local energy sources;
- ecologically and environmentally sound;
- flexible and adaptable (Jequier 1976:132).

While all of these criteria stand up to rigorous evaluation, the impact of the Alternative Technology school has not been as significant as planned, despite considerable efforts at disseminating its theories and practical achievements. This should be seen in relation to Stewart's (1977) analysis of the dominance of foreign technology, but can also be attributed in part to the movement's distancing itself from the governments of the developing world. It can be argued that only through mainstreaming these initiatives – making them part of

government policy – can they carry sufficient weight to make a substantial contribution to the alleviation of poverty and the creation of dignified employment.

In reviewing the work of the Intermediate Technology Group and reflecting on the writings of Stewart (1977) and Wells (1986), a number of factors can be identified that prevent the advantages of this approach from reaching target communities. At the level of policy, governments are frequently seen to favour 'modernity' with associated industrialized solutions. A change in technology spearheaded from the public sector requires policy, regulation, legislation and institutional structures that emanate from a high level of government, often championed by individuals. The small output by value of local small contractors prevents this re-engineering from developing and becoming entrenched from the bottom up, and users from the poorer sectors understandably resist innovation because of high risk and a perception that they are the subject of experimentation.

In *The Construction Industry in Developing Countries*, Wells (1986) argues for a more direct role for government than that contemplated by other writers, and is particularly critical of the wholesale adoption of western methods and principles that has been the subject of criticism even within developing countries. This is particularly prevalent in English speaking countries that suffer from the separation of design and production. She identifies a number of problems relating to the education of professionals stemming from their training, aspirations and benchmarking being modeled on an often outdated 'developed world' scenario. These include the lack of appreciation of construction efficiency and productivity, skills availability, costs and availability of materials. Moreover, the letting of contracts on a tender basis and 'one off' designs disallows a learning curve developing through continuity of work.

She summarizes the problems in the construction sector in developing countries by presenting the following evaluation criteria:

> These include: (1) the extent to which the construction projects in a country's development plan are actually implemented to time; (2) the percentage of imports in the total construction output; (3) the degree of development of local skills, and of local participation in contracting; (4) the extent of development of the local building materials industries; (5) the overall efficiency/productivity of the construction sector and the extent to which construction plans are implemented within the cost limits set. (Wells 1986:56)

The issues of cost and productivity are expanded through a discussion of the inadequacy of technical and managerial skills, which she identifies as being more critical in building than civil construction, and most demanding in the area of building maintenance.

She attributes poor performance in part to the low quality of locally produced building materials that "…may result in a tendency to over-design, or in a low quality of the finished project with high subsequent maintenance costs," (Wells 1986:58). To counter this tendency, she argues that: "…building materials industries need to be developed from locally available raw materials, local sources of energy, and using locally-produced items of plant and equipment," (Wells 1986:64). This is linked to a reduction in foreign exchange[32] and significantly for this research, to employment creation potential. This said, she warns that:

> Such a move must, however, be accompanied by an efficient programme of training in the new techniques of materials production, as well as in new craft and supervisory skills for the construction industry. (Wells 1986:65)

She acknowledges the problems associated with the establishment of suitable training programmes, and sees a more responsive role for designers through adapting plans to the available skills, with more standardized solutions to improve productivity and reduce time and cost overruns (Wells 1986:67).

[32] While this is less significant in South Africa, when read in conjunction with Stewart's analysis of dual-economy countries, this argument can be applied at a micro-scale in relation to under-developed rural areas and highly industrialized city based manufacturing.

One of the major barriers observed is the division of responsibility between design and production, with its attendant hierarchical structure, inherited from colonial times. This is identified as being most problematic in the "…isolation of the professionals from technical developments" with "their outlook, knowledge and experience of the construction process … closely related to the conditions prevailing in industrialized countries," (Wells 1986:68). In relation to the hierarchical and sequential structure of the industry, she notes that "by the time that the design complete with the engineer's contribution has reached the builder there is no opportunity for the builder's knowledge to influence it. … As a result the incentive to experiment with new methods or materials is stifled," (Wells 1986:70). This "freezing of technological progress" is exacerbated through competitive tendering, as there is little chance for "the contractor's experience of production on one project to be used to obtain a better performance on the next," (Wells 1986:74).

She summarizes the chapter on "Barriers to Development" with the following:

> The poorest countries must seek to find new and innovative forms and institutions for a fundamental re-structuring of their construction industries, in order to release their productive potential. In such attempts, indigenous resources must clearly play a prominent role as much also, in the absence of a developed private sector, the government. (Wells 1986:76)

This is followed by a thorough analysis of the potential role of the State, through multiple contracts, the early involvement of the contractor, and negotiated rather than competitive tendering. She sees the potential for much closer links between design, construction and maintenance of public works as a way of creating a learning curve, with a ripple effect into the private sector as skills and knowledge are enhanced. Thus the State becomes the driver of change, absorbing the initial risks, ensuring that social objectives are met, and providing greater accountability in the spending of public funds. In summary, she concludes that:

> It is therefore perhaps to the public sector that one should look for a closer integration of design and production, and for a more stable construction

> industry to emerge. For the public-sector is able, indeed as a major client it is obliged, to take a longer-term and more comprehensive view of the construction process as a whole. (Wells 1986:93)

Wells draws a number of parallels with reports published on the British construction industry dating back to the Banwell Report of 1964[33]. It is disturbing to observe that the criticisms have not been addressed substantially in the interim, in either the industrialized or the developing world. Only recently has there been a real attempt to bring about change in the UK and its ex-colonies that share the structure and characteristics of its construction sector (see 3.4.4 below).

Wells' prescription for redressing the problems of the industry, primarily through the State, shows a deep understanding of the dynamics of the situation. However, the problem of prejudice and conservatism in the professional fields is not substantially addressed. This is particularly of concern where there is severe shortage of these higher-level skills, and where government agencies find it difficult to attract quality staff through negative perceptions of working for the State that emanate from the education of these professionals. Thus, the role-players with the most influence at all stages of the decision-making process are fundamentally resistant to change, especially where it would lead to more modest buildings, in their design and the project cost.

3.2 CONSTRUCTION MATERIALS

The wide range of choices open to the building designer suggests that the one area in which the employment quotient of the building cost can be most significantly determined is through the choice of materials and the methods of their manufacture. This has the potential for a ripple effect through the whole

[33] This widely quoted report entitled *"The Placing and Management of Contracts for Building and Civil Engineering Work"* offers a fundamental challenge to the building industry, especially to professionals. However the very characteristics criticized in 1964 are still perpetuated through the Royal Institute of British Architects accreditation reviews of Schools of Architecture in the less-developed parts of the Anglophone world.

design and production process, providing this is conscientiously pursued. There is a wealth of literature in both published and less well-known sources on materials for the developing world, from which selected examples are chosen here.

3.2.1 International literature

Spence and Cook's *Building Materials in Developing Countries* (1983) provides a compendium that takes the reader through the manufacture and construction processes of a number of materials that have potential for increased labour-intensiveness. While not restricted to materials of local manufacture, this is clearly the bias of the book, stemming from the principle that:

> …the choice of technology will…be made as a balance between economic factors and other less quantifiable aspects of alternative techniques, in order to achieve the most satisfactory overall result. (Spence and Cook 1983:1)

The authors promote intermediate (or 'alternative') technology, especially where it improves on the inefficiency and low productivity of traditional methods, while avoiding the high capital costs, infrastructure and skills requirements of high technology. They identify the characteristics of 'appropriate' technology as:

- cheap to establish;
- small scale, needing less complex organization, simpler technology, shorter supply and distribution networks, and less fuel or power requirements;
- simple production methods, including locally manufactured equipment;
- local materials.

As has been the experience in civil engineering, the authors appreciate the need for introduction or improvement of simple equipment which, while making the technology less labour-intensive in the initial stages, substantially increases productivity for small capital outlay. This leads to the fundamental principle described as follows:

> …it is not labour-intensiveness but efficient and economic use of labour at low levels of capital which should be seen as a characteristic of intermediate technologies (Spence and Cook 1983:8).[34]

Three approaches are seen as effective: in rural areas through improving efficiency of traditional methods; in urban locations through adapting high technology to reduce cost, scale of production and complexity; and the third through blending traditional and industrialized systems, where a small input of a high-technology product serves to make a great difference in performance, as is the situation with soil stabilization. In all of these, 'modern scientific knowledge' is used primarily in relation to properties of materials, combustion and heat transfer.

The authors go beyond consideration of the purely technical aspects, in identifying the role of organizational improvement:

> …in such areas as production planning and control, labour management and financial control. …in many cases [intermediate technologies] can be shown to be as efficient as high technologies. (Spence and Cook 1983:9)

The initial chapters that establish the theoretical framework are followed by investigations into a range of materials that exemplify the approaches described above. The value lies mainly in giving direction to the designer or field worker for areas of more detailed investigation. For example, in the section on roofing (Spence and Cook 1983:Ch11), problems and factors are clearly identified and some interesting approaches are discussed, but no entirely satisfactory solutions or direction is given. This provides an important focus to the present thesis.

The final chapters of their book return to the broader context of the choice of materials and their associated technology, namely economic, social and institutional aspects. Of particular importance to the present study is their contention that:

---

[34] This is consistent with McCutcheon's work, see Chapter 4.1.1 below.

> All the industries in the small-scale and traditional sector create much more employment (mostly by a factor of ten or more), than do those in the modern industrial sector. (Spence and Cook 1983:296)

However, this should be read with reference to the ILO's *World Employment Report of 2004-2005*, in that the low productivity of this sector does not translate into a tenfold increase in wages.

Two other economic aspects that relate directly to the current research are the use of shadow pricing to evaluate the social costs and benefits of choice of technology. This is of particular significance where employment-intensive methods are contemplated, especially in relation to public works where the State has the option of deploying expenditure on productive jobs instead of on social services. The second issue is that of energy consumption, lifecycle consumption and maintenance. This usually weighs against traditional processes, but through their adaptation, low-grade energy sources and low consumption can be achieved through:

- more energy efficient manufacturing techniques;
- switching to less energy intensive processes;
- using recycling; and
- using less materials through reducing waste and through engineering the efficiency of materials.

These precepts go to the intellectual heart of Spence and Cook's book (and to the appropriate technology movement in general), in seeking solutions that synthesize the best of first and third world practice for any particular solution. While they serve only as guidelines, they deserve attention as fundamental decision tools.

A number of pertinent concerns are raised in the final chapter on institutional and social aspects of technological innovation and choice. These include:

- opinions and prejudices of end users and communities about the type of materials;

- institutional factors including building regulations, capacity of the construction industry, and education of builders and professionals;
- high technology methods of organization; and
- dissemination of results of laboratory research and field studies (Spence and Cook 1983:305-311).

These points are of particular significance to the present study, as they stress the need for integration of various factors when new or unfamiliar technology is introduced. The book as a whole, while not specifically directed at employment creation, has this as an undercurrent, and nevertheless provides important technical information that facilitates an understanding of the implications of new and adapted methods.

3.2.2 Decentralized manufacture

Read in conjunction with Spence and Cook, there is a wealth of more specialized information, much emanating directly from the major groups promoting intermediate technology. Norton's *Building with Earth: A Handbook* (1986) and Coburn, Dudley and Spence's *Gypsum Plaster: Its manufacture and use* (1989) were commissioned by the Intermediate Technology Development Group (ITDG).[35] These are comprehensive handbooks that provide the theoretical and practical guidelines for the use of these materials and for setting up small manufacturing plants. The focus on local industrial development is of particular relevance to the study area, in that one of the ways in which employment creation initiatives can be sustained is through setting up networks of manufacturing and construction entities, with skills development that is orientated towards particular techniques. In this way, the capital outlay for both plant and skills development can be amortized over numerous projects beyond the initial pilot.

Coburn explains the focus on small industry in the IDTG handbooks:

[35] The IDTG now operates as Practical Action, the focus of which appears to have shifted to specific field applications and away from the production of handbooks as described here.

In the building materials industries, studies have shown that in developing countries small-scale production units using local raw materials for local use offer a number of significant advantages:

- The smaller and less stringent raw materials requirements permit small plants to be established in locations unsuitable for large-scale production.
- Smaller-scale production plants can utilize a variety of locally obtainable, often low-grade, fuels.
- Smaller-scale production depends less on purchased energy and more on manual labour than large-scale production.
- Capital costs per unit of output are generally lower for smaller-scale production than for the larger scale.
- Installation, repair and maintenance of small-scale plants can be carried out locally without imported skills, parts or equipment. (Coburn et al 1989:33)

While these manuals give sound practical advice, they are biased towards traditional methods despite the input of higher levels of technology such as laboratory testing. To some extent this is justified by the economics – initial startup and running costs could be the significant factor in whether a change in technology can take place at all. However, the work of the intermediate technology group seems to be more orientated towards its acknowledgement of the constraints of the developing world rather than the opportunities offered by the knowledge derived from high technology environments. Thus, the field worker appears to be the driver of the technological adaptation process, which thereby can move forward only in very small increments.

Associated with these manuals on particular materials are ‘technical briefs’ that look at building types. IDTG’s *School Buildings in Developing Countries* (no date) is one of the better publications of this genre. Two aspects acknowledged in this work that are significant to the present study are the need for a higher level of quality and greater technical input for larger span roofs, electrical reticulation and

possibly plumbing. This work argues that community involvement in the construction process should be rewarded, but implies the need for more sophisticated technical and managerial skills than would be needed for low-cost housing if undertaken through the 'self-help' route. It is assumed that this would be introduced through an outside agency that would have to play a significant role in the on-site implementation.

Many of the recommendations, while always conscious of the cost to the final project, are generally adaptations of conventional practice: a stripped-down version of discredited colonial prototypes. Certainly, the level of rigorous investigation found in the works dedicated to materials is not present in this publication. Moreover, in contrast with the work by the ITDG on materials, there is far less evaluation of the energy efficiency, durability and productivity of labour in the recommendations presented. Where its value lies is in providing a check-list of parameters that relate universally to the building type in question, and specifically to tropical climates.[36]

However, it is the contention of this thesis that 'intermediate' technology, as presented by these and other authors, is insufficient to meet the needs of developing countries. Instead, re-engineering is needed that surpasses the highly industrialized countries in terms of design, use of materials, energy efficiency and management to maximize the scarce resources.

3.2.3 South African adaptation and innovation in materials

Two important institutions in South Africa provide the bulk of work relating to the development of materials: the Council for Scientific and Industrial Research (CSIR) and Agrément South Africa, the standards accreditation body. In contrast with the materials research of the Intermediate Technology Development Group, these South African institutes have tended to focus on higher technology.

[36] In this respect there are far more weighty publications, the most authoritative being the "Manual of Tropical Housing and Building," (Koenigsberger et al 1973).

The CSIR was recently commissioned by the national Department of Housing to investigate environmentally appropriate solutions to inform the national housing programme. This work, entitled *Feasibility Study into the Development of a Mechanism to Support Alternative Technologies and Indigenous knowledge Systems in a Rural Context* (CSIR 2006) was intended to support the Department's 'Breaking New Ground' strategy. While the focus of this CSIR study is on low-income housing, it relates low-energy principles to cost benefits for the capital expenditure on new building and for lifecycle energy consumption that can be applied to all building types. Moreover, it promotes the use of local materials, skills and labour; reducing fuel costs for transport and on-site machinery; and creating climatically comfortable buildings.

The feasibility study pays considerable attention to materials and techniques used in traditional building. Earth technology, as adapted to greater efficiency by the Intermediate Technology Group, CRATerre (France) and Auroville Earth Institute (India), among a number of environmental building groups, is given special attention because of its climatic performance, low processing requirements and ubiquitous use in traditional building in the Southern African region.

By contrast, the publications of Agrément South Africa tend to reflect much higher technology innovation. This is the institution that assesses new products for compliance with the National Building Regulations 'deemed to satisfy' rating. A survey of accredited materials and systems shows a preponderance of 'system building' elements, manufactured off-site and constructed through simplified 'clip-together' methods. The more appropriate to the present study are small-scale elements, where the innovation is in the material composition (often using a small volume of a high-technology ingredient), the method of production (eg hydraulic press), or the particular profile to facilitate accurate building by low-skilled site workers.

The value of the Agrément board lies in its using internationally recognised methods of testing and rating the various systems and materials that are submitted to it by the manufacturers. However, only technical evaluation is undertaken, with no indication of the environmental or socio-economic impact, so decision-makers have to look elsewhere for this information. Moreover, the manufacturers presenting products are concerned primarily with the marketing opportunities for their products, and for the most part see their products as substitutes for conventional materials, competitive through cost, speed of construction or built-in quality mechanisms.

3.3 LOW-COST HOUSING

Most of the literature on low-cost building focuses on housing, with its specific constraints and opportunities relating in particular to the debate around government provision and user self-help. The more general literature in this regard has a long history, dating formally from the 1930s with Crane's analysis of self-built housing as a mechanism for allowing poor households to acquire a reasonable level of shelter (Harris 1998:iv). Self-help has subsequently become a central theme in the literature on low-income housing, with its proponents stressing the long-term success of such a course of action with State support or tolerance, and the affordability of the process for both beneficiary and the State (Turner and Fichter 1972:79).

Moavenzadeh (Rodwin 1987:90-109) provides an overview of the interrelationships between the building sector and low-income housing. He identifies the factors which contribute to the lack of success in the fostering of the building sector in developing countries as being: the fluctuating demand for skilled workers; the influence of inappropriately high standards and building regulations; the low level of management training; and problems of recognising informal sector builders. He also identifies the need for management training for small-scale suppliers.

There is a widely held assumption that job creation in building should be focused on mass housing, not least because of the considerable need for this building type. This thesis proposes that public buildings should spearhead the innovation that is needed to generate significant additional employment. To be able to understand the limitations of low-cost housing in relation to the objectives of the present research, some of the key theories and approaches to mass housing are discussed below.

3.3.1 Self-help housing

Significant supporters of self-help as an employment generator can be found in Rodwin (1987:44 and 291), who with Dwyer (1975:198) point out the inflexibility of public housing projects in contrast to the financial flexibility characterising self-help approaches. Countering this is the acknowledgement of the inefficiency of skills development and physical resources because self-help builders will often have to learn a multiplicity of tasks only for their own dwelling, with no further opportunity to use or develop them (Mathéy 1992:20-21 and Dwyer 1975:232). This criticism is particularly relevant where an entire community is involved in a self-help programme, creating a saturation of relatively undeveloped levels of skill, thereby reducing the sustainability of employment in building related activities. Other arguments against self-help approaches include problems surrounding the initial provision of services and the inevitability of low-density urban sprawl (Dwyer 1975:201-204).

These contrasting viewpoints have created a polarized attitude to low-income housing for decades, waged largely on political and ethical grounds. The proponents for self-help have generally been field workers and empiricists responding to the financial and cultural complexities of the problem, while the opponents tend to argue from a Marxist or neo-Marxist stance that the poorest in society should not be expected to bear the burden of relieving their own homelessness. Lea (Murison and Lea 1979:51-53) gives a concise analysis of this debate, highlighting the flaws in both positions and calling for more intensive

and broader research, which focuses on local diversity to develop a greater understanding of the dynamics of settlement processes.

Seldom explicitly stated, but alluded to by opponents, is that self-help does not create jobs, it merely occupies under or unemployed household members for the duration of the work. Skills are seldom substantially developed beyond the most basic requirements of individual project-specific tasks.

3.3.2 The Cuban 'brigades'

Mathéy's *Beyond Self-help Housing* (1992), is a collection of essays and case studies that examine some of the more progressive approaches to housing, including the relationship between the State and the end-users in the process. Mathéy's essay in this work provides insight into a way of overcoming the lack of efficiency and low productivity that generally characterises self-help forms of construction.

This variation on the self-help approach to housing provision, was developed in Cuba in the 1970s, where the labour was provided by *'microbrigades'*, employed people who were sponsored by their work colleagues to build houses for the whole work group. Two benefits derived immediately from this arrangement: that the house builders could become more proficient through building several units, thus becoming more productive and efficient, and they continued to earn a cash-income through the earnings of their colleagues remaining in conventional employment. On completion of the housing project, the builders could return to their former employment. In this scenario, the State played the role of facilitator, leaving the bulk of the physical labour to the co-operative, and thereby keeping the costs down and the units affordable to the end users.

For this model to be effective, unemployment had to be relatively low, as the *'microbrigades'* merely resolved a situation of under-employment, and only on a temporary basis until the project was completed. Moreover, the programme in its

first phase was open only to those already employed. The programme was revitalized in 1986, but under the banner of 'social *microbrigade*' to include a wider target group of beneficiaries including those outside formal employment. In this essay, two of the more significant criticisms of low-cost housing initiatives are addressed in a progressive manner, namely the role of the State as neither laissez-faire nor paternalistic, and the developing of skills to a level of efficiency that would compare with conventional practice in the formal construction sector.

3.3.3 Hassan Fathy and his followers

Fathy's *Architecture for the poor* (1973) has become a seminal work for architects in both the developing and the industrialized world as a demonstration of high design despite extremely limited resources. His work at New Gourna in Egypt, described in this publication, exemplifies an integrative approach: of housing, public buildings and infrastructure; materials research and production; skills training programmes both for construction and for other activities. Fathy presents his vision for a healthy decentralized community, displaced from their location over ancient Egyptian sites and thereby dissociated from their principal occupation of tomb robbing.

The book is written largely as a defence of his innovative approach in the face of conservatism and obstruction from Egyptian government officials, despite his having been given approval for his methods. Fathy's primary concern in the field of low-cost housing was that the conventional material of reinforced concrete was unaffordable for his clientele at New Gourna. In looking at traditional methods of building with unfired clay, he identified other advantages, especially in climatic performance, which outweighed the need for substantial routine maintenance of the buildings. By using materials that could be sourced almost exclusively from the site itself, far more could be built for the project budget, and the bulk of the project cost could be retained within the community. It is significant that the only substantial item of expenditure that flowed out of the community was fuel for the few pieces of machinery.

By reverting to techniques of construction that were 4000 year old, the need for machines was nominal, used by Fathy largely for transporting the sun-dried bricks from the drying yard to the individual building sites. Even so, that fuel cost formed a substantial part of the project as materials and labour were factored in at the low wage rates that prevailed in the area. Earth for the bricks was available from the site, allowing all the cost of this item, the primary material, to be directed to labour for quarrying and manufacture.

Fathy provides a wealth of information on all aspects of the project, from the sourcing of craftsmen with knowledge of the traditional methods, through to the training process to revive these for a new generation of builders. He also gives detailed information on cost and quantities, allowing a comprehensive reconstruction of the entire project (see Chapter 5 below). Two other aspects of his approach are of particular importance to the present study. The first resonates with the experiences of the World Bank and ILO studies into labour-intensive civil construction analysed in Chapter 4. This is the importance of a pilot phase, in Fathy's case to give the community a direct appreciation of the kind of architecture that he was proposing, but had the additional advantage of testing out a number of assumptions. The second was in focusing initially on the public buildings of the new village, because:

> …. I suspected that once there was a good number of dwelling houses up, the government would say, 'Thank you very much; that is very nice indeed,' would rush the peasants into the houses, and would cut off all further money for anything else… (Fathy 1973:68)

This has been a criticism of the South African Department of Housing's delivery of mass housing since the 1994 democratic elections, and one of the reasons that this study focuses on public buildings (Huchzermeyer 2001).

Fathy's book, along with the buildings he describes, has provided inspiration for generations of architects, especially those working in Islamic parts of the world. However, much of the appeal is in the formal qualities, rather than the

construction methods, approach to training and environmental considerations. The exception is the legacy carried by professionals who worked with Fathy, for example John Norton whose work in the Sahel and related publications on woodless construction show a more profound understanding of Fathy's contribution.

3.3.4 Low-cost housing as employment generator

The conflicts dominating the theory and practice of low-cost housing delivery essentially emanate from the limited resources. For this reason, employment in their construction becomes a pawn in the debate. On the one hand, the State in developing areas has invariably only been able to provide unaffordable dwellings because of an insistence on high building standards. This is contrasted with self-help and incremental building approaches which, while a better quality and size of dwelling may be the long-term result, has only been successful in households with a cash surplus. There are few examples of these modes of delivery in areas of high unemployment or where large numbers in a community are engaged in forms of subsistence. Hence, the poorest continue to live in slums and unadapted traditional dwellings. Three other aspects have direct importance to the present study, namely:

- That assets are not created, or have low resale potential;
- The risk and cost of innovation and skills development have to be absorbed by the end-users, hence a tendency to conservatism;
- Self-help and community built structures are invariably constructed with low levels of skills, resulting in an unproductive and inefficient scenario, low quality buildings requiring high maintenance, and lack of sustainability of the jobs created because of skills saturation.

3.3.5 Public building as precursor to housing

From the discussion above, a number of factors suggest that the re-engineering needed for the level of employment-intensiveness found in civil engineering programmes cannot be easily reconciled with other objectives relating to low-cost housing. The principal deterrents are: the risk of innovation, often translated into

resistance from the end users; the initial cost of technology transfer, including training; and that the examples that attempt to include employment creation as an objective tend to follow the self-help or community building format and, even where wages are paid, often result in a saturation of low-level skills. The heart of the debate on housing for the poor is succinctly stated by Turner (1972): “Who decides and who provides," centring on the role of the State and the demands placed on the users.

By shifting the introduction of innovation to the State in the construction of its own buildings, the risk and cost can be absorbed into the greater objectives of revitalizing the construction sector through integrated skills programmes that lead to sustainable wage earning job creation. Moreover, consumer resistance can be minimised where housing beneficiaries can see the physical results of the technology proposed, along with the State’s commitment to the innovations.

The re-engineering of the construction industry for labour-intensive construction is exemplified in the field of road building, as discussed in the next section. From this experience, theoretical principles and a sense of the technical and managerial adaptations can be derived for other forms of construction, thereby giving a valuable input to the present thesis. These principles are discussed in more detail in Chapter 4, as the foundation for their application to the field of building.

3.4 ‘LABOUR-INTENSIVE’ CIVIL CONSTRUCTION

In the civil engineering domain, the relationship between theory and application in labour-intensive construction is far more developed than it is in the building of superstructures (McCutcheon and Taylor Parkins 2001). Based on formal project management principles, tempered with techniques emanating from development projects, a clear body of knowledge has been developed. This set of principles and examples of their application are analysed in more detail in Chapter 4 below while the major works in the literature on the topic are discussed here.

Work by McCutcheon (1993) and IHE Delft on road design and construction in sub-Saharan countries highlights the need for site-specific attention to both the engineering design and the employment creation programme. Mkhize (1994) gives a valuable structure for contractor development in his analysis of infrastructure renewal within Soweto. From both of these sub-disciplines parallels may be drawn with the building industry, but there is little evidence of the engineering experience being adapted to this sector except where engineers have been the leaders of the professional team.

In the 1930s extensive road building and maintenance projects were undertaken in Germany (Vahrenkamp 2006) and the United States (Couch 2008) as means of alleviating unemployment while generating valuable infrastructure. In the decades that followed, the use of Public Works as a way of tempering unemployment fell into disrepute, invariably because the focus in this period was on poverty relief, so there was little focus on quality and efficiency of delivery of the infrastructure. This lack of rigor contributed to labour-intensive Public Works becoming discredited, exemplified by Keynes' somewhat cynical comment that the unemployed should be put to work digging holes and filling them again, and that other mechanisms should be used to alleviate poverty, while infrastructure was 'done properly', using machines (Keynes 1936:Ch16 part III).

Nevertheless, in the 1960s there was growing criticism of the highly mechanized methods used for new infrastructure in the developing world, as has been discussed with reference to the work of Wells. A funding crisis in Honduras was the catalyst for the World Bank (International Bank for Reconstruction and Development) in conjunction with the ILO to launch the three phased *Study of the Substitution of Labour and Equipment in Civil Construction*, the Completion Report for which was published in 1986, fifteen years after the programme's inception.

The most important conclusion of the study was that: "Labor-intensive work

methods are technically and financially feasible for certain types of work under certain conditions," (IBRD 1986:vi). This statement is broadened by the assertion that through improvement in labour productivity and efficiency of traditional techniques, many other activities could become competitive. The assertion of financial feasibility means that labour-intensive work can be competitive with other more mechanized methods of construction, and the socio-economic advantages are a pure benefit and not subsidized by the project or programme.

The report enumerates various principles relating to the "certain conditions" prescribed in their conclusion which are examined in detail in Chapter 4 below, including management, training, community involvement, conditions of employment, and project selection, design and specification. The technical aspects are presented rather briefly in the Completion Report, which gives greater emphasis to management and economics. Of particular value is the establishment of task and piece-work as the basis for managing labour-intensive work, presented here in tabular format for several countries in the study, thereby providing a baseline for new work. The report provides data on productivities of different types of equipment, but with the caveat that work studies should be carried out to determine values for local conditions.

Accompanying the discussion of the Kenyan Rural Access Roads Programme is an analysis of the economic cost using shadow prices for labour and machinery. This provides an important planning tool at the national level when contemplating major public works programmes, as it factors in the cost of unemployment and foreign exchange expenditure on machinery and fuel.

The most important aspect of this report is that it presents labour-intensive delivery of infrastructure as 'official policy' of both the World Bank and the ILO as the largest and most influential funding agencies of such work in the developing world. However, it is cautious in the type of work recommended for labour-intensive methods, namely low-volume rural roads and irrigation schemes,

including dams. These projects generally need small budgets as a proportion of a country's spending on infrastructure, thus locating labour-intensive effort outside the major economy, an aspect challenged in McCutcheon and Taylor Parkins (2003:3) discussed below.

Concurrent with the IBRD programme was the publication of Edmonds and Howe's *Roads and Resources: Appropriate Technology in Road Construction in Developing Countries* (1980). The book is a compilation of theory and practice with specific reference to the World Employment Programme of the ILO and its links to the Intermediate Technology Development Group. Important in this work is the emphasis given to the choice of technology at the planning stage (Edmonds and Howe 1980:22) to avoid the trap of making cost comparisons on the basis of completed projects that were equipment orientated, and not necessarily the most suited to the project needs. The importance of "sophisticated analytical techniques", impeccable programme administration and site organization to maximize productivity of the workforce is stressed (Edmonds and Howe 1980: 31-40). The book is an important milestone in the development of understanding of the principles and practice of employment-intensive construction in its pioneering sector of road building.

In the 1990s, the Development Bank of South Africa (DBSA) commissioned a series of publications that were intended to facilitate projects that "…enhance opportunities for employment and the development of skills and entrepreneurial abilities," (McCutcheon and Marshall 1996:iii). *Labour-Intensive Construction and Maintenance of Rural Roads: Guidelines for the Training of Road Builders* by McCutcheon and Marshall (1996) is a comprehensive manual for the training of the most significant player in the implementation of labour-intensive civil engineering works. Embedded in this publication is a demonstration of the sophistication and high level of management needed for this method of delivery of infrastructure if it is to match conventional methods in terms of cost, time and quality. An in-depth evaluation of this work shows the high level of engineering

that has taken place over the last three decades to ensure that activities on site are simplified to accommodate large groups of unskilled labourers. This said, the critical importance of the hands-on site supervisor, or road builder, cannot be underestimated, as the person who translates the technical and managerial decisions made at the highest level into the actual work carried out. Two other areas of significance that flow from this are that a larger proportion of the project cost can be directed to targeted labour through less input being needed from the professional team, and that the people who take on this important position have sustainable employment through their meticulous training.[37]

A companion volume in this series by the same authors, *Institution, Organisation and Management for Large-Scale, Employment-Intensive Road Construction and Maintenance Programmes* (McCutcheon and Marshall 1998), is a handbook for decision makers: politicians, funding agencies and professionals. Particular importance is given here to the involvement of local communities, especially in the pre-feasibility and inception phases of a programme. The value of these two handbooks lies in adapting the international body of knowledge and experience of employment-intensive construction to the South African context. As with the IBRD report discussed above, these works are orientated towards the construction of low-volume roads, but in many respects only minor modification is needed to apply them to more sophisticated projects.

The argument for the relatively easy adaptation for more sophisticated types of construction projects is given in *Employment and high-standard infrastructure* (McCutcheon and Taylor Parkins 2003). The central premise of this work is that, for unemployment and poverty of the magnitude found in South Africa to be addressed meaningfully, labour-intensive construction needs to be part of the major economy, and not just used for peripheral expenditure on minor rural works. Underlying this is the assertion that two of the main objectives of employment-intensive construction are:

[37] For a more detailed analysis, see McCutcheon and Fitchett (2005a).

> a technically sound (good quality), economically efficient product: equivalent to that achieved by conventional construction without jeopardising cost, time and quality; and a significant increase in the amount of employment generated per unit of expenditure." (McCutcheon and Taylor Parkins 2003:22)

The publication is the result of extensive technical, managerial, financial and economic research, testing through pilot studies and evaluation through practical implementation by the various contributors. Notable achievements documented are the research into improvements in traditional materials and techniques, and development of new ones. A method of project and programme evaluation is provided, building on work documented in Edmonds and Howe (1980), called Choice of Technique Analysis. This allows decision-makers to adjudicate the increasingly wide array of methods when committing large capital budgets for infrastructure expenditure.

Another milestone of the book is the publication of the technique of team balancing, a significant advance on the concept of task work promoted by the World Bank in the work discussed above (IBRD 1986). This has the potential for substantial increases in productivity, essential for employment-intensive methods to be competitive with machine-intensive in high-standard construction. The significance of this management technique is described thus:

> If a person tasked with creating a budget uses this analysis, based on experience, then he/she will be able to create a budget approximating to reality. An added advantage is that it generates a reproducible trail relating to the make-up of the budget and can be examined critically at a later stage, either for comparisons or to provide input for future contract budgeting. (Croswell and McCutcheon 2003:405)

This publication has become the standard reference work for professional engineers and public servants involved in South Africa's Expanded Public Works Programme, an ambitious initiative at addressing one of the core causes of

unemployment, namely the lack of marketable skills in construction, among other strategic sectors.

The works discussed in this section show that considerable knowledge and experience of labour-intensive construction has been generated in the civil engineering sector, especially in the area of road building and maintenance. These principles are open to adaptation for a number of other applications, but a similar process of refinement and 're-engineering' would have to take place to achieve competitiveness.

3.5 NEW DIRECTIONS

3.5.1 Innovative public buildings

Throughout the history of architecture, until 1900, public buildings have been the focus of innovation and have expressed the highpoint of design. This importance was eroded in the 20th Century with a shift towards private sector commissions. In some developing countries, the distinction between public and private buildings is architecturally less distinct, and it is possibly for this reason that innovation in small public buildings can be found in these regions.

An important showcase for these is the annual Aga Khan Award that focuses on works by Islamic architects and/or designed for Islamic clients. Many of these are directly inspired by the work of Hassan Fathy, recipient of the highest award of this body. The annual publications of the awards give tantalizing information, suggestive of the range of concerns and objectives of the present study, but with insufficient commentary to analyse them fully. This characterizes many of the architectural publications that make passing reference to employment creation, skills development and use of local resources.

What can be inferred from the published material is that many of these public buildings are enhancements of the traditional methods and materials used in a

particular area. For this reason, the examples tend to have limited application outside their own region, and the lack of information makes it difficult to extrapolate beyond this.

3.5.2 Innovative structural systems

Various experiments have been undertaken in the last few decades into structural materials for low-cost building. Most of this work has related to housing, but in several cases, the opportunity of extending this research to allow for the somewhat larger spans required by public buildings has been acknowledged. In the Far East and parts of South America, lightweight timber and other organic fibres have been used in combination with industrialized materials to improve structural stability, resistance to rain and insects, and to reduce flammability. However, the applications of this work are restricted to areas of high rainfall, where such plant materials are abundant. This research has therefore turned to innovation and revival of masonry structures, and in particular the work of Guastavino and Eladio Dieste.

The work of Rafael Guastavino and his son is discussed in the context of the long tradition of timbrel vaulting by Huerta in *Essays on the History of Mechanics* (Becchi, Corradi, Foce and Pedemonte 2003). This system of construction appears to have its origins in 14th Century Spain, with the earliest known comprehensive description dating to the treatise of Fray Lorenzo de San Nicolás of 1647 (Huerta 2003:91). It was taken to France in the early 18th Century, where it was the subject of conflicting theories on its structural properties. One school of thought, led by Comte d'Espie, argued that the timbrel vault generates no outward thrust because the strength of the high quality mortar makes it "impossible to form cracks and divide itself," (Huerta 2003:94). The opposing view was stated by Ventura Rodriguez in 1776, whose observations of cracking and displacements demonstrated that these vaults do indeed generate thrust, although of much less magnitude than conventional vaults because of their smaller weight (Huerta 2003:97).

Timbrel vaulting was taken to the United States by Guastavino who built several important public buildings (Fig 6-14) including the Boston City Library. Guastavino and his son performed numerous experiments to demonstrate the exceptional strength of these vaults as a way of promoting their Guastavino Fireproof Construction Company. Several photographs of these tests remain in the Avery Library, Columbia University, including one of a barrel vault of 3m span carrying a load of over 50 000kg.

Huerta discusses Guastavino's two books[38] and his articles on timbrel vaulting in which he attributes the efficiency of the system to the 'cohesive' property that results from using two or more layers of tiles where the vertical joints are staggered. Guastavino contrasts this with conventional mechanical arches with voussoirs, with the following advantages:

- the vertical joints are protected from cracking by the overlapping of joints;
- there are fewer vertical joints;
- there is capacity to resist bending moments (Huerta 2003:104).

While Huerta's principal interest in this essay lies in the competing theories that have characterised an understanding of timbrel vaulting, the value to the present study lies in the discussion of the efficiency of this method of construction. It allows the designer to use far less material than for conventional vaulting, and the dictates of purely compressive forms permit the use of inexpensive materials that only need to resist the very low forces generated by the low weight of the thin vaults. The use of tiles and gypsum mortar that are self-supporting under construction allows one to dispense with formwork and shuttering, indicating the potential for employment-intensive construction as defined in Chapter 2 above. Huerta draws attention to the younger Guastavino's method of determining stability and equilibrium of his designs (Huerta 2003:114-120), a technique that would be taken up by researchers more than a century later and developed into a

[38] Guastavino's *Essay on the Theory and History of Cohesive Construction, applied especially to the timbrel arch* was published in 1893, and his *Prolegomenos on the use of masonry in modern constructions* in 1904.

three-dimensional method of applying thrust-line analysis (Block and Ochsendorf 2008). The innovative research carried out by Ochsendorf and his postgraduate students at MIT into timbrel and other thin-shell structures are discussed in more detail in Chapter 6.

Ochsendorf makes important links between the work of Dieste and the Guastavino family in his essay, "Eladio Dieste as Structural Artist" in *Eladio Dieste: Innovation in Structural Art* (Anderson 2004). He traces the structural legacy of both to the Catalonian tradition of timbrel vaulting, in Dieste's case through collaboration with the Spanish architect, Antoní Bonet.[39]

Pedreschi's *Eladio Dieste* (2000) is one of a series of monographs in the Telford series: 'The Engineer's contribution to Contemporary Architecture'. As the series title suggests, the focus of this work is on the architectural aspects of this engineer's work, and therefore makes only passing reference to the themes of the present study. This said, the underlying principles of Dieste's work have two important points of commonality:

- the use of indigenous materials to reduce the reliance on and cost of imports into Uruguay (Pedreschi 2000:13); and
- the use of sophisticated engineering to allow for simplicity of site operations, thus allowing the bulk of the construction work to be undertaken by unskilled labour (in Dieste's case, often farm workers) under the supervision of highly trained 'captains' (Pedreschi 2000:19).

Dieste's primary material is hand-made brick, used to create reinforced shell and folded plate structures, forms that have been predominantly of reinforced concrete in the twentieth century.[40] Two reasons prompted Dieste to move away from concrete: the complicated and expensive formwork required in the context of Uruguay's under-developed timber industry; and the versatility and control

[39] Bonet's influence on le Corbusier can be seen in the latter's use of 'catalan' vaults in Maisons Jaoul and Villa Sarabhai (Boesiger 1966:115-131; 208-221)
[40] The work of Felix Candela in Mexico is of significance in this respect (Faber 1963).

offered by the use of small brick components. In the course of his career, Dieste discovered other advantages in working with brick: the more rapid hardening of the grout through moisture absorption allowed for quicker striking of formwork; and the performance of the vault could be tested before being subjected to the full structural load.

In contrast with the work of Fathy, Dieste brings a twentieth century technical understanding to the traditional bulky masonry forms to create more economical and efficient solutions (Pedreschi 2000:21-22). Through his mathematical modelling of form, Dieste dispenses with ribs, heavy edge beams, gables and tympanums, allowing the pure geometry of the structure to be expressed, while at the same time simplifying the construction process and eliminating superfluous material.

Pedreschi provides a commendable overview of Dieste's work, from which one can extrapolate more detailed analyses of the process of construction as the basis for future development. Where Dieste's work is limited, though, is in the continued reliance on formwork and reinforcing, both of which add to the final cost of the building in overheads.

The work of the Guastavino family and Dieste provide considerable advances on traditional vault building such as used by Fathy. Thin-shell structures are far more efficient in the use of materials for both the vaulting and the supporting structure. While the ratio of labour to material costs will tend to remain the same, a more cost effective structure is the result, and generally with lower maintenance costs over the life of the building. This work is discussed in more detail in Chapter 6.3.2 which examines simpler alternatives to Dieste's designs to suit the needs of the South African context.

3.5.3 New approaches to management

All of the sources discussed above that have considered the application of employment-intensive methods have stressed, in varying degrees, the importance of management in ensuring competitiveness, efficiency and productivity. Apart from these practical issues, inadequate management of large numbers of people can have far more serious consequences than poor management of machinery. The importance of appropriate management is even more critical in building programmes than for civil engineering works because of the multiplicity of small-value activities, the interrelatedness of tasks and the abundance of choice of materials, detailing and method of construction.

As has been identified by Wells (see 3.1.6 above) the building industry in Anglophone countries has been compromised by the separation of design and construction, a problem that was identified as far back as 1964 in the UK with the Banwell Report. This has only recently been addressed directly, through the *Building Down Barriers* project in Britain. The authors explain the background to the project:

> For at least the last 70 years, there have been numerous reviews of the construction industry criticising the fragmentation, the adversarial attitudes, the inefficient use of labour, the wastage of materials, the high cost of construction and the functional inefficiencies of buildings. Despite this, the entrenched dysfunctional nature of the industry remains little changed. (Holti 1999:1)

The principle that governs the new approach is termed Supply Chain Management, and is modeled on best practice in manufacturing and service industries, underpinned by quality management concepts and techniques. The driver in the process is termed the ‘prime contractor’ and may be a conventional contractor, management contractor or professional entity. This provides a single point of contact and responsibility to the client, in a far more integrated delivery process than even ‘design-and-build’ or ‘turnkey’ projects of the recent past. In essence:

> Prime contracting replaces short-term, contractually driven single project adversarial inter-company relationships with long-term, multiple project relationships based on trust and cooperation. These long-term, strategic supply chain alliances incorporate continuous improvement targets to reduce costs and enhance quality, and focus on the through-life cost and functional performance of buildings. (Holti 1999:2)

The process is innovative from inception, where the client provides a 'strategic brief' outlining the business need and performance requirements, but entrusts the prime contractor with the detailed interpretation of these into a building project using value management techniques. This results in the formulation of an "initial guaranteed maximum price (GMP) based on the optimum through-life cost," (Holti 1999:4) as well as a "Proof of Compliance Plan" from which the client can validate the model of initial construction costs and cost-in-use.

The implementation of the design and construction takes place through the prime contractor forming long-term strategic alliances with specialists, suppliers, and subcontractors, in contrast to the competitive tendering that characterizes conventional procurement. The authors of this handbook explain that:

> Supply chain management of this kind ensures that all construction activities are 'right first time', that the construction solutions have optimum through-life cost characteristics, that labour is used to the maximum efficiency, and that there is minimum wastage of material. (Holti 1999:6)

Of the seven principle advantages listed, the last three have particular relevance in the context of small contractor and supplier development in South Africa, namely:

> Involve the supply chain in design and cost development – using target costing, value management and risk management
> Develop Continuous Improvement within the supply chain
> Promote collaboration through leadership, facilitation, training and incentives. (Holti 1999:7)

In this way, the prime contractor has direct financial incentive to support and nurture the suppliers and subcontractors that are part of the supply chain, sharing not just the profit, but knowledge, expertise, purchasing power and risk. The long-term partnerships envisaged in this system, moreover, can be the catalyst to improving the survival rate of the smaller players. Referring back to Wells' perception of the potential role for the State in developing countries, it is particularly noteworthy that the 'Building Down Barriers' project was driven by the government of the UK, specifically to be pioneered through the construction of public buildings.

Despite the innovation that characterises this initiative, there are still hangovers from the very system that it seeks to criticise and remedy. Most obvious is the retention of the sequential procedural route (PROCAP), criticised in the past for creating delays and lack of continuity between the Stages of Work. Moreover, the conventional separation of design and construction – the very basis of the criticism giving rise to this new proposal – now shifts to a separation of client and implementation team. The proponents would challenge this assertion, especially because of the importance given to the post-occupancy review, but this relationship essentially devolves into the 'contract' embodied in the "Proof of Compliance Plan".

Cain provides compelling argument for the adoption of the 'supply chain' model by contractors, professionals and clients in *Performance Management for Construction Profitability* (2004a) and *Profitable partnering for lean construction* (2004b). This argument hinges on the evidence that "at least 30% of the capital cost of construction is consumed by unnecessary costs," (Cain 2004a:16) of which the largest component is labour inefficiency, at 40% of the total in a conventionally constructed project. As one of the lead consultants in the 'Building Down Barriers' initiative, his evidence is taken from these pilot projects. The central element of his works is that all parties involved in construction should move away from a consideration of cost, especially capital expenditure, and on to

value and lifecycle costs. This resonates with much of the work on labour-intensive engineering, with the emphasis on maintenance and residual values (Phillips 1994; McCutcheon and Taylor Parkins 2003).

In essence these books are manuals for the implementation of Supply Chain Management and delivery of construction projects. However, some valuable insights into the principles and motivation are given. One such relates to the commitment to change by the UK government and major clients:

> By the end of 2004 20% of construction projects by value should be undertaken by integrated teams and supply chains; and, 20% of client activity by values should embrace the principles of the Clients' Charter. by the end of 2007 both these figures should rise to 50%. (Cain 2004a:124)

Another relates to performance improvement that is "intended to drive out unnecessary costs, drive up whole-life quality and drive down whole-life costs," (Cain 2004a:160). These savings, through the 'initial guaranteed maximum price' concept, are shared among all the parties of the supply chain according to their performance, while the client benefits through a more efficient and better cost-in-use facility. Thus the emphasis on quality is given financial incentive for all members of the team, especially in the area singled out as generating the most waste: reworking. "Right first time" is the rallying cry of this approach.

This emphasis on productivity emanates from studies undertaken by the UK Construction Best Practice Programme working with the British Quality Foundation Construction group and BQC Performance Management Ltd. Cain provides lists of avoidable delays and disruptions (Cain 2004a:116) followed by a list of methods to effect improvements (Cain 2004a:118), both of which are based on BSRIA documents. While the data for these emanate from a highly developed construction industry, they resonate with problems found in developing countries, with even more severe impact as one moves down the scale to smaller and less formal operations.

The processes and recommendations that flow from these British documents would need careful consideration and tailoring to implement effectively in South Africa. The direction provided in them gives an important starting point for a radical review of the management approach that prevails. This could lead to a far more productive environment, especially significant in the scenario of employment-intensive construction.

This said, the one area where the UK model would need modification in the early years of implementing such change is in the role of the client, especially where this is a government body. The massive technical and managerial skills void, especially in relation to employment-intensive construction, indicates that the 'client' needs to play a more assertive and integrated part. Experience from the civil engineering sector points to this being of critical importance in the pre-feasibility and pilot stages of a programme, as it would for any initial building in a particular locality. What is indicated is that the State can be the driver of a new management process, but through skills transfer, can incrementally withdraw to the distanced position visualised in the UK model. The ideal would be for the 'catalyst' building posited in this research to be the nursery for such skills, leading to a fully functional, experienced and sustainable 'supply chain' of professionals, contractors, manufacturers and suppliers.

3.6 CONCLUSIONS

South Africa shares many of the problems of the developing world, however its unique history, as demonstrated by Feinstein and Iliffe, demands particular solutions. Central to this is what has been termed the 'dual economy' characterized by a large disparity in wealth which, unlike other sub-Saharan countries, has a fully developed 'first economy'. Unemployment and poverty have to be addressed within this context, specifically in that even the most remote rural areas are linked to a cash economy. These areas, experiencing the highest levels of poverty and unemployment are also those of greatest backlogs of infrastructure provision. While volunteerism and self-help approaches can be

justified either where one or more household members are earning an income, or where a traditional subsistence is still viable, this cannot be supported in the case of South Africa, urban or rural. Thus, in addressing structural unemployment, people need to be equipped with marketable skills – skills for which there is a real need, and which can be decently remunerated.

In the construction sector, the duality of the economy is reflected in the size of the informal component, made up predominantly of people who have not had access to recognized training. Even in the formal sector, artisan training has declined to the extent that in South Africa it has been replaced by other forms of vocational training. Managerial skills amongst many of these participants in the industry have been learned entirely through observation, with some key areas of knowledge being absent. Wells criticizes the orientation of professionals towards a ‘first world’ scenario, exacerbating the separation between design and construction. This serves to make it even more difficult for emerging contractors to enter the formal sector, and results in inefficient and inappropriate designs and specifications that do not acknowledge the prevailing skills base. The innovations in management described by Cain and others, spearheaded by the public sector in the UK, indicate opportunities in the developing world where the advantages of unifying the industry could have even more positive consequences than those for which Supply Chain Management was developed.

The extensive research and field application of labour-intensive methods of construction used in civil engineering programmes forms an important benchmark for employment generating strategies in other sectors. The results of this work in various African countries show that if construction is to play a significant role in addressing poverty, these initiatives need to be competitive with other modes of delivery, achievable only through high productivity of the expanded workforce coupled with the management interventions necessary to support individual output. Thus, for employment-intensive construction to be viable, skills need to be developed across the whole spectrum, from manual

labourer through all the tiers of management, to the level of professionals and commissioning bodies.

A large number of building projects in South Africa have recently been undertaken with the ostensible objective of employment creation. However, this objective is not measured (or measurable) in that professionals and commissioning bodies have no method of evaluating the number of jobs created, ratios of wages to project cost, or number of labour hours. By contrast, Fathy provides a detailed account of the labour content of his projects, specifically at New Gourna, Egypt. Both Fathy and Dieste exemplify a rigorous approach to employment creation in their buildings that goes beyond merely the number of people on site. The high quality of their designs can be attributed in large measure to their appreciation of the potential offered through manual labour. They have each shown that for employment to be maximised, the design and specification needs to be regionally specific to accommodate local skills and materials, as well as being environmentally appropriate to reduce lifecycle costs and high levels of expensive services. However, this thesis challenges Fathy's need for high levels of maintenance, and Dieste's dependence on extensive formwork and technically demanding reinforcing.

The Intermediate Technology Group and others sharing similar views gives many clues to the solution of the interrelated challenges of poverty alleviation through employment and the production of quality construction works. Literature emanating from these sources provides theoretical weight as well as practical information in the implementation of new approaches. Read in conjunction with the processes implemented by the ILO, this can be viewed as the first step towards a more employment-intensive approach to building.

In summary, a number of clues are offered in the literature for the development of employment-intensive building, but the assumption that building is automatically labour-intensive must be dispelled to be able to move forward. The experience of

civil engineering has shown the extent to which re-engineering is necessary, drawing from ‘best practice’ in the choice of project type, design, specification, procurement methods, management, education and training. Only with this rigour can employment-intensive construction compete with other methods of delivery in terms of cost, time and quality, thereby assuring the credibility of this method of production in the long term.

In the following chapter, the principles of labour-intensive construction in civil engineering works are studied, following an introductory section on the history of the ILO’s seminal research and field work in *The Study of the Substitution of Labour and Equipment in Civil Construction* (IBRD 1986). Following this overview, various subsequent studies and techniques are examined, mostly in the South African context. This chapter concludes with a discussion of the technical, managerial and legislative innovations that underpin the delivery of the South African Expanded Public Works Programme. This has direct bearing on the present thesis, in that one of the Programme’s objectives is to expand the scope into the sub-sector of building construction and maintenance.

4 PRINCIPLES OF EMPLOYMENT-INTENSIVE CONSTRUCTION

4.1 OVERVIEW

This chapter charts the process that has taken place in civil engineering which has culminated in the establishment of employment-intensive construction as a domain in its own right. The World Bank/ILO study that initiated this as a viable mode of delivery of infrastructure forms the background to this chapter. Its central principles are discussed in an examination of materials and techniques, as are time and cost management systems that have been evolved to address efficiency.

Successful programmes share a number of characteristics that can be extrapolated to other construction sectors. Their application is demonstrated in a selection of case studies from the sub-Saharan region. The experience generated from these and other programmes has led to the 2004 inauguration of the Expanded Public Works Programme in South Africa, one of the most ambitious initiatives of its kind in the world. From this discussion, a number of principles are identified for consideration in the formulation of an equivalent approach for building construction.

4.1.1 Definition

Labour-intensive construction is defined in the Penguin Dictionary of Economics (1972) as follows:

> *Labour-intensive*[41] is a phrase in economics to describe an operation in which proportionately more labour is used than other factors of production.

[41] 'Labour-intensive' is used throughout this Chapter as the term most prevalent in the field of civil engineering, used in all recent South African policy documents and legislation. McCutcheon explains the provenance and the debate surrounding the term:

> "There has been further debate as to the terms 'labour-intensive' and 'labour-based'. Some authorities prefer to use 'labour-based' as opposed to 'labour-intensive'. They hold that labour-intensive implies that the work is done entirely by hand whereas labour-based allows the use of equipment where necessary. … As far as the authors are concerned, the essential difference is not between these two terms but between both of them and 'labour-**ex**tensive' where the emphasis is upon the size of the labour force with scant concern for either the product or productivity (as occurs during relief projects)," (McCutcheon, et al 2006:4, their emphasis).

McCutcheon expands on this definition:

> Labour-intensive[42] construction may be defined as the economically efficient employment of as great a proportion of labour as is technically feasible – ideally throughout the construction process, including the production of materials - to produce as high a standard of construction as demanded by the specification and allowed by the funding available; labour-intensive construction results in the generation of a significant increase in employment opportunities per unit of expenditure by comparison with conventionally capital-intensive methods. (McCutcheon 1995:332)

In the field of construction, the measure of labour-intensity has variously been the number of man-hours generated (especially for unskilled or targeted labour) and the ratio of direct project costs allocated to labour. In the latter case, the labour intensity focuses on the method of production, with quality, time and cost remaining as constants, thereby allowing evaluation of different combinations of labour and equipment. This stands in contrast to the uncritical attention to the number of jobs or person-hours of labour generated, irrespective of the productivity or quality of the infrastructure produced.

Several other terms and concepts in the above definition are the subject of more detailed study in this chapter, namely:

- economic efficiency;
- technical feasibility;
- standards and specifications.

McCutcheon (2003:20) emphasizes that labour-intensive construction produces the same (or better) quality of product, for the same cost and without taking longer than conventional machine-intensive methods. In the same context, he stresses that while an increase in expenditure will produce a *pro rata* increase in

[42] In later writings, McCutcheon prefers the term 'employment-intensive' to indicate the level of training, sophistication of management and quality of engineering needed to achieve the objectives embodied in his definition (McCutcheon, in McCutcheon and Taylor Parkins 2003:21).

employment if conventional methods are used, labour-intensive methods can generate three to seven times the number of jobs for the same cost. An example of the increases anticipated through changing to labour-intensive methods is indicated in Table 4-1.

Sub-Sector	Current Conventional Construction (%)	Employment-Intensive Construction (%)	E-I Potential Increase in Labour Expenditure (%)
Projects with low capacity building requirements	60-80	60-80	0-15
Low-cost housing	25-35	30-40	0-33
Social buildings	20-30	25-35	0-40
Water reticulation	5-15	25-35	150-250
Stormwater drainage	5-15	40-50	300-400
Sanitation	5-15	25-35	150-250
Roads	5-15	30-65	200-550
Dams and canals	10-20	50-80	230-430
Railways	5-15	20-30	100-200
Forestry	25-35	35-45	16-50
Electrification	10-15	12-17	0-36
Small scale agriculture-related infrastructure	40-80	40-80	0-33

Table 4-1: National Economic Forum estimates (1994) of potential for spending on targeted labour as a percentage of direct construction costs. (Adapted by Phillips 1995; cited in McCutcheon and Taylor Parkins 2003:76)

4.1.2 Background

From 1969, the ILO engaged in a programme to find ways of creating employment as a means to strengthening the economies of under-developed countries. (McCutcheon and Marshall 1998:13) Through this initiative, the link between poverty alleviation and employment creation was made, as was the enshrining of the dignity of work as opposed to the use of hand-outs or ‘make

work' projects.[43] In 1971 the World Bank added its weight to the initiative by instituting the *Study of the Substitution of Labour for Equipment in Road Construction,* which aimed to use field research to generate more consistent data on the productivity of labour. This was to facilitate more rigorous financial evaluations for labour-intensive programmes funded by the Bank in the developing world. Most of the work carried out in this first phase through the 1970s was the construction of low-volume rural roads (Singer 1992; Lal 1978).

In the second phase of the study, various combinations of labour and machinery were investigated for the construction of roads, dams and irrigation projects in Nepal, Indonesia and India. An important finding of this phase was that traditional methods had such low productivities that the work did not justify the wage rates, even where shadow prices were used in the evaluations. The recommendations of the study were that better management and higher quality equipment, in combination with task-based payment (directly related to labour output) would significantly improve the competitiveness of labour-intensive methods with more machine-intensive ones for certain activities. Another important conclusion was that sufficient lead-time was essential to ensure that adequate planning, training and organizational capacity building could take place before field implementation.

The third phase of the study expanded field work in India and Indonesia, and expanded into Kenya, Honduras, Chad, Benin, Lesotho, the Dominican Republic and Botswana. This culminated in the 1986 report entitled *The Study of the Substitution of Labour and Equipment in Civil Construction*, which recognized the positive role that construction could play in the creation of employment as a means of addressing poverty in the developing world (IBRD 1986). All of the construction in phase three of the study focused on the building of rural roads,

[43] There is still a school of thought that argues for the Keynesian proposition that the unemployed should be put to work on 'digging holes and filling them up again' while the 'real' delivery of public works is done conventionally with machines. This is challenged by the successes in labour-intensive work as indicated below, but is an indicator of the resistance to this mode of delivery, especially amongst professionals (McCutcheon and Fitchett 2005b:10).

but it was noted that the conclusions and principles could be applied to a wider range of types of civil engineering infrastructure provision and maintenance.

The report argued that only through increasing formal employment, could the masses gain a secure place in the major economy. Construction was seen as specifically important, not least because of its ability to “absorb the excluded” (Sousa 2000); people with low levels of education and lacking market-orientated skills. At the same time, the provision of infrastructure, in the form of basic services and buildings, would help to raise living standards and facilitate the development of the rest of the economy of poor countries and regions.

In the summary of the completion report to this study a number of ‘lessons’ were enumerated, the most pertinent of which were:

> (a) Labor-intensive work methods are technically and financially feasible for certain types of work under certain conditions.
> (b) There is a significant potential for the improvement of the efficiency of existing labor-intensive work methods where they are traditionally used. (IBRD 1986:vi-vii)

Other key elements relate to training (especially of site supervisors); pilot studies; the mix of labour and equipment; project selection and standards; payment methods; and maintenance of the assets created by the programme. Many of these are directed at improving productivity to allow labour-intensive techniques to compete in financial terms with machine-intensive ones.

The achievements of this study, measured through the national programmes in countries with diverse technical, geographic and socio-cultural environments, are summarized by McCutcheon:

> They have resulted in the generation of hundreds of thousands of person-years of employment and the construction of tens of thousands of kilometers of road. (McCutcheon 2003:31)

Through this, a body of knowledge has been established that includes: programme evaluation, preparation and planning; technical designs and specifications for a wide range of terrain types; organizational and management systems; training manuals; and task rates for many combinations of labour and equipment. This overview gives a sense of the complexity and reiteration needed to re-engineer the construction process if labour-intensive construction is to meet the demands embodied in McCutcheon's definition cited in section 4.1 above.

4.2 PRINCIPLES

As the discipline of labour-intensive construction has evolved, three important principles have been identified:

1. that the product should be of the same quality, take the same time to construct, and be cost competitive;
2. that the work should be part of the major economy; and
3. that it should be 'proper engineering'.

Labour-intensive construction has met with considerable resistance by the mainstream construction fraternity because these fundamentals have not always been clearly understood or upheld. In the latter instance, projects have been punted as 'labour-intensive', generally to gain political mileage, which has allowed this resistance to prevail.[44]

With respect to the 'time, cost, quality' principle, considerable research and field work has resulted in a suite of techniques, including: team balancing and task based work organization; Choice of Technique Analysis (COTA); and the development of designs, specifications and specialized equipment to facilitate employment-intensive methods. All three principles are interrelated in the characteristics of successful employment-intensive programmes discussed below. Here it is important to note that, for these methods to have a significant

[44] McCutcheon and Fitchett (2005c) have given several suggestions for the lack of acceptance of employment-intensive methods from professionals, commissioning bodies and contractors. These include resistance to change, professional risk, perceptions of additional managerial burden and notions of 'primitiveness' of 'pick and shovel' work. The principles enumerated here challenge all of these misconceptions.

impact on the creation of ‘proper’ jobs as a lasting way of alleviating poverty, employment-intensive methods need to be accepted as a viable alternative to the delivery of construction works and not a temporary means to address short-term political goals.

4.3 METHODS FOR EMPLOYMENT-INTENSIVE CONSTRUCTION

This section looks at the first principle stated above: the achievement of comparable performance in terms of time, cost and quality with other methods of production. The other two principles flow from the achievement of the first. Fundamental to this discussion is the investigations into materials and techniques that have taken place over the last three decades. This is central to the design and specification, and through this becomes the primary influence on the achievements that can be expected from the change in mode of production.

4.3.1 Materials and specification

An important principle of employment-intensive construction is that it is efficient and cost effective in comparison with other methods of production. This said, a government or other commissioning agency may opt for a balance of machines and labour that is not *financially* competitive, but generates such a significant increase in employment that it warrants the small increase in cost. This is discussed below in the Choice of Technique Analysis, where the socio-economic cost is factored in. However, at the first stage of analysis, the financial costs prevail, and studies have shown that four types of approach can be undertaken to improve the labour ratio.

- **a) ‘Reverse substitution’ of labour for machines**

From its inception, the research into ‘labour intensive’ construction worked from the premise that machines could be replaced by low-skilled labour, thereby contributing a significant number of jobs for the same expenditure on infrastructure. It became apparent that certain tasks had not become machine intensive in conventional construction, especially in the developing world. At the opposite end of the scale, some activities could not reasonably be done ‘by

hand', either because machines increase productivity significantly in comparison with traditional manufacture, or could attain much higher accuracy needed in certain applications (McCutcheon and Taylor Parkins 2003:61-62).

Out of this initial research, it became clear that a group of core activities in the construction of low-volume roads could provide a significant increase in employment if reverse substitution were exercised, the most significant sequence being 'excavation, load, haul, unload and spread' (ELHUS). If properly designed, specified and managed, these could reach productivities that could match equipment-intensive methods in terms of cost, time and quality. The World Bank completion report for *The Study for the Substitution of Labour and Equipment in Civil Construction* gave the comparative costs of haulage by basket, barrow, dozer and scraper for a range of distances. (IBRD 1986: fig 1) The critical factors were determined as (1) the haulage distance and (2) the daily wage of the labourers. The most important finding of the completion report for this study was that productivity was the key issue where the revival of traditional methods was contemplated. This report argued that, in theory, similar analysis for other types of infrastructure would yield equivalent results, especially for canals and ditches; pipelines; dams; soil conservation; airfields; small bridges; and low-cost building (IBRD 1986: fig 7).

- **b) Material substitution: Waterbound Macadam**

In 1992, Phillips began investigating the re-introduction of Waterbound Macadam as a base-course for high-standard roads. This material had fallen into disuse in South Africa because of the apartheid government's policy of mechanization in road building as a means of excluding unskilled blacks from construction of public works. In its place, crusher-run was used which could be spread using large equipment. Phillips demonstrated that the more traditional material not only was better suited to employment-intensive construction, but also produced a higher quality road, both initially and in the longer term. It required less maintenance, and had a longer life before extensive rehabilitation would be needed (Phillips 1994).

There are extensive implications in the re-introduction of such a material, as explained by McCutcheon and Taylor Parkins:

> Reconsideration of a material such as water bound macadam necessitates redefinition of the process in order to achieve a requisite specification. This involves an understanding of the nature of the material and the procedures for construction and testing; not as straightforward as it may seem. As with many construction processes certain "tricks of the trade" need to be mastered in order to achieve the desired result. Again, an iterative process is necessary in order to achieve as efficacious a result as possible. (McCutcheon and Taylor Parkins 2003:62)

A series of projects using waterbound macadam was implemented, increasing in scale, as is indicated in Table 4-2 below. Included in this field research and implementation was the National Public Works Programme (NPWP), launched in 1994, of which the Community Based Public Works programme served as the pilot component.

> The **key function** of the NPWP was to ensure that the infrastructural provision of the state was carried out in a way that also maximised productive employment, training and capacity building, and community empowerment. (McCutcheon et al 2005:25)

Theoretical studies by Phillips (1992 and 1994) allowed the public authorities to be assured of both the technical performance of waterbound macadam, as well as the economic benefit of the employment generated through its use.

Location	**Date**	**Distance**
Xavier St, Johannesburg	1994	180m
Club St, Johannesburg	1995	600m
Soweto	1991-1997	12km
N1: Matoks to Louis Trichardt	1997-1999	13km

Table 4-2: Field implementation of waterbound macadam (McCutcheon and Taylor Parkins 2003:67)

From a management perspective, Hattingh (2003:205-217) provides a model for small contractor empowerment that uses a franchising system for constructing waterbound macadam roads. His company of Potgieter, Hattingh and Raspi has implemented this approach for more than 400km of roads between 1997 and 2002 (McCutcheon and Taylor Parkins 2003:67).

The principles of labour-intensive road construction, specifically using waterbound macadam, were put into practice in the Gundo Lashu programme in South Africa's Limpopo Province from 2001. The success of this programme has played a significant part in building political confidence and technical understanding as the basis for the national Expanded Public Works Programme (see 4.6 below). Concurrently, a number of other materials have been the subject of research into their employment generating potential, such as rubble masonry for low-volume dams and interlocking concrete blocks for roads and sidewalks. In each case, research has been supported by pilot projects to test the technical viability of the material, refine the design and specification, and give insight into implications on the management of projects.

- **c) Adaptation of conventional materials and methods**

While bitumen is, in itself, the product of a capital-intensive process, laboratory tests and studies in the field have indicated ways in which this material may be adapted to facilitate employment-intensive methods (Van Steenderen and Lieuw Kie Song 2003: 221-228).

One of the applications studied is the use of bitumen as a stabilizer to low-grade gravel to form Emulsion Treated Base courses (EBT) that uses a small percentage (1.5%) of bitumen. This allows far greater scope for the use of locally quarried material, which avoids transport costs. The resultant base course has proved to be less critical for the timing of placing the surfacing, uses light machinery, and is suited to small work gangs. All of these factors make the material suitable for small contractors operating with little capital.

Related to this work is the research into the revival of hot-mixed asphalt (also termed bituminous concrete) for flexible surfacing of low-volume roads. This material had been used extensively with hand-placed methods before 1928 in the United States, but subsequently was spread by machines. The asphalt improves tensile strength and thereby increases life of low-volume roads by resisting cracking. Emery (2003:273-291) argues for the synergy of using asphalt in combination with labour-intensive base layers. Moreover, he notes its suitability in urban roads that carry services below the road surface, because of the ease of repairs when these services need to be accessed.

- **d) New materials**

As employment creation through infrastructure is given greater attention by policy makers, one can anticipate that more resources are directed to the research and development of new materials specifically orientated towards employment-intensive construction. Already there have been some initiatives in materials such as sulfonated petroleum for soil stabilization, as well as in the adaptation of familiar materials to new contexts. One example of the latter, of particular interest to this discussion, is the use of interlocking concrete blocks for high-standard roads.

A report carried out in 1998 described the potential for the labour-intensive use of concrete block for high-standard pavement construction in South Africa. This material as an option for expanding employment-intensive methods into providing infrastructure for the mainstream economy was suggested by its use in parts of Europe. The high quality that can be achieved with on-site manufacture of the blocks, as well as the dimensional accuracy in placement provides a valuable lesson to the building sector. Moreover, its use for suburban road upgrading has been advantageous where there are poor sub-grades (Bangma et al 2003:241-249).

Other methods of stabilization, in the form of sulfonated petroleum products, have likewise been the subject of laboratory and field testing. Investigations have

been made into the chemical structure of bitumen to allow for cold application as a surfacing material. In this way, the operation can be carried out with hand-sprayers, and the process is less hazardous for the workers (Van Steenderen and McCutcheon 2003:251-271).

4.3.2 Choice of Technique Analysis

Researchers and practitioners in employment-intensive construction in the WORK Research Centre, University of the Witwatersrand, have increasingly studied the potential for using labour-intensive methods for high-standard infrastructure and large-scale programmes. At the same time, there has been an appreciation of the need for public accountability through an objective method of evaluating levels of labour-intensity generated through different combinations of labour and equipment. The 'Choice of Technique Analysis' (COTA) that emerged from this was the product of several years of refinement by Phillips (1994) and Taylor Parkins (1997), and published by McCutcheon and Taylor Parkins (2003:57-72).

COTA is based on the acknowledgement that in any construction project

a) some of the activities are largely still labour-intensive, either because mechanization has not been introduced or because site conditions prevent the use of large machinery;
b) for some activities, it is not feasible to carry out the work without machines, either because of the volume (eg bulk excavation) or because a higher level of precision is needed than can be achieved by hand;
c) the remaining activities are those that have become machine-intensive in conventional practice, but with the requisite research and field studies, would be suitable for employment-intensive methods.

Following from an initial evaluation of a Bill of Quantities, the items corresponding to (a) and (b) above would not generate significant increase in the number of people employed to achieve the same result, whatever improvements were made

in this regard. However, those in category (c)[45] are evaluated to determine whether employment-intensive methods would be *technically* feasible.

Those that meet this requirement are the focus of financial analysis to see how they compare with conventional (machine-based) methods. If they are more expensive, the analysis can be taken further using shadow wages, machine and fuel costs to evaluate the economic cost of each item. Those that still cost more on this evaluation may be subjected to a final test that includes the social 'cost' of unemployment. This is determined by policy objectives such as poverty alleviation, targeting poor households, skills development, institutional capacity building and small enterprise development (McCutcheon and Taylor Parkins 2003:66).

At a theoretical level, evaluation can also take into account the level of labour-intensity, ranging from a small increase in employment to the maximum currently feasible, which would use in the region of 30 times the number of person days in comparison with the same Bill of Quantities item being done conventionally (McCutcheon and Taylor Parkins 2003:72). These very high figures tend to be achieved only with certain types of activity, and at a cost premium of double the price of conventional construction. COTA does, however, give a relatively objective method by which to compare the employment per unit of expenditure with other employment generating initiatives, often referred to as the 'cost per job'.

The final stage of COTA, after the technical and cost appraisal, is Monitoring and Evaluation that provides the feedback loop necessary for any innovative approach to provide the assurances central to its objectives. The results of Cost of Technique Analyses carried out to date are that: "…it is possible through good engineering to obtain a significant increase [in] employment per unit of

[45] Phillips (1994:96) has estimated that 70% of the cost of a project is given over to activities that have potential for significantly increasing their labour-intensity, ie category (c).

expenditure at market prices, which are cost competitive with those achieved using conventional methods," (McCutcheon and Taylor Parkins 2003:73).

4.3.3 Task-based organization and team balancing

The effectiveness and competitiveness with conventional construction relies on improved productivity of the much larger workforce (IBRD 1986:2). Therefore, concurrent with these strategic approaches has been the formulation of improved organizational and management structures. Their most significant features are the central importance of the 'hands-on site supervisor' and the use of task definition for the organization and payment of as much of the work as is possible to structure in this manner.

Research into deficiencies in productivity has shown that as much as 85% of low output can be attributed to management. While not discounting the importance of training for individual manual workers, problems relating to human resource management become critical where large numbers of people are employed. In the earlier phases of the IBRD study discussed above, it was found that the most effective and fairest way of ensuring productivity was through the task-based method of payment. Tasks are defined through work studies as reasonable for the average person to complete in an eight hour day. A worker can go home on completion of the day's task. In international best practice, each worker is restricted to performing one task per day, thereby ensuring equitable allocation of the jobs available and facilitating the planning and co-ordination of the project on a day-to-day basis.

This feeds in to the higher level of management, that of team balancing. In all of the projects undertaken to date, it has been found that not all activities are amenable to task-based definition, ie undertaken by an individual. Moreover, to ensure the smooth flow of dependant activities, the output per worker on a task needs to be considered in relation to the whole.

Croswell and McCutcheon (2003:387) have shown how the techniques for ensuring optimal usage of equipment in machine-based construction should have their equivalent in employment-intensive operations. In machine-intensive work, the productivity of labour is merely factored into the machine costs and scheduling on the assumption that if the machine is operating productively, the operator will be likewise. In this instance, the cost to the contractor of the labour in proportion to the machine is so small that it does not warrant disaggregation. By contrast, where the major factor of production is the labour itself, this has to become the primary focus of planning and monitoring of output and productivity. These authors provide the following definition of team balancing:

> The optimization of resources applied to any operation, or set of operations comprising a project, taking cognizance of parallel and subsequent tasks and the need to keep the entire workforce optimally employed. (Croswell and McCutcheon 2003:395)

Two important elements are enshrined in this process: while machines simply lie idle when not productively used, an idle workforce soon becomes demotivated; and where workers are paid on a task basis, with the corollary of ‘no work, no pay’, management has to ensure that the ability to carry out the task is assured.

Standard task rates have been developed for a range of civil engineering activities, as have straightforward techniques for team balancing. Central to the organization of the labour force on task-based and team balanced principles is the role of the ‘hands-on site supervisor’, the person who translates higher-level management decisions to the particular conditions on site:

> This is the person who ensures that the work is being performed properly in both technical and organizational terms; all day, every day. The result of this is that senior management can be reassured that something sensible is taking place in the field without the need for daily supervision. (McCutcheon and Fitchett 2005a:2)

Evaluation of these planning processes shows that they emanate from, and are consistent with, best practice in project management scheduling, and use similar tools for planning and control during construction. Thus there can be a seamless integration of activities performed highly employment-intensively and those done with a high machinery input.

This section has shown the degree to which re-engineering is needed to achieve the levels of employment contemplated in the definition given in 4.1.1. It has also indicated the innovation that has taken place and the intellectual rigor that has refined the processes characterizing this re-engineering. This stands in dramatic contrast to the perceptions of primitiveness and 'pick-and-shovel' labour that have undermined the full-scale adoption of employment-intensive construction.

4.4 ACHIEVEMENTS IN ROAD BUILDING

Following the launch of the World Bank and ILO *Study of the Substitution of Labor and Equipment in Civil Construction* in 1971, there has been a small but concerted effort at applying and refining the processes described above. In this section, a selected sample of these initiatives is explored, focusing on sub-Saharan Africa, to determine the commonalities and characteristics that point to successful implementation.

Where delivery has been particularly successful, it has been characterized by a programme approach in which training is integrated with construction and maintenance. By contrast, such efforts in building have been of a 'one-off' nature except in countries where the method of production has reverted to traditional practices, eg in India, the Near East and East Africa (Wells and Wall 2001:36-48). In section 4.5 the reasons for success and failure in civil engineering works are summarized as a preliminary framework for application to the field of building.

4.4.1 A new organizational structure: The Kenyan Programme

The initial phase of the IBRD study focused on the road building sequence of activities that looked most promising for establishing the validity of a labour-intensive mode of production, where large machinery had replaced work that technically could be done equally well by hand. This set of **E**xcavate, **L**oad, **H**aul, **U**nload and **S**pread (ELHUS), contributes a significant proportion of the cost of any road works, thereby justifying the expense of research and development into the new techniques.

Concurrent with the later phases of the IBRD study, the Kenyan Rural Access Roads Programme was begun, heralding the expansion from single-site projects into a nation-wide programme (McCutcheon and Marshall 1998:21). A pilot project was carried out for this Programme in which new designs and specifications were developed to suit employment-intensive construction methods. A number of radical innovations were introduced, including substantially increasing the camber of the road and making extensive use of *in situ* material through a design that minimizes bulk excavation. Compaction is achieved through natural consolidation in combination with the passage of vehicles (McCutcheon and Marshall 1998:22). Maintenance began immediately on opening the road to traffic, to fill the ruts formed by the vehicles as compaction was taking place.

Productivity of the large workforce was refined through extensive method and work-studies in the pilot phase. This permitted the fair setting of task rates for a number of activities, and team balancing to ensure the smooth flow of work. The pilot phase was used to develop and refine an integrated management system for employment-intensive work that was equivalent to best practice in conventional construction.[46]

[46] In most respects, the management systems of successful labour-intensive programmes follow the same techniques advocated in the Project Management Institute's Body of Knowledge (Duncan 1996). Where they differ, this is directly related to the much larger labour force employed and the low level of skill that prevails.

The other important innovation of the Kenyan Programme was instituting an integrated in-house training programme that provided the technical and managerial skills required at all levels, from head-office to individual construction sites. Two important objectives led to the particular organization developed in Kenya, namely;

a) That the dispersed and isolated location of sites required that well-trained and competent people were needed to direct work on site, all day and every day; and
b) For the ratio of project cost to be shifted in favour of wages to targeted communities and individuals, the conventional management structure needed to be re-conceptualized.

These two principles led to the development of the road builder (hands-on site supervisor) as the critical figure who translates the intentions and methods formulated at head office to the specific conditions as they unfold on site. The selection and training of the road builder thus received special attention to ensure the required level of technical, managerial and human relations skills.

The road builder oversees the work of 5 to 25 ordinary labourers (Fig 4-1) while engaged in the physical work herself (McCutcheon and Taylor Parkins 2003:37). In this way, she becomes more than just an interface between higher management and the manual workers, by being a productive member of her team. She is also responsible for pegging out the works and determining, from day to day, which activities are to be carried out. She determines what is a ‘fair day’s work for a fair day’s pay’ in relation to the constantly changing terrain, thereby determining the productivity of her team, whether the work is measured by individual task, group task or on a daily wage basis.

After careful selection, based on academic qualification, demonstration of leadership qualities, and a short period of orientation in employment-intensive construction, the road builders in Kenya were taken through technical and site managerial training, alternating one week in the classroom (located near the

construction site) with one week on site. From the beginning of each person's training period, productive work was undertaken on site where the short spells of classroom learning could be immediately assimilated through practical application (McCutcheon and Fitchett 2005a:3-4).

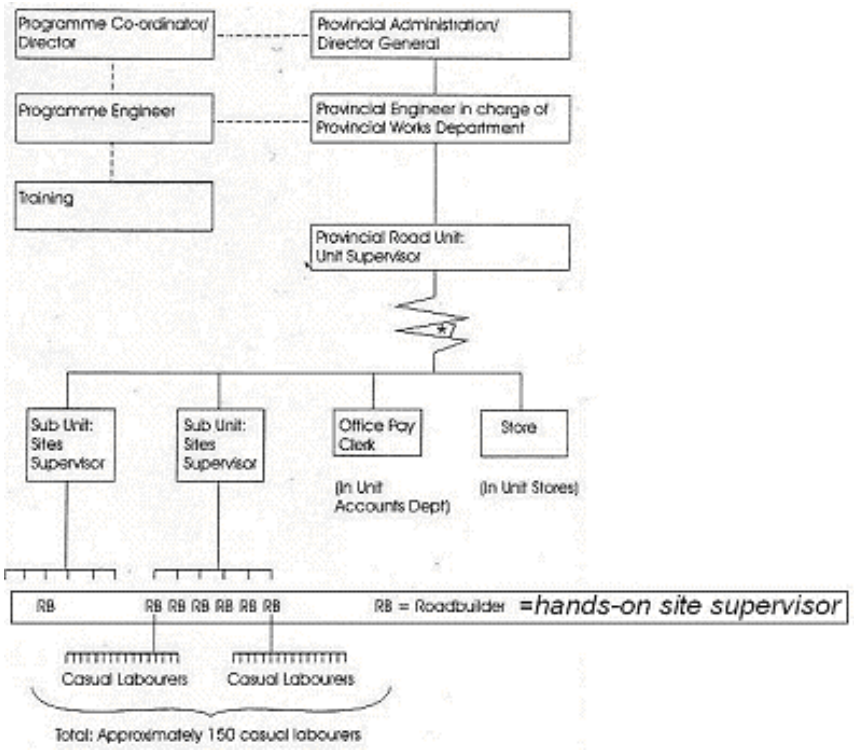


Fig 4-1: Organizational structure for employment-intensive construction (McCutcheon and Marshall 1998: 95)

While the capability of the road builders is extremely significant for ensuring quality and productivity, they can only be effective if senior personnel are similarly proficient in both the technical and managerial aspects particular to employment-intensive construction. McCutcheon and Marshall (1998) stress the importance of institutional capacity and knowledge within the commissioning body. At the broadest scale, this requires a commitment to a programme approach that has the following characteristics:

a) Identification of local skills, industries and materials;
b) Negotiation with local communities on conditions of employment, especially wages and eligibility;

c) A demonstration project that develops and refines technical and managerial issues; and
d) Integration of a training programme with the physical delivery of infrastructure – the programme of construction expands only at the rate that trained personnel become available (McCutcheon and Taylor Parkins 2003:37).

The Kenyan Rural Access Roads Programme has provided compelling evidence of the value of the 'programme approach'. Until employment-intensive methods are completely assimilated into the mainstream of construction practice, the slow delivery and high overhead costs of the first few years of implementation prevent this method from being competitive in the short term (Fig 4-2).

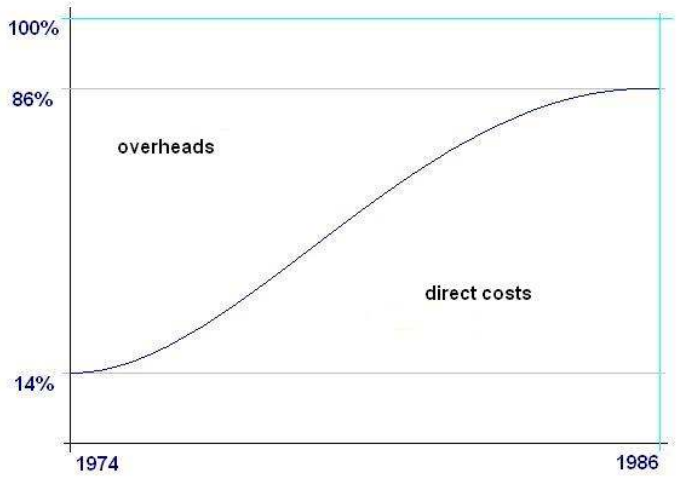


Fig 4-2: Ratio of direct costs to overheads in the Kenyan Rural Access Roads Programme

However, where the programme approach has been fully implemented, not only have the social benefits of employment creation been experienced, but the high costs of the early years is completely reversed, making employment-intensive construction the most viable method of delivery in terms of time, cost and quality (McCutcheon and Fitchett 2005a:5-6).

4.4.2 Botswana

In Botswana's Fifth and Sixth Development Plans (1976-1991) a policy decision was made to use labour-intensive methods to improve and maintain 13 000km of non-gazetted District Council roads (McCutcheon 1992). A pilot study was carried out between 1980 and 1981, based on the experience of the Kenyan Rural Access Roads Programme. This revealed that there would have to be a change in the design and specification to accommodate the flatter terrain and better quality of vehicles. The resulting roads were of higher standard than those in Kenya, thereby encouraging investigation into urban road construction in South Africa, as described below in section 4.4.4.

From 1982 the programme was expanded into all nine provinces, with more than 2 000km of roads constructed and 3 000 people employed. An important feature of this programme was the design of customized donkey carts that became the principal means of haulage, using animals owned and driven by local farmers (McCutcheon 1985).

In total, there were six programmes that used labour-intensive methods, of which only one, the District Roads Programme (LG34) was completely successful. Achievements of these programmes were:

- Targeted labour increased to over 3000 employed in 1990
- The proportion of women increased, in the Road Builder[47] group from 21% in 1985 to over 80% in 1990;
- Approximately 200km of earth road was constructed per year, with a total of nearly 2 000km by 1995 (Muatjetjetja 2005).

The programme subsequently collapsed, largely because the wages were too low to attract people away from relief programmes that did not have a work requirement. This was exacerbated by insufficient technical training and inadequate organizational methods. It is instructive to compare the extent to

[47] This post is the equivalent of the 'hands-on site supervisor' or 'site supervisor' in South Africa.

which the Kenyan programme transferred high level skills to locals, with almost all the posts for engineers being taken up by Kenyan nationals by the end of the programme. By contrast, when Norwegian funding ceased in Botswana, many of the high level posts were left vacant when the European staff left (Muatjetjetja 2005).

4.4.3 Lesotho

As discussed above (section 4.1.2) the third phase of the World Bank and ILO *Study of the Substitution of Labor and Equipment in Civil Construction* saw expansion into a number of countries, including Lesotho. Here a food-aid programme had been running from 1968, two years after the country gained independence (Pama 1992:32). Migrant workers returning from the mining and other industries in South Africa posed a problem of mass unemployment, so the opportunity was taken to create jobs in labour-intensive road construction in exchange for food. This programme lost credibility with donors because of the lack of monitoring, low productivity and inferior technical standards of the roads (Pama 1992:35).

When the World Bank and ILO set up the Labour Construction Unit in 1977, this was with the experience of the importance of training and capacity building to address the concerns of the donors in the food programme which was still in operation. Lesotho's terrain is challenging for labour-intensive work, as it is entirely mountainous, necessitating far more cut and fill than had been experienced in the first two phases of the World Bank programme. The Labour Construction Unit was set up as a branch within the Ministry of Works, the staff of which were trained for high level supervision so that the expatriate company (Scott Wilson Kirkpatrick) that administered the pilot project could be dispensed with as the programme was rolled out (Pama 1992:56).

Labour-intensive delivery of civil engineering infrastructure continues to the present, with several modifications including a small contractor development

programme established in 1993 (Ntoi 2000). Currently solid waste disposal is carried out labour-intensively through small contractors in the capital city of Maseru as a means of creating long-term jobs (ILO 2008).

4.4.4 Malawi

Road construction in Malawi was another component of the World Bank and ILO programme from 1977, under the District Road Improvement and Maintenance Programme. This was to run for several decades along lines very similar to those described above in Kenya, but appears to have ceased in 1988 (Pama 1992:108-109).

Between 2001 and 2005 the Government of Malawi instituted an integrated programme of durable poverty alleviation in rural areas through road upgrading and maintenance; irrigation and dry season agriculture; and forestry management. Esterhuizen (2005:2-3) describes the combination of short and long term benefits:

> The employment created by the road rehabilitation ensures an immediate injection of cash while the village based road maintenance system ensures a long-term injection of cash into the rural community. The forestry component generates immediate cash through the performance payments while the future wood supplies ensure long term benefits. In co-operation with these components the irrigation component generates immediate food supplies while also generating immediate and long-term cash and food prospects. The implementation approach and combination of programme activities work in a coordinated and unified manner to build upon and compliment each other and reinforce collective participation.

The roads component targeted almost 3 000 km of classified roads, and included the replacement of 69 timber bridges with concrete decks. Work was carried out by ‘entry level’ contractors, using simplified contract documents for an average 10 km contract.

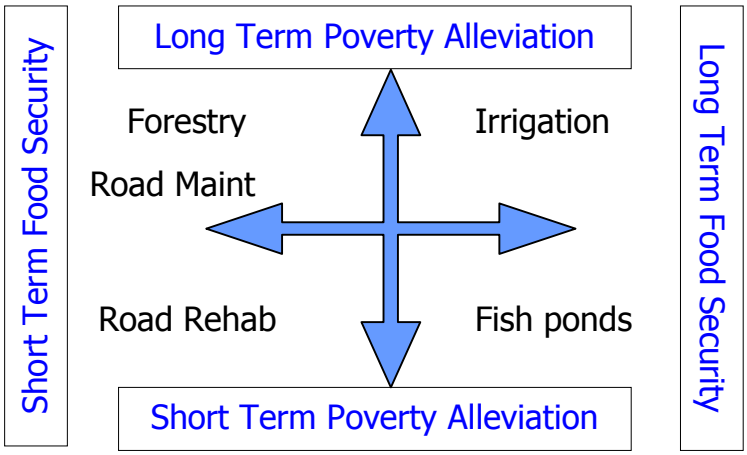


Fig 4-3: GoM/EU PWP Organizational Structure (Courtesy: Africon 2005)

The achievements of the programme's primary objectives were as follows:

- 2 481 km of roads upgraded and rehabilitated;
- 69 bridges completed (825m);
- 32 877 people provided with temporary employment (in excess of 2 600 000 person-days of employment have been created);
- Total cost of the road works approximately US$ 7.9 million with more than US$ 2.45 million paid to communities in the form of wages (Esterhuizen 2005:5).

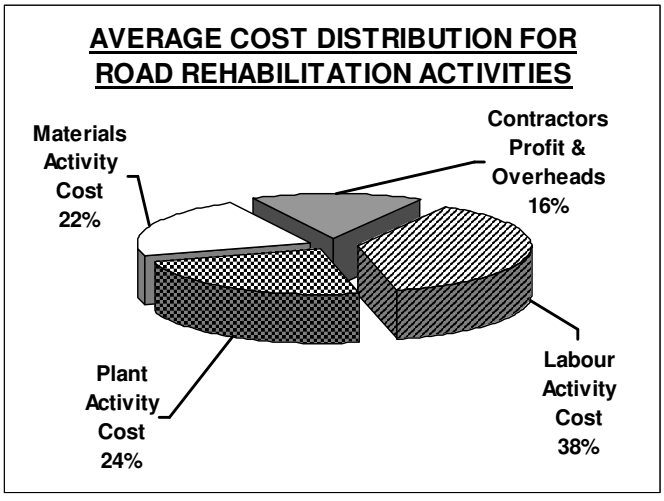


Fig 4-4: GoM/EU PWP Cost ratio for road rehabilitation (Courtesy: Africon 2005)

Maintenance of the roads is through ‘road maintenance clubs’ in each village based on the length-man system, with preference given to people involved in the construction phase. “The success of communities involved with routine road maintenance work is remarkable with the clubs taking full ownership of the maintenance and operating as a small business enterprise,” (Esterhuizen 2005:7).

The consultants responsible for the programme have stressed the importance of support from all stakeholders, especially through its being community driven, and being flexible in its ability to respond to market needs. At the highest level of government there is commitment to policies and assured funding, thereby assisting in the success of the programme that “has in all respects far exceeded its targets as planned,” (Esterhuizen 2005:13).

An important principle that is well demonstrated in this programme is the integration of a range of initiatives to address immediate needs and to consolidate a more lasting initiative in poverty alleviation.

4.4.5 High-standard roads

For many years, labour-intensive construction was synonymous with low-volume rural roads, following the ILO/World Bank study described above. While other types of infrastructure were considered to have potential as vehicles for employment creation, these were invariably rural, using adaptations of traditional methods, and as a result peripheral to the major expenditure on infrastructure.

In South Africa’s transformation to democracy, an urgent concern was for the many dormitory ‘townships’ that the apartheid government had established to house the black workforce serving the ‘white’ towns. These suffered from inadequate infrastructure that had been poorly maintained on the last decades of Nationalist Government rule. In the transition to democracy, attention turned to redressing the imbalances in service provision, in Johannesburg’s satellite

township through the Soweto Contractor Development Programme (Mkhize 1994).

This programme provided 250 km of secondary water mains with 30 000 house connections, and 33 km of high quality surfaced residential streets using innovative materials suitable for labour-intensive methods. The concurrent development of small-scale equipment facilitated the small contractor through low startup capital (Van Steenderen and McCutcheon 2003:165). Five different combinations of conventional and labour-intensive methods were investigated, ranging from totally conventional (machine-intensive) to maximum labour-intensity that could be achieved without compromising the high-standard specifications. The largest part of the works (24 km) was carried out at the median mix of labour-intensive and machinery, with layer-works up to base-course done conventionally to meet time constraints (Gertzen et al 2003:157-8).

Research was carried out to modify the base-course, kerbing and associated activities to facilitate the operations of emerging contractors. (Gertzen et al 2003:159).[48] The design, specification, training and management processes were based on the experience of rural gravel roads, but the higher standards of product necessitated “re-development of the design and specifications, technical skills, construction methods, and contractual arrangements,” (Gertzen et al 2003:161). The training of contractors that was undertaken in the programme followed a five-step process, with exit opportunities at each stage, leading to a fully-fledged operation that could be competitive for a range of tender sizes (Table 4-3).

In the early 1990s there was growing acknowledgement that, for labour-intensive provision of infrastructure to have a significant impact on poverty and unemployment, it had to become part of the major economy. To this end, a private consultant, EIEC, was commissioned in 1995 to prepare a feasibility

[48] For example, while earthworks generate high employment, the number of jobs is not sustainable for later activities, requiring the small contractor to manage a widely varying workforce with extensive hiring and firing.

study to reconstruct a 13km portion of the N1, the national freeway between Matoks and Machado (Louis Trichardt), Limpopo Province. This feasibility study recommended that:

- only works not on critical path should be labour-intensive;
- unproven methods should be used in temporary works first; and
- that “the project should be used to generate reliable data on production rates and methods,” (Van Steenderen and McCutcheon 2003:163).

Implementation took place from 1996 to 1998. Despite far less of the work being done labour-intensively and a low rate of success with small contractor development, it nevertheless did prove the effectiveness of Waterbound Macadam as a material suitable for high-standard roads (Van Steenderen and McCutcheon 2003:184-5). Here it is worth noting the significance of specifying this material, which through the difficulty of placing it with large machinery, *de facto* ensures that labour-intensive methods are used. Following from this principle, this project showed the importance of the decision to use employment-intensive technology being the ‘design driver’ that should influence every decision in the design, specification and contractual process (Van Steenderen and McCutcheon 2003:185-6).

Moreover, one of the long-term benefits was that clear recommendations and calculation of labour-intensive rates could be made for future high-standard roads in South African context (Van Steenderen and McCutcheon 2003:187-8). The project was also instrumental in the promulgation of legislation allowing for task-based payment of labourers, following extensive negotiations between government and organized labour (COSATU), which had resulted in the 1993 Framework Agreement (Croswell and McCutcheon 2003:300-316).

Level	Contractors qualifications and expertise	Contractors contractual responsibility	Construction/ material managers duties	Basis of tender award
1	Exhibits potential to organize and manage labour	Provide labour Provide small tools	Offer advice, practical assistance and training Provide and distribute materials Provide plant other than small tools Finance fortnightly wages	Most suitable candidate who submits a realistic tender
2	Has either i) Successfully completed three level 1 contracts ii) Successfully completed one level 1 contract and has attended a recognized site management course iii) Successfully completed conventional or labour only contracts elsewhere	Provide labour Provide small tools Provide consumables and administer transport for collection and distribution of materials and plant	Offer advice, practical assistance and training Issue materials and other consumables Provide plant other than small tools	Modified tender award – eliminate tenderers whose tenders are more than 15% below and 20% above Construction Managers estimate Rank tenders from lowest to highest and award contract to tenderer who is ranked 1/3 above lowest subject to suitability
3	Has either i) Successfully completed three level 2 contracts ii) Successfully completed conventional or labour only contracts elsewhere	Provide labour Provide small tools Provide all materials Provide all transport Finance fortnightly wages	Offer advice, practical assistance and training Provide plant other than small tools Finance materials Offer materials for purchase	Modified tender as for level 2
4	Has either i) Successfully completed three level 3 contracts ii) Successfully completed conventional or labour only contracts elsewhere	Provide labour Provide all materials Provide all plant and transport Finance all contractual aspects including the provision of a surety	Offer advice, practical assistance and training Offer materials for purchase and plant for hire	Lowest tender subject to suitability and with rates substantiation
5	Has either i) Successfully completed three level 4 contracts ii) Successfully completed conventional or labour only contracts elsewhere	Provide all labour, plant and materials Finance all contractual obligations	None	Lowest tender subject to suitability

Table 4-3: Soweto Small Contractor Programme (Mkhize 1994:88-89)

During the period from 1999-2001 the Department of Labour engaged in wide-ranging discussions regarding limited modifications to labour legislation in order facilitate implementation of Special Public Works Projects. In essence, this allowed designated public works programmes to be carried out using task-based (or output-based) payment in contrast with time-based wages. Experience from labour-intensive programmes elsewhere in sub-Saharan Africa had shown that without the link between output and wages, productivity levels could not be assured, thus the central significance of these pieces of legislation to the large-scale implementation of programmes in South Africa. The Basic Conditions of Employment Act, 1997 was amended, and in January 2002 the Government Gazette (No. 23045) of South Africa published the following:

- No R63 Basic Conditions of Employment Act, 1997: Ministerial Determination: Special Public Works Programmes; and
- No R64 Basic Conditions of Employment Act, 1997; Code of Good Practice for Employment and Conditions of Work for Special Public Works Programmes.

As a concession to organised labour, these conditions could be applied as a temporary measure only, with any one worker being employed in this way for less than two years in a five year cycle. Moreover, the labourer would be given compulsory training under the conditions to improve his or her employment opportunities in the future (McCutcheon 2005b:14).

4.5 CHARACTERISTICS OF SUCCESSFUL PROGRAMMES

From the foregoing discussion, a set of characteristics can be distilled that distinguish successful programmes from those that have either not fulfilled their objectives[49], or have not progressed beyond the pilot stage. Foremost is that a programme approach is essential. This allows the start-up costs of research and

[49] An example of this is the South African National Public Works Programme. Most of the reasons for failure of this Programme related to institutional incapacity, inappropriate project selection and lack of adequate training. The consequences were that: “Most of the projects degenerated into poverty relief handouts with very little sustainable product: infrastructural, individual or institutional,” (McCutcheon 2005b:11).

development; pilot studies and initial training to be amortized over a larger volume of work.

The suitability of the type of work for employment-intensive techniques is critical, although recent research has shown that a far broader range of activities are amenable to labour-intensive techniques. Other objectives of the programme, such as targeting women, facilitating entry-level contractors, or particular training objectives should also be assessed when considering the choice of suitable projects for inclusion in the programme. It is important to reiterate here that the primary objective is to create a valuable asset, through the *medium* of employment-intensive techniques, and not primarily to make jobs (as is the case with most poverty relief initiatives). The pre-feasibility stage needs to include community involvement to determine: whether there are sufficient people willing to work; rates of pay; and other conditions of employment, such as task-based payment and that the labourers provide their own transport to work.

Once these are determined, the programme has to proceed with commitment to ‘proper engineering’, and with employment-intensive methods as the ‘design driver’. From this flows the necessity for detailed technical analyses, resulting in appropriate design, specifications and tender documents. These are tested through pilot studies in which method and work studies are used to determine operations and activities and their sequencing, fair daily tasks and team balancing, and to verify earlier technical studies. Health and safety issues should also be revealed and managed through the pilot stage.

Training is fundamental to the success of an employment-intensive programme, to the extent that the programme should expand only at the rate that suitably trained personnel are made available. The training should be integral with the programme, and with special focus on the hands-on site supervisor (McCutcheon and Fitchett 2005a). This is the key to ensuring productivity on site, and must be linked to labourers accepting instructions from the Supervisor, and good

management systems throughout, including that tools and equipment are of high quality and in good repair.

In summary, the whole programme has to have long-term commitment at the highest level, with good management systems implemented through strong organizations (McCutcheon and Taylor Parkins 2003:32-34.).

4.6 THE EXPANDED PUBLIC WORKS PROGRAMME

As has been shown in section 4.3.1, considerable work has been done on materials testing in conjunction with the development of standard designs and specifications, time-and-motion and method studies applicable to the South African context. This has taken place concurrently with pilot studies such as Gundo Lashu road construction and maintenance programme. Policy and legislation have been formulated to allow for the use of task-based payment for "special public works" that specifically use labour-intensive methods. This significant breakthrough, fundamental to ensuring productivity, was the result of years of negotiation between government and COSATU, representing organized labour in all sectors.[50]

The South African Expanded Public Works Programme (EPWP) was formally launched by President Mbeki in his State of the Nation Address in February 2003 as one of a cluster of initiatives to halve the country's unemployment by 2014. Its primary objectives were stated as:

- Redirecting existing public budgets for goods and services towards employment generation and support of small businesses; and
- Providing work opportunities with a training component for one million currently unemployed people over the first five years, in an effort to improve their long-term employability. (Phillips et al 2005)

[50] For a full account of the process leading up to the Framework Agreement and a critique of it, see Croswell and McCutcheon (2003:300-316) and McCutcheon et al (2005b).

It differs from previous Public Works programmes in several ways reflecting the developments in employment-intensive construction outlined above, namely:

1. that it is funded out of normal provincial and municipal budgets, with a concomitant focus on efficiency and competitiveness;
2. that the Division of Revenue Act (2004) requires that provinces and municipalities carry out specified types of infrastructure labour-intensively;
3. that compliance with this Act's 'conditionalities' is in terms of published guidelines and conditions of contract; and
4. that there is guaranteed training for all participants, including casual labourers (McCutcheon et al 2005b).

Management, professional and construction labour training in the Programme are discussed in Appendix 1.

The Programme extends beyond infrastructure provision to include social services, environmental management and public procurement. In all of these, there is provision for vocational training and for the development of small entrepreneurs. This section will focus on the infrastructure component of the Programme, however, the other three sectors have a bearing on other parts of this thesis, and inferences will be drawn from them in later chapters.

When formulating the infrastructure component of the Programme, four types of civil engineering works were identified for which laboratory and field tests provided the assurance that labour-intensive[51] methods could be used that could compete with conventional construction in terms of time, cost and quality. These are: low-volume roads; trenching and pipe laying; storm-water control; and sidewalks. To date, Cost of Technique Analysis provides fairly reliable (if conservative) figures for the four types of infrastructure earmarked for the initial phase. As more data is gathered from the Programme itself, its pilot projects and theoretical research, this technique of analysis will become both broader in the types of activities, and more accurate as a predictive tool.

[51] The term 'labour-intensive' is used throughout the official documentation for this Programme.

From the inception of the Programme, any provincial or municipal body undertaking any of the specified types of infrastructure projects was compelled to perform the work labour-intensively according to the gazetted ‘Guidelines’ (DPW 2005). Failing this, legislation has been promulgated that results in the public body forfeiting the value of the work in their budget for the subsequent fiscal year. This controlling function is administered and audited by the Department of Revenue through specifically enacted legislation that sets ‘conditionalities’ for the release of funds to Municipalities and Provinces only if work designated as ‘labour-intensive’ has been carried out in compliance with these Guidelines.

Before the Programme could be launched, two important principles of employment-intensive construction, both relating to conditions of employment, required extensive negotiation with the Department of Labour and the trade union COSATU, namely: the use of task-based payment; and the pitching of wages low enough that the Programme would not attract people already in some form of employment. This resulted in two pieces of legislation, the ‘Code of Good Practice for Special Public Works Programmes’ (Department of Labour 2002) and the ‘Learnership Determination for unemployed learners’ (Department of Labour 1997). These special conditions of employment are conditional on workers having an entitlement to training, and that the employment of a worker under these special conditions is of limited duration.

Legislation also requires that individuals from both the commissioning body and the private sector consultants appointed by them are suitably qualified to define, design and supervise labour-intensive work. To this end, courses have been developed at NQF level 5 for technologists and level 7 for professionals to supplement their existing qualifications. (See Appendix 1 for an outline of the National Qualifications Framework.)

Municipalities and provincial departments are encouraged to use labour-intensive practices in other types of projects than those specified in the Division of

Revenue Act, and it is planned that the scope of the Programme will expand as sufficient research allows for their cost competitiveness to be assured. Areas under investigation that are of particular relevance to this study are:

- maintenance of existing public building stock;
- construction of new public buildings;
- delivery of low-income housing.

4.7 APPLICATION OF PRINCIPLES TO BUILDING

The discussion of the Expanded Public Works Programme highlights the need for assurances on the effectiveness of employment-intensive construction. As discussed above, most of the research, field studies and full-scale programmes have been focused on low-volume rural roads as the type of infrastructure that was patently suitable from the ILO's initial investigations. However, proponents of employment-intensive construction have argued that the same principles hold for most types of construction.

In policy documents of the Expanded Public Works Programme, the initial focus has been on the types of construction for which employment-intensive methods have been established and shown to be financially competitive with conventional modes of delivery. However, it has always been the intention that, as the Programme matured, the range of types would broaden to include, on the one hand higher standard civil engineering works, and on the other the construction and maintenance of public buildings. The latter is of particular concern to the implementing body, the Department of Public Works, as the 'State's landlord'.[52] For this to take place effectively, acknowledging the need for accountability in public expenditure, the following guidelines can be inferred from the thirty years of experience in the labour-intensive construction and maintenance of civil engineering infrastructure.

[52] An anomaly of the Expanded Public Works Programme emanates from its history: the Gundo Lashu programme was a provincial initiative, where public works and roads are part of the same department, but at national level these are in separate departments with inevitable problems of interfacing the objectives of the Programme with the needs of line departments.

There needs to be **institutional support** at the highest level of decision-making. A programme approach with clearly articulated objectives and integrated training at all levels is essential to justify initial overheads and start-up costs.

Community involvement from the earliest stages is required, to agree on terms of employment (wage rates, task-based payment, gender equality and labourers' transport to site). This process of negotiation should include determining that there are sufficient people willing to work in labour-intensive construction.

The above discussion has highlighted the critical importance of appropriate **project selection**. Civil engineering experience and research has shown four approaches to the choice and development of materials and methods of construction. These are then evaluated through the systematized **Choice of Technique Analysis** for the optimal combination of labour and equipment. This feeds in to the **re-engineering** of designs and specifications to prevent changes during construction, with the negative effects on morale and productivity.

The importance of **demonstration** projects wherever there is a significant change in conditions has been highlighted in the discussion of the Botswana experience. In the pilot, design, specification and methods of construction are modified and refined; **task definition** and **team balancing** are adapted; management procedures are clarified, including the **procurement and maintenance of tools** and the **monitoring and evaluation** functions; and the first phase of **training** is undertaken, with a focus on the hands-on site supervisor. It is indicated that the pilot (and possibly the earlier phases of programme roll-out) are performed through in-house construction management to iron out technical and managerial issues and procedures.

In the implementation of the programme, **expansion** proceeds only as fast as trained personnel become available. A programme for **emerging contractors**

and **materials manufacturers** can be initiated, following a similar structure to that used in the Soweto Contractor Development Programme.

In the close-out to each element ('project') of the programme, a **review process** should take place from which to refine the standard designs and specifications, training programme and **benchmarks** such as task definition and Choice of Technique Analysis data. Special attention should be paid to the **redeployment** of trained personnel, whether within the broader programme, as independent contractors or suppliers, or re-trained for employment in a related field.

These pointers cannot guarantee success in meeting employment and other socio-economic objectives, but the evidence described in this chapter indicates that they are essential to minimize failure. The following chapter investigates the extent to which building construction is employment-intensive, through the analysis of a selection of examples that provide a range from intentionally labour-intensive, through conventional practice, through to a system that is highly machine-intensive. Without this data, the effects of change of technique cannot be measured, and the expression "employment-intensive" loses its meaning in the context of building. The range of labour ratios generated from this survey of case studies forms the springboard for subsequent Choice of Technique Analysis, thereby paralleling the principles described above.

5 PROJECT REVIEW

The purpose of this chapter is to investigate a number of buildings, similar in scale and type to the school prototype contemplated in this research, to determine the ratio of project cost allocated to labour. The Primary School prototype currently used by the Department of Public Works in rural areas is analysed to provide a datum against which the other case studies can be measured. More importantly, it is this design that would be superseded by the model proposed here if sufficient gains in employment creation can be shown.

The work of Hassan Fathy is highly respected by architects working on community projects throughout the developing world. Through the revival of ancient techniques of domes and vaulting constructed of sun-dried adobe, he challenged the prevailing view of the Egyptian government that the only suitable structural system for mass housing was reinforced concrete. Fathy's approach allowed for the construction of several public buildings within a budget established purely for housing in the relocation of the village of Gourna.

There are many elements of Fathy's work that are relevant to the present research, foremost of which is his holistic approach including: urban planning; materials research; a novel concept for training that addresses problems in the apprenticeship system; an appreciation of community involvement when unfamiliar designs and techniques are proposed; and a deep-seated effort at addressing poverty and employment extending beyond the building project. His innovations with regard to building were extended into other crafts and activities that included weaving and baking as a means to creating a self-sufficient community.

In this chapter, the focus is on his School for Girls built at New Gourna. While it is larger than the Limpopo school prototype, the percentages for key indicators are used as the basis for comparisons. Fathy has provided detailed information on

the manufacture of the sun-dried and fired bricks, as well as their use in construction, allowing a reconstruction of material and labour costs for all the masonry work. However, he makes only passing reference to the other building trades: carpentry, glazing and plumbing, so no ratios can be derived for the overall building project.

The third case study is an extension to the offices of LITE, a trust company set up to provide training in employment-intensive engineering, with a specific emphasis on road building. Despite being for different functions (an office component and bedrooms for staff) it is similar in scale and complexity to the Limpopo school used as the datum for this study. The value of this project lies in the management processes that draw on civil construction experience. This has provided extremely detailed information on materials, equipment and labour for the construction process as well as for quarrying.[53] The project has also piloted materials and techniques originally developed for road building, such as rubble stone foundations and bitumen stabilized earth blocks for the walling.

At the other end of the scale of mechanization, a number of products have been certified by Agrément South Africa as complying with a series of performance specifications with stated equivalence with conventional practice. Most of these substitute a single building element with a factory produced equivalent that is simply and quickly erected on site. The most common of these are walling panels that either use metal frames with a sandwich construction with a core of insulation, or pre-cast concrete. The Lightweight Steel System analysed here offers the option of complete two-roomed units, including floor and roof, which are delivered to site and bolted to the foundations. Thus, apart from the foundations and finishing trades (painting and glazing) the only work carried out on site is the bolting of units to the foundations and to each other. For schools, these complete units are not feasible because of the span required for

[53] The LITE training programme for hands-on site supervisors includes instruction in quarrying activities and supply to site using labour-intensive methods.

classrooms: transport by road restricts the width of an abnormal load to 3.5m. Where the configuration of the building prevents the transportation of completed units, large components such as completed roof trusses and wall panels are delivered to site in standard shipping containers and coded for rapid assembly. Concrete surface beds are cast *in situ* by local labour, while the panels, roof trusses and profiled steel sheeting are assembled by the manufacturer's staff, assisted by local labour as recommended by the manufacturers.

Throughout this chapter, ratios have been used as a basis for comparison of data from different dates and places to minimise the effect of inflation. Source material has been presented as recorded to preserve the integrity of the data. Appendix 3 gives more detail on those case studies where comprehensive information is available, and attempts to bring costs to a common set of rates. However, it should be noted that this is an artificial exercise as labour rates, productivity, material costs and transport needs vary considerably, even within a single country at any point in time. The purpose of this chapter is not to provide absolute values, but to give a sense of the **range** of labour intensity as the basis for the investigation outlined in Chapter 6.

The purpose of this chapter is therefore twofold: to gain a sense of the range of labour-intensity in projects as a whole; and to determine which activities lend themselves to further investigation to improve the ratio of cost allocated to labour.

5.1 PRELIMINARY INVESTIGATION: ALEXANDRA FAR EAST BANK

While the documentation of many of building projects in the developing world speaks of a concern for employment creation and labour-intensive construction, most of these projects are in the housing sector with few giving sufficient information on the labour aspect to allow detailed analysis. An exception is a mass housing project in Alexandra, a township of Johannesburg[54], where the

[54] Alexandra was a designated Black area under the apartheid government, despite being adjacent to white residential suburbs. It is currently experiencing upgrading through the

architects also acted as project managers and, to some extent, as management contractors. Records of material quantities and costs, labour hours and rates, equipment and overheads have been made available for the present study.[55] (Fig 5-1)

The lack of information on labour for most projects derives from the structure of the tendering system in Anglophone Africa. Items in a Bill of Quantities combine labour, materials, overheads and profit into a single price, and contractors compete largely through adjusting these factors to achieve a competitive price for the whole project. Contractors are unwilling to divulge their breakdown of items as the see this as giving away their trade secrets and compromising their competitiveness. This has severely hampered research into employment-intensive building, as much of the data has to be guessed on a pro rata basis, so that the radical advances in employment ratios achieved in civil engineering are difficult to initiate.[56] This is exacerbated through the conventional divide of design and construction, preventing a feedback loop to increase the percentage of costs allocated to labour, as well as improving efficiency and productivity. This has been discussed in the Literature Review (Chapter 3) with reference to the works of Wells (1986), Stewart (1977) and Cain (2004 a & b).

The focus in the Alexandra Far East Bank project was on small contractor development within the national Reconstruction and Development Programme that saw the establishment of a Capital Housing Subsidy scheme for mass housing. It was anticipated that by using small contractors who had little capital for plant and machinery, that the works would be inherently labour-intensive. However, no specific study that modelled the labour content was undertaken, nor were any conditions of contract placed on the contractors in this regard. This can

---

government driven Alexandra Renewal Programme, of which the Far East Bank housing development was an early initiative.

[55] Courtesy Michael Hart and Christos Daskalakos Architects, 2002.

[56] An important source of information on labour and other building costs is the detailed *Master Builders Pricing Guide* (Master Builders Association 2003), which was published annually until 2003 which has been used as the datum year for calculating ratios where information is absent in the data for the South African examples.

be contrasted with the Expanded Public Works Programme, where labour-intensive methods were compulsory for designated types of work and activities.

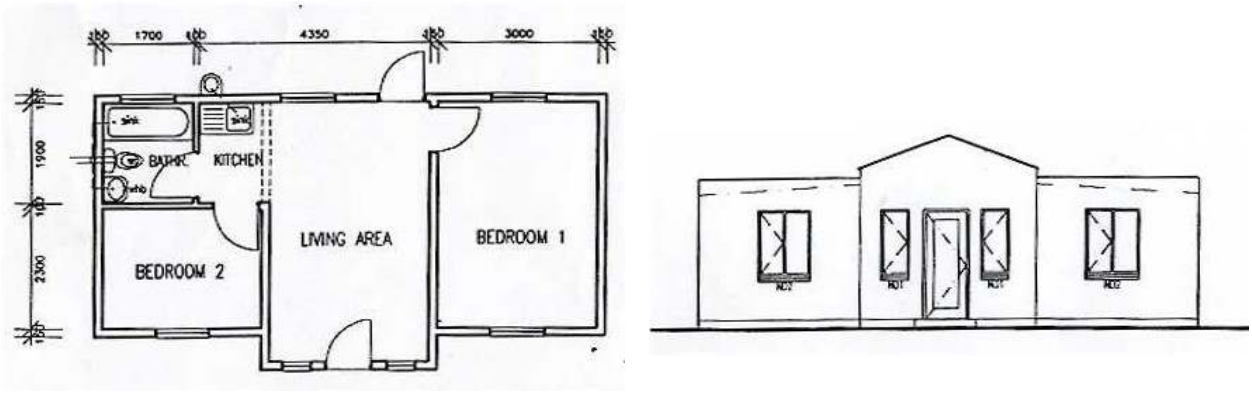


Fig 5-1: Alexandra Far East Bank House Type B (Michael Hart Christos Daskalakos Architects, 2002)

The analysis summarised in Tables 5-1 and 5-2 below is based on one of the single-storey freestanding housing types. The houses have concrete foundations and floor slabs, concrete brick walling, profiled galvanised steel roof sheeting on prefabricated timber trusses, standard steel windows and door frames, and fibre cement ceilings.

Trade	Labour	Materials	Plant & OH	Total	Trade %
Foundations	1 444	3 738	622	5 804	18.72
Walling	1 662	4 376	724	6 762	21.82
Roof	758	3 778	1 302	5 838	16.39
Ceilings	60	156	26	242	0.78
Plaster	1 283	1 223	301	2 807	9.05
Doors	300	1 011	157	1 468	4.74
Glazing	inclusive[57]	541	65	606	1.96
Plumbing	670	3 027	468	4 165	13.44
Electrical	710	1 330	395	2 435	7.86
Painting	670	783	174	1 627	5.25
Total	**7 557**	**19 963**	**4 234**	**31 754**	

Table 5-1: Ratio of trade to project cost, Alexandra Far East Bank (Prices in 2002 SA Rands)

[57] The glazing was negotiated with an emerging subcontractor at a flat rate per pane of glass. The overheads and profit cited for this item are those taken by the main contractor for attendance on the subcontractor.

Table 5-1 indicates which trades should be the subject of investigation for improved labour content, as those that account for a small percentage of the total project cost may be adapted for considerable increase the labour ratio, but would have little impact on the overall amount of employment generated. Some of these smaller items may result in higher labour content as a consequence of changing the design and/or specification of major ones, but the initial research and development should be focused on the areas of greatest impact.

This said, a superficial examination of the materials and methods employed in smaller items may indicate scope for reverse substitution of labour for machinery, reversion to more traditional local materials, or simply choosing a different method from the wide range available in building, without the need for extensive research. It is a contention of this thesis that building, in contrast with much civil engineering work, offers far greater choice to achieve similar performance criteria, but in many cases the decision-maker is hampered by lack of precise information on the employment generating potential of each option.

Trade	**Labour**	**Total**	**Labour %**
Foundations	1 444	5 804	24.88
Walling	1 662	6 762	24.58
Roof	758	5 838	14.92
Ceilings	60	242	24.79
Plaster	1 283	2 807	45.72
Doors	300	1 468	20.44
Glazing	inclusive	606	N/A
Plumbing	670	4 165	16.09
Electrical	710	2 435	29.16
Painting	670	1 627	41.15
Total	**7 557**	**31 754**	**23.80**

Table 5-2: Labour as percentage of trade, Alexandra Far East Bank (Prices in 2002 SA Rands)

The ratios of wages to overall item cost in Table 5-2 give the lowest values to roofing and plumbing. The latter has potential for investigation into obsolete

technologies such as salt-glazed stoneware piping, developed in pre-industrial Europe. This would also allow a return to more environmentally responsive materials than the current PVC piping, and could be revived alongside other clay products to provide opportunities for small industry in rural areas through diversification within a single technology and using entirely local materials. For this proposal to be completely effective, research should be directed to energy sources that do not require fossil fuels or timber for firing the kilns.

The roofing system, with the variety of structural systems, materials and processes available to the designer, was chosen as the primary focus for the present research. This decision was reinforced because of the opportunities of integrating roof, ceiling and walling to some extent, thereby justifying the time and cost of research and development into new materials and techniques. Moreover, the roofing component of the Alexandra project had a cost for plant and overheads of almost double the value of the other trades (see Table 5.3).

Trade	**Trade total**	**Labour %**	**Materials %**	**Plant & OH %**
Foundations	5 804	24.88	64.31	10.72
Walling	6 762	24.58	64.71	10.71
Roof	5 838	14.92	64.63	22.30
Ceilings	242	24.79	64.46	10.74
Plaster	2 807	45.72	43.57	10.72
Doors	1 468	20.44	68.87	10.69
Glazing	606	89.27 (labour and materials)		10.72
Plumbing	4 165	16.09	72.68	11.24
Electrical	2 435	29.16	54.62	16.22
Painting	1 627	41.15	48.12	10.69
Total	31 754	23.80	62.87	13.33

Table 5-3: Cost ratios of labour, materials and plant/overheads by trade, Alexandra Far East Bank (Prices in 2002 SA Rands)

From Table 5-3 some important distinctions can be made between engineering projects and small-scale building works. The profit and overhead component is

generally in the region of 10% of the project cost, and in a Bill of Quantities this would generally be distributed *pro rata* through the trades.[58] The Alexandra project therefore indicates plant and large equipment only for roofing and electrical, with the cost of purchase, depreciation and repair of small tools absorbed into the labour cost. In engineering works, as shown in Chapter 4, the development of employment-intensive construction started with the substitution of labour for large machinery especially in the sequence of Excavate, Load, Haul, Unload and Spread.

By contrast, in building the effects of industrialization tend to play out in the manufacturing of materials and components off site, while both traditional and industrialized elements are assembled using very little large plant. (It should be noted that in larger and more prestigious buildings, extensive use may be made of plant, depending on the design and specification of the professional team, and the *modus operandi* of the contractor.) This indicates that the entire process from sourcing bulk materials, through processing, delivery to site and erection, need to be considered to allow for informed decisions to be made. In the present study, the target community for both employment creation and retention of the project cost is defined, therefore the labour component of materials bought in from elsewhere is ignored, whereas local labour for quarrying, processing and supply is included in the employment calculations.

5.2 PROTOTYPICAL SOUTH AFRICAN PRIMARY SCHOOL

The standard Primary School type built by the Department of Public Works in rural areas of South Africa is the subject of this section. The design originated in the 1950s as the outcome of studies by the National Building Research Institute (NBRI) to establish prototypes that met certain performance standards, especially with regard to materials, lighting and ventilation. Through the NBRI, separate prototypes were developed for different racial groups, based on cost

[58] It is common practice in competitive tendering either to load items that are insufficiently documented in the anticipation of variation orders during construction, or to 'front-load' the pricing of a Bill of Quantities to improve cash-flow in the early months of the contract.

formulae that allocated the highest budget per learner to white pupils, and the lowest for blacks in rural areas. As has been shown in Chapter 3, under the Nationalist (apartheid) government black education had been placed under the control of the Bantu Affairs Department, and no longer the Department of Education. Elements of this legacy still linger in the current prototype because of its cost effectiveness in the face of massive backlogs in the provision of schools in many areas of the country.

There are two separate buildings: a row of four classrooms with a roofed corridor that was originally planned to be situated on the north face (Fig 5-2); and a toilet block with pit-latrines, located at some distance from the classes (Fig 5-3). Consistent with the 'scientific' approach used by the NBRI, north orientation takes precedence over terrain features in the siting of the classroom wing, with large windows to north and south for optimal daylight and ventilation. The classrooms are 7.5 x 7m, with concrete floors, plastered and painted walls and fibre-cement ceilings. Fittings are rudimentary: two pinning boards, a chalk board and a single steel cupboard, all manufactured in one of the large industrial centres at considerable distance from the school site, as are the steel windows, door frames and security gates. Exterior walling is of facebrick, with a galvanised corrugated steel roof on prefabricated timber trusses. The classroom wing is electrified on the national grid, with four fluorescent strip lights and one plug point per classroom, and four external light fittings mounted on the walls. A 1m wide concrete apron surrounds the entire classroom block to shed stormwater away from the building, but no other earthworks or landscaping is undertaken by the Public Works Department.

The majority of the industrialised materials are sourced through local building supply company, while the bricks are procured directly from the manufacturer. Sand and stone would be delivered directly from a commercial quarry or one established by the Department of Public Works for engineering projects in the area.

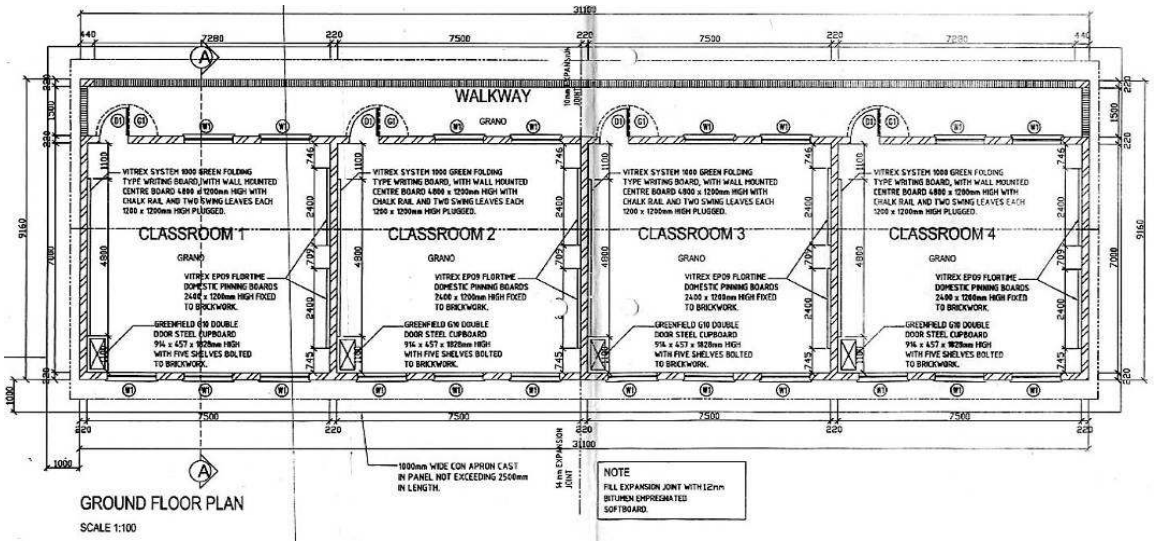


Fig 5-2: Typical block of four classrooms, Department of Public Works

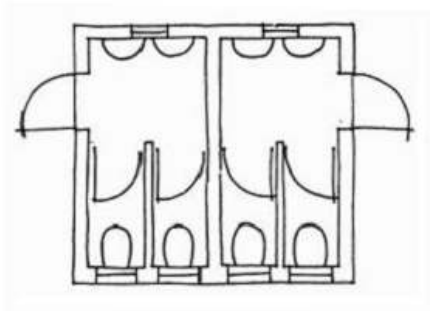


Fig 5-3: Assumed configuration of typical toilet block

5.2.1 Cost and Labour Analysis - DPW school

The data on which this analysis is based comprise: a summary, by trade, of the estimated Bill of Quantities; detailed quotes for building materials from a supplier near the school site; and a summary of the estimated days and wage rates for different categories and trades of workers. All this material was provided by the Limpopo Department of Public Works, courtesy the Department's chief quantity surveyor, Mr Faizel Goode, who provided valuable insights into the interpretation of this information.

Trade	Cost per trade	Trade % of total
Preliminaries	17 000	5.39
Foundations	42 089	13.36
Concrete work	26 296	8.34

Masonry	70 466	22.36
Waterproofing	2 904	0.92
Roof covering	21 984	6.98
Carpentry & joinery	28 796	9.14
Ceilings	21 100	6.70
Ironmongery	23 248	7.38
Metalwork	16 292	5.17
Plastering	6 400	2.03
Plumbing & drainage	3 400	1.08
Electrical	18 285	5.80
Glazing	7 084	2.25
Painting	9 789	3.11
Subtotal	**315 133**	**100.00**
Contingency	5 000	
Value Added Tax	44 818	
TOTAL	**364 951**	

Table 5-4: Limpopo DPW School, Bill of Quantities summary (DPW 2003) (Prices in 2003 SA Rands)

The summary of the Bill of Quantities (Table 5-4) reveals that the project cost is concentrated in three trades: in order of magnitude these are Masonry; Foundations; and Carpentry and Joinery. The last of these is a complex combination of activities, the largest group (by cost) of which relate to the construction of the roof structure and battens for the ceiling. If all the known items that relate to the roof (sheeting, waterproofing, timbers and ceiling) are extracted and aggregated, the following can be derived:

Roof carpentry	16 381.57
Sheeting	18 697.04
Waterproofing	3 566.24
Ceilings	7 334.61
Total material	45 979.46
Labour	1 120.00
Overheads	15 015.00
Total roof	62 114.46

This compares with the R 70 466 for Masonry, so the basic envelope of the building: foundations, walling and roof, together comprise almost 60% of the project cost before contingencies and tax are included.

Grade	Trade	Number*		Days	Total	Rate/day	Cost**
Unskilled		3+9	12	10	120	35	4 200
Semi-skilled	Brickwork	4+4	8	24	192	45	8 640
	Carpentry	1+1	2	14	28	35	980
	Electrical	0+1	1	14	14	35	490
	Plumbing	0+1	1	7	7	35	245
Skilled	Brickwork	7+0	7	24	168	95	15 960
	Carpentry	1+0	1	14	14	90	1 260
	Electrical	1+0	1	14	14	90	1 260
	Plumbing	1+0	1	7	7	90	630
Supervisor		1+0	1	90	90	65	5 850
Clerk		0+1	1	90	90	65	5 850
Manager		1+0	1	90	90	200	18 000
Professional		0+1	1	20	20	200	4 000
Total							**67 365**

Table 5-5: Human resources – Department of Public Works school (DPW 2003)
Note: * This column indicates “Male + female”. The Department of Public Works is committed to redressing gender inequity in the construction sector, reflected in the absence of women in the skilled grade, but predominating in the lower grades to arrive at a gender balance for the project as a whole.

The service trades of plumbing and electrical form considerably less of the project cost than the house type at Alexandra discussed above. This can be attributed to the difference in building type, as well as the location of the school in a rural area, with less stringent building by-laws than in urban areas, especially with regard to plumbing and sewerage reticulation.

The information provided by the Department of Public Works for labour, shown in Table 5-5, appears to be optimistic, especially with regard to earthworks and excavation. The labour for carpentry also seems to be slightly low, although the tasks are simple, with long runs of components, large rooms and small amounts of cutting. These figures have been compared with the tabulated guidelines for labour in the Master Builders Pricing Guide 2002/2003.

In reconciling the broad categories of labour with the Bill of Quantities summary, the latter are grouped into masonry, carpentry, electrical and plumbing to establish labour ratios. Carpentry has been separated into items relating to the roof and ceiling, and other activities such as hanging doors and installing fittings.

Trade	Labour	Materials		Other	Total
		Supplier	Manufacturer		
P & G	11 000	nil	nil	6 000	17 000
Wet trades	28 200	49 334	36 734	47 856	162 124
Carpentry	1 120	36 623	nil	9 827	47 570
Roofing	1 120	45 979	nil	19 655	66 754
Plumbing	875	1 914	nil	611	3 400
Electrical	1 750	12 898	nil	3 637	18 285
Total	**44 065**	**146 748**	**36 734**	**87 586**	**315 133**

Table 5-6: Breakdown of costs by trade, Department of Public Works school

A number of assumptions and estimates were necessary in order to generate Table 5-6 in relation to the apportionment of labour to the Bill of Quantity trades. Professional and high-level management fees were omitted in this calculation, as they are time-based and do not relate to the value of work undertaken in each trade. The labour of the clerk and supervisor were attributed to Preliminaries and General as the artisans would supervise their own trades. The Wet trades include concrete work, walling (including building in door and window frames), plastering, painting and glazing. It is assumed that the unskilled labour would perform earthworks and be involved in the wet trades. Bricks, sand and stone that would be sourced directly from the manufacturer and quarry were calculated at 2003 prices from the Master Builders Association Pricing Guide. It must be noted that the most significant items under carpentry are the chalk boards, pin-boards and security gates, all of which are manufactured in the industrial centres.

The percentages of labour to each of the aggregated trade categories from Table 5-6 are shown in Table 5-7.

Trade	Total	Materials	% material	Labour	% labour
P & G	17 000	nil	0.00	11 000	64.71
Wet trades	162 124	86 068	53.09	28 200	17.39
Carpentry	47 570	36 623	76.99	1 120	2.35
Roofing	66 754	45 979	68.88	1 120	1.68
Plumbing	3 400	1 914	56.29	875	25.74
Electrical	18 285	12 898	70.54	1 750	0.10
Total	**315 133**	**183 482**	**58.22**	**44 065**	**13.98**

Table 5-7: Ratio of materials and labour to trade price, Department of Public Works school

The unknown costs, designated “other” in Table 5-6 are assumed to include plant and overheads, including attendance on the service subcontractors. The critical assumption in Table 5-6 was the apportioning of labour for roofing and carpentry components. The extremely low figures for both of these components indicate that the exact number of days worked on each is not significant. The overall ratio of labour costs at 14% of the net project cost indicates that this prototype cannot be classified as employment-intensive in the sense that the Department of Public Works uses the term for the Expanded Public Works Programme.

5.3 GIRLS SCHOOL: NEW GOURNA

The work of Hassan Fathy has exceptional status among architects, writers and field workers in the development arena. This respect can be attributed in large measure to the architectural quality of the work done under his direction (a factor which in no way should be discounted[59]) rather than for the values that were his stated primary concerns. In his own modest words:

> “All our buildings must consist of the same elements, slightly varied in shape and size, arranged in different combinations, but all to the human scale, all recognizably of a kind and making harmony with one another.



Fig 5-4: Boys’ school and house courtyard, New Gourna (Aga Khan Trust for Culture)

[59] The importance of design and construction quality should not be ignored: this is a critical area in which employment-intensive methods can do more than just produce ‘the same as’ at no extra cost. In the building field, the highest level of skills development is in craftsmanship and artistry, neither of which should ‘cost’ more, except possibly in time, which is balanced by the increase in quality as ‘value added’ even where this is difficult to quantify.

> The situation imposes its own solution, which is – perhaps fortunately, perhaps inevitably – a beautiful one." (Fathy 1973: 37, his emphasis)

Underpinning his work at New Gourna in the 1950s was the high cost of 'conventional' concrete frame construction, hence his research into 4 000 year old building methods using sun-dried clay bricks for vaulted and domed structures, the masonry skills for which still existed in the area, although disparaged and largely falling into disuse. His investigations into bitumen stabilization to improve weatherproofing had to be abandoned because of cost, so the traditional mixture of local clay, desert sand and straw was used, employing a hand press to reduce the water content (Fathy 1973: 89). This reliance on traditional techniques limits the span of the vaults and requires thick walling, but these constraints contribute to the climatic performance.

The village of New Gourna provides an excellent example of integrative design where all components of the villagers' lifestyle is considered, and accommodated with a feeling of identity and uniqueness deriving from his approach of developing each building individually with its end users. His consistent use of a small repertoire of roof forms and spans, and essentially a single material – sun-dried adobe and fired clay brick – for roofing and walls, produced a harmony throughout the village, with public buildings distinguished by their greater formality in design and a step up in scale.



Fig 5-5: Brickmaking at New Gourna (Aga Khan Trust for Culture)

Moreover, the choice of material is both climatically excellent[60] and less environmentally damaging than the reinforced concrete that was being used in the rest of Egypt at the time for mass housing. Fathy acknowledges the lower specification and its consequently higher maintenance needs. He justifies this through his discussions with the villagers in which they opted for a larger dwelling with the acceptance of the need for regular repairs, especially to mend the cracks that appear in the first few years until the vaulting and foundations have settled and compacted fully.

Fathy uses three types of vaulted structure in his work, the simplest being a barrel vault with a parabolic section so that the structure is entirely compressive under normal loading, which is critical in a system that has no reinforcing. The stability of the structures is enhanced through their thickness and through minor vaults acting as buttresses to the major spans. The other two structural types are the dome on squinches and the dome on pendentives. In all of these structures, no formwork is used, fairly simply solved in the case of the barrel vaults where the coursing is set at an angle braced by the end wall. Fathy does not describe how the domes are constructed, but there are examples throughout the world of different ways in which this can be achieved. The primary challenge is in the accuracy of the geometry, as deviation from a purely compressive form will generate shear stresses.

5.3.1 The Girls' School

Two schools were built at New Gourna for gender separation, with the girls' school being the smaller. It has been chosen for detailed study because of the detailed plan, a section and an elevation from which to take off quantities. It is also closer in scale and complexity to the Limpopo Public Works School with the major difference being the dining hall as shown in Figure 5-6.

[60] Adobe is the preferred material in climates with high diurnal temperature variation as its high U-value and the characteristic thick walls allows it to store heat in the daytime and radiate it back into the building at night.

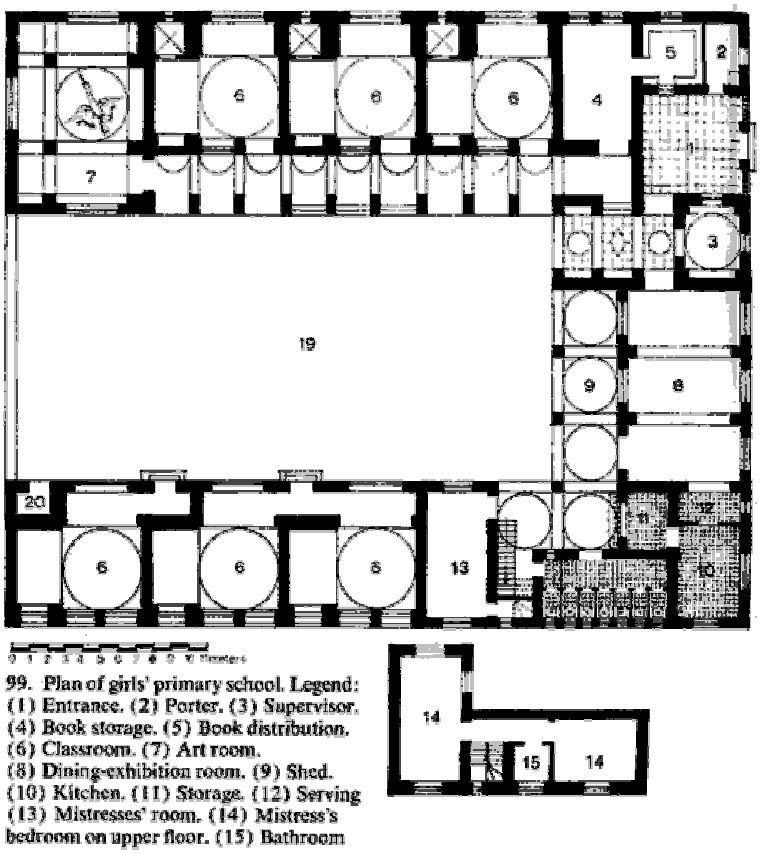


Fig 5-6: Plan of Girls School, New Gourna (Fathy 1973)

The standard classroom is a domed space with an attached barrel vault to create a more elongated teaching area. This module is repeated in the generic house type, where the central living space is domed with one to four barrel vaults opening off for the subsidiary activities.[61] This is consistent with Fathy's use of the public buildings to train the artisans before moving on to the domestic buildings. It also contributes to the urban quality of New Gourna through the consistency of forms, materials and spatial quality. Corridors, offices, the dining hall and ablutions are all roofed in a combination of the dome and barrel vault, varying in height to distinguish the more important spaces and to accommodate the different spans. In general, the domes are buttressed by the barrel vaults, and the remaining lateral loads are taken up in the thick walling.

[61] This house type, also called a four iwan house, dates to the Fatimid expansion of Cairo into the suburb of Fustat in the 10th Century. (Creswell 1978)

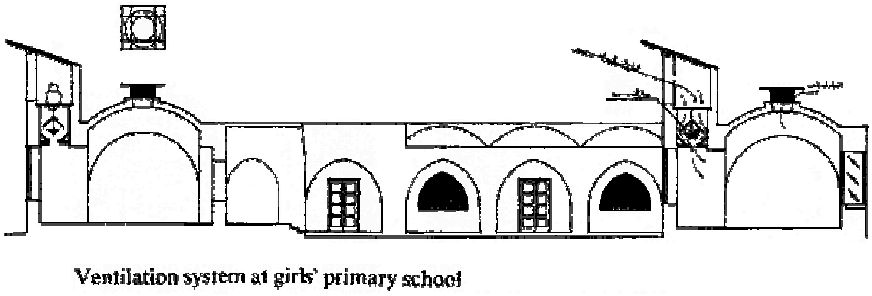


Fig 5-7: Section through Girls School, New Gourna. (Egypt Architecture online)

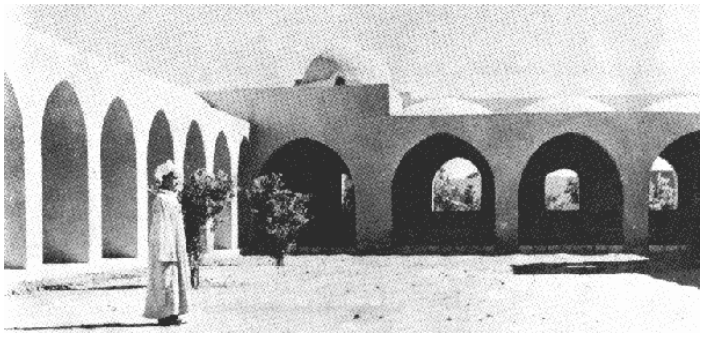


Fig 5-8: Courtyard of Girls School, New Gourna. (Egypt Architecture online)

The Girls' School at New Gourna no longer exists, so some of the interpretation of the three drawings is reliant on inferences from other buildings at New Gourna (Figs 5-9 and 5-10) and Fathy's school at Fares (Figs 5-11 and 5-12).





Fig 5-9 and 5-10: Ablutions and market, New Gourna (Aga Khan Trust for Culture)





Fig 5-11 and 5-12: School at Fares (Aga Khan Trust for Culture)

5.3.2 Cost and Labour Analysis – New Gourna

Fathy provides comprehensive data for the training, materials manufacture and construction of all the wet trade components of the buildings, namely: rubble masonry foundations; sun-dried brick walling; and roof vaults of fired brick. (Fathy 1973: 197-213). The dimensions for the School for Girls were scaled from the plans and elevations (Fathy 1973: figs 99-101) and confirmed by the standard roof sizes referred to in his text. The summary of the analysis of materials and labour for these wet trades is presented here in Table 5-8.

Element	**Labour**	**Materials**	**Total**	**Labour %**
Foundations > 0.7 wide	4 544	1 196	5 740	79.16
Foundations < 0.7 wide	12 679	4 021	16 700	75.92
Floors	4 127	1 909	6 036	68.37
Walls to cill height	10 432	2 181	12 613	82.71
Walls above cill	28 677	5 697	34 374	83.43
Roofing	15 484	13 450	28 934	53.51
Total	**75 943**	**28 454**	**104 397**	**72.74**

Table 5-8: Cost summary, New Gourna (See also Appendix 3)

It is important to note that almost all the material costs of this project are for fuel for the water pump (21% of the cost of unfired bricks), kiln (48% of the total cost of fired bricks) and for transport. The high ratio for labour confirms the importance of the choice of methods and materials to suit the particular

circumstances of time, place and performance requirements. Appendix 3 gives a set of equivalent figures if Fathy's design were to be built in South Africa in 2003. The same labour productivity is used, but some of the materials have been adapted where their manufacture would not be possible in the present context. In this analysis, the labour ratio falls from 73% to 42%, supporting the hypothesis stated above.

What this cost analysis does highlight is that all the factors of production need to be considered if the labour objective is to be maximised. In the case of New Gourna, a highly labour-intensive method of manufacturing the primary building material, combined with a high labour content in the construction process, is eroded by the need to transport the bricks by machine intensive methods that consume a significant part of the project budget.

5.3.3 Fathy's approach to training

In his *Architecture for the Poor*, Fathy (1973) identified a number of problems that would be encountered in reviving craft skills if the apprenticeship system were reinstated in its traditional form: "…the common practice in apprenticeship would have to be speeded up. We could not have boys kept for three years cleaning the master's tools and winding balls of string. …In the normal course of life a community can absorb only a limited number of craftsmen in any one trade," (Fathy 1973:65) followed by observation that, in apprenticeship system, the master ensures that there is no over-supply. At New Gourna, the dearth of craftsmen "…needed some system that would combine the large output of a school with the flexibility and low cost of the apprenticeship system…" He established a 'Crafts Khan' in which master-craftsmen were brought in from elsewhere in Egypt on a 'contract' system of short duration. By not staying long-term they would pass on their skills quickly and not worry about flooding the market with skills as Gourna was outside their own territory. This system also had the advantage that the combined skills and abilities of several masters would help to ensure that all components of the training would be adequately met.

Through his adaptation of an ancient tradition of building, he creates the need for semi-skilled workers rather than a glut of highly trained masons. He argues for on-the-job training, where the **public buildings** are used as the initial training environment. “By training the villagers on the public buildings … we can make use of the architects and master craftsmen engaged by the building authority, and they can pass on their skills to the people,” (Fathy 1973:122).

The training programme is structured into classroom learning that is immediately practiced in the yard, followed by periods of application on the building sites. The latter is carried out at lower wages than the trained workforce, which subsidizes the cost of the trainers. He warns against speeding up this training: “…formulas can be taught quickly but not the understanding of principle, so trainees would have difficulty in applying their skills to new problems,” (Fathy 1973:123).

				Grade cost			Repayment*		
Stage	Week	Activity	Grade	Wage	Days	Total	V-A	Days	Total
A	1 2	Learns to square layout, dry brick walls, 1, 1½, 2	Helper	8	12	96	-	-	-
B	3 4	Works on job, handling materials and watching	Helper	8	12	-	0	12	0
C	5 6	Learns to do above work, but using mortar. Also partitions	Helper	8	12	96	-	-	-
D	7 8	Works on job, helping 2 masons by filling cores of walls. Does ¼ work of two masons	Apprentice	12	12	-	8	12	96
E	9	Learns to build segmental arches	Apprentice	12	6	72	-	-	-
F	10	Works on job as assist-ant mason with one master mason (40-18=22)	Assistant mason	18	6	-	22	6	132
G	11	Learns to build vaults and a Byzantine dome	Assistant mason	18	12	216	-	-	-
H	12-14	Works on job as mason	Mason	25	12	-	12	180	8*
I	15 16	Learns to build domes on squinches, vaults on unparallel walls	Mason	25	12	300	-	-	-
J	17	Practices stone building on the job	Mason	25	6	-	15	6	90
			Master Mason	30	24	-	10	24	240
						780			738

Table 5-9: Training programme, New Gourna. (Fathy 1973)

It is instructive that his teaching philosophy and its application mirror the training system for site supervisors of labour-intensive road building described by McCutcheon and Marshall (1996).

This case study highlights the difficulties in making comparisons between projects in vastly different contexts. However, several important principles can be learned:

a. Consideration of the entire process, from sourcing of bulk materials through to construction, allows a maximum of the project value to remain with the target community;
b. Training needs to be an integral part of the programme of work;
c. Choice of materials and techniques should be evaluated in consultation with the end users to determine the best balance of initial cost with maintenance requirements.

5.4 LITE OFFICES AND STAFF ACCOMMODATION

LITE (Labour Intensive Training and Engineering) is a non-profit organization that specializes in the training of hands-on site supervisors for road construction. The buildings considered in this case study are extensions to the infrastructure used for the Mohlaletse Youth Service Programme in Limpopo Province, LITE's first major training programme. Its purpose was to test out the adaptation of programmes and training approaches used elsewhere in sub-Saharan Africa for the building of rural roads using employment-intensive methods. Its principal objective has been to direct the highest percentage of construction cost to less-skilled workers, while matching other methods of construction in terms of cost, time, scope and quality. The focus is on efficiency and productivity and in this context the hands-on site supervisor is the key to achieving this on site. Training for the 'hands-on site supervisor' had been developed as a combination of classroom and closely supervised on-site training, followed by an internship or probationary period. Material covered combines technical, management and

entrepreneurial aspects required to fulfil the duties of the ‘hands-on site supervisor’.

The initial buildings that LITE constructed at Mohlaletse comprised offices and classrooms on two separate sites. These and their extensions that are the subject of the present analysis were built by trainers and learners, using the management techniques promoted in the programme. Wherever feasible, local materials were used and techniques developed in road building, such as rubble foundations and bitumen stabilized earth for the bricks. While two of the trainers had some expertise in building, most of the activities had to be planned for unskilled workers. Despite this, roof trusses were constructed on site (in contrast with the factory made trusses used by the Department of Public Works), using the trainers’ and trainees’ knowledge of geometry and carpentry necessary for building bridges.

The extensions for the school were a single space that could be subdivided into two classrooms, while the office extensions included office space, bedrooms for staff, and a small plumbing component. As the scale and complexity of the offices were closer to the standard Limpopo school analysed above, this formed the basis for the comparisons given here.

The management system used throughout the project has left a comprehensive body of data from the feasibility study through to final completion that matches best practice in labour-intensive civil engineering works. This gives a thorough analysis of quantities and costs of materials (including from quarry); and plant, equipment and tools, including their maintenance and depreciation. Labour is broken down into individual activities and number of workers of each skill level for each task. (See Appendix 3 for detailed data.)

In the planning stage, a reiterative process was used to allocate as much of the work as possible to lower skills levels. Consistent with the focus of the training

programme, the supervisor is employed in a far more central role to reduce professional and higher level management input. To some extent this rigour was used in team balancing, although the lack of experience in building work meant that this was not as thorough as in road works. Critical path planning and programming were employed using MSProject so that constant updates and revisions could be tracked and responded to by high level management located in Johannesburg, 450 km from the site.

The specialized and regulated trades of plumbing and electrical were performed by outside subcontractors. The most commonly encountered problems were with the more highly skilled activities in the finishing trades, where tiling and cement screed were specified instead of finishes that were more appropriate to the level of accuracy that could be expected of the basic structure.

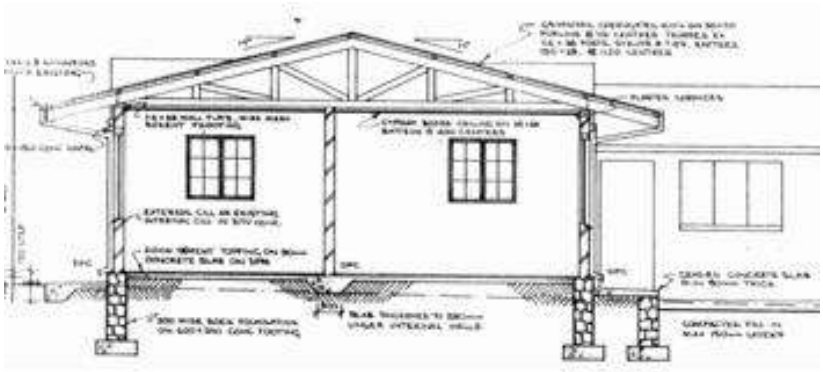


Fig 5-13: LITE offices

5.4.1 Cost and Labour Analysis – LITE offices

In the analysis presented in Table 5-10, high level management and professional costs are omitted, which accounted for R19 686 of the final project cost. In all the documentation, this was distributed pro rata relative to the labour costs. Equipment totalled R5 728, and was either allocated to specific tasks or distributed among the relevant tasks in proportion to the value of the task. The following wage rates were used (all rates are in 2003 South African Rands): Labourer R25/day; Builder R35/day; Team leader R45/day.

Activity	Labour	Materials	Item total	% of total	Labour %
Site preparation	75	0	343	0.24	21.9
Foundations	3 330	7 073	18 302	12.93	18.2
Surface bed	984	3 049	7 405	5.23	14.8
Walling	4 809	16 430	33 826	23.91	14.2
Roof and ceiling	2 821	27 026	42 550	30.07	6.6
Interior finish	1 274	7 154	17 119	12.10	7.4
Plumbing	50	325	1 220	0.86	4.1
Electrical	75	1 500	2 170	1.53	3.5
External works	385	861	2 441	1.73	15.8
Clean	283	932	1 077	0.76	26.3
Brick manufacture	5 110	4 932	15 041	10.63	34.0
Total	**19 196**	**69 282**	**141 494**	**100.00**	**13.57**

Table 5-10: Cost analysis with unadjusted labour rate, LITE offices

To allow for a more direct comparison between this project and the Limpopo Department of Public Works school, the equivalent wage rates are used to calculate the brick manufacture costs shown in Table 5-11. The materials cost for this activity is R4 746, so the labour is 62% of the cost of this activity (50% using actual wages), money that would otherwise be lost to the community if the bricks were bought from a commercial brick manufacturer. The ‘imported’ items in the brick-making at LITE are bitumen, cement and fuel, of which 40% of the total brick cost goes to the bitumen for stabilization and waterproofing. However, the result of using this material is a brick that is equivalent to a commercially made one, where all the cost flows out of the project area.

Labourer	R35/day x 120 days	4 200
Builder	R60/day x 0 days	0
Team leader	R90/day x 40 days	3 600
Supervisor	R200/day x 0 days	0
		7 800

Table 5-11: Adjusted wage rates and labour cost for brick-making, LITE offices

Activity	S/visor	T/leader	Builder	Labourer	Artisan	Wage (R)
Site preparation	1.0	-	-	3.0	-	305.00
Foundations	0.5	6.0	28.5	82.5	-	5 237.50
Surface bed	-	3.5	9.5	25.0	-	1 760.00
Walling	-	-	56.5	113.5	-	7 362.50
Roof & ceiling	8.0	13.0	29.0	48.0	-	6 190.00
Interior finish	-	2.5	10.5	32.0	-	1 975.00
Plumbing	-	-	-	2.0	2.0	250.00
Electrical	-	-	-	3.0	3.0	375.00
External works	-	1.5	2.0	6.5	-	482.50
Clean	-	1.0	-	9.5	-	422.50
Total days	**9.5**	**27.5**	**136.0**	**325.0**	**5.0**	
Total wages (R)	**1 900**	**2 475**	**8 160**	**11 375**	**450**	**24 360**

Table 5-12: Labour days by grade, per activity, LITE offices

Using the same wage adjustments for the construction process, the labour cost totals R19 875. The material cost, excluding labour for brick-making is R67 500, of which the roof and ceiling materials comprise 40% as the largest component. Thus the total adjusted figures are:

Brick-making labour	7 800
Construction labour	24 360
Total labour	**32 160**
Materials	69 282
Net project cost	**101 442**

In this calculation, the total labour accounts for 31.7% of the net project value, and construction labour for 24.0%. Detailed analysis is given in Table 5-13.

Activity	Labour	Materials	Total	Labour%	Activity %
Site preparation	305.0	0	305.0	100.0	0.3
Foundations	5 237.5	7 073	12 310.5	45.5	12.1
Surface bed	1 760.0	3 050	4 810.0	36.6	4.7
Walling	7 362.5	16 430	23 792.5	30.9	23.5
Roof & ceiling	6 190.0	27 026	33 216.0	18.6	32.7
Interior finish	1 975.0	7 154	9 129.0	21.6	9.0

Plumbing	250.0	325	575.0	76.9	0.6
Electrical	375.0	1 500	1 875.0	25.0	1.8
External works	482.5	861	1 343.5	35.9	1.3
Clean	422.5	932	1 354.5	31.2	1.4
Brick making	7 800.0	4 932	12 732.0	61.2	12.6
Total	**32 160**	**69 282**	**101 442**	**31.7**	**100.0**

Table 5-13: Cost analysis using adjusted labour rates, LITE offices

This leads to two important conclusions:

- One of the two largest activities by value has the smallest labour ratio, namely roof and ceiling, which is consistent with the findings in the other two South African case studies;
- The manufacturing of bricks on site contributes significantly to the creation of local employment, where if the entire brick cost were allocated as a material cost, the labour ratio for walling would drop from 31% to 20%.

5.5 LIGHTWEIGHT STEEL SYSTEMS BUILDING

For several decades in South Africa, manufacturers supplying the building industry have researched and promoted various systems that minimise the labour content, especially on site. These ‘system-build’ methods range from clip-together small components through to large elements. Invariably the connectors are simple, removing or highly simplifying the traditional artisan activities. In the 1950s and 1960s, hundreds of classrooms were built of steel framed walling with large infill panels of asbestos sheeting to accommodate the rapid increase in numbers of pupils.

One of the most effective systems currently on the market is the Lightweight Steel Frame building system which is marketed specifically as one where cost savings are achieved through the low labour content. It is promoted through the Southern African Steel Framing Association, which brings together the major

material and component suppliers for the system. The Association was launched after research in Australia and the United States to develop a highly mechanised and computerised system in response to the lack of skilled artisans in South Africa.

The system comprises a steel frame constructed on an in situ cast concrete slab, clad with panels of various specifications to meet different climatic and other performance criteria, but generally of gypsum board or fibre reinforced cement. The frame and roof members are made from small gauge steel with complex cross-sections to improve material efficiency. The steel components are pre-drilled in the factory for fixing bolts and to carry electrical and plumbing services. Roofing is generally of profiled steel, in keeping with the lightweight frame and dimensional precision, although other roof coverings can be accommodated.

Figures 5-14 to 5-19 illustrate the sequence of activities from transferring the general layout design to computer through to the completed structure. The structural design is carried out automatically on a CAD/CAM programme, after which the specifications and costing are calculated. The design facility is linked to a roll profiling machine. Sections are produced to the exact lengths, holes punched and each section marked in the correct sequence for assembly. Wall panel frames and roof trusses are assembled in the factory. The frame is erected within two days and the panels, doors, roof sheeting and rendering are completed within three weeks.





Fig 5-14 and 5-15: LWSF design on CAD/CAM and profiling machine (Group5 2007)

The system is also capable of delivering complete buildings or large components complete with wall panels and roof covering, however this is limited to a 3.5m width for road transport. For this reason, the most highly mechanized form is not considered here, as the typical school classroom needs to be between 6m and 8m.



Fig 5-16: Completed framework (Group5 2007)



Fig 5-17: Flexible conduit (Group5 2007)



Fig 5-18: Interior (Group5 2007)



Fig 5-19: Completed building (Group5 2007)

5.5.1 Cost and Labour Analysis – Lightweight Steel Frame System

In the analysis that follows, a detailed design, costing and labour requirements were provided by Vela Construction, one of the companies certified by the Association. Much of the erection is carried out by this company's personnel, with the client providing one skilled worker, two semi-skilled and three general workers for the two days to erect the framework.

From this analysis it is clear that the Lightweight Steel Frame system meets its manufacturers' claims of having an extremely low labour content. What is disturbing in the South African context is that it is being promoted as an alternative to conventional construction for school buildings in rural and urban areas. It is tempting for public authorities to follow this procurement route as it simplifies the management of the entire construction process, with only the site preparation and surface bed being carried out through conventional means. The construction period is significantly less than any other method analysed in this thesis, which could also be persuasive.

Trade	**Cost per trade**	**Trade % of total**
Preliminary & general	23 367	5.19
Site preparation	4 666	1.03
Foundations and slab	27 388	6.08
Superstructure	163 446	36.31
Roof sheeting	40 122	8.91
Ceilings	46 372	10.30
Doors	3 318	0.74
Ironmongery	38 383	8.53
Metalwork	26 889	5.97
Plastering	10 558	2.35
Plumbing & drainage	5 617	1.25
Electrical	30 166	6.70
Glazing	13 680	3.04
Painting	16 175	3.59
Subtotal	**450 147**	**100.00**
Value Added Tax	63 021	
Contingency	8 000	
TOTAL	**521 168**	

Table 5-14: Lightweight Steel System cost breakdown by activity (Compiled from Vela Construction quote, 2007, other quantities from Limpopo DPW School – prices adjusted to 2007 rates courtesy Prof A Taluchaba, University of the Witwatersrand)

Activity	Labour	Materials	Total	Labour%	Activity %
Site preparation	4 666	0	4 666	100.0	1.09
Foundation & slab	4 762	12 894	27 388	17.39	6.42
Superstructure	723	162 723	163 446	0.44	38.30
Roof sheeting	1 958	18 199	40 122	4.88	9.40
Ceiling	3 977	27 792	46 372	8.58	10.87
Finishing trades	2 997	65 995	109 003	2.75	25.54
Plumbing	1 446	3 017	5 617	25.74	1.31
Electrical	2 887	20 098	30 166	9.57	7.07
Total	**23 416**	**310 718**	**426 780**	**5.49**	

Table 5-15: Lightweight Steel System, Labour and activities as percentages of direct construction costs, P&G omitted. (Figures from A Taluchaba and Vela)

It is the contention of this thesis that, at the end of construction, almost all of the project expenditure reverts back to the main industrial centres, almost no local employment is generated, and the users of the building are locked in to the system should they ever need to alter or extend the building.

5.6 CONCLUSIONS

In this chapter, several approaches to the construction of single storey buildings have been investigated to show the extent to which this scale of building work is employment-intensive. The measure of this has been the ratio of activity or project cost to the equivalent wage bill to allow for comparison between the case studies. These results are summarised in Table 5-16, where the activities relating to the roof and ceiling construction are highlighted as the most promising for further investigation.

Project	Total labour % of project cost	Roof labour % of roof activities	Total roof cost % of project cost
Alexandra	23.80	13.78	19.15
Limpopo school	14.40	4.44	22.53
New Gourna	not available	53.51	not available
LITE offices	29.36	17.04	27.49
Lightweight Steel	5.49	4.88	+/- 20

Table 5-16: Summary of labour ratios

From this table, it can be seen that the standard method of constructing schools, as currently used by the Limpopo Department of Public Works, has a labour content considerably less than was assumed by the National Economic Forum in 1994 (see Table 4-1). This supports one of the contentions of this thesis that statements about the labour-intensity of building are not founded on evidence or analysis. Moreover, as is shown in the school at New Gourna, while the materials and/or the methods of construction may favour a high labour content, these positive decisions can be undermined by other choices, in this case through the use of machine intensive transport of the bricks to the site, with exceptionally high fuel costs. The range of labour values for different building activities is worthy of attention, especially where an activity contributes a large amount to the overall direct project cost.

In all of the case studies[62], the labour ratio for the roof activities is considerably lower than the average for the whole project. This should be considered in relation to the other activities that form the envelope of the building: foundations, floor slab and walling, which in all cases except the walling in the Lightweight Steel Frame System have a much higher labour ratio than the average. The materials for services and finishes tend to be determined by performance specifications, with services moreover being determined by the National Building Regulations so that there is little scope for changing the method of production and materials without changing legislation.

By contrast, doors, windows, finishes and fittings can form a valuable area for increasing employment. While this would have fairly low impact on individual projects, the development of local carpentry and metal working skills should be seen in the context of self-sufficient decentralised communities.

[62] The exception is possibly New Gourna, but the lack of information on many of the activities makes this impossible to determine.

An aspect of considerable importance to decision-makers is that, apart from the buildings at New Gourna, the performance and appearance of all the examples are similar, so the decision to use materials and methods with greater employment-intensity within the range studied in this chapter is not technically or aesthetically driven. Resistance to manufacture on site (bricks and roof trusses in the LITE offices) seems to revolve around real or perceived lack of skills, prejudice against certain materials, and the acknowledgement of greater managerial input, especially in the early stages. Here it should be noted that architects, as the most usual leaders of the professional team, have almost no training in management in their academic education and rely largely on empirical methods. The converse of this attitude is that the actual labour content is not known, objectives relating to labour-intensity are not stated in measurable terms, and there is no feedback to determine whether any more jobs were created than would have been the case through conventional construction. In summary, until designers are prepared to construct and consult data on labour ratios, they will not be in a position to make any statements on how employment-intensive their designs are, nor will they be able to make any advances in increasing the labour content or advising their commissioning bodies.

The next chapter charts the process of investigating alternative roofing methods for greater employment content. This is a process that integrates engineering and architectural design, materials manufacture, methods of construction, training and management functions to take advantage of the greatest change to the wage ratio, especially as regards workers in the lower skills grades.

6 TECHNICAL INVESTIGATION: STABILIZED EARTH

Analysis of the case studies indicates that in moderately simple single-storey buildings, conventional construction is a combination of activities that range from very low to fairly high labour content. The latter activities have retained their traditional methods using hand tools generally through economy of scale, where large machinery is not cost effective, or through complexity and uniqueness. In each set of activities, analysed by conventional trade definition, there is some scope for increasing the labour content in relation to material, transport and energy costs. In the more traditionally performed activities such as site clearance, trenching and fencing, the design and management team can, for example, facilitate the use of wheelbarrows in place of motorised transport, through specifying locally sourced materials and re-use of excavated material from the site.

At the other end of the scale, activities use materials that have been highly processed at factories in industrialized centres, transported to site, and installed with a small number of specialized workers. Steel sheeting, metal windows and door frames, sanitary and electrical fittings, prefabricated roof trusses, for example, all follow this pattern of production. In the context of the present research, plumbing and electrical work does not offer much potential for increased local labour content, although innovation into more ecologically responsible systems suggest that this can change in the near future.

The walls and roof, as the primary envelope of the building, appear to be the parts offering the most scope for an increase in employment. This offers wide choice of materials and systems, ranging from a wealth of traditional examples through to recently developed products. In previous chapters, the advantages and shortcomings of reversion to traditional methods and materials, high technology, and ‘intermediate technology’ have been explored. It is the contention of this research that each of these approaches has merit, but for

employment generating initiatives to have lasting credibility, other avenues need to be explored. In this respect, the work of Eladio Dieste has the most immediate influence, through the use of sophisticated engineering that allows for a high percentage of unskilled workers and low-cost local materials to produce buildings of high quality.

The focus of the technical studies in this research is on the structural-spatial envelope of the building. As with any architectural design, secondary elements such as the windows and doors need to be considered in conjunction with the primary envelope to ensure appropriate forms and junctions with the primary elements. Evaluation of locally available materials and climatic considerations has prompted research into various methods of unfired stabilized earth blocks and tiles as the principal elements. These have the advantage of combining envelope and structure, roof and wall in a single system, leading to greater volumes of demand from a single supplier and concentrating training in a single trade.

6.1 OBJECTIVES OF THE TECHNICAL STUDY

In Chapter 5, a study of single-storey buildings shows that, even in the most employment-intensive examples, the number of employment opportunities that can be generated through building cannot compare with the achievements in civil engineering projects. Phillips shows that an average of 60% of the project cost for a road-building project will be given over to a small number of activities (Phillips 1994:76). By focusing on these, the process of analysis is simplified and the amount of re-engineering is reduced while still making a great improvement in the targeted labour content. Moreover, several of these ‘large’ items naturally lend themselves to reverse substitution of labour for machinery, especially the sequence of Excavate, Load, Haul, Unload and Spread for the layering-work of road construction. By contrast, the small scale and complexity of building work suggests that a greater number of activities needs to be considered as an integrated system.

Evidence in the case studies indicates that a more modest but nonetheless valuable contribution to employment creation can be achieved through building. For building work to achieve its full potential as an employment creator, decision makers have to be aware that far more extensive research and development needs to be undertaken than is currently assumed. The broad range of options available to the building designer suggests that the method pursued in this study can be applied to many more activities and tasks in the building programme, each one with limited impact in isolation. This is why the 'model' proposed in Chapter 7 is in the form of a framework for decision making, using illustrations drawn from the technical studies described below. One of the aims of this is to supplement the Choice of Analysis Technique (COTA) pioneered by Phillips, Taylor Parkins and McCutcheon for evaluating employment-intensive options in civil engineering works (Phillips 1994; McCutcheon and Taylor Parkins 2003).

The focus of this section of the research leading up to the formulation of the 'model' is to increase the *wage component* of project cost, especially for targeted labour. Such labour would include unskilled and inexperienced workers, through to those engaged in training via a public building programme to the point of becoming self-sufficient contractors or independent artisans.[63] The emphasis is on productive and cost-effective use of labour that in the longer term can be justified, in contrast with a mere 'numbers' approach that degenerates into make-work or poverty relief projects and opens the door to a reversion to machine intensive methods.

The objectives of this chapter of the study are fourfold:

1) Improving the percentage of project cost allocated to targeted labour by -

[63] Professional and higher management fees are specifically excluded in calculations as falling outside the target group. Even where these people have originated from rural communities and have progressed through several skills levels in the programme, their scarce skills are highly marketable and portable.

- Reducing the cost of material; lowering fuel and other imported energy consumption during construction[64]; minimising costs of 'preliminary and general' items, specifically formwork and shuttering; and lowering the ratio of professional and high-level management fees.
- Increasing the local content in terms of supply and manufacture; labour and skills; and raw materials.

2) Using the construction of public buildings as a training facilitator whereby members of a community can learn skills to enhance subsequent private-sector building, and to enable the formation of small artisan, contracting, manufacturing and supplier businesses.
3) Ensuring that the building follows climatic and environmental 'best practice' so that –

- The building can act as exemplar to private-sector construction;
- 'Costs-in-use' can be reduced, especially related to lighting, heating and ventilation;
- The cost and risk of introducing unfamiliar energy technologies can be borne by the public sector, and can be monitored in use by public sector employees occupying the building.

4) Demonstrating good architectural and engineering design in terms of efficiency, economy and durability.

McCutcheon and Taylor Parkins (2003:61-62) have shown that activities in construction projects can be classified into:

i. Those that have remained labour-intensive;
ii. Those that have potential for significant increase in labour content; and
iii. Those unsuited to replacement of machines by labour.

In their analysis, only the activities in category (ii) are the subject of investigation into reverse substitution, material substitution, material adaptation and new

[64] Solar and wind energy are encouraged in this scenario, especially where the project can introduce and popularise their use in subsequent applications for future building work as the preferred power source within the targeted community, see objective 3.

materials and techniques (see Chapter 4.3.1 above).[65] In the construction of building, the small scale and complexity of the work in the context of a far wider choice of materials and techniques, suggests that this process of substitution, adaptation and innovation needs to be carried out within a decision-making framework that allows the effect of choices to be clear throughout the design, documentation and implementation phases of a project.

The first step in this process is to identify the set of activities that have the potential to make the most significant contribution to employment creation that also retains most of the project outlay within the targeted population through the use of local materials, transport and energy consumption.

6.1.1 Increasing the local content

In all the literature and initiatives where employment creation is intended as a measure to alleviate poverty, the focus is on targeted groups and individuals. This principle can be extended to include all activities in the supply chain leading to the final constructed works, seen for example in the sequence of activities of Excavate, Load, Haul, Unload and Spread (ELHUS) in road building. In programmes such as the Botswana District Roads Programme, quarries were established alongside the road, facilitating the use of donkey carts for haulage. These carts were specifically designed for the programme to allow for their local manufacture and maintenance. This obviated the need for imported forms of transport, generally requiring operators drawn from outside the target population and consuming fossil fuel with its negative effect on foreign exchange, project overheads and the environment (McCutcheon 1992).

To achieve the greatest impact, decision-makers need to consider the whole supply chain, including the primary industries of quarrying, reclaiming recycled

[65] It is important for decision makers to re-evaluate activities in the first and third categories on a regular basis. For example, sidewalk maintenance is generally regarded as having an inherently high labour ratio, but as the traditional hand equipment is replaced by petrol driven mowers and edge trimmers, this balance is lost. Well engineered and maintained hand powered mowers can achieve similar productivities, are quieter and are more versatile in thick vegetation, as are machetes.

materials, agriculture and forestry; manufacture of materials and components; storage and transportation; construction; and maintenance. Traditional building often offers insight, although it is argued here that one needs to go beyond these technologies to achieve greater efficiency with lower maintenance demands.

6.1.2 Stabilized earth blocks and tiles

Earth stabilized with cement, gypsum, lime, fly-ash or other additives has been the subject of several decades of research and field application, especially in low-cost housing and other small buildings in the developing world. It has several advantages over other materials, being far more durable and predictable than traditional adobe or rammed earth, yet being more energy efficient and cost effective than conventional clay and cement brick. It is versatile in the soil that can be used, because the type and proportion of stabilizer compensates for specific soil characteristics. Ideally the soil should have a wide spectrum of particle sizes, with a significant percentage of clay for cohesion through to coarse grains for compressive strength and to reduce shrinkage. This can be achieved by mixing soils from different locations. The precise properties of the soil need to be determined for optimal results through laboratory tests[66], although Norton (1986:10-23) provides simple tests that can be carried out on site with minimal equipment. This is particularly suitable for preliminary assessment as well as for routine checks on the soil composition during manufacture.

Compressing the blocks increases the crushing and shear strength of the blocks and improves the predictability of performance. The low moisture content and coarse particles reduce shrinkage and associated cracking experienced with traditional sun-dried clay. Two methods of compression were used in the study: a portable hand press producing blocks with all faces flat; and a diesel operated hydraulic press profiled on all faces to create a mechanical interlock. (Fig 6-1)

[66] Standard tests were carried out for this study including: compaction; particle size distribution using mechanical method and hydrometer analysis; Atterburg Limits; shrinkage; moisture density relationship; and determination of plasticity index. Two weeks should be allowed in the programme for a complete set of laboratory tests to be carried out, an essential task where stabilized earth is used. Cured tiles were tested for compression and durability, the latter with a wet-dry scrub test over three weeks.

For the tile manufacture, the hand press was used, with composition-board spacers to adjust the tile thickness.



Fig 6-1: Hydraform diesel block press and standard profiled block (www.hydraform.com: accessed May 2007)

The advantages of the diesel press were in the greater compression and resultant strength that could be achieved, while the interlocking profile is designed for mortar-free construction that is self-levelling, straight and plumb after the first course of blocks is laid, facilitating high productivity and quality with relatively unskilled workers. However, the blocks at 11kg each do not allow for rhythmical movement as in proficient bricklaying, which is physically demanding when used for vaulted roofs. Manufacture of blocks is in teams of five to six workers, rotating activities to prevent tiredness. The action of the press can contribute to productivity, but on-site manufacture never reached the targets achieved in the block yard, possibly because wages were not related to production in the pilot project. The cost of fuel, equivalent to the wages of the manufacturing team, and the noise of the diesel engine were also noted as disadvantages of this method.

The hand press proved to be more versatile, both for manufacturing components of different sizes and in the broader context of establishing small businesses. The small initial outlay for the machine, lack of fuel costs and mobility for *in situ* manufacture[67] means that this is an ideal method of production in rural areas where transport is potentially a large cost, and where quantity and type of

[67] Double handling should be avoided whenever feasible as it adds to construction cost through lowered productivity and loss of materials through damage

production can be unpredictable. With this machine, blocks for walling, roofing and floor tiles, window cills and decorative tiles can be manufactured. (Fig 6-2)



Fig 6-2: Hand press by Hydraform (www.hydraform.com: accessed May 2007)

Work-studies have shown that the optimal production cycle is 50 tiles or blocks, with a daily output of 750 to 800 units per press. Two teams of three people alternate batching and production as shown in Fig 6-3. The change from one type of component to another is achieved by adding, changing or removing spacers and adjusting the mix of soil types and stabilizers. Thus a small manufacturing enterprise can be set up with minimal overheads in the micro-credit bracket because of low input costs. Moreover, the business can be responsive to varied demand and, through diversity of output, one of the primary causes of failure of small businesses through over-specialization is overcome.

	7:00		7:30		8:00		8:30 etc	
Team A	S	B	M		R	B	M	
Team B	Curing			B	M		R	B

Key: S = stacking; B = batching; M = manufacture; R = rest

Fig 6-3: Work cycle for two teams of tile makers

The potential for compressed earth block and tile as the predominant material has been explored in various construction environments in the developing world: Development Workshop in the Sahel (http://www.dwf.org/) and Auroville in India (www.auroville.org/); Dieste in Uruguay (Pedreschi 2000) to cite some of the

more significant. All of these initiatives have acknowledged the potential for stabilized earth for roof vaulting as well as for walling. In addition to the cost advantages outlined above, stabilized earth has high thermal capacity, making it advantageous in the warm climate of the study area (Koenigsberger et al 1973: 205-9). It performs far better than the ubiquitous profiled steel sheeting and is especially worth consideration where timber for roofing is scarce.

One of the constraints of stabilized earth is that it has low resistance to tensile forces. Ideally when used for roofing, forms should be chosen that are inherently purely compressive, and care needs to be taken to ensure that construction follows these forms precisely. Movement due to settlement, thermal expansion and other forms of normal loading should not cause distortion that generates tensile stresses. This has been one of the primary considerations of the technical studies in the present research – a twofold approach that explores structural form while considering methods of construction that ensure accuracy while being simple to build with a minimum of supervision. This is critical where widespread use of a system is contemplated in a country that suffers a shortage of skilled and professionally qualified personnel. Where possible, formwork and shuttering should be simple, easy to construct and repair, and should use material economically to reduce overhead costs.

In summary, this technical study has aimed to discover a method of building that favours a high labour content with low machinery and fuel requirements. The majority of the labour force must be assumed to be relatively unskilled at the beginning of a project in any one location, but through the building process, skills can be developed to a reasonable level of sophistication – the building becomes the teaching vehicle.

The lessons learned from this research can provide a model for research into other materials and methods, services and secondary components. Materials that immediately suggest investigation are: clay piping; recycled glass; gypsum

plaster; rubble construction; laminated wattle and other low-grade organic material.

6.1.3 Public building as training facilitator

The role of the public sector in skills development has been discussed in the context of both the developing (Wells 1986; Stewart 1977) and the industrialized world (Cain, 2004a; Dainty and Ison, 2003). Skills training is one of the primary objectives of the current South African Expanded Public Works Programme, as a long-term strategy for countering poverty and unemployment. However, the training in this Programme has been criticised for being of too short a duration for individuals to be employable or to set up on their own. In a country of the size of South Africa, and with its backlog of needs in public facilities, there is lack of continuity in any one location as public resources for building are allocated equitably. For these reasons, the 'Supply Chain' model for the delivery of public buildings in the United Kingdom has been investigated (see Chapter 7). This shows potential for the public sector to act as catalyst in the transformation of the construction industry through the initiative and example provided by its own projects. In a wider application, small-scale decentralized manufacturing and supply companies can be fostered, each assisting the others in creating a viable business environment.[68]

In the first public project in an area that uses the proposed model, the Public Works department acts as the prime supplier, setting up the supply network of local enterprises, building managerial capacity and developing artisan and other vocational skills among the local population. The initial research, development, training and other start-up costs can be absorbed by the public sector. Innovation in materials, structural systems and methods of construction can be showcased by this initial building, reducing the fears and suspicion that generally face novel

[68] In Norway, loans granted to small and medium sized enterprises (SMEs) "…are provided with an expected annual loss of approx. 25% on a national basis," (Farstad 2001:351). This is supported by research in the UK (Johnstone 1986) where 30-50% of businesses fail within three years. Merrifield's (2000) assessment of the South African business environment is that an even higher failure rate is experienced.

approaches when these are to be used for housing and other privately owned buildings. The initial costs and risks can better be taken by the public sector, partly through economies of scale and through the use of a programme approach, where a learning curve is established over a number of projects in different locations.

The model proposed here is intended to develop a planned sequence of skills of increasing complexity. Selected workers can progress to higher skills levels on other sites, returning to their communities to set up fully fledged artisan and contracting companies. While this technical study has focused on masonry construction, if the same principles are applied through all trades in a "linked up" manner, as proposed in the Supply Chain model used in the UK, a balanced workforce of artisans can be produced to meet the broader demands of the industry.[69]

6.1.4 Climatic and environmental considerations

Locally sourced and manufactured materials, and human power rather than fossil fuels, will tend to be less damaging to the environment than conventional construction. However, this should be a consideration throughout the building process, from the choice of materials to the location of quarries, block yards and other manufacturing industries. The prototype should be carefully assessed in terms of siting to minimize environmental disruption, for example by following contours, respecting existing vegetation (especially indigenous trees) and taking cognisance of sun orientation and prevailing winds. For example, it is good practice in employment-intensive road construction to minimize bulk excavation as this is unsuited to hand tools, thus the method of construction is inherently less environmentally destructive.

[69] This is in contrast to the 'demand driven' approach to training in the Expanded Public Works Programme, where people are trained to meet the immediate needs of a project in any one location. This can result in a saturation of a limited range of skill types and/or levels of skill, thereby reducing the employment prospects of those trained in the Programme.

The climate of study area is characterized by fairly high variation in night and day temperatures, but in general is classed as hot-temperate. The roof therefore becomes an important element in ensuring internal comfort levels either through insulation, or more effectively through high thermal mass. Earth vaulting is well suited to this, especially if the underside can be ventilated with adjustable controls. Windows to east and west should be kept small and narrow to prevent direct solar radiation, and openings to the north should have overhangs designed to exclude direct sunrays in the summer months. Traditional construction provides a wealth of techniques for shaded outdoor space, and courtyards surrounded by seating ledges are important elements for outdoor living, while enhancing air-flow through the enclosed rooms surrounding them.

It is important that buildings for poorer communities respect these natural climatic controls to minimize service costs-in-use for lighting and ventilation. In general, conventional construction does not serve this requirement well, especially where there has been cost reduction through making walls thinner, and omitting insulation where metal sheeting has been used. In this respect, buildings commissioned by the public sector should serve as exemplars, both providing the model for private construction and reducing running costs paid out of public funding.

6.2 SMALL PUBLIC BUILDINGS

Chapter 2 provides the rationale for focusing on small public buildings in creating the opportunity for fulfilling government objectives of employment creation, development of technical skills, small contractor development and the initiation of small-scale supply and manufacturing businesses. The scale of these buildings provides a natural link to the needs of the private sector in rural communities – shops, buildings for small-scale industry, as well as housing. The government's commitment to redressing the backlog of schools, clinics, police stations, post offices and other public facilities suggests that there will be several opportunities for public projects in any one area, allowing skills development to take place.

Common to all small public buildings is a hierarchy of spaces from public to private and potential for active outdoor and semi-enclosed space. A limited range of space sizes characterizes them with structural spans between 3 and 8m, and usually single storey in rural areas. These buildings require various levels of finish and internal climatic requirements that allow a training programme to be devised within a single building that progresses from simple to sophisticated techniques. (See Fig 6-4 and Appendix 1)



Fig 6-4: Process of construction for skills development (see Appendix 1).

6.2.1 Small business development

Previously in the English-speaking world, the need for public accountability has been used as a pretext for the use of open competitive tendering for public commissions. Numerous authors have questioned the validity of this approach, especially in the developing world (Wells 1986:74). More recently, the United Kingdom has completely revisited its approach to the procurement of public buildings and is now enforcing the use of a less adversarial approach in an effort to achieve better and more cost effective buildings. The need for accountability is still there, but can be used in a more positive way as part of the constant improvement objective of Supply Chain management (Cain 2004a:160). In the context of the present study, this can be manifested in follow-on commissions

orchestrated by government until the training and entrepreneurial viability of local builders is assured. In any one locale, these can take the form of public buildings for other organs of government, subsidised housing, and artisan work in civil engineering contracts, such as bridges, drain-laying and paving sidewalks.

The global problem of the high failure rate of small entrepreneurs can be mitigated through the establishment of small-scale networks of specialist contractors, suppliers and manufacturers, where the public building is the catalyst and training ground. These networks would also be a viable structure for accessing micro-credit, where each entity would not be able to access larger items (vehicles, computers and communication technologies) but a network sharing these facilities could break the stranglehold of isolation.

6.2.2 Choice of prototype

Schools provide a particularly suitable vehicle to achieve all the objectives enumerated above, in that they offer the full range of activities and techniques that would be needed for private-sector work (domestic and commercial) and thereby allow people to use the skills acquired from the project in a marketable environment on completion. The levels of services and finishes in schools are not excessively stringent, thus allowing greater scope for skills development and for choice of materials and construction processes. The proportion of the project cost devoted to the spatial-structural envelope is relatively high, so that the employment-intensive methods applied to these components will have a greater aggregate result than in buildings needing high levels of services, such as hospitals. The range of finishes needed in a school allows for incremental improvement in artisan skills: ordinary classrooms can be fairly basic and robust, while greater precision is needed for science laboratories and Home Economics classes to accommodate piped services and tiling.

Structurally, the spans required for classrooms are within the same range as needed for shops and small-scale manufacture, as well as being at the upper limit of that required for most domestic work. The analytical and experimental

work carried out in this research has concentrated exclusively on single-storey structures, partly to reduce the risk during and subsequent to construction, and to limit the quantity of scaffolding and structural supports, with the attendant cost factor. This decision is appropriate in the context of rural locations, but multi-storey structures could become an important consideration in more urban areas.

Two preliminary prototype plan arrangements were devised for this purpose, with the assumption that similar structural types, materials, skills development methods and management approaches would be used. The variation is a demonstration of the versatility of the methods proposed in response to different socio-cultural contexts in the broader study area. (Figs 6-5 and 6-6)

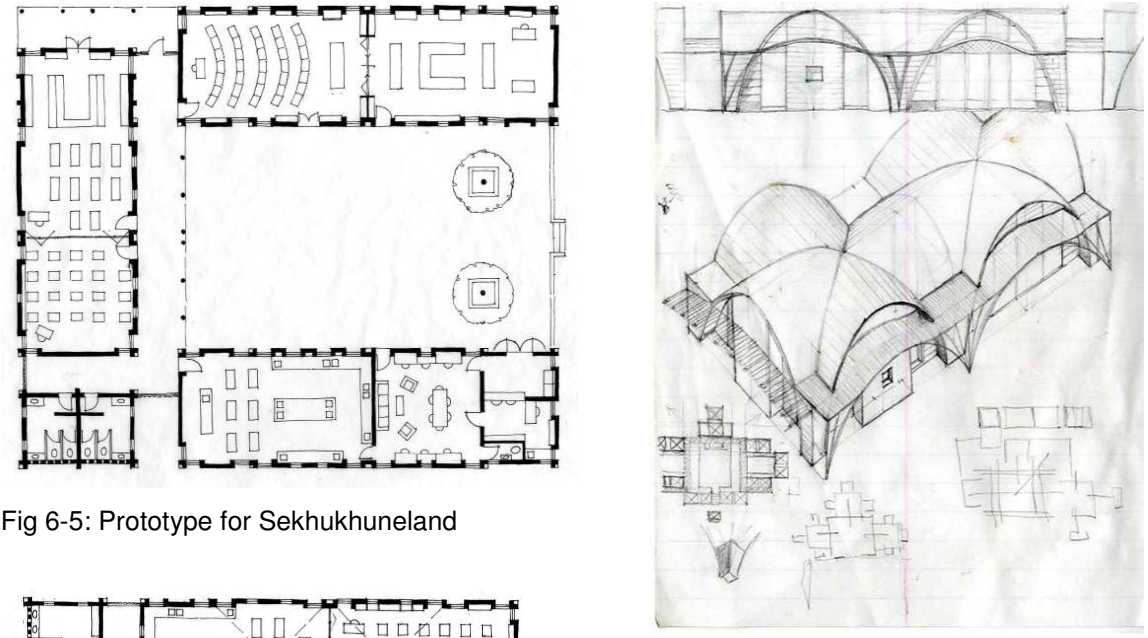


Fig 6-5: Prototype for Sekhukhuneland

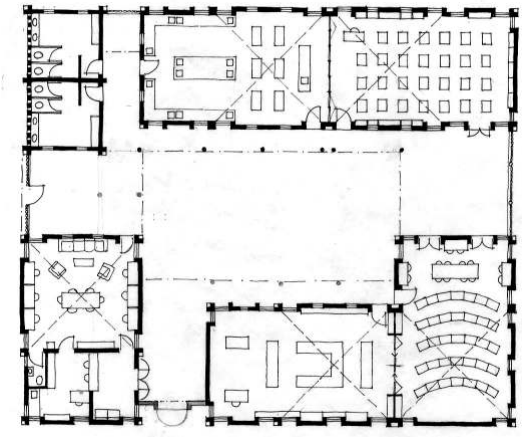


Fig 6-6: Prototype for Northern Limpopo

In both prototypes, the classrooms are arranged around a central courtyard that provides an outdoor assembly area, relaxation space and the focus to the school. This follows traditional homestead design in the Limpopo region, especially strongly defined in the architecture of the Ndebele and Venda people. The courtyard has important climatic benefits in creating a heat sink that induces airflow through the adjacent roofed spaces. There are shaded walls forming the perimeter at all times of day, a feature that has been enhanced in the detailed development of each prototype through the articulation of these wall surfaces. In traditional Ndebele and Venda architecture (Fig 6-7 and 6-8), continuous seating ledges are provided around all sides of the major courtyards, facilitating the use of outdoor space as the primary living-room of the homestead. Transitions between closed and open space are an important feature of the prototypes, a development of the spatial hierarchies found in the traditional forms. This is in diametric contrast with the school type that grew out of apartheid policy, with its roots in International Modernism.



Fig 6-7: Ndebele homestead (http://www.primaleyecreations.com/)

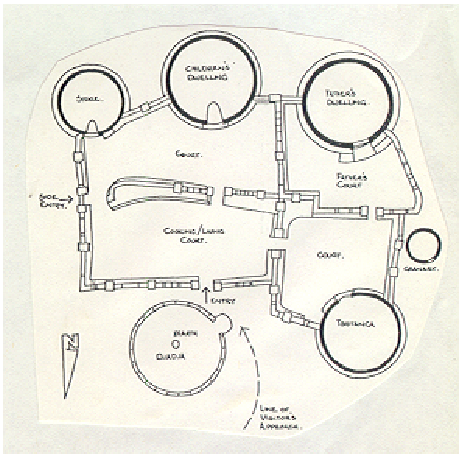


Fig 6-8: Venda homestead (Frescura)

Structured courtyard spaces are an important feature of both prototypes, in contrast with the current arrangement of schools that are characterised by wings of classes strung across neutral open space. This is a fundamental characteristic of Southern African traditional settlements, with important cultural and climatic

rationale (Rich 1991). Moreover, these outdoor rooms offer a potential facet of the training programme through the construction of low (non-structural) walls, seating ledges and paving that do not require the same technical expertise as the interiors. They also give the opportunity for self-expression and pride in workmanship that links these new buildings to a robust tradition of architectural decoration.

Both designs allow for an incremental improvement in construction skills, with the complexes being articulated into separate structural units. It is envisaged that the final part to be built would be the most heavily serviced, including the ablution block and the science classrooms that are more intensively equipped with built-in fittings, piped services and the need for smoother floor and wall finishes to facilitate tiling. This articulation also has its roots in traditional homestead design, where each of the roofed ‘rooms’ of the settlement is independent of the next, joined by the linking walls of the courtyards.

Classrooms are generally clustered in pairs with moveable partitions between to allow them to be used as a continuous space for larger classes, exam venues and social activities. The remaining wall surfaces mirror the U-shaped forms of the exterior to provide small study spaces, consistent with the needs of the ‘outcomes based’ curriculum newly introduced into the South African schooling system. This has a structural benefit, in that each section of walling is self-stabilizing, thereby allowing for relatively low levels of masonry skill and avoiding the need for ring-beams. The U-format permits the windows to be set far in from the outer surface of the wall to minimize direct solar radiation.

While not central to the present study, all elements of the buildings have been considered in terms of the objectives outlined above. For example, opening windows have been replaced by fixed glazing and pivot-hung ventilation panels. This simplifies the construction of frames, allows for lower-grade glass with the

possibility of using recycled glass processed at low temperatures, and eliminates the need for sophisticated ironmongery.

Earthworks and foundations can draw on the experience of civil engineering projects using labour-intensive techniques. An abundance of research has already been done on labour-intensive methods of stone quarrying and construction from rubble through to dressed masonry.

The principal area for investigation in the present study has been of the structure and envelope of the building, as the component that showed the most potential for increasing the employment content. The advantages of stabilized earth as the primary material in hot and relatively dry climates are well established. In South Africa, these techniques have been given additional refinement through the development of profiled compressed blocks with a high degree of dimensional control of the individual element as well as in the construction process through vertical and horizontal interlocking surfaces. (See Fig 6-1)

The prototypes developed for this study have two main purposes: to provide a basis from which to investigate the objectives stated in Chapter 2; and to create a framework for future projects with their individual sites and accommodation needs. While the structures are generic, the layouts follow socio-cultural patterns using principles, discussion of which is beyond the scope of the present study (Rich 1991; Frescura 1988).

6.2.3 Focus on the envelope

In Chapter 5 the cost-to-labour analysis of a conventionally built school showed that the groups of activities that had the greatest potential for increasing the labour content were:

- Excavation and foundations;
- Superstructure, including the roof;
- Piped services, especially plumbing.

Currently, traditional methods for excavation are still used for individual building projects in rural areas, although this is being overtaken by machinery in large housing schemes. Foundations of rubble and brick have been used in some instances, but depend on local soil conditions, so have limited application in the present development of a prototype except for cost-to-labour modelling of the complete building (Rodwin 1987).

Two approaches to plumbing services are worthy of investigation. Firstly recent developments in waterless latrines, recycling of grey water and related “green” systems are often consonant with labour-intensive methods of component production and installation. The second approach would be to re-examine traditional piping materials such as salt-glazed earthenware, a technology invented in the 17th Century as a cottage industry.

With both the foundations and the plumbing services, technical constraints and building by-laws limit scope for innovation, but employment-intensive systems should nevertheless be considered in the decision-making process described in Chapter 7, especially where a change in technique would enhance a Supply Chain network through the use of similar materials or by-products of another process, and/or that use the same equipment, such as a kiln.

By contrast, the envelope of a building offers a variety of materials and systems that satisfy the requirements of climatic performance and structural stability. The more successful solutions around the world have been those that use abundant and cheap local materials, often drawing on traditional techniques of manufacture and construction. Development Workshop (http://www.dwf.org/), the Intermediate Technology Group (Jequier 1976) and Auroville (www.auroville.org/) all work from these premises. The present research builds on their work, but the focus here is to use advanced engineering and architectural design to simplify construction so that there can be a higher proportion of less-skilled labour and lower costs to high-level managerial and professional personnel for supervision.

In essence, after the initial geometries have been established, the labour force should be able to proceed with simple instructions and basic tools without compromising the stability and soundness of the structure.

In the study area, traditional materials of timber, reeds and thatching grass have been depleted through climate change and overgrazing. The timber that is available should be conserved for door, window and furniture components, as it is unsuitable for structural members. The door and window design can be adapted to allow for lower grade timber and to simplify their manufacture and installation. For example, in le Corbusier's design for the Secretariat at Chandigarh, India, the functions of daylighting and ventilation are separated in the brise-soleil to avoid opening glazed sections.[70]

6.3 PHYSICAL MODELLING

In investigating stabilized earth blocks and tiles as the primary material for the building element, the next consideration is the type of roofing structure to use. In theory, vaulted structures that follow a catenary arch form should not generate tensile forces under dead load. This is critical because of the low tensile resistance of the material, so a limited range of structural types is imposed unless reinforcing is to be introduced, as has been done by Eladio Dieste. In this study, pure compressive structures were considered, in line with the two objectives of limiting materials such as reinforcing steel imported to the site and simplifying the construction process to minimize the cost of high-level technical expertise.

While computer modelling will inevitably play an increasingly important role in modelling vaulted structures, to date the programmes available have shown limitations through the complex and time consuming entering and analysis of

[70] This iconic example of Modernism is less well known for its labour-intensive methods of construction, where concrete was carried and placed by women using baskets. This is important for emphasizing that employment-intensive construction does not necessarily lead to rustic, traditional or vernacular looking buildings. Dieste's work is equally advanced visually, a direct consequence of sophisticated engineering that allows for simplicity in construction.

data, as well as being unreliable in computing shear stresses. For these reasons, physical scale models have been used extensively in the present study, generally using materials and methods of construction that closely parallel the final buildings contemplated. In the final phase of the study, computer and physical models were used together to give a sense of the limitations and advantages of each.

The emphasis on skills development and efficient use of labour is aided through modelling the techniques of construction. Here the aim has been to devise methods that require a small input of high technical skill, mainly in setting out the vaults in three dimensions, with simple and economical methods of providing formwork. Thereafter, relatively unskilled people should be able to construct the vault itself with simple tools and equipment, providing the importance of preserving the geometry is made clear. The physical models have therefore been constructed with individual blocks or tiles at the same scale as the model so that the same process of construction can be simulated. (Fig 6-9)



Fig 6-9: Model of groin vault, scale 1:10

In South Africa, many construction workers have learned their trade entirely through informal on-the-job experience without any theoretical support, which has led to widespread bad practice. In a study of 2006, Doku observed that bricklayers have little understanding of brick bonding, the purpose of gauge rods, and other fundamental techniques. Re-education through conventional building

activities is seldom successful and is met with resentment, but less conventional structures could provide the vehicle for entrenching good practice.

The physical modelling in this study has therefore been directed at simplicity of construction where process becomes more important than theoretically perfect forms that are more difficult to achieve. Much of the experimentation has been in testing methods of building, means of controlling critical dimensions and geometries, and determining critical and non-critical activities.[71]

Sabnis et al (1983:217-220) identify the observed phenomenon of the 'size effect' in models, whereby the strength tends to increase as the model scale decreases. Because shell structures have a complex relationship of parameters - span, thickness, depth and strength of materials - the larger the model, and the more closely it represents the full size structure, the more accurately its performance can be simulated. However, in the present research, logistics have restricted the models for the most part to a maximum of 1:10.

6.3.1 Barrel vaulting

One of the major advantages of vaulted roofing is that the same material and components can be used for both the walling and the roof. On the one hand this streamlines the research and the training in manufacture, and on the other, the economies of scale facilitate the development of small-scale manufacturing with a single piece of equipment required.

The University of the Witwatersrand's School of Civil and Environmental Engineering has been engaged in research into domed structures of stabilized earth blocks, under the direction of Professor Mitchell Gohnert. These have been extensively analysed on computer, and several have been built. While these have been largely successful in producing a cost effective solution, several

[71] Dieste's method of construction relies on shuttering & profile rods as the geometric control, with the brick or tile coursing non-critical providing that the profile is followed meticulously for correct surface curvature (Pedreschi 2000).

limitations have become apparent. Foremost are the limitations on spatial use, with a circular plan form proving difficult to furnish. Junctions between domes are awkward so essentially one is restricted to single-space units. To overcome the problem of wasted space through lack of headroom, the domes are raised on cylinders that compromise the load path to the ground. Openings need to be small and narrow because of the large compressive loads of the domed roof. While the thick and dense dome and walling has good thermal performance, the form distorts as the dome heats during the day, generating tensile forces that produce surface cracking. These have been accommodated through the use of low-grade wire ‘stitching’ at the critical places. This raises an important property of vaulted structures: that the restraint against outward thrust needed for a dead-load condition tends to fix the base so that under thermal variation, the ideal (purely compressive) form is lost.

To overcome the planning problems of the dome, barrel vaults were investigated because of the advantages of a rectangular plan and, since the gable ends theoretically take no load from the vault, these are freed for large openings. The building can also be extended indefinitely in the longitudinal direction, but the structure is still limited by the load bearing walls. Initially 1:20 models (Fig 6-11) were built of the barrel vault, using individual tiles of unfired clay so that the construction process could be modelled, and to simulate the non-homogeneous shell. The lateral restraints were initially modelled as corbelled blocks that would take light reinforcing, and the vault would sweep into these as a quasi-horizontal beam. (Fig 6-10)

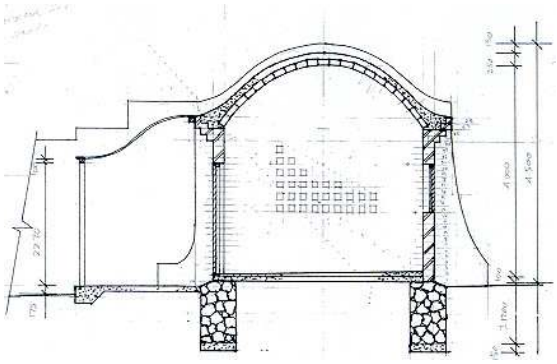


Fig 6-10: Pilot structure, Stables at Hunts End

The models showed that the vault was vulnerable at the point of counter-flexure, but as this was only revealed under extreme loading, no reinforcing of the shell itself was to be used. The use of corbelling for the edge beams was assessed to be too complex in the pilot structure, so reinforced concrete beams were used instead. The thrust of the vault was to be contained by buttresses spaced at 3.5m, which were to continue the catenary form of the shell itself.

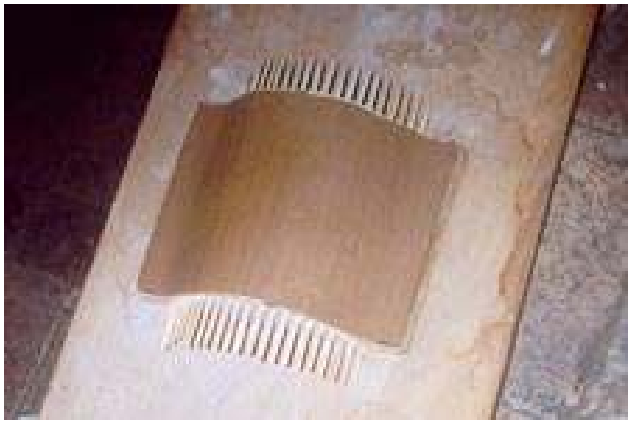


Fig 6-11: Model of barrel vault, scale 1:20

The first work on vaulting for this study examined the use of horizontal timber bearers as formwork to a vault of interlocking compressed earth blocks weighing 11kg each. The rationale for this choice is that a locally developed and patented system of manufacture produces blocks profiled on all faces for ease of construction by workers with limited training. The mix for the blocks was theoretically determined through laboratory testing as a 5:5:1 of pit-sand (with a high clay and silt content), coarse river sand and standard grade Portland cement as the stabilizer. On site this was modified to a 6:4 mix of pit to river sand to improve cohesiveness, thereby improving the handling of the green blocks from the press to the curing yard. A diesel press was used, and manufacture took place adjacent to the construction site to minimise handling and transport costs. The profile on the upper face of a calculated number of blocks was stripped to allow for corner bonding, and half-blocks were manufactured (generally at the end of the day when workers were tired) according to the measured quantities.

An advantage of on-site manufacture was the waste reduction through being able to make exact numbers of special blocks.

The experimental building (a range of stables) was designed from the detailed junctions of block-work outwards to eliminate the need for cut blocks. Despite training by an experienced block-maker and regular quality checks, the length of blocks was not consistent, nor was the compressive strength. Both of these interrelated factors can be attributed to the inconsistent moisture content of the mix, but the inexperienced workers seldom applied a simple check with a measuring stick except when directly supervised.

The same gang of workers was employed to make the blocks and to construct the building. Their previous construction experience was largely in informal settlements and farm buildings using cement blocks. They had very little understanding of measurement, geometry or any other technical aspects of construction. Many of the processes were devised from observation on their previous building jobs, without knowing the purpose of equipment such as profile boards, gauge rods and builders line. They resisted re-training, as they could not see how the work differed from their experience. This had particularly serious consequences when constructing the structurally critical elements; foundations and the buttresses.

The initial design followed thrust-line principles where the buttresses continued the catenary form of the vault into the foundations. Between the buttresses, the horizontal component of the vault force was to be taken up by an edge-beam. To reduce the depth of the buttresses on the access way, these were made more slender, on the assumption that if they were to be fully grouted, their monolithic properties and overall weight would prevent collapse. A combination of poor workmanship and inadequate design resulted in the failure due to overturning as described by Ochsendorf, Hernando and Huerta (2004). (Fig 6-12)



Fig 6-12: Buttress collapse, Hunts End

However, a number of valuable lessons were learned:

- Weight of blocks: one of the problems of block-work is that each block has to be placed as a distinct activity, unlike brickwork, where a skilled artisan will develop a rhythm of continuous movement. This factor with the compressed block is accentuated through the weight, and becomes a serious constraint when used in the higher parts of the building. The vault is extremely heavy in proportion to the span, necessitating large buttress or other forms of restraint.
- Site-experienced but untrained workers were resistant to refining the knowledge they had, and were particularly intractable with new methods. The workers who had no site experience at all were far more responsive to training.
- Productivity and incentives: because of the experimental nature of the project, workers were contracted on a daily wage and as work approached completion, productivity sunk to zero.
- Supervision and control over materials and manufacture by a qualified person is essential until good practice is entrenched. Thereafter, wages should be based on both quality and output. A full-time hands-on site supervisor would be the most effective insurance of productivity, compliance and quality.
- Simplify techniques. Despite detailing of the block work so that no cutting was required, this principle could have been taken further to simplify

building in doors and windows. Later research into the vaulting had simplification as one of the primary considerations, as described below.

The failure of this structure indicated a radical re-evaluation of the theoretical basis for the design and prompted a search for a method of construction in which the dual constraints of a purely compressive structure and a low-skilled workforce could be addressed. Distortions in the geometry of the vault and the junction between the vault and lower supporting elements led to the investigation of timbrel vaulting. This system is characterised by very thin shells of multiple tile layers that rely on precise geometry defined through thrust-line analysis. The process of developing a design and method of construction that would inherently produce the correct geometry is described below.

6.3.2 Timbrel Vaulting

In this method of construction, flat tiles are used with quick-setting gypsum that allows a dome or vault to be built without shuttering except for the four springing arches. At least two layers of tiles are used, with the first acting as permanent shuttering for the upper layers that are constructed so that the vertical joints are staggered. The vault and arches are pure compressive forms, and theoretically need no reinforcement, although restraining ties at the springing point of the arches allow smaller foundations or buttresses to be used. The structure is designed to accommodate thermal expansion, retaining the geometry while the rise increases. (Fig 6-13) To avoid the necessity for reinforcing, the shape of the structure is critical, an aspect that has been the subject of extensive research recently. (Huerta 2003; Block, DeJong and Ochsendorf 2006; Block, Ciblac and Ochsendorf 2006; and Block and Ochsendorf 2008)

In the past, geometrical methods were used to determine the equilibrium of the vault, with the limitation that this method could only be used two-dimensionally, and complex three-dimensional vault analysis relied on a number of assumptions

about how the thrust-lines related to each other. (Block and Ochsendorf 2006:1848.)

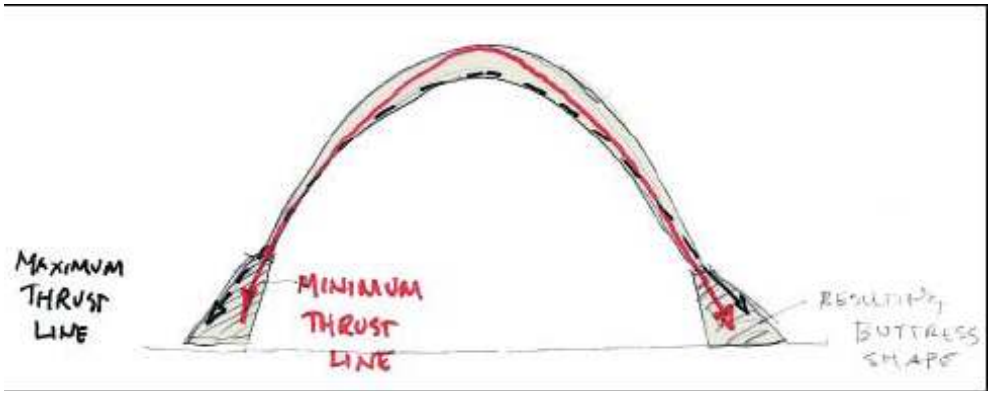


Fig 6-13: Thermal expansion in a timbrel vault (M Ramage)

Block and Ochsendorf have introduced two innovative methods for evaluating equilibrium in complex timbrel structures: a combination of static and kinematic analysis to understand the process of collapse where distortion or displacement of supports is experienced (Block and Ochsendorf 2006); and thrust network analysis that draws on Maxwell's principle of reciprocal duality between the geometry of a network and its internal forces (Block and Ochsendorf 2008).[72]

Timbrel vaulting has several advantages over the barrel vault using block work: the lack of shuttering, thereby reducing overhead costs;

the light weight of the components allowing more accurate placement;
the herringbone bonding that supports each additional tile;
the construction in layers that reduces the risk of a faulty tile or joint.

Plywood strips are sprung from the diagonal corners as visual guides for the curvature of the dome, but experienced craftsmen are needed to ensure a regular curve and consistency of bonding. The use of a herringbone bond and the plywood as visual guide are the only controls to the curvature which, because

[72] Equilibrium is particularly important in thin-shell structures, as the forces need to be contained within the thickness of the vault and supports. If the thrust-line crosses the material boundary, there will be a tendency for the vault to crack and form a hinge. Thrust-lines contained within the middle third of the material will ensure that no tensile forces are generated, so that no reinforcing is required.

the system relies on the form being purely compressive, can cause failure if not sufficiently monitored by an expert.

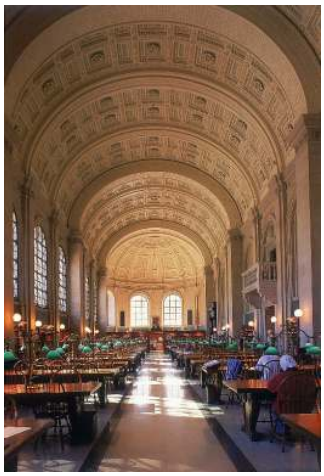




Fig 6-14: Boston Public Library (http://www.cslib.org/) and Guastavino Club, Boston (uweb.ucsb.edu/)

The research into timbrel and other thin-shell masonry structures at MIT has included the construction of a number of prototype structures as well as extensive computer modelling. A variant was built in the United Kingdom, the Pines Calyx project for an ecological centre (Fig 6-16), where the tiles were made predominantly from recycled brick.





Fig 6-15: Timbrel vault, scale 1:4



Fig 6-16: Pines Calyx Ecological Centre, UK (architecture.mit.edu)

In South Africa, this system is under investigation for the World Heritage complex at Mapungubwe. (Fig 6-17) Here the intention is to use hand compressed tiles of stabilized earth, made by unemployed community members trained specifically for the purpose. Some preliminary studies were carried out with a hydraulic press forming interlocking tiles, but this method could not produce tiles thin enough. In the event, the hand press is more in keeping with the present research: the machine is easily transported to the block making site; it is inexpensive and easy to use and maintain; blocks and tiles of widely varying thickness can be made through the simple expedient of adding timber spacers to reduce thickness; and most significantly, it uses human power rather than fossil fuel.[73]



Fig 6-17: Mapungubwe World Heritage Site Visitors Centre (Lerotholi Rich Architects)

[73] At Mapungubwe, the manufacture of the tiles was seen as an opportunity to meet poverty relief targets, but in the process there was little attention given to efficiency of production, despite detailed a work study provided by the architects to the project manager. The result was that the tiles which should have cost R1.70 ended up costing over R7.00 because of the low output in relation to the daily wage.

From a cost perspective, a disadvantage of the timbrel system is that high-grade rapid hardening gypsum has to be used so that shuttering can be omitted. Some initial work is in progress on modifying waste gypsum, generated in abundance through mining. However, while standard grade (type ß hemihydrate) is easily produced at low temperature (110º C), quick setting gypsum requires processing at much greater temperatures and under pressure, suggesting that this would not be suitable for decentralized small industries. The present demand for highly processed gypsum in Southern Africa is so small that, despite the vast quantities of natural and waste gypsum, local production is not viable.

6.3.3 Groin vaulting: Historical examples

The next step in structural modelling was the investigation of groin vaults as a system that could combine the advantages of the barrel vault and the dome. The architectural possibilities of this configuration were well understood by the Ancient Romans and by the master masons of the Medieval period in Europe. The greatest architectural advantage over other traditional vaulting systems lies in opening up all four sides because the load is concentrated on the four corners of each bay. The three-dimensional configuration has less of a problem of unusable internal space where the curvature is beneath head height, a problem encountered with domes that spring directly from their foundations. The problem of raising a shell structure on supporting walls can therefore be avoided, with the vault springing directly from the foundations where the tendency to flex at the springing point can be more easily controlled than at a junction with a wall.

The Romans used a semicircular arch as the basis for the vault, generally constructed of pozzolana, a material with properties similar to modern Portland cement. There are surviving examples that have a first layer of tiles creating a permanent shutter to the concrete, but it has not been established whether the tiles were laid on full timber shuttering or whether they were self supporting as in the much later timbrel vault.

Stability of the vault was achieved through the weight of the thick shell, with additional weight, the overburden, placed over the lower third to contain some of the outward thrust. (Fig 6-18) Two problems emerge from the Roman choice of the semicircular arch: the barrel vault extruded from this shape does not follow the ideal catenary form, thereby generating tensile forces; and this is exacerbated when one considers the section on the diagonal which is even flatter than the cross section, introducing the tendency to flatten and counter-flex. The Romans overcame the problem of tensile forces by increasing the thickness of their vaults, but with the consequence of the need for extremely thick walls and massive foundations.

The introduction of the pointed arch as the generator of cross-vaulting in the Gothic era overcame the problem of flattening of the vault, but in the process produced an extreme height to span ratio. While this has created one of the high points of Western architecture, its justification in a religious context cannot always be sustained in more pragmatic buildings. Robert Mark's landmark research into Gothic vaulting, *Experiments in Gothic Structure* (1982), uses photo-elastic modelling to give valuable insight into the rationale and performance of these structures.

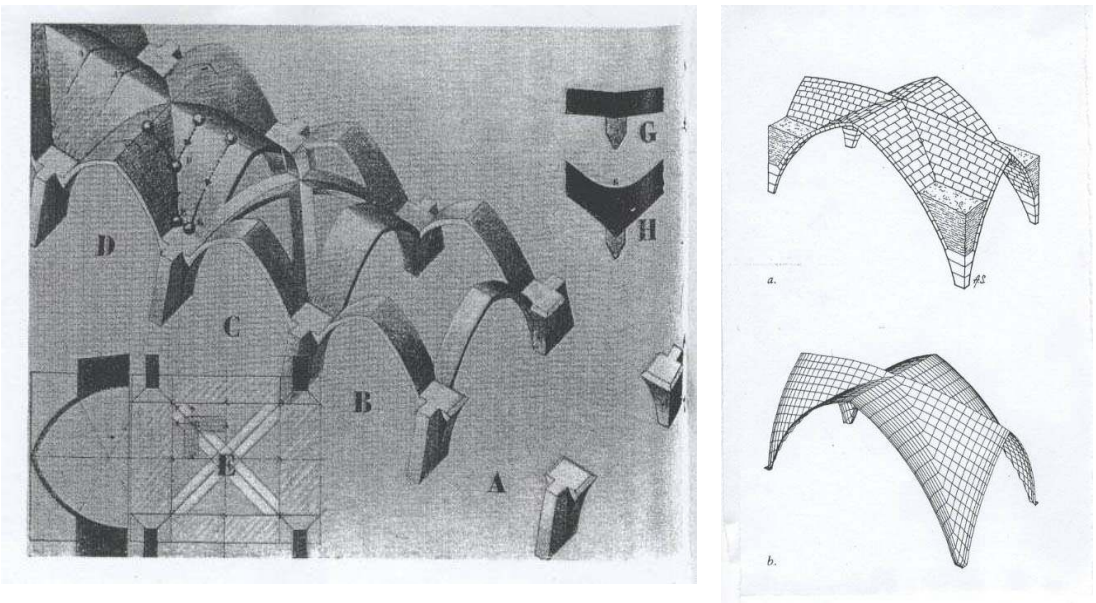
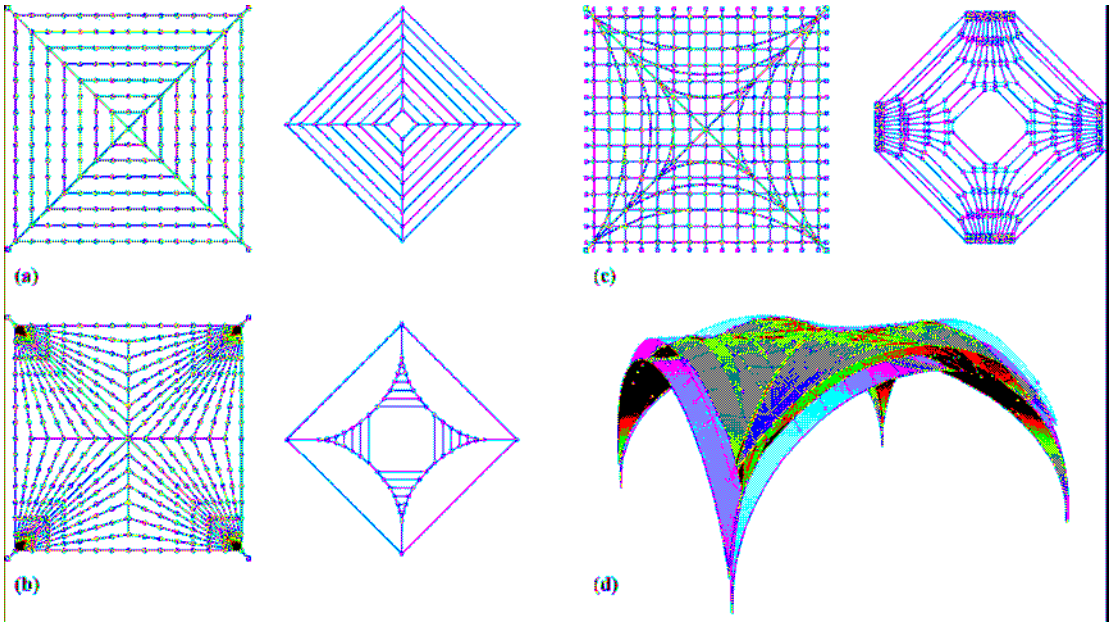


Fig 6-18: Gothic vaulting (Mark 1993:161)

His work shows that the forces generated by the purely masonry vaults are channelled into axial vertical loads through additional weight in the lower sections of the shells, the location of flying buttresses and positioning of pinnacles. His research gives less detailed information on the forces within the shell components, although a three-dimensional photo-elastic model indicates that forces are directed on the shortest path to the corner supports and not to the diagonal ribs as was previously assumed (Mark 1993:160-163).

Recent work by Block and Ochsendorf (2008) using Thrust-Network Analysis, a three-dimensional computational method for determining lower-bound solutions for vaults, suggests that the primary force lines in a groin vault form curves tangential to the ribs in an arc down to the supports. (Fig 6-19c)



Different possible force patterns for a groin or rib vault: (a) the diagonal ribs bring down the forces to the corner supports, arches in the web span in between the ribs; (b) all force lines go directly to the corner supports; and, (c) primary force lines accumulate towards the supports and a continuous 3-D mesh distributes the loads to these force lines. (d) shows the three-dimensional thrust network, resulting from the assumptions in (c), which fit within the vault's geometry.

Fig 6-19: Thrust-Network Analysis of groin vault (Block and Ochsendorf 2008)

From a theoretical point of view, because the cross section of a Gothic vault is generated from two segments of a circle, the internal forces will not be purely

compressive, although the steepness of the two segments would make any non-vertical forces negligible. However, with a lower height to span ratio, this would be significant in introducing zones of tensile force. It is interesting that Antonio Gaudi consistently used the catenary vault to avoid this problem, especially of note in the Sagrada Familia (begun 1881) with its overt references to the Gothic tradition. In this building, the experience of historical methods is combined with the engineering understanding of its time to achieve a more efficient solution.

Gaudi developed a method of establishing the stability of his vaults using a three-dimensional system of strings, pulleys and weights, thereby extending the thrust-line theory into the third dimension. (De Sola-Morales 1986:26) His inverted models generated the funicular lines that he inverted for his purely compressive structures. The inspiration of his work prompted the investigation into inverted catenary forms described in the next section. Because there is considerable debate about the most effective method for analysing complex vaults, a range of different analytical systems have been used, including ‘classical’ membrane analysis and Finite Element Method. However, the simplicity of the Thrust-Network Analysis method suggests that this will become an important analytical tool in future. As this work has very recently been published, the method could not be included in the present study.

6.4 CATENARY GROIN VAULT

A purely compressive form is relatively easy to achieve in laboratory conditions, but on site the two significant factors are accuracy of construction to achieve perfect geometric shapes, and the ability of the structure to expand and contract under thermal loading without substantially altering the compressive shape. To address these, the final stage in the present technical study was to investigate groin vaults.



Fig 6-20: 1:20 models of groin vaults

Preliminary physical models at 1:20 scale were used to test out different methods of tile bonding, with the final proposal using a herringbone pattern. (Fig 6-20) On site, the four edge arches would be constructed on formwork, tentatively proposed as laminated wattle[74], a system of construction pioneered by Van Staden (2005), with pegs built in at every tile joint. The setting out of the formwork would be the one critical activity in ensuring accuracy of the vault and the building as a whole. Thereafter the pegs would be used for carrying the builder's line, here primarily to ensure the correct curvature, but would also promote regularity of coursing.[75] In this way, the bulk of the work could be carried out with minimal supervision, economical formwork and simple tools. The cost for the building element would then be almost entirely devoted to labour of the construction team, tile manufacturers and quarries. This is entirely consistent with the definition of employment-intensive construction presented throughout this research (McCutcheon 2003:21 and Chapter 4.1.1).

[74] One component of the Expanded Public Works Programme is environmental management, in which the removal of invasive alien plant species such as Australian Black Wattle plays a significant role.

[75] As with Dieste's structures, the curvature is more critical than the coursing, a factor that should be stressed in the training (Pedreschi 2000:73-74). However, if workers are encouraged to respect the regularity given by the builders' line, this would entrench good practice for the subsequent construction of the infill walls.

To overcome the problems of thermal expansion experienced in domes of stabilized earth described above, this study aimed to investigate whether the free edges of the groin vault would allow the structure to expand vertically while preserving the catenary cross-section. To aid construction of the model, the arch supports were left in place until the entire vault was complete. The tiles were made individually from a mixture of brick clay and a small proportion of kaolin to aid cohesion. Clay slip was used for the joints, with the consistency of paste kept fairly thick so that the tiles would not absorb too much water and thereby lose their integrity. This minimized shrinkage of the whole vault, but nevertheless the entire structure tended to lift off the base, resting on the crowns of the arch supports. It appeared that the catenary shape was retained as the vault shrunk, suggesting that, under thermal expansion and contraction, a full scale structure would perform in the same way.

When the supports were removed, the structure retained its integrity as it dropped onto the base, and was stable under its self weight. Collapse invariably was the result of vibration and cracked in a symmetrical pattern suggesting that the supports had splayed outwards. Analysis of the computer model indicated that this corresponded with a line of tensile stress demarcating a square close to the centre point, as can be seen in Figure 6-29.

The 1:20 models were built with no reinforcing against tensile or shear forces so that the pattern of cracking at ultimate failure could be seen, and thereby provide insight into the different types of bonding. With each one of this series of models, the junction (groin) was especially resilient, particularly nearest the supports. This, with the position of the cracking, suggests that the failure was the result of slight outward movement of the supports, causing the central area to flatten and then develop deflection similar to a flat slab. Minor damage to the edges of the arches during construction and after completion did not affect the integrity of the rest of the structure, which suggests that edge beams or other methods of

strengthening the free edges are unnecessary. This is consistent with Felix Candela's theories of shell structures (Faber 1963).

6.4.1 Technical evaluation: physical model

Finally, two parallel investigations of the same design were carried out, the one through physical modelling, and the second through computer modelling by two final year BSc (Eng) students at the University of the Witwatersrand under the joint direction of Professor Mitchell Gohnert and the author. One of the aims was to compare the effectiveness of each method, especially as there was some concern about the reliability of the computer model's prediction of shear failure.

The two methods of testing in combination aimed to give an understanding of:

- areas of tensile and shear forces;
- maximum compressive loading and forces on supports (magnitude, direction and type);
- type(s) of failure that could be expected;
- the necessity for reinforcing, its type and placement[76];
- size and detailing of ties or buttresses;
- validity of construction method – simplicity and accuracy that would allow inexperienced workers to create a quality product.

A 1:10 model was constructed using individual air-dried clay tiles at the same scale (15 x 30mm) and simulating the proposed construction methods. This allowed a closer modelling of the process than was possible at 1:20 scale as lines could be strung from arch to arch to achieve the correct curvature. A core of cotton fabric was sandwiched between the two layers of tiles to slow down the process of collapse, The upper tile layer was constructed to avoid straight joints through the two layers. (Fig 6-21)

[76] Any reinforcement would increase the complexity of construction, necessitating additional professional supervision. This, with the cost of importing the steel, would draw money away from the targeted labour, thereby compromising the principal objective of the present study.



Fig 6-21: 1:10 Catenary groin vault under construction

The cardboard formers were removed after completion of the whole vault, at which point three of the bases dislocated outwards, to a maximum of 2mm. The model was allowed to stand for several weeks before loading to determine the performance under self-weight and to see the effects of thermal loading. In the latter case, the structure expanded and contracted, apparently preserving the catenary profile, without any sign of cracking or movement at the unrestrained bases. Initially the bases of the vault were held in place with clay slip, but timber buttresses were introduced before loading, fixed to the base board with high-strength putty adhesive.

Prior to loading, the model was painted with white PVA paint on the upper and lower surfaces to allow cracking to be visible. The model was loaded and unloaded on five occasions, deflection being measured with dial gauges and the process recorded on video. The initial loads used coins in a uniform pattern attached to fabric. (Fig 6-22) Subsequent loads used steel bolts and granite chips, in all cases spread so that the load did not form a structural bridge. In the final loading, the structure withstood a load of over 85kg, showing significant deflection in the centre, buckling on one of the legs, and separation of the tile layer at two of the supports.



Fig 6-22: Catenary groin vault loading method

On removing the loads from this last test cycle, the dial gauges indicated that buckling had taken place in the entire shell, with the two outer gauges remaining constant until the load was reduced to 2.6 kg, at which point the model sprang back to its former shape. (Fig 6-23)



Fig 6-23: Buckling of catenary groin vault

In between two of the loading cycles, the model was damaged on one edge and repaired. (Fig 6-24) This area showed no signs of distress in the subsequent loading cycles, suggesting that one of the areas most susceptible to damage during the construction process could be repaired without compromising the structural integrity.



Fig 6-24: Damage and repair to edge of vault

The model was tested on five occasions, each time with greater load, and the load removed between test sessions. Figure 6-25 and Table 6-1 give the results of the first test session that show an initial rise in the centre of the vault with the application of the first layer of coins. As this phenomenon was not repeated in any of the other tests, it could be attributable to the vault correcting itself to approximate the ideal compressive form. This would be consistent with the phenomenon observed under thermal expansion and contraction, where the catenary curve was preserved while the slope of the curve changed.

Load testing: 29 August 2007				
load 1(N)	25.506	50.826	76.695	101.230
deflectn a	0.00	0.05	0.09	0.14
deflectn b	-0.04	0.05	0.09	0.16
deflectn c	0.05	0.10	0.15	0.20

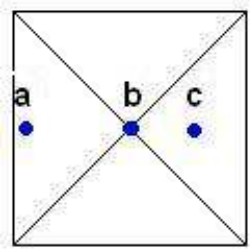


Table 6-1: Catenary groin vault - first sequence of testing and position of dial gauges.

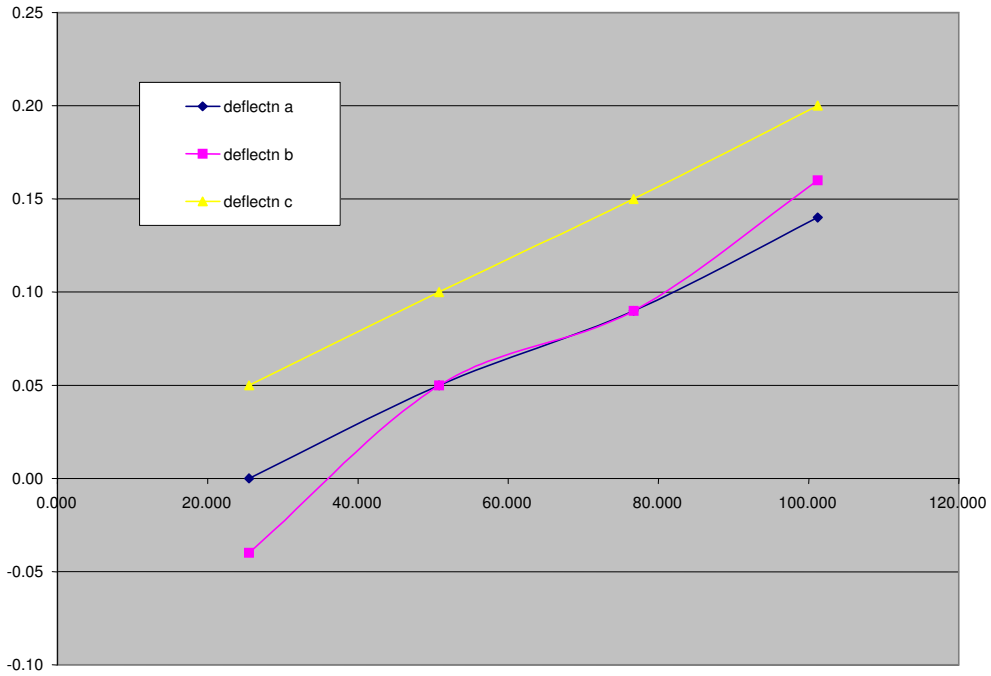


Fig 6-25: Catenary groin vault - first sequence of testing

During the final (fifth) sequence of loading, the model showed signs of buckling in one of the legs, and in two places at the supports the two layers of tiles separated as recorded in Figure 6-23. However, a more significant indication of the buckling of the entire vault was given when removing the load. Figure 6-27 maps how the deflection in the centre reduced in a similar pattern to that under application of load, but the other two dials (positions a and c) remained almost constant until the load was reduced to 212 N, at which point the structure 'popped' back almost to its original shape. (Table 6-2)

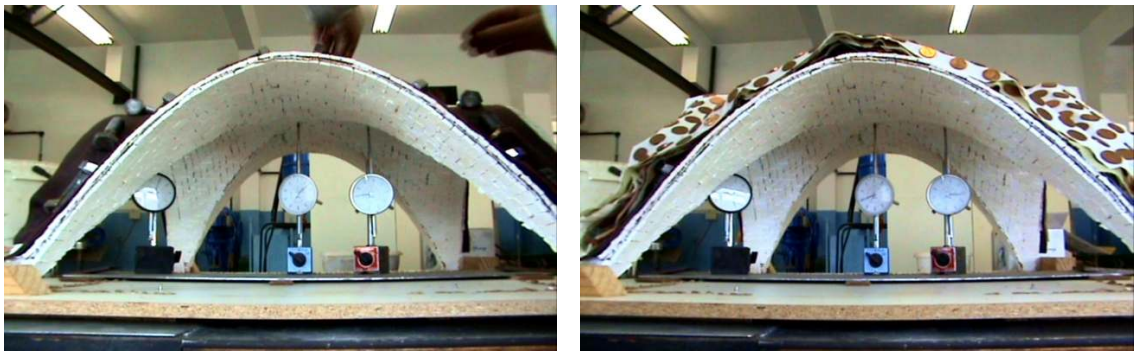


Fig 6-26: Video stills at 212 N when removing load

This is visible in the video, in which this can be seen as an instantaneous event. (Fig 6-26 & 27) The final readings show that after the load is removed the vault remains most distorted at the position between the centre point and the edge (dial c). This is consistent with the computer modelling described below.

Load testing: 14 September 2007						
load 5 (N)	deflectn a	deflectn b	deflectn c	unload a	unload b	unload c
0.00	0.00	0.00	0.00	0.34	0.47	2.23
101.112	0.23	0.32	0.27	1.03	1.38	2.65
155.558	0.39	0.54	0.47	1.06	1.78	2.78
212.554	0.51	0.78	0.69	2.52	2.22	3.16
238.060	0.58	0.87	0.79	2.61	2.47	5.87
263.380	0.67	0.97	0.89	2.61	2.65	5.87
289.249	0.75	1.08	1.00	2.61	2.8	5.87
313.784	0.82	1.21	1.13	2.61	2.96	5.87
339.849	0.89	1.33	1.25	2.61	3.09	5.87
365.953	0.96	1.45	1.37	2.61	3.23	5.87
406.174	1.15	1.78	1.68	2.61	3.55	5.87
446.886	1.25	1.96	1.96	2.61	4.19	5.87
518.009	1.55	2.54	2.39	2.61	4.32	5.87
560.192	1.70	2.88	2.72	2.61	4.44	5.87
600.413	1.83	3.15	3.00	2.61	4.58	5.87
641.124	1.97	3.37	3.22	2.61	4.73	5.87
713.718	2.26	4.03	3.81	2.62	4.98	5.87
755.901	2.40	4.37	5.11	2.66	5.09	5.87
795.141	2.54	4.76	5.46	2.71	5.18	5.89
837.324	2.75	5.21	5.92	2.75	5.21	5.92

Table 6-2: Catenary groin vault - final sequence of testing

In conclusion, while the physical model showed considerable resistance to compressive loading, it was compressive forces that caused the failure with no evidence of tensile or shear failure. At this stage of testing it would suggest that reinforcing of the vault itself is not necessary, thereby meeting the objective that the vault would be constructed entirely of materials locally sourced in the rural community. Future research should be directed at developing a rapid-setting grouting material that can be locally manufactured for the entire cost of the vault to be retained within the target population.

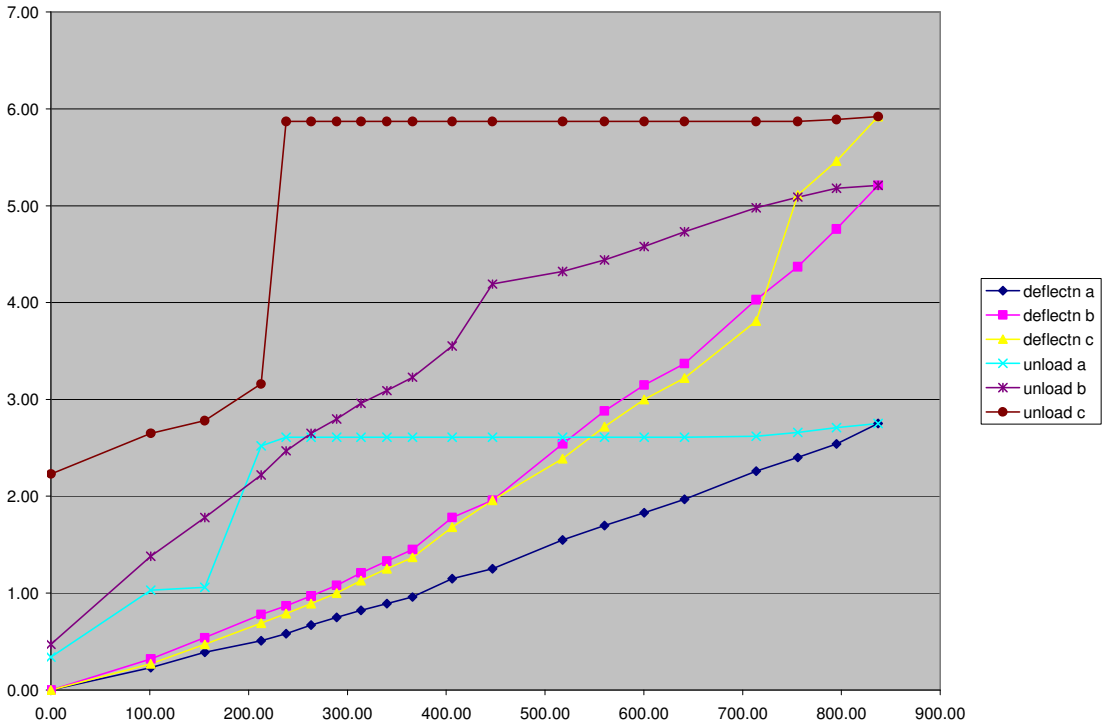


Fig 6-27: Catenary groin vault - final sequence of testing

6.4.2 Technical evaluation: computer model

Concurrently with the physical modelling of the catenary groin vault described above, the design was analysed using ABAQUS, a finite element computer package. This work was undertaken by Mokoena and Malepfane, two final year BSc Civil Engineering students at the University of the Witwatersrand under the direction of Professor Mitchell Gohnert.

The objectives of this parallel study were:

a) to determine how stresses flow in the structure;
b) to identify areas needing reinforcement;
c) to investigate change in the height to span ratio; and
d) to investigate similar configurations with other cross-sectional geometries.

As the structure is classified as a 'thin shell' with a ratio of radius to thickness between 50 and 150, a six node triangular element with five degrees of freedom

(STR165) was used. The results generated by the computer programme were analysed using Mohr circle theory to derive the principle stresses and moments.

Three significant assumptions were made:

1. The strength of the tiles was taken as 5.9 MPa based on the cement stabilized tiles manufactured for the Mapungubwe Visitors Centre. This equates to 2.6 MPa after partial safety factors are applied.
2. Tensile strength of the tiles was assumed to be zero.
3. Wind loading was assumed to be equivalent to a rectangular structure of the same width and height as the vaulted structure. (Mokoena and Malepfana 2007:10)

A variety of different load combinations was modelled including distributed, concentrated and wind loads. (Fig 6-28) In general, it was found that the meridional stresses are purely compressive while the hoop stresses generate a tensile area in a zone around the centre, for example as shown in Figure 6-28.

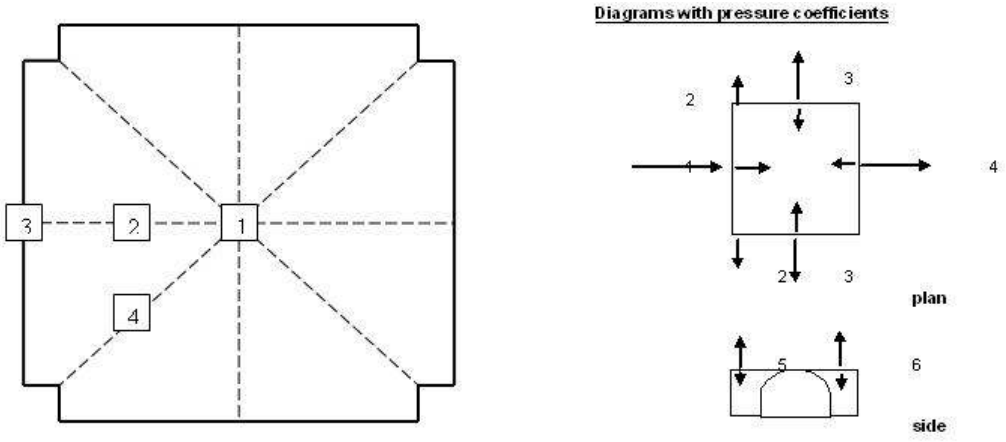
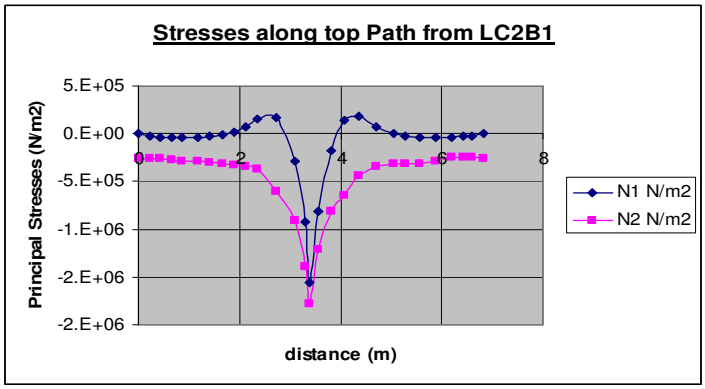


Fig 6-28: Position of concentrated and wind load (Mokoena and Malepfane 2007:23 & 73)



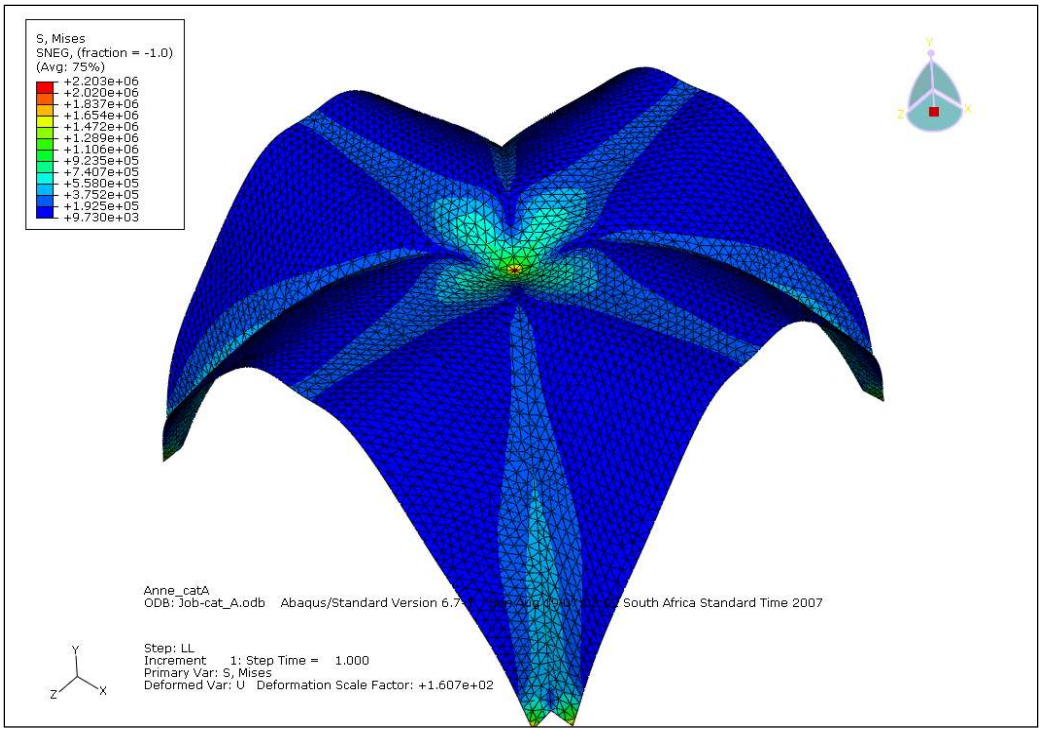


Fig 6-29: Contour plot of Von Mises stress invariant for distributed dead and live loads, and a concentrated load at point 2 in Fig 6-28 (Mokoena and Malepfane 2007:32)

The conclusions from the study of the catenary vault of 6m span and 3m height showed that under recommended loading the maximum compressive force within the vault would be 1.2 MPa, well within the strength of the compressed earth tiles manufactured at Mapungubwe.[77] However, the need for reinforcing is indicated in

[77] The soil conditions at Mapungubwe are not ideal for stabilised earth building as the clay content is extremely low. For this reason, a relatively high cement content of 10% was required. There is also scope for research into recycled waste gypsum, fly ash and lime as environmentally preferable stabilisers with the additional advantage of promoting decentralised manufacture.

the central zone where tensile forces of 0.05 MPa are generated. Moments were found to be greatest at the four supports under all load conditions, with a maximum value of 17 Nm.

In addition to modelling the catenary vault of 3m high, Mokoena and Malepfane investigated the performance of vaults of the same configuration and span, but with heights of 3.5m and 4m. They found that increasing the height to span ratio improves the overall performance of the vault, especially with regard to the magnitude of the stresses at the supports and in the more even distribution of stresses throughout the shell (Mokoena and Malepfane 2007:57). This is consistent with Mark's (1982) photo-elastic modelling of Gothic vaulting. However, the structural advantages of the increased height would need to be evaluated in relation to the additional material required for the larger surface area of the shell.

Mokoena and Malepfane (2007: 58-70) also examined groin vaults with semicircular, elliptical and parabolic cross sections, all with a 6m span. The results of the modelling of the semicircular and elliptical vaults indicated zones of tensile forces in the areas that would experience counterflexure. However, an unexpected result was the performance of the parabolic vault that showed lower tensile stresses than the catenary vault of the same span and height, with the vault of 3.5m height having no tensile forces present at all. This is of particular importance in respect of the present study in that reinforcing can be eliminated completely within the vault, thereby reducing the quantity of material to be transported to decentralized sites, as well as simplifying the process of construction. This said, Mokoena and Malepfane (2007:68) note that "…overall the catenary-vault has the better stress flow than the parabolic-vault structure." This indicates that future stages of testing should include both of these variants to determine which of the two geometries is more effective over a wider range of parameters.

In comparing the results of the physical and computer modelling, in general the conclusions were identical, even to the extent that when each of the physical models failed (generally the result of mishandling) collapse was in the tensile zone identified in the computer model. The computer model is invaluable in locating precisely the point at which the shell experiences a change from compressive to tensile forces, as well as quantifying stresses and moments throughout the surface of the vault. The physical model provides insight into construction processes and gives an indication of the variables that might be experienced, such as tile thickness and small deviations from the ideal geometric curvature. In this latter instance, imperfections in the physical model, notably the slight sagging in the centre, did not appear to affect performance, although the computer model indicates that this should be avoided as exacerbating the tendency to develop tensile stresses.

The Finite Element Method of analysing vaulted structures has come under criticism from a number of researchers into thin-shell structures. Huerta notes two major problems, the first being that it is highly sensitive to support conditions and secondly it assumed a continuum with certain elastic properties. Neither of these conditions is supported by the physical evidence of a large number of thin-shell structures that have retained stability despite movement in their supports and cracking in the vault. He concludes his criticism by stating:

> …the results from an elastic analysis or the FEM have little significance, and are of no assistance in understanding the structural behaviour of the timbrel vault or masonry structure in question. (Huerta 2003:126)

Block, Ciblac and Ochsendorf (2006:1842) agree with this evaluation, demonstrating graphically how the Finite Element analysis of two arches of different thickness will give highly similar results, although one may be unstable because the thrust-line lies outside the thickness of the vault, because the method assumes that the material can withstand tensile forces. This said, the same authors recommend that thrust-line and thrust-network analyses be used to determine stability of the structure, followed by numerical analysis to confirm that

the material strength is adequate. An example of this, using classical membrane analysis, follows.

6.4.3 Classical analysis

The following analysis, based on the work of Billington (1965:266-267), was performed under the direction of Professor Mitchell Gohnert, University of the Witwatersrand. To simplify the calculations, a groin vault of parabolic rather than catenary cross-section was used. (Fig 6-30) The similarity of these two forms is sufficient for the purposes of this method of analysis.

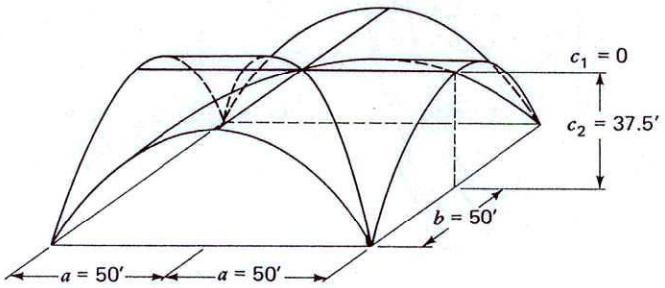


Fig 6-30: Diagram of square-plan groined vault (Billington 1965:266)

Billington (1965:266-267) provides the following equations, assuming the shell thickness to be constant:

$$q = -\bar{p}_{z0}\left(k_1 + k_2 \cos\frac{\pi y}{2b}\right) \qquad [6\text{-}1]$$

where

$$k_1 = \sqrt{1 + (2c_2/b)^2} = (1/\cos\theta) \text{ when } y = b$$
$$k_2 = 1 - k_1 \qquad [6\text{-}2]$$

This loading assumes the shell thickness to be constant.

$$\frac{\partial^2 F}{\partial x^2}\frac{2}{h_2} = -\bar{p}_{z0}\left(k_1 + k_2 \cos\frac{\pi y}{2b}\right) \qquad [6\text{-}3]$$

This equation is satisfied by the stress function

$$F = -\tfrac{1}{4}\bar{p}_{z0}h_2\left[x^2 k_1 + (a - x)^2 k_2 \cos\frac{\pi y}{2b}\right] \qquad [6\text{-}4]$$

The following are tabulated below

$$\bar{N}'_x = \frac{\pi^2 \bar{p}_{z0} h_2}{16} \left(\frac{a}{b}\right)^2 \left(1 - \frac{x}{a}\right)^2 k_2 \cos \frac{\pi y}{2b}$$
$$\bar{N}'_y = -\frac{\bar{p}_{z0} h_2}{2} k_1 \left(1 + \frac{k_2}{k_1} \cos \frac{\pi y}{2b}\right)$$
$$\bar{N}'_{xy} = \frac{\pi \bar{p}_{z0} h_2}{4} \frac{a}{b} \left(1 - \frac{x}{a}\right) k_2 \sin \frac{\pi y}{2b} \qquad [6\text{-}5]$$

Because the parabolic arch used in this calculation deviates from the loading in [6-1] the non-uniform loading will give rise to shear. Billington provides the following equations for the actual stress resultants, tabulated below:

$$\cos \theta = \frac{1}{\sqrt{1 + (2y/h_2)^2}}$$
$$N'_x = \bar{N}'_x \cos \theta$$
$$N'_y = \bar{N}'_y / \cos \theta$$
$$N'_{xy} = \bar{N}'_{xy} \qquad [6\text{-}6]$$

The values of N'x, N'y, N'xy and cosθ are calculated for half of one quadrant of the groin vault, as tabulated below (Table 6-3). These show that the primary forces are in the y direction (arch forces), with the presence of small shearing forces at the groin junction. Billington (1965:267) notes that the forces at the groin of each of the segments will "meet similar forces from the adjacent x-direction arches" but recommends thickening of the vault at these junctions.

The analysis assumes that the vault is constructed of two layers of 20mm thick tiles with 20mm mortar bed between to accommodate the length of tiles, curvature and staggered vertical joints. It is assumed that weatherproofing would be with paint, following a range of tests on different coatings by Hydraform, manufacturers of the block and tile press used throughout this research.

Density of tiles is taken as 19.5 kN/m^3
Dead load = 19.5 kN/m^3 (0.06) = 1.17 kN/m^2
Live load = 0.5 kN/m^2 (from SABS 0160)
Safety factors of 1.2 for dead load and 1.6 for live load from SABS 0160
Total loading: 1.17 (1.2) + 0.5 (1.6) = 2.20 kN/m^2

Tile Pzo =	2.2	kN/m2	UDL on horizontal projection
a =	3	M	
b =	3	M	
c1 =	0	M	
c2 =	3	M	
h1 =	#DIV/0!		
h2 =	3.00		
k1 =	2.236068		
k2 =	-1.23607		
a/b =	1		
k2/k1 =	-0.55279		

	N'x										
	x/a										
y/b	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	-5.03	-4.08	-3.22	-2.47	-1.81	-1.26	-0.81	-0.45	-0.20	-0.05	0.00
0.1		-3.95	-3.12	-2.39	-1.75	-1.22	-0.78	-0.44	-0.19	-0.05	0.00
0.2			-2.84	-2.18	-1.60	-1.11	-0.71	-0.40	-0.18	-0.04	0.00
0.3				-1.88	-1.38	-0.96	-0.62	-0.35	-0.15	-0.04	0.00
0.4					-1.14	-0.79	-0.51	-0.29	-0.13	-0.03	0.00
0.5						-0.63	-0.40	-0.23	-0.10	-0.03	0.00
0.6							-0.30	-0.17	-0.08	-0.02	0.00
0.7								-0.12	-0.05	-0.01	0.00
0.8									-0.03	-0.01	0.00
0.9										0.00	0.00
1											0.00

	N'y										
	x/a										
y/b	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	-3.30	-3.30	-3.30	-3.30	-3.30	-3.30	-3.30	-3.30	-3.30	-3.30	-3.30
0.1		-3.42	-3.42	-3.42	-3.42	-3.42	-3.42	-3.42	-3.42	-3.42	-3.42
0.2			-3.77	-3.77	-3.77	-3.77	-3.77	-3.77	-3.77	-3.77	-3.77
0.3				-4.37	-4.37	-4.37	-4.37	-4.37	-4.37	-4.37	-4.37
0.4					-5.22	-5.22	-5.22	-5.22	-5.22	-5.22	-5.22
0.5						-6.36	-6.36	-6.36	-6.36	-6.36	-6.36
0.6							-7.78	-7.78	-7.78	-7.78	-7.78
0.7								-9.51	-9.51	-9.51	-9.51
0.8									-11.54	-11.54	-11.54
0.9										-13.88	-13.88
1											-16.50

	N'xy										
	x/a										
y/b	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1		-0.90	-0.80	-0.70	-0.60	-0.50	-0.40	-0.30	-0.20	-0.10	0.00
0.2			-1.58	-1.39	-1.19	-0.99	-0.79	-0.59	-0.40	-0.20	0.00
0.3				-2.04	-1.75	-1.45	-1.16	-0.87	-0.58	-0.29	0.00
0.4					-2.26	-1.88	-1.51	-1.13	-0.75	-0.38	0.00
0.5						-2.27	-1.81	-1.36	-0.91	-0.45	0.00
0.6							-2.07	-1.56	-1.04	-0.52	0.00
0.7								-1.71	-1.14	-0.57	0.00
0.8									-1.22	-0.61	0.00
0.9										-0.63	0.00
1											0.00

	Principal stress: Sigma 1 (N/mm2)										
						x/a					
y/b	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	-0.06	-0.06	-0.05	-0.04	-0.03	-0.02	-0.01	-0.01	0.00	0.00	0.00
0.1		-0.05	-0.05	-0.04	-0.03	-0.02	-0.01	-0.01	0.00	0.00	0.00
0.2			-0.04	-0.03	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.00
0.3				-0.03	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.00
0.4					-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
0.5						-0.01	0.00	0.00	0.00	0.00	0.00
0.6							0.00	0.00	0.00	0.00	0.00
0.7								0.00	0.00	0.00	0.00
0.8									0.00	0.00	0.00
0.9										0.00	0.00
1											0.00

	Principal stress: Sigma 2 (N/mm2)										
						x/a					
y/b	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	-0.08	-0.07	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
0.1		-0.07	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
0.2			-0.07	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
0.3				-0.08	-0.08	-0.08	-0.07	-0.07	-0.07	-0.07	-0.07
0.4					-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09
0.5						-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
0.6							-0.13	-0.13	-0.13	-0.13	-0.13
0.7								-0.16	-0.16	-0.16	-0.16
0.8									-0.19	-0.19	-0.19
0.9										-0.23	-0.23
1											-0.28

	Principal Angle (deg.)										
						x/a					
y/b	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1		29.75	-34.83	-17.15	-9.95	-6.42	-4.32	-2.88	-1.78	-0.85	0.00
0.2			-29.85	-20.52	-14.35	-10.21	-7.26	-5.00	-3.15	-1.52	0.00
0.3				-19.68	-15.17	-11.56	-8.62	-6.12	-3.93	-1.92	0.00
0.4					-14.49	-11.52	-8.86	-6.44	-4.20	-2.07	0.00
0.5						-10.79	-8.46	-6.25	-4.12	-2.05	0.00
0.6							-7.75	-5.77	-3.83	-1.91	0.00
0.7								-5.17	-3.44	-1.72	0.00
0.8									-3.02	-1.51	0.00
0.9										-1.31	0.00
1											0.00

Table 6-3: Classical analysis of groin vault (Gohnert 2009)

N'x gives the highest value at the crown of the vault. All values of N'x show compression for horizontal membrane forces. N'y gives the highest values at the points of support, as expected from all other analyses. All values of N'y show compression for vertical membrane forces, with the highest values being well within the strength of the compressed earth tiles (5Mpa). If all the values in N'xy are zero, this would indicate an absence of shear. The table for N'xy shows that there are no shear forces along the top of the vault or the free edges, but increase to a maximum approximately half way along the rib. This is not easily revealed in the Finite Element Analysis, as noted by Huerta (2003:126) and Block, Ciblac and Ochsendorf (2006:1842) as discussed above in 6.4.2.

The limitations of the classical method of analysis relate to the boundary condition, in the groin vault being the four points of support. The difficulty with this type of boundary condition is generally resolved by thickening structure to three times designed thickness. The ideal support would have foundation haunches angled to form a right-angle to resultant force line at the base, with supports on rollers. However, this would not be practical for masonry vaults and would be excessively complex for the available skills under consideration in the present study.

It must be stressed that all of the technical analysis in this work is by way of example, and should not be used without verification by a qualified structural engineer, paying particular attention to soil conditions, foundation design and the junction between the foundations and the vault.

6.4.4 Employment Calculations

The cost evaluation and labour calculations draw substantially from the data for the standard Limpopo Province school and the buildings constructed by LITE analysed in Chapter 5. Both case studies were costed in 2003, so in the calculations that follow, the 2002/2003 Master Builders Association Pricing Guide has been consulted for additional items. Labour rates are based on those used by the Department of Public Works. Plumbing and electrical installation are drawn in their entirety from the Limpopo Department of Public Work's Bill of Quantities, as considerable research needs to be undertaken to determine new performance specifications that allow for greater labour input in comparison with the material costs.

For ease of comparison, a four classroom wing with a separate toilet building is priced, using groin vaults for the classes, and a Guastavino dome for the smaller span of the toilet block, where the problems of accurate geometry would be less critical. A significant amount is included for louvered ventilators and fittings to be constructed locally, thereby broadening the skills base.
Foundations and stabilized earth blocks for walling are based on the rates and specifications used in the LITE buildings, as these had been adapted previously to maximize their employment component in the quarrying, manufacturing and construction activities.

Productivity rates for the roof tiles are based on work and method studies carried out at the University of the Witwatersrand. Using a hand-press, the minimum daily productivity per press should be 750 tiles per day. To achieve this, a number of management issues arise, at the strategic level, as well as at the level

of site supervisor. Guidelines for the production of tiles are presented in Appendix 2.

	Labour (l)	Material	Activity (a)	l/a %	a/t %
Site prep	450	0	450	100.0	0.19
Foundation	10 400	14 146	24 546	42.4	10.32
Floor slab	3 520	6 100	9 720	36.6	4.08
Walls	36 930	32 860	69 790	52.9	29.33
Roof	42 268	8 154	60 750	69.6	25.53
Interior	3 950	14 308	18 258	21.6	7.67
Plumbing	875	1 900	3 400	25.7	1.43
Electrical	1 750	12 900	18 285	9.6	7.68
Fittings	1 280	20 400	25 250	5.1	10.61
Glazing	600	824	2 107	28.3	0.89
External	456	1 640	2 096	21.8	0.88
Clean	1 524	1 776	3 300	46.2	1.39
TOTAL (t)	**104 003**	**115 008**	**R 237 952**	**43.7**	**100.00**

Table 6-4: Cost and labour analysis for groined vault classroom block

The labour rates for the vault construction have been provided by Michael Ramage, based on theoretical research and the construction of several prototypes. His labour estimates have been evaluated by a South African quantity surveyor for local conditions on the premise that an experienced vault builder will conduct the training on site.[78]

6.5 CONCLUSION

The investigations discussed in this chapter provide an illustration of the process and the outcomes that can be expected from pursuing employment-intensive objectives with the same rigour that has characterised innovation in this domain of civil engineering. The results of the study of a single component of a typical building show that the local labour content can be expanded to approximately

[78] These studies on the tile manufacture and construction were carried out for the Mapungubwe Visitors Centre, and adapted for groin vaulting using the insights gained from the various scale models.

70% of the value of that component. While the initial analysis indicated that the roof and ceiling would be the area where the biggest gains can be made, similar studies of all the other elements and activities could result in a significant increase in the value of the building being allocated to targeted labour. At the same time, this chapter has shown that small manufacturing industries and suppliers of bulk materials can be fostered through this process, while technical and managerial skills can be developed through this process of re-engineering for employment-intensive construction.

Building has been classified as already labour-intensive and therefore government expenditure on buildings that purport to have job creation as an objective will only result in a *pro rata* increase in employment. This chapter has demonstrated the limitations of such thinking, when the labour content of the tiled vaulting system developed here is compared with conventional construction, exemplified by the Department of Public Works school. This is even more pronounced in a comparison with the Lightweight Steel Frame system analysed in Chapter 5 as a potential competitor to conventional construction.

Project	**Labour % of direct project cost**	**Roof labour % of roof activities**	**Total roof cost % of project cost**
Alexandra	23.80	13.78	19.15
Limpopo school	14.40	4.44	22.53
New Gourna	(72.74)	53.31	(total not available)
LITE offices	29.36	17.04	27.49
Lightweight Steel	5.49	4.88	+/- 20
Tiled vault	**43.7**	**69.6**	**25.53**

Table 6-5: Summary of labour ratios including tiled vault

This technical study has been limited to the group of activities that were immediately apparent as having a high potential for increasing the labour content with out compromising productivity. Future studies into other activities and components could increase the overall labour ratios even more, although possibly less dramatically than for the tiled vaults. The potential for increasing productive employment generation has particular significance in South Africa,

where the legacy of apartheid has resulted in the need to generate employment opportunities for many people with no marketable skills. The technical study in this chapter shows how design for employment-intensive construction can result in a vehicle for fostering artisan skills as well as small contractors and suppliers, who would themselves create jobs for the relatively unskilled. This is the focus of the chapter that follows, which integrates the findings of the technical study into the broader framework of a programme for the construction of public buildings.

7 THE MODEL

7.1 OVERVIEW

The model proposed in this chapter is a synthesis of research into the many facets of the building programme. Piecemeal efforts at increasing the employment potential of a building project will tend to be of insignificant impact in terms of numbers and the sustainability of the jobs created. For more permanent results, a holistic approach is needed, one that integrates management; design, detailing and specification; training; construction; and the manufacture and supply of components and bulk material; in a seamless system. For this to be effective, the Supply Chain model proposed for public commissions in the United Kingdom appears to hold many of the clues (Cain 2004b).

One significant element that has emerged in the present research is that truly effective solutions result from an in-depth analysis of 'state-of-the-art' methods and investigation of how they may be adapted to the present objectives. This stands in contrast to the Alternative or Intermediate Technology approach that has tended to look to improving traditional methods or down-scaling methods from highly industrialized countries. The results inevitably look second best – a compromise that satisfies none of the programme participants and exacerbates the poor self-esteem of the target communities that the projects purport to be benefiting. Instead, less industrialized countries can, through rigorous evaluation of best practice throughout the world, devise new solutions to their particular circumstances. This is pertinent in the context of global warming and the appreciation that following the Western world's route of industrialization is environmentally unsupportable, as enshrined in the Millennium Goals (United Nations 2000).

To allow the effective development of a more innovative approach, a long-term programme is the only viable mechanism for ensuring enough trained personnel and guaranteeing that sufficient research and development is undertaken. Large-scale road building programmes in Botswana (McCutcheon 1991) and Kenya

(McCutcheon 1995) have shown that the high start-up costs in the first few years need several more years of sustained activity to amortize the initial training, research and development and other preliminary expenses. This has been one of the key reasons for locating the present study in the arena of public building, where a programme approach has a natural home and where building typologies are embraced to ensure equitable delivery of public infrastructure.

While the focus of this study is on strengthening impoverished decentralized communities, this model proposes that construction training should be seen in a broader regional and national context. This is especially the case for higher-level technical and managerial expertise, which take several years of academic and on-the-job training to nurture. One of the failings of the first years of skills development in democratic South Africa has been a narrow interpretation of development of local skills, resulting in a saturation of low-level skills with no market value or portability. The model proposed here is structured on the career-path framework devised by the Construction Sector Education and Training Authority. (Fig 7-1) While the majority of those employed in any one project within the programme will elect not to engage in higher levels of training, the system should allow for individuals to reach their full potential, whether within the programme or with supplementary training to diversify into other sectors or assist them to become independent operatives.

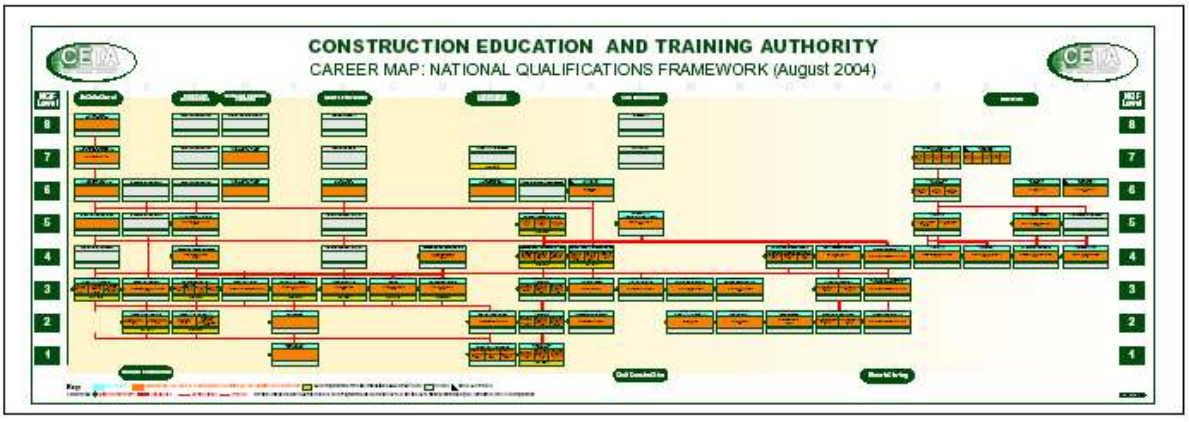


Fig 7-1: CETA Career Map (http://www.ceta.org.za/ accessed 19/09/2007)

This chapter is loosely structured around the time-line that would see the inception of the programme, followed by pilot studies and leading to local, regional and national roll-out. For the sake of clarity, overlaps and re-iterations in the process are to some extent underplayed, but contingencies in both budget and programme should be made for these. Two distinct levels of management are proposed in this model:

1. the centralized 'head office' determines policy, deploys highly trained personnel, and administers quality control and feedback that allows for constant improvement in performance of both process and product; and
2. the local level, determined by the physical extent of a district of local government.

The Local Authority plays a critical role in prioritizing individual building projects, providing day-to-day supervision, nurturing small business in the area and ensuring a balanced supply of artisan and manufacturing skills. Their role in the early phases of the programme in their area would be equivalent to the multi-site supervisor of the Kenyan Rural Access Roads Programme (Fig 4-1) and can be linked to a single person responsibility at professional level in the provincial Departments of Public Works.

7.2 PROGRAMME INCEPTION

Many initiatives to alleviate poverty through the generation of employment for constructing public facilities have failed on all fronts because the extent of innovation has not been appreciated. For many decision makers, 'labour-intensive' equates to turning back the technological clock, reverting to more 'primitive' means, therefore not requiring the same level of management and personnel that 'state-of-the-art' engineering and design warrant. Engineers experienced in employment-intensive construction reiterate the need for innovation and for the highest caliber of professionals to be appointed (McCutcheon and Fitchett 2005a).

Successful programmes have been characterized by best practice in management, where the workforce as the primary 'engine' of delivery is given central importance – design, specification and detailing are adapted or completely reconsidered to facilitate hand construction. Management is structured around ensuring a cost effective and productive workforce. Only through impeccable control of productivity and the elimination of material waste, can ratios of project cost allocated to targeted labour be met. Thus, the management of employment-intensive construction is more demanding, more sophisticated and demands greater ingenuity than conventional modes of production. Invariably in any specific location these management frameworks need to be revisited, often substantially restructured, to meet new contexts and different objectives.[79]

Start-up costs and time frames for preliminary work that would be prohibitive in a single project become more justifiable as a programme is rolled out. If this is not acknowledged, either preparation work will be inadequate and lead to the failure of the project, or the project will run massively over budget and programme. In either scenario, employment-intensive objectives will invariably be the victim. The process of technical investigation into materials and construction systems appropriate to employment-intensive production needs to be supported by work and method studies to maximize efficiency and to test the validity of their choice. This is a reiterative process, as was shown in Chapter 6, and the more thorough, the greater the chances of optimizing the targets of employment generation and the individual project objectives.

Training that takes place entirely within a single project is also a drain on the project performance. Moreover, only low level skills can be developed in this way, as has been demonstrated repeatedly. For training to have a real impact on

[79] This is vividly evident in McCutcheon's evaluation of the Botswana Rural Roads Programme, where the experience and methods successfully developed in the Kenyan Rural Access Roads Programme were to be applied wholesale. Significant changes were necessitated to meet local needs, and others were introduced through openness of the implementation team to local opportunities, such as the use of specially designed donkey carts for haulage.

poverty alleviation, skills need to have a market value beyond the life of the single project and small businesses need germination time for any reasonable chance of success. The South African government has put in place policy, structures and legislation to support education and training through a broad range of initiatives that respond to the inequity of opportunity that characterized the pre-democracy era, but to make these effective, the national structures need to be devolved down into each sector. In this respect, public works programmes need to play the role of catalyst in creating well balanced skills capacity within each sector, and not just in response to immediate market demand.

Other national policy frameworks that should form part of the pre-feasibility phase of a programme might include: strengthening rural economies; environmental management; and a progressive approach to manufacturing, including beneficiation of raw materials and recycling industrial waste. In this regard, South Africa's commitment to the Millennium Goals should be devolved to the building industry through its public works.

Finally, in the pre-feasibility phase, the model proposed here places importance on strategic planning with the client organization[80] as a consequence of the shift from a conventional building brief to a statement of objectives and performance criteria. The changes introduced in the South African education system provides a useful base from which to conduct these discussions as the Department of Education has already acknowledged the need for new building types to suit its 'outcomes based' framework. A new school building type would also be in line with its post-apartheid school management model in which the parent body plays a leading role. Thus, strategic discussions at a national level would explore existing and new norms and standards; performance specifications; cost targets; and a national programme of delivery that plans the number of new school buildings, their size, and their geographical location.

[80] Throughout this chapter, "client" refers to the organ of government commissioning the building, generally funding it out of its capital budget as well as being the end user. For schools, this would be the national and provincial Departments of Education.

7.2.1 Programme objectives

Recent United Kingdom experience in management models for the delivery of public buildings has stressed the importance of clarifying the objectives of the 'client', the organ of government that will be the end user of the building. This is in contrast with the traditional provision of a brief, often accompanied with unit designs, details and specifications that leave the implementation team little scope to formulate a more effective solution. These objectives should be in a format that is measurable as far as possible either in the absolute (for example, interior thermal levels) or relative to a defined predecessor, generally expressed as unit costs, such as cost per scholar or per 1 000 people of the target population. The objectives should be framed in terms of the 'whole life performance' of the building, and not limited to the construction period.

It is important that the people who establish these criteria look beyond conventional space designations, and focus on functions and activities, to give the implementing team the greatest flexibility in achieving the project and programme outcomes. Flexible spaces and greater use of covered outdoor spaces are two options that could have far greater application in most climatic regions of Southern Africa, as is demonstrated in the design developed in the present research. One method of examining these requirements afresh would be to undertake a critical analysis of the school curriculum in the light of the physical needs for its successful implementation.

At this early stage, it is valuable to record these objectives and priorities in a way that can be continuously monitored, such as using the Log-frame method. Not only does this assist all participants in generating clearly stated objectives with their methods of measurement, but becomes a standard by which programme status is assessed and a common framework from which necessary or strategic divergence can be planned.

7.2.2 Research and Development

Concurrently with the establishments of client objectives, the core technical team can begin research into materials and systems that are consistent with the broader programme priorities. It is assumed that these would include, among others, the use of employment-intensive methods, decentralized sourcing of materials and component manufacture, and environmentally responsible methods of construction and servicing buildings. Research into these factors will become more focused as the client parameters are more clearly defined and as the programme's physical roll-out is mapped in terms of the location of individual buildings. The third phase of research will only begin to be implemented when the decentralized Supply Chain teams are formed, but because of the lack of research into technical aspects, a considerable lead time is needed.[81] Moreover, each supply team would benefit from a compendium of possible methods and materials for which the preliminary studies have already been done. At the same time, the capacity of decentralized laboratories and testing stations[82] can be enhanced in anticipation of the building programme.

The first phase of research should focus on the development of structural types, design typologies and customizing standardized documentation (specifications and contract provisions) to facilitate employment-intensive construction, Supply Chain management structures and small business capacity building. This has largely been done for various types of civil engineering infrastructure to guide the implementation of the South African Expanded Public Works Programme. Standard contract clauses accompanied by a set of Guidelines are in electronic format for easy introduction into contract documentation (DPW 2005). Similar provisions still need to be introduced for government building projects to facilitate wider scope for the EPWP.

[81] This is the primary reason that the construction and maintenance of buildings has not yet been included in the Expanded Public Works Programme, although it has been contemplated in all the policy documents from the outset.

[82] Soil testing stations for road building are obvious targets for this kind of capacity building.

It is the contention of this thesis that for employment-intensive construction to achieve its full potential, researchers need to look to state-of-the-art engineering and design to meet the following:

- low energy, low environmental impact;
- local materials, energy, skills, and organizational capacity;
- low entry level skills, with potential for development;
- low supervision requirements because of lack of local capacity and the high percentage of project cost to high level skills.

While traditional construction can provide valuable clues and inspiration, only through sophisticated approaches can the traditional be elevated to meet high levels of efficiency and productivity, and at the same time meet ever greater expectations of the end users.

One of the findings of the technical part of this research is the importance of small but repetitive components to improve the employment intensity. The following factors are important on sites where skilled workers are scarce:

- complexity of engineering using advanced modelling and laboratory testing to ensure simplicity on site;
- on-site control over geometry using straightforward methods that can be implemented for the most part by relatively unskilled workers;
- junctions between components and materials that require a minimum of cutting and complex jointing methods;
- component strength and dimensional consistency in manufacture, especially of materials from decentralized sources;
- simple controls for manufacture using whole numbers and exact-size containers for measurement of materials; and
- simple controls for construction using elementary formwork and builder's line except for the initial setting out of elements by a supervisor.

Linked to the research into materials and systems outlined above, an important task in the pre-feasibility phase is performing a comprehensive set of method studies. This is essential to ensure productivity and efficiency when translated to actual site operations. Moreover, the most effective employment-intensive programmes have shown the necessity of making as much of the work as possible paid on individual or group tasks. These have to be established before any work begins on site, as it is difficult to re-negotiate task rates and daily wages. These negotiations should happen with community representatives from the start to be able to make reasonable cost predictions of the labour component. The work and method studies should be carried out on full size prototypes as part of the structural and constructional investigations, and concurrently give insight into the buildability of any proposals. At this early stage of the programme, there is scope to adjust difficult processes as well as those that inherently create delays and/or wasted material. Parker and Oglesby (1972) provide step-by-step guidance on improving productivity through work and method studies.

7.2.3 Management structure

The project management framework needs to be instituted at programme level before it is devolved to local level, with guidelines and templates[83] for individual projects, but leaving room for innovation and localized systems devised by each project team. Higher level training (as outlined below) and the Monitoring and Evaluation structure should be directed from head office, with the latter information being captured in a consistent format nationwide. Following the Project Management Institute's format (Duncan 1996), at programme level the following need to be integrated into the programme planning:

- **programme**

  For head office to plan for training and the letting of individual projects, a constantly updated programme of work is essential. Initially, a strategic decision making process with the client is required to determine location,

[83] Templates take on special importance in a scenario of low management capacity, although feedback should be encouraged to allow these to evolve through critical review as part of the process of constant improvement, one of the pillars of Supply Chain management.

sequencing and timing of projects so that the client body can ensure staffing from its side as each building nears completion. This is especially significant in education, where the shortage of teachers, especially in the key disciplines of Mathematics and Science, could result in a successfully completed building that has to stand empty and be vulnerable to natural degradation and vandalism.

- **cost framework**

One of the primary reasons for the UK investigation into Supply Chain management in construction is because of the endemic budget overruns in public projects. This problem is even more severe in the developing world, exacerbated by scarce resources, massive backlogs and inequitable provision of public facilities. When an unconventional approach is introduced, lack of financial management discredits the method even when budget overruns are not likely.[84] It is the contention of this thesis that government should serve as exemplar, as much in management at the highest level as in method of construction and design. Moreover, it is important for head office to set the example for the decentralized projects and to establish straightforward systems of cost planning and control as a central element of the Monitoring and Evaluation function.

- **scope**

At the higher level of management, strategic decisions need to be made with the client on the scope of the overall programme. This has an implication on training as well as the sustainability of jobs created for the trained personnel, some of whom need to be encouraged to remain in the programme for additional levels of training or to become trainers themselves. Most of those choosing to leave the programme should form the core of competence in construction in their locality so that valuable skills are not lost to the target community.

[84] For example, with the Visitors Centre at Mapungubwe World Heritage site, the cost effective system of stabilized earth vaulting was challenged by the client as being more expensive than reinforced concrete. A full cost comparison was undertaken before the economy of the proposed system was finally accepted.

When planning the scope of the programme, the broad climatic regions will determine a range of building types, each of which will require research and development as described above. The programme team will have to decide whether to expand geographically from the initial pilot project, or whether to establish a number of pilot schemes spread across these regions from the outset. This is both a political and resource decision that cannot be made by the programme team alone, but has a profound effect on how the other aspects of the programme are conceptualized.

- **quality management plan**

Total Quality Management is fundamental to Supply Chain management, with constant improvement being one of its core principles. One of the obstacles that must be overcome in relation to employment-intensive construction is the preconception that its products will be of lower quality than those produced by conventional or machine intensive methods. With proper preparation, training and management, the opposite should be the case, especially in the context of buildings. Moreover, the conscious shift in construction techniques offers the potential to train workers to higher standards of workmanship that would meet resistance from site-experienced personnel if conventional methods were upgraded.

- **resource management**

At the level of the programme, one aspect of physical resource planning needs special attention, namely tools. In all successful programmes of employment-intensive construction, it has been found that the quality of tools and equipment is central to productivity. This said, tools should be easy to maintain and repair locally without compromising their performance.

In relation to human resources, training is discussed below. Career planning is a more contentious issue, in that the competing objectives of retaining key staff to strengthen the programme has to be weighed against the skills needs of the decentralized communities. For this reason, it is advocated that a skills programme be developed by each Local Authority in which the programme

will be operating. From this, the training programme can be structured so that the ratio of people moving to higher levels of training, moving to new locations within the programme or setting up as local entrepreneurs can be adequately managed. This is particularly important for strategic skills personnel: trainers; researchers; specialist artisans (electricians and plumbers); and on-site supervisors. Head office staff will also fall into the category of scarce skills.

- **communications**

In the context of a national programme, the relationship of the central head office to the peripheral sites needs careful consideration. The degree of autonomy of each site has to be planned so that the detailed data is captured without overloading the system with excessive reporting. Detailed records of productivity and decisions are essential for the constant improvement of the programme as a whole, and indispensable for the strategic and detailed planning of projects downstream. Here the opportunities offered by networked computers can be used to expedite responses from head office, while pro forma data capturing can allow the detail to be immediately available without being part of the main reporting system. At remote sites, this communication can take place via cell phone to facilitate daily or weekly updates from the site supervisor.

- **risk management**

Construction projects are inherently risky, especially where the sites are in remote locations. In employment-intensive construction, the stakes are higher simply because of the number of people involved. The most obvious risks relate to occupational health and safety, where good management and awareness training of supervisors and of the entire workforce are the surest ways of mitigating problems. Beyond the normal risks of construction in rural areas are those introduced through structural innovation, but to these must be added labour problems (especially regarding conditions of employment), tools, and the timeous delivery of materials of consistent quality. The special conditions proposed in this model point to the need for smooth and prompt

flow of information and impeccable availability of resources so that the large workforce is not standing idle or doing abortive work.

One of the premises of this research is that the public sector, through the construction of its own buildings, takes much of the risk of innovation that cannot easily be borne by the private sector, especially in the poorer rural areas. In the same way, the central programme management, through sharing the experience of a number of projects, needs to absorb as much of the risk as possible to ensure the smooth running of decentralized projects. This risk is managed largely through ensuring high quality training, sufficient research and development before innovation is applied on site, and exemplary central planning and management. The communication framework is especially important in this regard.

- **procurement options and structures**

While this model promotes the use of Supply Chain management with a fully integrated team, it may be that in areas of very low management capacity that some bridging procurement model is used, more similar to traditional direct labour contracting. At the other end of the scale, it may be advantageous to introduce contractors and suppliers to competitive tendering to smooth their transition into the commercial environment on termination of the public works projects.

Each of these management tasks should follow Project Management best practice, bearing in mind the provisions for Supply Chain procurement. This is consistent with British guidelines and practice, and while the inexperience of many of the players in the present context needs to be factored in, this must not be used as an excuse for inadequate planning at the highest level.

7.2.4 Initiating the training programme

McCutcheon (2001), in emphasizing the central importance of training, has expressed that a programme should expand only at the rate that qualified personnel are able to perform. In this regard, he specifically refers to the critical

importance of the Hands-on Site Supervisor, a position that has evolved through decades of employment-intensive road construction in sub-Saharan Africa (McCutcheon and Fitchett 2005a). In the scenario of building, the site supervisor takes on a more complex role of managing several trades, as did the foreman of the past. For this reason the supervisor's training will necessarily be longer and will involve a greater managerial orientation. This training needs an appreciable lead time, with the first generation gaining their site experience through the construction of prototypes and pilot projects.

- **government personnel**

Elsewhere, we have discussed the need for orientation of high-level civil servants and politicians in the principles of employment-intensive construction in general, and in their role in the programme contemplated here. Their ability to direct strategic decisions and co-ordinate objectives of the line Department and the implementing organ of government requires special skills and knowledge. Specifically, the officials involved in the day-to-day administration of the programme should be required to hold a qualification in employment-intensive construction as has been legislated for the South African Expanded Public Works Programme (http://www.epwp.gov.za/).

- **professionals**

The EPWP has also specified the qualifications for professionals and trainers who will translate the strategic decisions to the individual projects and site personnel. In the case of professionals, a number of entrenched values and methods of working need reappraisal. This model requires that professionals replace their privileged status in favour of a collaborative process where they are equal partners with the key construction personnel and the suppliers. While one of the professional disciplines may head the supply team, this will still require a significant shift from the way professionals currently operate and are educated. The professions will adapt to this only through exposure to the advantages demonstrated in the management approach developed in the UK for its public building procurement (Cain 2004b).

In relation to employment-intensive objectives, many professionals profess to have job creation as an objective in their work, but their understanding of its application is invariably piecemeal, and choices relating to some methods and activities can undermine the gains in others. This calls for a more systematic and informed approach.

- **hands-on site supervisors**

In section 6.1.3, the role of the construction of decentralized public buildings has been discussed from the perspective of research and development. A pilot training programme at Mohlaletse in South Africa's Limpopo Province provides a starting point for a broader training model that could expand to site supervisors for building work. At Mohlaletse, a rigorous selection process ensured that participants had a reasonable chance of success in the academic demands of the programme[85], as well as showing leadership qualities and capacity for holding responsibility. These latter two characteristics are fundamental to the success of employment-intensive sites, as the supervisor has to motivate the workforce, ensure equitable working conditions and translate the contract documentation into the built reality with the decision making that this entails.

In the context of the Supply Chain framework posited, the lead contractor would be the supervisor's employer, with the supervisor directing much of the on-site training of the ordinary labourers. Given the complexity of a building site, the supervisor would need to be familiar with all trades, although competent in only one of them. Traditionally, the site foreman has been drawn from masonry and carpentry artisans, particularly because of their competence in geometry. In South Africa, as in many parts of the developing world, the pool of artisans from whom supervisors can be selected is too small, and the decline in quality of their training would necessitate retraining (McCutcheon et al 2004). Experience has shown that retraining people who have extensive site experience is problematic,

[85] This is in the context of very low levels of Maths and Science teaching at high school. This said, all those selected for the Mohlaletse programme held Matric, the high school exit qualification, which is an indicator of the extremely high levels of unemployment and low prospects in the formal job market. More than 50% were female, dispelling the assumption that women would not find road building a suitable occupation.

but a shift from conventional building could be the catalyst. Here we propose that the supervisors are trained in vaulted construction, where the necessity for precision can become the norm for all activities. The supervisors would be trained alongside the artisans for a period of two years, following which those showing particular leadership and managerial aptitude would be invited to proceed into the supervisor programme.

As at Mohlaletse, classroom training would alternate with productive site work on a fortnightly cycle so that the building programme for the pilot structure in each area would run in parallel with the training. Thereafter, new trainees would be paired with fully trained people to ensure the required levels of productivity. With timbrel vaulting, the ideal team has two people laying tiles and one mixing mortar. A fourth person can service two teams in cleaning and pointing the joints on the underside of the vault.

The role of the public building as catalyst that underpins the present thesis is extended into the domain of training. The Supply Chain model, in this catalytic building in each area, has the Department of Public Works as the lead contractor to the line department. Public Works would be ideally placed to oversee training by all the other participants; suppliers, manufacturers and subcontractors, and would be able to advise local authorities on the development of their skills strategy described above. Public Works is also the most knowledgeable with respect to sources and mechanisms of funding for training. After the initial building is completed in an area, subsequent training could take place through classroom components being conducted at regional centres with on-site experience at the trainee's home village. It should be noted that private sector contractors resent being contractually bound to the provision or even accommodation of training, as they see this as disrupting productivity.

- **artisans**

The collapse of the artisan system is a complex phenomenon, experienced in both sub-Saharan Africa and Europe (Fitchett and McCutcheon 2005b). The

South African Construction and Training Authority (CETA) has established a new model to address the collapse of apprenticeships and the consequential lack of vocational training in the industry. In place of a four year continuous training programme, certified modules are offered, allowing short spells of intensive study. Linked to this are two important concepts, Recognition of Prior Learning, and lifelong learning structured on individual career path planning. The CETA assists individuals in both of these processes, and keeps a data bank that integrates and certifies both formal and experiential learning.

The model presented here builds on the CETA system, from within a single project that is structured in stages of progressively more stringent quality requirements, and in the establishment of local networks. People choosing to remain in their area can specialize in the materials, components and methods introduced through the local pilot project, supported by other members of the network. Those opting to take on additional training modules can follow the programme to other locations. It must be accepted that individuals from poor communities need institutional support to continue training, as they generally are supporting other family members and cannot operate from a stipend income.

In the Anglophone world, electrical and plumbing work has to be performed by fully qualified artisans, thus precluding the incremental approach to training described above. A more conventional centralized training school would be more appropriate for the classroom teaching, with apprentices indentured to experienced artisans for their on-the-job training. In both of these fields, there is not the same skills gap because legislation has ensured that there is guaranteed work for registered people. Electrical work does not presently offer much scope for increasing job creation because of the highly industrialized components, although South Africa’s national electricity supplier has made headway through the labour-intensive provision of infrastructure to extend the national grid up to property boundaries.

By contrast, evidence of piped plumbing dates back to the ancient Indian and Indus Valley civilizations, with sophisticated systems being constructed in the Roman Empire and early Islamic cultures. A superficial investigation suggests that the techniques for salt-glazed stoneware, developed as a cottage industry in the 1600s could provide a starting point for a more employment-intensive approach. The traditional manufacturing method uses relatively low firing temperatures and simple technology, and there are now new opportunities for research into new additives, profiles and components that introduce water saving systems.

- **contractor development**

In acknowledgement of the considerable number of self-taught builders operating in the rural areas and urban informal sector, the Expanded Public Works Programme has created a framework for small contractor development for people with low formal education levels. They are partnered with site supervisors in the expectation that the site supervisors will manage the technical aspects, while the contractor looks after the business side. This somewhat anomalous situation where the 'boss' needs to defer to the supervisors on most of the actual building has been challenged, even from within the Department of Public Works.

In parallel to this is a mentoring programme to assist small contractors in learning formal contracting skills. This has had a low success rate, largely because of a lack of trust between mentor and contractor, as has been investigated by Egbeonu (2004). Mkhize (1994), in researching the Soweto Small Contractor Development Programme, provides a model of the structured incremental process that should take place to match the small contractor's skills with client expectations.

Mkhize's model, adapted to Supply Chain processes, can give a more palatable form of skills transfer than mentoring by being less paternalistic, and both the experienced and emerging contractor can see the immediate benefits through

improved productivity and direct profits. In contrast to the South African small contractor programmes[86] what is proposed here is that a potential contractor first begins technical training as an artisan, progresses through supervisor levels and only then, when both the technical and managerial skills have been mastered, engages in contracting. This grows out of the supportive Supply Chain environment, and only when the emerging contractor is able to provide realistic costing and scheduling, when supply networks and a team of productive workers are in place, should the contractor be exposed to competitive tendering.

7.3 THE PILOT PROJECT

The Botswana Rural Roads Programme highlights the importance of the pilot project in synthesizing all aspects of the programme within the local context. The pilot translates the work and method studies from the theoretical and laboratory work into real site operations to determine realistic productivities. Moreover, it provides the first data in the Monitoring and Evaluation cycle, generating essential costing and scheduling information for the broader programme design. Through it, the design, specification and detailing can be refined, wear and tear on tools and equipment can be assessed, and general site organization can be planned more effectively.

Cost data plays a central role in Supply Chain management to estimate the Guaranteed Maximum Price (GMP) from which the Supply Chain team develops its implementation strategy. The GMP is the basis on which the design, detailing, specification, planning and scheduling of the entire project is developed for each site. Cost savings are achieved through streamlined site operations: team balancing; scheduling of materials and activities; optimizing the use of equipment; and the organization of specialist subcontractors and artisans.

[86] In particular, the Expanded Public Works Programme admits contractors who have not engaged in any secondary schooling. (http://www.epwp.gov.za/)

The pilot project provides the first step in the training process, often the seedbed for future trainers and site supervisors. In the Supply Chain model, it allows for the first generation of manufacturers and suppliers to become established. Lastly, the client department and the Department of Public Works, as the implementing agency, can refine objectives in the light of a built example.

A team should be formed for this inception phase that comprises key decision makers from the Local Authority, the client department, the Department of Public Works and the key professionals. The active role of the Local Authority should be restricted to this phase of the programme and should focus on skills and entrepreneurial development, local conditions of employment, consultation with local communities, broader developmental strategies and land issues. Thereafter, the Local Authority would take an observer's role, to resume an active part towards the end of each building project when skills and entrepreneurial strategies are revisited.

The first task of this strategic team is in its own education and training of key participants in employment-intensive construction and related aspects discussed below in this section.

7.3.1 The Supply Chain model

Cain, quoting the UK *Accelerating Change* report, proposes for a new framework for the construction industry that can be reinterpreted in the context of rural Southern Africa:

> Clients need a construction industry that is efficient. An industry that works in a 'joined up' manner, where integrated teams move from project to project, learning as they go, driving out waste and embracing a culture of continuous improvement. (Cain 2004a:135)

He shows how "… at least 30% of the capital cost of (a construction project in the UK) is consumed by unnecessary costs," (Cain 2004a:16). In South Africa, this figure would be significantly higher as indicated by Doku's (2007) observations,

with double handling and waste of materials being greater than in the UK. More importantly, the low level of artisan skills, lack of basic site management, inadequate co-ordination of activities and shortage of suitable equipment all contribute to massive inefficiency. In the context of the present study, efficiency is central to the establishment of a credible employment-intensive approach as contrasted with poverty relief programmes where the mere transfer of cash to the needy is the primary objective, while the job has only a secondary purpose of conferring dignity on the recipient.

The rationale for adopting a variant of the Supply Chain model here is that it creates value for money for the client while developing local construction skills and capacity through the medium of a small number of public buildings. It is argued here that the problems associated with small contractors, manufacturers and materials suppliers can be mitigated through more direct involvement from government and through the local networks sharing risk, customers and capital expenses. For example, while it would be difficult for an individual to raise capital for a truck and a computer to access a greater geographical market, a group of networked small businesses would be able to share these resources. This has the advantages over a community based model, namely greater flexibility and directly rewarding personal initiative and commitment.

The key features of the Supply Chain model are customer focus and continuous improvement, both of which are discussed below in the context of rural development.

- **Customer focus**

In the formulation of objectives with the client, both the commissioning body and the end users are considered. For an education department this would include meeting cost-per-learner and space norms, clear objectives on the relationship between capital outlay and maintenance costs, and aspects that lead to meeting educational strategies and objectives. In relation to the end users - educators, learners and school governing bodies - comfort levels, accessibility and

circulation, spatial attributes, amenities and running costs are considered. An important break with conventional practice is that the client does not pre-empt the design or specification but leaves this to the Supply Chain team so that they can optimize the design within the target cost. This reflects the more product orientated approach found in successful industries outside construction that have been the exemplars for this system.

- **Continuous improvement**

Integral with the Supply Chain approach is a striving for labour efficiency and elimination of materials waste. This is achieved through close collaboration of network partners, in contrast to the competitive and adversarial tendering and subcontracting systems that prevail in the industry. Participants work together to optimize resources, to streamline activities on the principle of 'right first time' and to share project risk. A constant feedback loop is instituted from the start, with all partners collaborating to meet targets and to bring about improvements. The project is not seen in isolation, and experience is fed into subsequent ventures so that the advantages of improvement are part of the business ethos and not seen as benefiting future competitors[87] (McCutcheon et al 2004:5).

Cain (2004a:81-82) cites the EFQM Excellence Model's structured approach to improvement through the nine criteria of: leadership; development of the organization's people; policy and strategy; partnerships and resources; processes; people results; customer results; society results; and key performance results. These are discussed in more detail below.

- **Leadership**

In the Supply Chain model, leadership of the team is conferred on the party most able to take this role, but this is generally assumed to be the equivalent of the main or management contractor. The professionals and specialist suppliers answer to the team leader, another break from the traditional procurement route

[87] The ILO (2000) identify this negative effect of competition in the building industry with reference to the unwillingness of contractors to sponsor training for their workforce, as the informalization and mobility of workers leads to the perception that the cost of training plays into the hands of competitors. This view is extrapolated here to other strategic improvements.

where the professional team is usually appointed directly by the client in a privileged relationship. In the scenario proposed here, the Department of Public Works takes on the leadership role for the initial catalyst building as the partner that is best capable of taking risk and of setting up relationships in areas where construction capacity is under developed. It is envisaged that the Supply Chain network is sufficiently robust by the end of this initial project in any one area that a local partner can take over the role of lead supplier for subsequent projects, with the Department playing an advisory and monitoring role.

In order for the Department's role as leader to have credibility, the initial process of internal education must be ensured. In Cain's words:

> The leadership role … must be earned by demonstrating to the other supply-side firms a deep and comprehensive understanding of what needs to be improved across the entire design and construction process, why it needs to be improved, who needs to be involved in the improvement process, how the improved performance can be sustained and delivered for all end-user customers, what the end result of the improvement process needs to deliver in terms of end-user aspirations, and how the improved performance will be measured. (Cain 2004a:163)

Only a government department would have the capacity to reverse the traditional hierarchy of the construction process in which professionals have the powerful position of dictating quality levels to the construction team, while distancing themselves from the method of construction.[88] Thus, the Department becomes facilitator in reuniting the aspects of design and delivery as a means of driving out waste and ensuring the achievement of the client's objectives.

- **People development and results**

In the context of employment-intensive construction, technical and managerial skills are the most direct areas in which human development needs to take place.

[88] For a critique on the role of professionals and the potential for governments in the developing world to reverse the harmful effects of this dislocation in construction, see Wells (1986:68) as discussed in the Literature Review above.

This is in contrast to most poverty relief programmes that provide jobs, where the product of this work is secondary and training is usually superficial, only as required to perform the job at hand. Where the product is the primary objective, and the creation of jobs through employment-intensive construction is the *mode* of production, skills take on a central role (McCutcheon and Fitchett 2005a). Important to the Supply Chain philosophy is that this is seen as a two way process where the organization or network measures its own achievements in human development.

Therefore, in the present scenario, training is a central, integrated and ongoing part of the process. The first task required in this respect is a general survey of skills and interest in the programme within the locality of the project. This should be carried out by the Local Authority with the Department of Public Works as technical advisor, and should lead to a local skills plan that extends beyond the immediate construction programme. The South African National Qualifications Framework provides the means by which acquisition of skills and knowledge in the workplace can be assessed and integrated with formal education. This is especially important in areas where many have had to cut their schooling short because of political, social or economic reasons, leaving them with low employment opportunities. These people should be guided through the process known as Recognition of Prior Learning, leading to formal accreditation of their present skills and knowledge gained through institutionalized and experiential means. This gives the starting point for mapping individual Career Paths, which can then be related to the local skills plan and immediate project needs. People with higher level skills and construction experience should be the focus of a twofold process of training and project development as network partners to bring local knowledge to the planning phase of the project. In the development of the proposed model at local level, existing skills are institutionalized and enhanced, in contrast with projects in which inferior local skills are either accepted, or local labour is marginalized.

A significant part of the transfer of formal skills and knowledge from Public Works employees, professionals and more experienced locals would take place through this integration of training and networking, while the more formally trained participants will gain insight into local conditions and traditional knowledge. At the same time, critical team building takes place.

Successful employment-intensive civil engineering programmes have shown the critical importance of the hands-on site supervisor, the individual who translates the project plan into reality through working alongside the ordinary labourers all day, and making the day-to-day decisions and evaluations that lead to efficient construction. Their training prior to project inception is essential, and projects that have tried to conflate training with construction have failed.[89] It is also critical to ensure that there are sufficient trainers at all times, and that the expansion of the programme happens only at the rate that there are suitably qualified and experienced trainers to lead the process (McCutcheon and Marshall1998:21).

The initial phase of the South African Expanded Public Works Programme provides a valuable model for training. Professionals and public officials were trained in employment-intensive construction initially, to allow them to plan the programme. Legislation ensured that only people who had been through this formal training could carry out the work of the EPWP. Thereafter, training rippled down to supervisor level, and only the casual labour was intended to be given training entirely on the job. This system has not always been applied meticulously, especially at the level of supervisor, which has been a concern of many of the programme participants at all levels.

- **Policy and strategy**

Fundamental to Supply Chain strategy is the concept of Guaranteed Maximum Price, the total capital cost of the project within which the Supply Chain network

[89] Elsewhere (McCutcheon and Fitchett 2005a) we have argued the importance of alternating one week of on-site application with one week in the classroom for the first 18 months of the Hands-on Site Supervisor's training. This should be contrasted with attempts to train "on the job", where the demands of programme and productivity prevail over the demands of the training programme.

operates to achieve the project objectives. This price is determined by an integrated team of professionals, contractors and suppliers, and stands in diametric contrast to the traditional separation of design and implementation, with the tendering process as the interface between the two. For decades, this tendering system has been upheld on the argument of best value for money and market orientated pricing because of the element of competition. However, critics in both the highly industrialized and the developing world have shown the flaws in this approach, criticism that extends to fundamental problems characterizing the building industry as a whole.

Attachment to the traditional tendering system has been particularly prevalent in the public sector on the grounds of public accountability and accessibility through open (advertised) tenders. However, when the output of the construction industry is compared with other sectors, the exorbitant waste negates both of these arguments. It is therefore not surprising that Supply Chain Management in the UK was spearheaded by government in its own projects to set an example for the industry as a whole. Vrijhoef and Koskela (1999:135) define the change in strategic approach as follows: “SCM looks across the entire supply chain, rather than just the next entity or level, and aims to increase transparency and alignment of the supply chain’s coordination and configuration, *regardless of functional or corporate boundaries*,” (emphasis added).

In relation to rural communities in the developing world, there are basic elements of Supply Chain management that have a bearing on strengthening small businesses. These include:

- Network based inventories with a “distribution centre” orientation, cost efficiencies, and sharing of risk;
- Focus on communications, sharing information, co-ordination and joint planning;
- Long term focus on risks, rewards, sharing of information and human development;

- Small network orientated supplier base with profit sharing rather than competitive pricing.

This last point is central to the policy and strategy of this model, in that where one is looking at a current 30% waste in the industry, the ostensible savings achieved via competitive tendering are trivial. By contrast, the Supply Chain management emphasis on integration and process, on communication and shared resources, offers a more solid basis for small entrepreneur and contractor development.

The client benefits in two ways, firstly through the focus on value for money and secondly through an emphasis on cost-in-use and not just the capital outlay.[90] By contrast, the conventional tendering system breeds waste through the lack of integration of design and construction, leading to wasted materials and inefficient use of labour. An adversarial contractual environment is set up from the start, often leading to claims, litigation, passing off responsibility and lack of collaborative feedback. Finally, contractual responsibility effectively stops at the end of the construction period.[91] In this system, the client pays several times over, and generally with little or no benefit to the other participants.

- **Partnerships and resources**

The principal strategy of the Supply Chain model is that of linking up all the business elements in the construction process so that each decision and action contributed positively towards meeting the client's objectives. It is through this that the most cost effective design can be forged, especially with regard to its implementation by eliminating wasted resources. If this model is related to the developing world, as analysed by Wells (1986) and Stewart (1977), its value lies moreover in the optimal use of scarce managerial and technical skills. The conventional separation of design and construct is exacerbated in the developing

[90] This is built in to the objectives at the outset of the project, and in the UK model, the team only receives final payment once the cost-in-use has been independently verified, often a year or more after completion (Cain 2004a).

[91] While most of the standard building contracts have defects liability clauses, these are generally difficult to enforce and are invoked only where the defect has substantial cost implications.

world, and in the worst case with respect to employment creation, can lead to industrialized building systems being used.

In the present model, the Department of Public Works plays a dual role in the ‘seed’ building project in any area. On the one hand, it is the lead contractor to this initial building, providing the interface between the client department and all the construction industry personnel. Through this building, exemplary management, design, and technical processes are developed and entrenched in all the other members of the Supply Chain to achieve a successful project. The other role is more subtle – that of mentor in handing over the position of lead supplier to another network participant for future work.

An important element of the proposed model relates to local resources, especially where stabilized earth and rubble masonry are used. The significance of soils testing must be impressed on all participants, as a factor that influences the structural design, component manufacture and method of construction. This can become the focus of skills transfer, while ensuring that local materials, suppliers and manufacturers continue to develop their network in future ventures. In this way, some of the negative perceptions of mentorship can be eliminated, with the representatives of the Public Works Department seen as providing technical and managerial expertise that has self evident benefit to the new lead supplier and the rest of the network.

Moreover, if the delivery of other public buildings in an area is programmed to give continuity of work to these fledgling networks, the Public Works Department continues to have a role in interfacing with new client departments: Health for clinics and small hospitals; Social Development for foster homes; Safety and Security for police stations. As team leaders they have the role of forming the rest of the team, establishing client requirements, setting quality standards and the means by which they will be measured and controlled, evaluating technical

and managerial capacity and formulating additional components of the training programme.

- **Processes**

In section 7.2.3 above, we have discussed the application of formal Project Management processes to rural development programmes. Of critical importance in the research and pilot phases is the use of work and method studies to ensure equitable wage rates, as well as contributing to effective planning and scheduling. These elements form the basis for the Monitoring and Evaluation process, the key to continuous improvement within each building project, and of the larger programme.

An important theme in the UK initiative is that quality comes from within the supply chain, and not imposed from outside as characterizes current conventional practice. The lead contractor, working closely with the professionals, is simultaneously the entity with the greatest leverage and is minutely involved in the production. It should be reiterated that a significant contributor to labour inefficiency and materials wastage is the lack of integration between decision-making (design) and implementation (construction) through: non-standard sizes; awkward processes and sequencing; difficult junctions; and detailing that compromises activity sequencing.

- **Customer results**

In the conventional procurement of public buildings, both the designers and contractors look to the commissioning body as their ‘client’, since this entity is the formal party to the contracts, adjudicating scope and quality as the basis on which the other participants are paid. In the new UK model, this scenario is shifted to focus on establishing and satisfying the needs of the end users. The importance of this to decentralized rural schools lies in the responsibility for day-to-day maintenance and running costs lying with the schools’ governing bodies and not the Department of Education. This indicates that any prototype should be sufficiently flexible to accommodate local needs and skills to ensure the community’s capacity to perform minor repairs and routine maintenance.

The global concern for energy efficient buildings is closely linked to the ability of rural communities to afford service costs and routine maintenance of their public facilities. Throughout the present research, the embodied energy in the construction of public buildings has focused on human labour rather than other energy sources. This theme should be extended into the rest of the planned life of the building, where solar, biogas, wind and other ‘green’ energy sources should be investigated to reduce both the actual running costs, and the eco-footprint of each building.

Fathy has shown the importance of weighing initial building costs with the cost of long-term maintenance. At New Gourna in the 1950s, the equation was in favour of low initial cost and high maintenance, as there was little initial funding relative to the community’s needs and the low levels of employment suggested that there would always be people who could devote time to routine repairs. This was particularly appropriate where the components that would require the most attention were the earth vaults that would not need externally sourced materials for their upkeep. However, the balancing of initial and long term costs should be considered from the outset, both at the programme level, and as applied to individual locations. Here the innovation in materials technology can lead to solutions that achieve both of these goals more effectively than in the past.

The overriding factor to be considered in a lifecycle cost analysis relates to the expected duration of the building’s use. Flexibility and the ability of the building to be modified over time can prolong its useful life, whether through adapting to changing needs of the original users, or for entirely new purposes. This also has to be weighed against initial construction cost, maintenance and servicing, as this generally speaks of loose-fit spaces somewhat larger than the immediate requirements. In the prototype generated for this study, however, this objective is addressed through modular design, where the separation of structure from the enclosing walls allows for the latter to be modified, repositioned or removed as circumstances dictate.

- **Society results**

This broad area of consideration in Supply Chain management, in contrast with conventional practice, sees the objectives of the building project extending far beyond the expressed needs of the commissioning body and end users. In the present context, these issues include the social cost of unemployment, variously associated with crime, domestic violence, psychological malaise and physical health problems. One of the expressed aims of the present research is the strengthening of decentralized communities through establishing viable businesses, with public building works acting as the seed.

Vocational training is central to this process, as well as having value in generating self-sufficiency in key skills, of particular importance to the rural areas of Southern Africa that suffered under the apartheid homeland policy. The creation of long term job prospects is one element in reversing the trend of migrancy into urban centres, with its negative consequences on family life.

- **Key performance results**

Elsewhere we have examined the role of Monitoring and Evaluation, with the necessity for clear and measurable deliverables from the outset of the programme. Only through accurate measurement and effective reporting can the objective of continuous improvement be met. In UK, the inefficient utilization of labour is attributed to "…reworking, lack of adequate pre-planning, delays with the previous trades, access problems, errors in the drawings, faulty materials, insufficient or inappropriate labour, untidy or cluttered working spaces, delays in the delivery of materials, or changes to the brief," (Cain 2004a: 17). Clearly, in highly industrialized countries such as the UK, most of the unnecessary costs identified in the 1994 Latham Report are either directly attributable to poor management, or emanate from workers no longer taking on the responsibilities previously expected of the artisan.

These problems are exacerbated in developing countries where both the technical and the managerial skills are far lower – drawings are misread, setting

out and other measurement is inaccurate, poor workmanship leads to high levels of reworking, and following trades or activities are compromised by inaccuracy of the preceding ones (Doku 2007).

The key outcome of the programme, as distinct from the successful delivery of individual buildings, is the establishment of viable networks in the construction sector, capable of carrying out efficient and cost effective work without government or other external support. When this is achieved, the role of government shifts to smoothing out volatility of demand in the industry. Repeat government work and maintenance are ongoing initiatives that can provide a steady supply of work, while ensuring that quality is upheld and ongoing training is supported.

7.3.2 Evaluation of Resources

One of the fundamental principles that emerges from this research is that, as far as feasible, material and human resources should be drawn from local communities in which the building projects are implemented. Following from this, in rural areas it is imperative that construction related processes do not have a negative effect on the environment, especially where this compromises agricultural activities. For example, where organic materials such as timber and thatching grasses are contemplated, this should be researched in terms of renewing the resource, its demand for land and water, and priced for as an overhead of the project. The EU/GoM project gives insight in this regard, where the programme was devised as an integrated approach to employment, construction and sustainable land and water use. As with structural systems described above, traditional uses of organic products to improve performance such as plant juices for waterproofing and fibres to reduce shrinkage and improve tensile properties of clay, can provide clues that can be the subject of technological development to improve effectiveness and develop new equivalents.

Potential quarry sites should likewise be evaluated for their environmental impact, along with the technical characteristics of the soil and stone. Rehabilitation of quarry sites should also be factored into the project overheads, whether included in the project close-out phase or as compensation to the community if the quarry is still active on project completion.

The recycling of waste products, both domestic and industrial, is receiving considerable attention in the global community. Construction, as one of the major contributors to global warming and other aspects of environmental degradation, should take a positive stand, especially in projects commissioned by government. Clark (1992) has shown how domestic waste[92] was the catalyst for the development of the West End of London in the eighteenth century. The Pines Calyx Environmental Centre in Devon, UK, is an exemplary recent example of imaginative recycling where most of the bricks were made from recycled ones within an eight mile radius of the site to reduce fuel for transport. Industrial and mining operations in South Africa generate mountains of waste gypsum and fly-ash, both of which have been shown to be effective stabilizers for compressed earth blocks, replacing cement.[93]

The seminal ILO study on the substitution of labour for machinery (IBRD 1986) tabulates productivity rates for several manual methods of transporting bulk materials, including barrows and baskets. These have obvious merit within the building site, but greater distances need alternatives, as shown creatively in the Botswana Rural Roads Programme with the design for donkey carts. This allowed for a service industry to emerge for people who did not have the financial resources to enter the conventional transport and supply market. Moreover, as fuel prices rise, these kinds of inventions will become increasingly significant.

---

[92] This was predominantly ash from household fires, mixed with the local clay to create a better quality of brick. The remainder of the waste was used to build back the road levels after the clay had been quarried from the sites (Clark 1992).

[93] Raw gypsum needs to be heated to 110º to produce plaster, whereas cement needs processing at 1600º. Experiments into small scale cement production in India have been moderately successful, but its considerable use of energy will become increasingly difficult to justify in the context of global warming and scarce energy resources.

7.3.3 Materials and component manufacture

In a linked up system, quarrying, manufacture of basic elements and component assembly are an integral part of the design and detailing process. Ideally, the creation of the materials for construction should take place close to the building site, thereby minimizing transport and double handling. Where stabilized earth blocks and tiles are used, the versatility of soil type generally allows this in rural areas. When a hand press is used, manufacture can happen on or adjacent to the site, with the leveled area for the block yard being used as a courtyard or playing field on completion of the project.

Each building design should consider the process of construction in a two-way mediation between manufacture and assembly. In an employment-intensive scenario it is far easier to fabricate short runs of customized elements that can then reduce material wastage and unnecessary labour in cutting. At the same time, dimensions should derive from the elements and components, an obvious technique that is largely ignored in current practice.

One of the problems of establishing a small business in rural areas is the small quantity of demand. To overcome this, designers can look at specifying several products that use the same process and equipment rather than choosing a wide range of materials from different sources. For example, a hand block press can be modified to make floor and roofing tiles, coping pieces and window sills simply by inserting spacers in the press and adjusting the mix for different performance specifications.

7.3.4 Design and specification

Above, we have argued for the development of prototype designs to allow for thorough research to be carried out without compromising the budget and time constraints of each individual building. This research is indispensable where traditional methods are enhanced through modern technological advances, or where new techniques and materials are investigated. Only though this process

can the full employment potential of construction be achieved while ensuring efficiency and competitiveness with other methods of production. These prototypes then form the basis for refinement in the individual physical and social context once the studies into resources have been carried out and the implementation team formed. Thus there are two stages to design in the programme approach proposed here.

Architectural design, by its nature, offers a wide spectrum of choice in materials, detailing, structural systems and spatial arrangements. It is important to stress that employment-intensive methods neither preclude nor presuppose any particular style or other architectural consequence, nor does adhering to an image assure greater job creation: each set of decisions must be driven by the project and programme objectives.[94] Likewise, management and training should become drivers of the design process, and not just viewed as facilitators in the construction phases.

There have been several types of approach to employment creation, especially in the context of low skills levels. At the one end of the scale, highly industrialised components that are simply clipped together on site are promoted as creating jobs because of the very low level of skill demanded on site. This needs to be evaluated in relation to the skills and resources needed for manufacture and transport, the low portability of any skills that might be gained in the process of construction, and the limitations imposed for future adaptation of the structure. While these methods allow for rapid delivery of buildings of a fairly high quality, this approach is limited in achieving broader objectives or more lasting solutions. This said, there have been valuable examples where industrialized components

[94] The converse of this proposition is often found where second generation followers of a school of thought will imitate the forms that emanated from research without a clear understanding of the underlying principles. This is evident in the ‘appropriate/intermediate technology’ group, as well as those purporting to produce ‘green architecture’.

have allowed for dimensional accuracy and structural safety, thereby facilitating the achievement of the broader objectives at lower levels of risk.[95]

More successful in generating employment throughout the whole construction process is the approach of the Intermediate Technology group and others following similar principles. By returning to traditional design, construction methods and materials, insights are provided into climatically suitable choices, existing skills can be enhanced and the design is more likely to be culturally acceptable. Here examples abound throughout the developing world, as has been indicated in the Literature Review in Chapter 3. The two principal approaches in this respect have been driven by earth construction in dry climates, and bamboo in the Far East. Timber building has been promoted by Segal (http://www.segalselfbuild.co.uk/) and others, but has not been extensively used in the developing world, even where timber is plentiful, because of its high value as an export material and for higher value products such as furniture and tourist goods.

A number of principles can be extracted from these examples for designers in other parts of the world, such as:

- Simplification of manufacturing and construction process;
- Quality control through the design of components; and
- Focus on a smaller spectrum of materials to facilitate the achievement of higher skills within one trade.

From these broad principles, the designer of prototypes needs to explore each element and system in the building in terms of the following opportunities to increase the amount of employment:

1. substitution of labour in machine intensive trades/activities;

[95] In Alexandra, north of Johannesburg, prefabricated lightweight concrete panels were used for upper floors in the Far East Bank housing project that was built by small emerging contractors who did not have skills for *in situ* reinforced concrete, and a structural steel frame was used at the Mandela's Yard Heritage Centre to allow for stabilized earth block infill panels in a multi-storey building.

2. substitution of labour in conventional trades and activities that have a low labour content;

3. look at traditional methods, especially when they parallel sophisticated ones, eg the Zulu beehive dome uses a mesh framework that uses principles similar to that of Shigeru Ban in Japan, using state-of-the-art engineering (Fig 7-2 and Fig 7-3);

4. look at new uses of existing materials;

5. look at new materials and methods;

6. completely 're-engineer' the design, construction and commissioning process through a rigorous investigation into materials, methods and management.

This last stage will, in principle, be the most effective in generating productive and lasting employment, but is feasible only where there is commitment to a long term programme approach. Within the process of re-engineering, all the other methods of labour substitution and new technologies are investigated and integrated.



Fig 7-2: Japan Pavilion, Expo 2000, Hanover (http://www.shigerubanarchitects.com/)



Fig 7-3: Zulu beehive dwelling (Coetzee 1982:27)

The following principles should guide the research and decision making to ensure that, in changing over to employment-intensive methods, the results can compete with other more machine intensive methods, thereby ensuring credibility of this re-engineering process:

a) Buildability for high productivity

Processes and detailing should be developed with the designers and builders in close collaboration. In general, this should lead to simplification of the method of production, although the overall design may be complex.

One of the main contributors to material waste in the construction industry is the specification of non-standard sizes. This is especially critical in the present scenario where materials are brought in from the main centres. Detailing should integrate components with different modular dimensions to prevent waste of labour.

b) Technical appropriateness in structure, services and materials

Skills evaluation before building work is started will help to satisfy this requirement, but in the planning of the skills programme, there should be a reasonable evaluation of the level of skills remaining in the community on completion to ensure that maintenance and additions can be carried out within the capacity of those staying in the area.

c) Social appropriateness and acceptability

Field workers have frequently noted the failure of new projects through users rejecting unfamiliar materials and technologies. This is especially so with housing, where householders' perceptions range from a sense that they are being given inferior buildings, to a real perception of higher risk through innovation.

This is one of the main reasons that the present thesis proposes the introduction of novel methods and materials by the public sector, showing government's commitment to the systems as well as providing built examples that can be viewed and understood before being adopted for domestic and commercial use.

d) Appreciation of existing and target skills

In the prototypes presented here, the sequence of construction is planned to allow trainees to progress from fairly low skills levels to more refined. In each area, the prototypes should be evaluated to accommodate local skills, which may require adjustment to the design and detailing.[96]

7.4 SITE IMPLEMENTATION

In rural areas, special consideration needs to be given to the management of individual sites so that, on the one hand, the objectives of the programme are fully met, while not allocating high level personnel for excessive time to decentralized sites. This has two negative consequences – that scarce skills are devolved to low levels that compromise the expansion of the programme; and that the cost of this involvement places an unnecessary burden on the projects. In employment-intensive programmes throughout the developing world, the ratio of costs allocated to professionals and higher management is a drain on resources, and ethically questionable when compared with the wages of ordinary labour. The following pointers can assist in keeping the greatest proportion of project cost with the decentralized communities without compromising timeframes or quality.

7.4.1 Design as process

The relationship between prototype design and its adaptation for each individual project within the programme has been discussed above. During the construction phase, this process should continue, with site operatives giving feedback to improve buildability, reduce waste and improve labour efficiency. This feedback aids the designer in refining the prototype, gives insight for future projects and contributes to the enhancement of the training programme. Site operatives, especially the site supervisor, should be encouraged to solve day-to-day problems on site and contribute to the solution of the bigger ones in conjunction

[96] At the Mapungubwe Visitors Centre, workers were trained in vault building with the office wing which could be plastered if the tiles were not laid evenly enough to be left fair-faced, as planned for the public areas.

with higher level participants. This is in contrast with conventional practice, where implementation problems are entirely the concern of the construction team that conversely has no say in any design changes. The integration of professional and construction personnel that characterizes the inception stage of each project needs to continue to completion, with professionals and managers serving a number of proximate sites.

7.4.2 Integration of manufacture and construction

In the development of each project plan, manufacture and construction should be structured in a seamless system. This is particularly important where manufacture takes place on site, requiring the co-ordination of the spatial arrangement, rate of output and possibly the scheduling of low skilled labour. Off-site manufacture by small emerging suppliers may need special assistance to ensure timeous delivery and accuracy in quantities. Quality control in the manufacturing process should be integrated with construction, with the site supervisor playing the key role.

7.4.3 Site management for efficiency and productivity

Materials efficiency and labour effectiveness are the principle concerns, for example labour efficiency is vastly enhanced through good site layout to avoid double handling of materials, facilitating shared equipment, and to avoid paths of labourers crossing. Exact estimating of materials also plays a role when they are moved to the point of assembly, especially where scaffolding is used.[97]

7.4.4 The site supervisor

Elsewhere (McCutcheon and Fitchett 2005a) we have discussed the critical role of the Hands-on Site Supervisor in the context of employment-intensive civil engineering programmes. The role of the site supervisor in a building project is more complex, as far more activities of greater complexity are needed. Traditionally a site foreman was drawn from the ranks of artisan masons or

[97] Doku (2006) provides evidence of the waste of labour when too much material is loaded onto scaffolding, necessitating its removal before the scaffold can be raised.

carpenters because of their knowledge of geometry. Their site experience gave them the insight into the other trades. In the present scenario, the shortage of skilled and experienced artisans indicates that a more structured approach to the training of supervisors is needed to give them the expertise to manage a site with low levels of intervention from higher management. In a programme of the scale envisaged here, the programme would be able to generate its supervisors from within, after a period of five years. In the early years a higher level of involvement from professionals and civil servants should be expected, but always with the objective of skills transfer to enable the supervisor to act independently wherever possible.

7.4.5 Quality management

This should be seen as a task of every participant in the programme, right down to the casual labourer. The key to successful quality management on site is the site supervisor: only through this person is there a guarantee that even the concealed parts of the building have been adequately constructed. The supervisor should monitor all materials and components manufactured on or off site before they are included in the works. All quality related information should be captured in *pro forma* data storage systems that aggregate and filter the information to the higher levels of the programme quality management system. In this way, detailed queries can be traced, yet only the significant information for overall project performance is routinely fed to higher levels, thereby preventing information overload.

In keeping with best practice, each activity[98] that deviated significantly from its cost or duration estimate would be reported to the next level of management, to enhance planning of future projects. The conventional practice of absorbing these variations in subsequent items can be condoned to keep the overall project on track, but management should be aware of whether the causes are through

[98] This would be the equivalent of a Bill of Quantities item, but in the present scenario it would be a Work Package for which there would be a scope description, duration estimate and cost as a component of the project plan.

site specific conditions or of a more general nature. This leads to improved methods that reduce the time requirements or replacing faulty tools that result in excessive down-time.

7.5 CLOSE-OUT OF EACH BUILDING CONTRACT

One of the primary objectives of the building projects that form the programme discussed here is to create a well functioning construction industry in rural areas. For this reason, each individual project should be seen primarily as a catalyst in promoting good technical and managerial practice, climatically appropriate buildings and an ethos of lifelong learning and improvement. For these reasons, the close-out phase of each of the building projects could be seen as the most significant part of the programme at the local level, in that here the framework for long term capacity is established.

Throughout the implementation, Supply Chain networks are formed and refined, but in the final phase there should be evaluation of whether these can act independently of government implementing agents for future projects. Both the human and physical resources need to be assessed and further training, micro-credit and other forms of support instituted.

Several of the participants may need additional training for diversification of building components that were not required in the catalyst building, including associated specification and detailing. Others might be trained in activities that are extensions from those learned in construction, for example the manufacture of household goods and items for the tourist trade. Similarly, those involved in managerial and supervisory tasks could engage in other forms of business training. Advice on future training and career development should be carried out by the project team in conjunction with the Local Authority to assist in filling out its local skills plan (see 7.2.2 above).

In civil engineering programmes, the importance of routine maintenance of the

created infrastructure has been recognized and ideally budgeted into the capital expenditure. People who have been involved in the initial construction will be far better equipped to perform the maintenance function, and would require relatively little post-construction training. In both Kenya and Botswana, the “lengthman” system has been effective. One person or household is responsible for the routine maintenance of a length of road, for which they receive a regular wage (McCutcheon and Marshall 1996).

At the highest level of management, a rigorous post-construction evaluation should be undertaken for each and every building in the programme. This audit should be carried out by an independent body with feedback to the implementing team who should carry out a self-evaluation as a means of enhancing the performance of their fledgling network. Both of these evaluations need to be fed into the central Monitoring and Evaluation system with recommendations on design, construction and training for future projects.

7.6 GEOGRAPHICAL EXPANSION

A central proposition of the model proposed here is that, for employment creation strategies to have a real impact on impoverished rural communities, training and nurturing of small enterprises should be aimed at increasing local self-sufficiency. This extends beyond those directly involved in the construction process and needs to include capacity building both in local government and the private sector enterprises. For Local Authorities to be effective clients to the construction sector, the principal decision makers in these decentralized institutions need orientation in skills programmes and employment-intensive construction. The validity of this has been demonstrated in civil engineering works through the South African Expanded Public Works Programme and the numerous programmes throughout sub-Saharan Africa that provided the precedents for it. One of the pillars of the EPWP has been that the programme is driven predominantly at Municipal level, but its cost benefits can only be accessed by

those bodies that have proven capacity for undertaking employment-intensive works.[99]

There is the temptation, when the initial phases of a programme are running successfully, for politicians to exert pressure for rapid expansion over a wide geographic area. This is often prompted at local level where communities anticipate a speedy response to the backlogs in infrastructure provision. Technical and medium level managerial training require at least two years for each individual, and need a lead time to prepare the trainers. Often the trainers will be selected from the ranks of those trained within the programme, lengthening this process even more. McCutcheon has reiterated that a programme should expand only at the rate that these trained personnel are available. This should be seen particularly in relation to the degree of sophistication and innovation needed for employment-intensive work, often overlooked by politicians when it is expedient to push the programme's rate of delivery. It is particularly critical where the principal mode of production is human labour: exemplary management is essential to ensure "that something sensible is taking place on site – all day and every day" (McCutcheon and Fitchett 2005a).

The building type developed in the present research is specifically designed for hot and relatively dry climates, with seasonal rainfall generally characterized by thunderstorms. For this reason, it uses materials with high U-values, ventilation and recessed windows. The use of outdoor space is developed out of cultural practices in the regions studied. When the programme moves out of these climatic and socio-cultural regions, the type needs to be reconsidered, with provision made for research and development of new materials and building prototypes. Linked to this process is the need for new work and method studies,

[99] This capacity resides with individuals who have undergone training in labour-intensive construction. For a Municipality or Provincial Department to be eligible for the concessions in terms of the Division of Revenue Act, they need to ensure that they have the full complement of trained personnel for the duration of any EPWP work, failing which, the cost of the work has to be absorbed into the institution's main budget, and not from the designated Infrastructure Grant (http://www.epwp.gov.za/).

essential before production begins on site. This indicates the necessity for full-scale pilot structures whenever significant changes are contemplated through regional variations, for example where different materials are more suitable or are abundantly available, as in areas where high volumes of fly-ash or gypsum are generated as waste from mining.

Increasingly there will be greater emphasis on renewable materials, but where these are promoted in public works, government needs to set the example in ensuring that this is in line with other strategic needs[100], and that the planning and implementation for their replenishment is in place. This is particularly challenging in relation to water and land needs, which should be factored into any planning that proposes extensive use of organic materials.

7.7 EXPANSION TO OTHER BUILDING TYPES

The model developed in the present study would be suitable for a range of other small public building types – libraries, clinics, police stations, post offices and multipurpose municipal service centres. The value of this lies in creating follow-on projects for people trained in an area, as well as the networks of small enterprises formed in the schools programme. This can be used as a mechanism to continue the local skills initiative, and to serve as a direct method of monitoring the continuous improvement objective adopted from Supply Chain Management.

Here, the importance of orientation for a new line department is highlighted, with the entire process presented from section 7.2.3 onwards being undertaken anew, instead of attempting to make minor design, specification and layout adaptations to a type that may have become well entrenched at the higher levels of the programme.

[100] In Britain and parts of Europe in the Middle Ages, extensive areas of forest were cleared for ship building, and innovation was required in building as the strategically less important sector, giving rise to Hammerbeam trusses and Stave Churches, both of which used small and often misshapen pieces of timber.

7.8 DECISION TREE FOR EMPLOYMENT-INTENSIVE CONSTRUCTION

The ideal scenario proposed here is that a government department is committed to a programme of building in which employment-intensive construction is an integral objective. In this situation, the evidence suggests that, if all the steps described above are followed, a high ratio of employment can be generated in the programme, it would have good prospects for a healthy decentralised network of construction businesses on completion of each project in any area. This said, the employment content of individual projects can be improved by following some of the guidelines presented below.

In order to maximise the labour content of a project or programme, it is essential for decision makers to develop a set of performance criteria rather that attempting to make minor modifications to a conventionally framed brief or an existing prototype. In this regard, line function departments that are in the process of reviewing their existing prototypes would be the most amenable to the processes described here. The South African Department of Education is being forced to reconsider its approach to school buildings in the light of a new educational system; the Department of Social Welfare is looking at de-institutionalised residential units for orphanages; and one can imagine this extending to other organs of government as democratic processes are reflected in their building stock. By evaluating the needs of the building users, outdated and inappropriate standards can be reviewed to open op the spectrum of materials and methods with higher labour content.

In revisiting the four stages of labour-intensity developed in civil engineering works, a model for decision making can be formulated that acknowledges the overheads, time and effort required at each stage, and conversely the proportionately higher labour ratios that can be expected.

7.8.1 Reverse Substitution

In Chapter 5, the change in labour content achieved by returning to older methods of construction was shown in the LITE project, where rubble stone foundations were used instead of concrete footings, and timber roof trusses were constructed on site instead of bringing in factory manufactured trusses.
In general small components, local manufacture and assembly, locally sourced raw materials will tend to give a higher labour ratio that will guarantee a small improvement.

Clearly, the greater the number of individual activities that can be made more employment-intensive, the better the overall result will be. However, decision makers should be advised to model the whole construction process, as advances in one activity could result in job losses elsewhere if the detailing requires highly industrialised components to complement traditional activities and yet achieve the same performance. Table 7.1 gives some examples of the first level of substitution in comparison with conventional methods, which could from the basis for an evaluation of different options within the project parameters.

Following the argument presented in Chapter 6, the greatest impact can be expected to derive from activities or trades that constitute a significant proportion of the overall project, as well as having potential for a significant increase in employment whether through reverse substitution or through the other methods described below.

7.8.2 Material Substitution

In Chapter 6, the technical study into thin shell structures demonstrates the advances that can be made in employment-intensity through the use of hand-pressed stabilized earth tiles. Primarily this is compared with profiled metal roof sheeting, but similar results can be expected where stabilized earth tiles replace reinforced concrete shells.[101] The building designer has considerable choice of

[101] The quantity surveyor of the Mapungubwe Visitors Centre modeled a cost comparison

materials for most elements and finishes, each with an implication on the labour content on site and during manufacturing. For example, the same overall performance is achieved using facebrick or plastered stock-brick, concrete block or stabilised earth. These are but a few of the more common options of the more employment favouring materials.

As environmental considerations play a bigger role, two divergent tendencies are becoming apparent. On the one hand, materials with low embodied energy will tend to favour local sourcing and manufacture in small industries, but may produce buildings that do not adapt easily to different uses. The converse trend is towards highly efficient use of industrialised materials, especially steel, with the argument that the building is easy to modify and the elements can be recycled. The study of the Light Weight Steel system in Chapter 5 gives an indication of how local labour is almost entirely eliminated in this type of approach.

Two important points need to be observed when alternative materials are considered:

- To avoid material wastage and labour inefficiency, dimensions need to be adjusted to suit the different sizes of components;
- The buildings should be fairly 'loose fit' so that they can adapt to change in use without substantially needing to modify the basic envelope and services.

7.8.3 Adaptation of Conventional Materials and Methods

Two types of materials adaptation have been discussed in the previous chapters: change in processing; and the use of small quantities of high-value additives. In both instances, the aim is to improve the performance of predominantly locally sourced materials to match conventional equivalents. The former can be seen in the use of hand and hydraulic presses to increase density, consistency and compressive strength of adobe.

---

between earth tiles and reinforced concrete, where the former was slightly cheaper overall and had a far higher labour ratio, predominantly in the unskilled grade.

Several additives to adobe are the subject of ongoing research, for example:

- Cement, gypsum, lime and fly-ash to improve compressive strength and durability;
- Bitumen to increase water resistance;
- Fibre, eg hemp, to provide tensile and shear resistance.

As the analysis of the LITE offices showed, even a small volume of high-value material can have a significantly detrimental effect in the labour ratio of the manufacture of bulk materials. Therefore, it is important to interrogate the standards used in conventional construction to ensure that one is not trying to emulate performance levels that are inappropriate (see Wells 1986).

7.8.4 New Materials

Most of the work in this category has been carried out with the primary objective of environmentally sustainable materials and processing. The two focus areas are: recycling of waste; and the more efficient use of renewable resources. In principle, this research is consistent with the broader objectives of the present study, but further work is needed to assess labour implications with respect to manufacture and construction. To date, the majority of these new materials are essentially substitutes for conventional ones, for example profiled sheeting from recycled plastics, and therefore can be assumed to have similar labour requirements to those that are being replaced.

In the developing world, employment opportunities need to be generated within a broad framework of sustainable practices that are particular to a region. Advances in highly industrialised countries should be the subject of rigorous evaluation in terms of a range of strategic objectives, of which poverty alleviation through employment is critical. This is acknowledged in the Millennium Goals, but is not always fully appreciated by designers and other decision makers.

7.8.5 Re-engineering Design and Construction

Table 7-1 is an example of a method for capturing and comparing different materials and methods. This would summarise the early stages of Cost of

Technique Analysis similar to that used in civil engineering work (see Chapter 4), and should be revisited as more information is generated through work and method studies, material and component research, and pilot projects.

Throughout this chapter, a process that integrates design, construction and management has been postulated. If this is pursued within a programme approach that integrates training and a rigorous quality cycle, employment-intensive construction can be achieved that can compete with conventional construction in terms of cost, time and quality. The fundamental difference lies in where the cost of the buildings is directed – to the large manufacturers in the industrialised centres or the wages and profits of the targeted populations of decentralised communities.

Table 7-1: Evaluation of labour content for different materials and method.

Trade	Method	Labour hours			Labour cost	Material cost	Plant & o/head	BoQ price	Labour ratio	Trade % of total
		sk	S/s	u/s						
Foundations & slab	A. Readymix concrete									
	B. In situ concrete, local aggregates									
	C. Stone foundations, concrete slab									
	D. New specification									
Walling	A. Factory brick, cement plaster									
	B. Local concrete block									
	C. Stabilized earth block									
	D. Alternative technology (eg cob)									
Roofing	A. IBR on steel truss									
	B. IBR on in situ timber truss									
	C. Local tiles on in situ truss									
	D. New approach, eg timbrel vaulting									
Internal finishes	A. Cement plaster, gypsum ceiling									
	B. Limewash, locally made tiles									
	C. Recycled gypsum plaster									
	D. All local materials									
Electrical	A. All industrialised components									
	B. N/A									
	C. Locally made fittings									
	D. Innovative reticulation									
Plumbing	A. PVC piping, imported fittings									
	B. Local earthenware pipework									
	C. Local pipes and fittings									
	D. As above & local solar water heating									
Doors & windows	A. All imported									
	B. Imported materials, local manufacture									
	C. Local & recycled materials									
	D. Innovative design									
External finishes	A. Cement plaster, PVA paint									
	B. Natural pigment, earth plaster									
	C. Recycled gypsum plaster & limewash									
	D. New specification									
Totals	Conventional (A)									
	Stage 1 (B)									
	Stage 2 (C)									
	Stage 3 (D)									

8 CONCLUSIONS AND RECOMMENDATIONS

This thesis is set within the context of high levels of poverty and associated unemployment, specifically in South Africa, but a phenomenon found throughout the developing world. Various approaches to addressing poverty are acknowledged; however these seldom have the advantage of creating high quality products (if any at all) and moreover discount the dignity that productive work confers. There have been many instances where so-called employment-intensive construction programmes have degenerated into mere poverty relief where the output has been of inferior standard, thereby discrediting the programme and, by inference, employment-intensive methods themselves.

This becomes critical in the study area, where apartheid policies have resulted in the poorest citizens suffering a lack of infrastructure, both civil engineering services and basic public buildings such as clinics, police stations and schools. The latter is the specific focus of the present study in that school building offers a range of construction techniques and a scale that is easily transferred to other public buildings, domestic, small industrial and commercial works. This allows the participants of the programmes contemplated here to have skills and capacity that can be marketable on completion of their direct involvement.

A central question posed in this research is: “How employment-intensive is building?” This emanates from the numerous building projects that profess to have job creation as an objective, yet no data is given on how many jobs are generated, how many more are provided than would have been the case using other methods, and other measurable indicators. There has been a distinct tendency over the past decades to a reduction in the direct construction costs allocated to wages: a rule-of-thumb in the 1950s was that 40% to 60% of the direct cost of any activity was attributable to labour. Analyses of a range of case studies in Chapter 5 shows that these figures are significantly lower in conventional construction (the Public Works school prototype) and vastly lower in

highly mechanised construction, where the Lightweight Steel Frame system is used as an example. Only with this type of information can there be meaningful and measurable objectives in respect of job creation through building, a factor well understood in the field of labour-intensive road building since the early 1970s, as is demonstrated in Chapter 4.

In Chapter 2 (section 2.2) a number of questions are framed, which Chapters 6 and 7 go some way towards answering. The dominant parameter is that the greatest possible portion of the project cost in any one location should be retained within that community, in particular via wages to targeted individuals. This is manifested in reducing the value of materials and equipment imported from outside the target area, with the attendant fuel costs. The technical study and managerial framework are grounded in an acknowledgement of the low levels of formal education and marketable construction skills that prevail in the study area. Through the model proposed in this thesis, the intention is to address these challenges as a way of strengthening the construction industry through a process of re-engineering for employment-intensive construction that is competitive with other methods in terms of time, cost and quality. In this way it is not necessary for government to ‘subsidise’ projects through shadow wage calculations: the methods are competitive at the level of financial analysis.

The technical study (Chapter 6) shows the advantages of a complete re-evaluation of a significant component of a prototypical design with the objective of maximising the efficiency of materials, and minimizing equipment and fuel costs in both the manufacture and construction. This is directed at increasing the ratio of direct costs allocated to wages while containing the overall costs. Moreover, it is a demonstration of a construction system that is inherently employment-intensive as well as providing a medium for incremental skills development.

8.1 REVISITING THE RESEARCH QUESTION

At the outset of this research the following question was posed:

> *"What are the parameters within which a significant increase in employment can be generated through the design and construction of small public buildings?"*

Through analysis of individual buildings and examination of the successful implementation of employment-intensive civil engineering programmes, the following factors have been shown to be significant:

1. a programme approach that capitalises on initial overheads;
2. an integrated training programme;
3. choice of materials;
4. location and method of sourcing and manufacturing materials and components;
5. design and detailing that minimise material waste;
6. exemplary management that devolves tasks to the lowest responsible level;
7. an ethos of continual improvement and commitment to quality management.

While the last three points may not appear to contribute to the generation of jobs, elsewhere we have shown their importance for the longer term credibility of an employment-intensive programme, as well as in situations where a programme approach may not be possible, such as a single domestic or commercial project.

The case studies have shown that, even within conventional practice, the employment intensity can vary considerably with different trades, methods of construction and materials. This is even more pronounced where there has been a determined approach to the mode of production, seen in the dramatic contrast between the buildings at New Gourna and the Light Weight Steel Frame system, the former being consciously labour-intensive, while the latter has the reduction of labour as one of its objectives, driven by the shortage of critical skills.

The Light Weight Steel system has significance to the present study in more than merely providing a comparison as a 'worst case scenario'[102], as it is currently being promoted as an alternative to conventional construction of schools, and is therefore a direct competitor to the model proposed here. This highlights the importance of training and management if employment-intensive construction is to be competitive, and thereby justifiable for buildings using public expenditure.

This chapter summarises the findings in relation to each of the parameters that have been revealed as contributing to the employment-intensity of a building programme. Following this, the achievement of the objectives of the research is evaluated, leading to recommendations for future research and implementation of the outcomes of the study.

8.1.1 A Programme Approach

The re-engineering needed for the competitive use of employment-intensive construction has to carry substantial overheads in the initial phases. These expenses include pre-feasibility studies, research into materials, and the development of construction and structural methods that are suited to manual production, yet match other methods in terms of time, cost and quality. This requires modification of conventional management structures and processes that build on the formal sector's Project Management Body of Knowledge. In the model proposed here, personnel from the implementing organ of government would need to engage in additional training in Supply Chain management techniques and the mentorship role that would follow the completion of a school building in any one area.

The importance of training at all levels in the production team and orientation of decision-makers in employment-intensive processes has been stressed. Integral with this training is the application through on-the-job training in a sequence of structured working environments, especially critical for the site supervisor. This

[102] This should be seen in the light of the objective of the present study, that of job creation. In its own terms, this system is one of the most sophisticated of its kind on the market.

aspect is discussed below. The development of training materials and educating the trainers can only occur when the pre-feasibility studies and research are fairly advanced, a factor that adds a substantial lead time to the inception phase. The formulation of skills plans at regional and local levels provides the framework within which the training material would be articulated and therefore must precede the training of the first group of trainers.

While prototypes are accepted as the most equitable framework from which most small public buildings are generated, if a highly employment-intensive system is to be used, these require considerable modification or a completely new approach consistent with the research into materials and systems. This entails verification through pilot studies that also provide the basis on which labour rates are determined. We have shown that this process must be established before the wage rates can be negotiated if the construction phase is to be cost competitive.

In summary, if the objective is to construct buildings that make a significant contribution to job creation, this cannot be achieved through minor modifications to processes, or simple substitution of materials and components that require a higher labour ratio. The considerable costs and time factors in the initial phase of re-engineering need to be amortised through a planned programme that extends over a number of years in which hundreds of buildings are constructed. The experience of the Kenyan Rural Access Roads Programme (see Chapter 4) is testament to this, and can be anticipated to be even more significant in the case of buildings, with their greater complexity and smaller contribution of individual activities to the overall project cost.

8.1.2 An Integrated Training Programme

Training is fundamental to the establishment of employment-intensive construction, and should be seen as an investment in human capital. Only with marketable skills can participants in a programme have a real prospect of continued employment. The credibility of the programme itself depends on the capacity of all participants, but most significantly of the hands-on supervisor who

translates planning and decisions formulated at higher levels to the immediate specifics of the site.

The location of skills development within a regional and local framework can play an important role in strengthening an industry debilitated globally by flexible labour practices and the disintegration of the apprenticeship system. Public Works programmes can provide the initiative for restoring credibility of the industry, with its dual objectives of training and delivery of building stock.

Experience in national programmes of labour-intensive road building in sub-Saharan Africa has shown the advantages of integrating formal classes with on-the-job training in sufficient and continuous projects to consolidate learning so that good practice becomes habitual. In this way, some of the advantages of the apprenticeship system can be captured, while the trainee can be a productive worker for much of the training period, justifying a wage earning post and not just a stipend.[103]

There should always be opportunities to move up within the programme, or to exit with marketable skills. The model proposed here goes a step beyond this in establishing mechanisms to foster small businesses – contractors, specialist subcontractors, component manufacturers and bulk material suppliers. The Supply Chain framework provides the initial structure, while follow-on public works projects in the area are used to monitor and refine management structures, efficiency and productivity in the decentralised network.

8.1.3 Materials and Components

The choice of raw materials should be determined primarily by what is locally abundant (such as soil), from renewable sources or recycled from nearby

[103] To reiterate, in areas of extreme unemployment, most of the participants in an employment creation programme will be supporting several other family members. In some training programmes, the participants are required to eat all meals on the premises to ensure that they have the stamina for a full day's work, and that their food allocation is not shared among other household members.

sources. The location and method of sourcing primary materials can provide the opportunity for high content of low-skilled labour. Proximity to the site not only saves on fuel and other transport costs, but can open up opportunities for small entrepreneurs with manual and animal drawn haulage. This also applies to manufacturing of elements and components, which if close to or on the site can prevent double handling with its waste of labour and loss of materials through damage. If sourcing and/or manufacture take place on the construction site, these areas need to be planned to maximise efficiency.

In general, to improve the employment intensity, small components should be used that need simple tools and equipment for construction. This principle facilitates later additions and alterations to the buildings constructed within the programme, especially if several of the participants choose to remain in the area.

8.1.4 Design and Detailing

At the most basic level, reduction in materials waste through better design will create an improved ratio of labour to materials cost. Secondary benefits of this lie in improved productivity and reduced maintenance through the integrity of components. Where the design uses standard sizes, cutting can be avoided, and where this cannot be achieved, the designer can capitalise on the potential for small runs of special components where manufacturing takes place on or near the site. This has been described in Chapter 6 with regard to making half-blocks with the diesel press, and various tile thicknesses with a hand press. Moreover, with stabilised earth components, these can be cut or modified on the day that they are manufactured (when they are ‘green’) with a minimum of effort.

At the design and management planning stages, there should be a focus on the construction processes so that work on site is streamlined. This helps to avoid frustration, with its negative impact on productivity. The designer should also consider increasing the complexity and quality through each building, as part of training process. Instead of the conventional approach where a single standard of workmanship is expected throughout, the designer can plan out the sequence

of construction so that there is a progression as skills improve. This requires a more integrated relationship between the design team and the construction personnel by considering process and product simultaneously. Standards of workmanship should be developed directly from the needs of the end users rather than falling back on inherited norms.[104]

In the model proposed here, it is important for designers to make efficient use of internal space through reduction of space either used purely for circulation or unnecessary duplication. An element of life-cycle costing is in servicing and staffing, both of which can be made more efficient by better space utilization, with financial benefits to the end users. Greater response to climate can contribute to lowering service costs, particularly lighting and artificial ventilation, and alternative energy sources should be explored. Within the concept of Guaranteed Maximum Price, more efficient design equates to better value for client and end user.

This concept can be extended to greater use of defined outdoor space and partially enclosed areas, often parts of the building that can be built by less skilled people where elements are not structural and where the level of finish is less critical. Closer interaction with client and users throughout the planning stages can assist in allocating the budget in the most effective manner, a principle that should include strategic decisions on the relationship between maintenance and capital costs, especially where the former is carried largely by the users in the form of the school governing bodies.

8.1.5 Exemplary Management

The study of successful employment-intensive road building programmes has shown that management has to advance from best practice in conventional construction. This flows from the complexity of the larger labour force, and

[104] Doku (2006) has recorded bricklayers cutting every face-brick in a double skin wall because the inner skin was so irregular. The visual appearance predominated over the integrity of the component, and will no doubt create a maintenance problem throughout the building's life.

through devolving management tasks to the lowest responsible level to allocate the maximum wage component to targeted workers. The hands-on site supervisor is of critical importance in this regard, the training of whom is the insurance of efficiency and productivity in the implementation phase.

McCutcheon and Fitchett (2005a) have argued that the training of one member in a poor household to this level of responsibility provides that person with a sustainable job, within the programme and in a competitive job market, thereby lifting the family out of the poverty trap. This is a more satisfactory method of addressing poverty than many other relief mechanisms in that the person is a productive member of the major economy. Moreover she or he has the satisfaction of meaningful employment.

Following the proposition that high technology should be adopted where it makes a significant contribution to programme objectives, computers and other electronic media should be used to capture detail for improved efficiency, economy and quality, yet prevent information overload at higher levels of the programme. This becomes an important tool for reducing the need for higher level management at site.

8.1.6 An Ethos of Continual Improvement

The innovation required for a successful employment-intensive programme of building will necessarily have a steep learning curve in the early years of implementation. This will occur only where there is a commitment to quality management at all levels of the programme. In Chapter 7, the components of a Total Quality Management plan are discussed, and the importance of following these principles for the entire duration of the programme. The model also posits that this ethos is entrenched in all participants so that, on leaving the programme, they can ensure a healthy decentralised construction industry.

It is the contention of this thesis that employment-intensive construction should match other competing methods of delivery in terms of time, cost and quality.

Through the re-engineering that this entails, many of the current technical and managerial problems characterising the building sector can be rectified. Central to this is the focus on customer orientated quality, as experienced in other industries. Moreover, the exorbitant waste of labour and materials experienced in the construction industry will be corrected only through a long-term commitment to improvement.

8.2 THE OBJECTIVES

In Chapter 2, the objectives of this study were stated as:

1. To develop an approach to building that can be used as a vehicle for skills enhancement and employment creation.

This approach is described in detail in Chapter 7, which concludes with a method of evaluation and decision making. It is envisaged that, as employment-intensive construction becomes more entrenched, more data will be generated from research and field application to expand this framework, offering greater choice and insight to programme directors and clients. Fundamental to this is the integration of design and implementation, within a management structure that is underpinned by the commitment to constant improvement.

Evaluation of material and human resources is central to the method proposed, with guidelines for increasing the local content of both. Chapter 6 provides an example of the process of developing a structural system that uses almost entirely locally sourced materials, is easy to build with simple hand tools, and requires a minimum of high-level supervision. The innovation lies in adapting a sophisticated structural system, conventionally built from reinforced concrete, to reduce formwork to a simple arch, and in devising a method of construction that ensures geometrical accuracy and a bonding method that is inherently stable during construction, thereby contributing to safety on site. The versatility of the structure allows its use in a variety of building types so that programme participants would be able to use the methods learned in future public, commercial and domestic work. The single piece of machinery is inexpensive,

requires no fuel, and is simple to maintain and repair, making it suitable for small manufacturing businesses located in areas where demand is inconsistent.

For building to provide a significant increase in the number of jobs and ratio of project cost allocated to targeted wages, design and implementation needs to surpass the conventional and look to state-of-the-art design and management. It is essential that employment-intensive construction is at least as effective as its competing methods of delivery for long-term credibility of this mode of production, as well as for the lasting value of the jobs created.

2. To create a replicable programme for skills and managerial capacity enhancement through the medium of construction.

The skills development programme flows from the new South African Education and Training system, acknowledging the collapse of traditional methods of technical training in the construction sector, specifically apprenticeships. It respects the basis on which the National Skills Framework was conceived, both in its recognition of non-formal skills acquisition, and in the need for lifelong learning through small discrete formal learning modules. This is adapted here in response to criticism of this Framework, specifically in the lack of continuity of the learning process, leaving people with either a low level of conventional skills, or highly specialised skills applicable only to a particular system. In the model proposed here, a planned sequence of learning experiences is structured within each building in the programme, and participants can move to higher levels in other parts of the programme or form part of a local network with the possibility of other public commissions to supplement private sector work.

The UK's Supply Chain system developed for the delivery of public buildings is modified here in the light of extreme shortages of technical and managerial capacity. This revised framework is married to the training method developed in sub-Saharan Africa for the labour-intensive construction of roads. Some of the advantages of mentorship as used in the South African small contractor

development programme are retained, but with a greater focus on commercial benefits to the emerging entrepreneur/contractor and the more experienced network partner.

3. To establish a framework within which to generate a body of knowledge of 'best practice' in employment intensive affordable building.

The technical study (Chapter 6) of the present research is intended as a worked example that embodies the theory of labour-intensive construction (Chapter 4) and the results of the analysis of existing building projects (Chapter 5). This thesis is but a first step that provides direction for future research and implementation. The innovation required for a fully employment-intensive approach will, of necessity, take several years of additional research and implementation to achieve results equivalent to successful programmes such as the Kenyan Rural Access Roads Programme. The present research, however, shows that there is considerable potential for the construction of buildings to make a contribution to job creation, and through this, the alleviation of poverty in decentralised areas.

For labour-intensive construction to be recognised in the domain of civil engineering, it needed the evidence of successful programmes and the dissemination of these, supported by theoretical work, in conferences and publications. In the construction sector, validity is measured in built works, yet commissioning of innovative projects is risky – a further argument in favour of government taking the lead on the basis of full-scale pilot projects.

8.3 AREAS FOR FUTURE RESEARCH

Approaches to employment-intensive construction of buildings have, to date, been piecemeal and generally characterised by job creation being a secondary objective.[105] It is therefore a field in which substantial research work and

[105] Job creation is frequently found in the long list of social objectives that characterize public building in the developing world. This unrealistic formulation of objectives results in few of them

implementation needs to be carried out to reach its full potential. This study provides a starting point for the structuring of a programme, and an example of how a group of interrelated activities can be re-engineered to achieve a greater labour content. The present research has aimed at giving the broad outline of an effective employment-intensive programme of building work, but as with the experience of its civil engineering equivalents, many years of desktop, laboratory and field research is essential for this to achieve its full potential.

The most immediate requirements to consolidate the work done to date lie in translating research into full-scale buildings, initially as pilot studies. Through this, a clearer management framework can be forged, a realistic training programme formulated, and discussions held with the client department and user groups for the initial roll-out of a programme. Important costing information can be gleaned from a pilot study, a necessary step in the establishment of a budget as the basis for high level planning and scheduling. It would form the Guaranteed Maximum Price on which the Supply Chain network would base its detailed planning for the first buildings in the programme, and the basis for improvement as the Monitoring and Evaluation function produces data.

8.3.1 New materials

At two levels, the choice of materials can improve the labour ratio of building work: through the process of construction; and in manufacturing. Traditional materials are incrementally being discarded, through depletion or because they do not meet the users' needs or aspirations. The materials that are chosen to replace these are almost invariably highly industrialized, with low labour content. This suggests that there is scope for materials that are more socially acceptable than the traditional, yet are more climatically and environmentally suitable than those currently brought in from the industrialized centres.

---

being met, with the more difficult to implement being the most vulnerable. For example, the Constitutional Court in Johannesburg was promoted as an employment generating project, yet independent analysis showed that the building fared somewhat worse than conventional construction especially in the earthworks and basement construction. The contractor and project manager excused this because of time constraints. (Tariq Ali 2003:8)

Two avenues of research are in their early phase: additives where a small volume makes a considerable improvement in performance of an inexpensive bulk material; and the recycling of industrial and other sources of waste. In both cases, there is potential for small decentralized industries.

Innovations into structural systems that favour a more employment-intensive approach than conventional construction are suggested by, for example, the three-dimensional frameworks of paper tubing by Shigeru Ban. As traditional sources of material become depleted or prohibitively costly because of their energy demands in production, innovation and far greater efficiency will be essential. If research is directed towards systems that favour labour, two objectives can be met simultaneously. Here it is pertinent to reflect on Stewart's observations on how the "foreign sector" in the less developed world has absorbed the majority of research funding, at the expense of indigenous needs.

In the civil engineering field, decades of research and implementation of labour-intensive programmes have contributed to the formulation of a framework that allows decision makers to make informed choices: the Choice of Technique Analysis. A similar framework should be developed for buildings, the more necessary for informed decisions because of the vast choice of materials and techniques on offer.

8.3.2 Services

Building services – water supply, plumbing, drainage, electrical reticulation, air treatment, mechanical access systems, etc – all create a drain on the project cost, largely because regulations demand standards that can only be feasibly achieved with components manufactured in highly industrialized factories. This view is being challenged by environmental groups because of the energy used in manufacture as well as the opportunities lost through, for example, waste water being removed from the site with expensive reticulation systems.

As with the discussion on materials and structural systems, this offers an opportunity for addressing two objectives simultaneously. The environmental benefits of labour-intensive construction have been acknowledged with regard to installation of services in existing residential areas (Mkhize 1994), as well as in ecologically sensitive areas. In both instances, the noise and air pollution of large machinery are avoided, and more careful earthworks and trenching can be performed by hand. Moreover the connection between environmental management and poverty alleviation is enshrined in the Millennium Goals (United Nations 2000).

Two aspects of management in the construction industry deserve attention: on the one hand the tendency for formal sector companies to shelve their technical staff to concentrate on management contracting; and the problems surrounding the effective development of small contractors. In the model proposed here, the second of these is addressed in the form of Supply Chain management, with the Public Works Department in the role of lead contractor. This proposal needs to be tested through pilot projects and other applied research, possibly leading to other forms of economical decentralized systems as relationships between the centre and the periphery are explored.

The application of any management system needs to be tested and adapted to local conditions. It is as much a socio-cultural issue as a practical one, given the negative experiences in other contractor development programmes. This may entail the development of a range of management methods and styles that meet the broader objectives of a programme and mesh with its higher level management structures.

8.3.3 Training

In the domain of civil engineering, the training of the hands-on site supervisor has been refined through theoretical and field research into a system that guarantees technical and managerial competence at remote sites. In the present study there

have been suggestions of some of the elements and structure of the training of site supervisors for building work but these need to be fleshed out with the development of training content and pilot studies to test effectiveness of these assumptions. Central to this research is the need to generate a training method that addresses the complexity of a building site.

Artisan training requires a similar process that draws on the apprenticeship system yet adapts this to the realities of communities where high unemployment prevents people from engaging in lengthy periods without a wage income. The Construction Education and Training Authority's framework has the elements from which an effective system could be developed. However, the present mode of delivery of training is fragmented, and does not ensure that workers can operate with a measure of independence. There is scope for investigating adaptations in the implementation of the CETA model to produce workers with the depth and breadth of skills that characterized artisans and foremen of the past. This is discussed in more detail in Appendix 1, which traces the historical background to the artisan crisis in South Africa in the context of global challenges confronting the development of a robust construction industry.

Small contractor training is similarly challenged on the one hand by the low levels of education of many informal sector operatives, and on the other by the global tendency towards multi-level contracting. Mentorship initiatives have not proved to be successful, but other methods of enhancing expertise is needed for these small contractors to be able to perform adequately in the major economy.

8.4 CONCLUSIONS

The goal of this research has been to develop methods of employment-intensive construction that match conventional building practice in terms of cost, time and quality. A method has been proposed as a decision framework that integrates all aspects of the construction programme, as described in Chapter 7. The technical study presented in Chapter 6 gives an example of this process in one component

of a small public building, namely a rural school. The extent of research and development required for building construction to start approaching the levels of employment intensity found in labour-intensive civil engineering works point to the use of a programme approach that unfolds through a planned sequence of building projects. This is supported by the training and management structure proposed in Chapter 7.

This research has shown that building has not entirely lost its high labour content, as is made evident in the tables in Chapter 5. For example in Tables 5-3 and 5-7 the labour ratios vary from 45.72% for plastering to 1.68% for roofing. There are still many instances where labour predominates over machinery, but the tendency is towards mechanization especially where artisan skills are inadequate. In terms of job creation, the worst-case scenario is where skills, and hence productivity, are so low that highly industrialized methods are introduced in factories that are rapidly reducing the labour content to a handful of inspectors, as computers feed the data directly to the factory floor.

The study of tiled vaulting gives an indication of how this trend can be reversed without compromising the performance of the building. In Table 6-4, the change from conventional roofing used in the Limpopo school to tiled vaulting shows an improvement in the labour ratio from 4.44% to 69.6%, achieving targets of the order of magnitude consistent with McCutcheon's definition of labour-intensive (McCutcheon 1995:332; see 4.1.1). The improvement is even more significant when compared with the Lightweight Steel example, where labour accounts for a mere 1.4% of the cost of the roofing.

Designers and other decision-makers are not always clear on the implications of the choices that they make in relation to their impact on employment objectives. The framework presented in Chapter 7 is aimed at assisting this process, but awareness of the principles and techniques of effective strategy and implementation need to be widely disseminated. The present legal requirement

for Continuing Professional Development in the construction sector professions can provide an important forum in this regard. This first step towards professional awareness needs to be followed by sustained effort in bridging the separation of design and construction (including supply and manufacture) as exemplified in the United Kingdom initiative. (CITB 2004)

Good practice and a sound body of knowledge can be entrenched while employment is high on the political agenda. The legislation underpinning the Expanded Public Works Programme provides a powerful framework for ensuring the education of professionals and public servants in employment-intensive principles and methods for the types of work designated for labour-intensive construction. The only thing preventing the expansion of this programme into the building sphere is the lack of research and data on which to base guidelines for implementation.

A cornerstone of the Expanded Public Works Programme is that, because employment-intensive work is funded out of the normal budgets of provinces and municipalities, it has to be cost competitive with conventional methods. The present research has highlighted the need for improved training of artisans, and the development of effective management systems to ensure productivity and efficiency. While these need to be part of an integrated effort at re-engineering the building industry, individual skills are the more urgent, as current practice is so inefficient that improvement in overall management structures will have little impact.

It is the contention of the present research that management functions should be inculcated at all levels, pointing to a far more structured education of artisans and supervisors where theory, self-management and productivity are integrated with technical skills. Management needs to complement the drive towards efficiency and productivity, setting the example in ensuring availability of materials and smooth sequencing of activities, especially with following trades. Management

should not stand in the way of individual productivity improvement: for example by avoiding reworking through misinterpreting documents, wrong instructions, setting out errors, and should seek ways to facilitate individual improvement. This is but part of a process. Just as participants are called on to adopt an ethos of continual improvement, at the highest level there is a need to revisit objectives regularly and rigorously and not merely 'business as usual' even when a programme is established and ostensibly successful in meeting its targets.

Employment-intensive construction will never become a part of the major economy unless it establishes its own credentials through matching conventional practice in terms of time, cost and quality. This is achieved not through turning back the clock to pre-industrial methods, but rather through a synthesis that comes from critical analysis of traditional and current methods, while exploiting state-of-the-art technology. The recipients as well as the participants deserve more than third-rate solutions that are neither economically nor environmentally responsible in the longer term. The model presented here aims at a dignified product that is the outcome of dignified and meaningful work.

Internationally, meaningful employment has been acknowledged as the most sustainable way of addressing poverty and assisting in building healthy decentralized communities. To conclude, the United Nations Millennium Declaration (Resolution 55/2, 8 September 2000) asserts in clause 11:

> *We will spare no effort to free our fellow men, women and children from the abject and dehumanizing conditions of extreme poverty, to which more than a billion of them are currently subjected. We are committed to making the right to development a reality for everyone and to freeing the entire human race from want.* (United Nations 2000)

9 REFERENCES

Abedian, I and Standish, B. (1986) "Public Works Programme in South Africa: Coming to Terms with Reality." Development Southern Africa Journal; Vol. 3, No. 2.

Agrément South Africa. (1998) An Introduction to Innovation in the Building and Construction Industry. Pretoria: Agrement South Africa.

Alexander, C et al. (1969) Houses Generated By Patterns. Berkeley: Center for Environmental Structure.

ANC (African National Congress). (1993) Reconstruction and Development Programme. Pretoria: Government Printer.

Anderson, S. (ed) (2004) Eladio Dieste: Innovation in Structural Art. Princeton Architectural Press.

Austen, R. (1987) African Economic History: Internal Development and External Dependency. London: James Curry / Heinemann.

Ball, M; Drewer, S; Landsell, H and McCutcheon, R. (1979) Labour Mobility Study, The Employers Perspective: A Research Report prepared for the Department of the Environment. London: University College London, Building Economics Research Unit.

Bangma, S-R; de Bruijn, E and McCutcheon, R. (2003) "Employment-intensive concrete block pavement construction for upgrading township roads in South Africa." In: McCutcheon, RT and Taylor Parkins, FLM (editors). (2003) Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

Banwell Report. (1964) The Placing and Management of Contracts for Building and Civil Engineering Work. London: HMSO.

Banwell, I J. and Edmonds, G A. (1985) Rural Transport In Developing Countries. London: Intermediate Technology Publications.

Becchi, A; Corradi, M; Foce, F and Pedemonte, O (eds). (2003) Essays on the History of Mechanics. Birkhauser.

BIFSA. (2000) BIFSA Statistical Yearbook 1999/2000. Building Industries Federation South Africa.

BIFSA. (2002) Annual Report. Midrand: Building Industries Federation of South Africa.

Billington, DP. (1965) Thin shell concrete structures. New York: McGraw-Hill.

Bird, A. (2001) “Youth and Work in South Africa: Issues, experiences and ideas from a young democracy.” ILO Cinterfor (http://www.ilo.org) Presented at: Department of Labour, South Africa; in: Round Table on The integration of youth into working life, Second International Vocational and Technical Education Congress, Seoul, Korea April 26 to 30 1999.

Black Construction Industry (BCI). (1996a). Proposals for increasing the effectiveness of the emerging contractor sector. Southfield: BCI.

Blier, S P. (1987) The anatomy of architecture: ontology and metaphor in Batammaliba architectural expression. Cambridge: Cambridge University Press.

Block, P; Ciblac, T and Ochsendorf, J. (2006) “Real-time limit analysis of vaulted masonry buildings.” Computers and Structures 84. Elsevier.

Block, P; DeJong, M and Ochsendorf, J. (2006) "As Hangs the Flexible Line: Equilibrium of Masonry Arches." The Nexus Network Journal, Vol. 8, No 2.

Block, P and Ochsendorf, J. (2007) “Thrust Network Analysis: A New Methodology for Three-Dimensional Equilibrium.” Journal of the International Association for Shell and Spatial Structures, Vol. 48, No 3.

Block, P and Ochsendorf, J. (2008) “Lower-bound Analysis of Masonry Vaults.” Proceedings of the 6th International Conference on Structural Analysis of Historical Construction. Bath, UK.

Boesiger, W. (1966) Le Corbusier: The Complete Architectural Works Volume VI 1952-1957. London: Thames and Hudson.

Bonner, P, Delius, P and Posel, D (eds). (1993) Apartheid’s Genesis: 1935-1962. Johannesburg: Ravan.

Bond, P. and Tait, A. (1997) “The Failure of Housing Policy in Post-Apartheid South Africa.” Urban Forum, 8(1). Johannesburg.

Breslin, E. 1995. "Evaluating an Evaluation - An Evaluation of the Relief Development Programme of the Independent Development Trust by Lieb Loots and André Roux." Food for Thought. *(Operation Hunger Development Update Quarterly Revie*w) Number One.

Bundy, C. (1988) The Rise and Fall of the South African Peasantry. Cape Town: David Philip.

Cain, C T. (2004a) Performance measurement for construction profitability. Oxford: Blackwell.

Cain, C T. (2004b) Profitable partnering for lean construction. Oxford: Blackwell.

Calitz, J; van Wijk, AJ; Horak, E; Ras, C and McCutcheon, RT. (1995) "Waterbound macadam: Design, construction and performance." Annual Transportation Convention. Pretoria: SATC.

Centre for Development Enterprise. (2003) “Labour-Intensive Public Works: Towards Providing Employment for all South Africans willing to work.” In Depth. Johannesburg: CDE.

Chan, P; Puybaraud, MC and Kaka, A. (2001) “Construction training: a linkage to productivity improvements.” In: Akintoye, A. (Ed.) Proceedings of the seventeenth annual ARCOM conference. University of Salford, Association of Researchers in Construction Management.

Christie, P. (1991) The Right to Learn. Johannesburg: Sached Trust.

CITB. (2004) Bridging the Gap: Eastmidlands. Loughborough: CITB (Electronic format).

Clarke, L. (1992) Building capitalism: historical change and the labour process in the production of the built environment. London: Routledge.

Coburn, A; Dudley, E and Spence, R. (1989) Gypsum Plaster: Its manufacture and use. London: Intermediate Technology Publications.

Coetzee, R. (1982) Funa: Food from Africa. Durban: Butterworths.

Construction Charter. (2005) Construction Sector Black Economic Empowerment Charter: Second Draft. South Africa: Department of Trade and Industry.

Construction Industry Development Board (CIDB). (2005) “Best Practice Guidelines for Labour-based Methods and Technologies for Employment Intensive Construction Works.” Pretoria: Department of Public Works and CIDB. Sourced from www.cidb.org.za.

Couch, J. (2008) "Works Progress Administration.” EH.Net Encyclopedia. Edited by Robert Whaples. Sourced from: http://eh.net/encyclopedia/article/couch.works.progress.administration

Coukis, B et al. (1983) Labour-based Construction Programmes - A Practical Guide for Planning and Management. Oxford: OUP for the World Bank.

Creswell, KAC. (1978) The Muslim Architecture of Egypt. New York: Hacker.

Croswell, JA and McCutcheon, RT. (1997) Guidelines for training. Vol 1: Public Sector Guidelines and Vol 2: Practical Guidelines for the implementation of a training programme. Pretoria: Department of Public Works.

Croswell, JA and McCutcheon, RT. (1999) "An approach to the preparation for and submission of tenders for competitive labour-based construction contracts." Seventh Regional Seminar for Labour-based practitioners, Lusaka, Zambia. Geneva: ILO.

Croswell, JA and McCutcheon, RT. (2000) "The use of improved management and testing procedures in labour-based construction." ILO 8th Regional Seminar for Labour Based Practitioners, Cairo, Egypt. Geneva: ILO.

Croswell JA and McCutcheon, RT. (2001) "Small Contractor Development and Employment - A Brief Survey of Sub-Saharan Experience in Relation to Civil Construction." Urban Forum. Vol. 12, No. 3-4.

Croswell, J and McCutcheon, R. (2003) "Group tasks and group balancing." In: McCutcheon, RT and Taylor Parkins, FLM (editors). (2003) Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

CSIR. (2006) Feasibility Study into the Development of a Mechanism to Support Alternative Technologies and Indigenous knowledge Systems in a Rural Context. Pretoria: Department of Housing.

Dainty, A and Ison, S. (2003) Constructing Nottinghamshire. Loughborough: CITB (Electronic format)

Delius, P. (1996) A lion amongst the cattle : reconstruction and resistance in the Northern Transvaal. Johannesburg : Ravan Press.

Department of Finance. (1995) Growth, Employment and Redistribution: a Macro-Economic Strategy. Pretoria: Government Publishers.

Department of Housing. (1994) White Paper: A New Housing Policy and Strategy for South Africa. Pretoria: Government Gazette.

Department of Labour. (2002) Code of Good Practice for employment and conditions of work for Special Public Works Programmes. Issued under the

Basic Conditions of Employment Act, 1997. Pretoria: Government Gazette No 23045, 25 January 2002.

Department of Labour (No date) Towards a National Skills Development Strategy. Sourced from http://www.labour.gov.za/docs/legislation/skills/docs/nsds.htm

Department of Public Works. (1995) Establishing an enabling environment to ensure that the objectives of the RDP and related initiatives by Government are realised in the construction and allied industries. Pretoria: Department of Public Works.

Department of Public Works/ILO. (2003) Business Plan for an Expanded Public Works Programme. Pretoria: Department of Public Works.

Department of Public Works. (2004) Expanded Public Works Programme (EPWP), DRAFT Consolidated Programme Overview and Logical Framework. Pretoria: Department of Public Works.

Department of Public Works (DPW). (2005) Guidelines for the Implementation of Labour-Intensive Infrastructure Projects under the Expanded Public Works Programme (EPWP). http://www.epwp.gov.za/downloads/legal/guidelines.pdf

De Solà-Morales, I. (1986) Gaudi. New York: Rizzoli.

De Sousa, U. 2000. Managing workers in production: Overview of labour in the building industry. Translation of a presentation (TG-007). University of São Paulo.

Development Bank of Southern Africa. (1998) Infrastructure for Development – development report. Johannesburg: Development Bank of Southern Africa.

Doku, I. (2007) The establishment of baseline artisan productivities as a means to monitoring employment-intensive construction : comparison to a South African case study. Unpublished MSc (Eng) thesis. Johannesburg: University of the Witwatersrand.

Duncan, W R. (1996) A guide to the project management body of knowledge. Upper Darby, Pa.: Project Management Institute.

Dwyer, D J. (1975) People and Housing in Third World Cities. London: Longman.

Edmonds, G A and Howe, J D G F. (1980) Roads And Resources: Appropriate Technology In Road Construction In Developing Countries. London:

Intermediate Technology.

Edmonds, G A. (1984) Foundations For Change: Aspects Of The Construction Industry In Developing Countries. London: Intermediate Technology Publications.

Edmonds, G A. (1991) Technology Choice For The Construction And Maintenance Of Roads In Developing Countries: Developments And Guidelines. Geneva: International Labour Office.

Egbeonu, E. (2006) An appraisal of mentorship within the black prime contractor of the emerging contractor development programmme of South Africa. Johannesburg: University of the Witwatersrand, Unpublished MSc.

Elphick, R and Giliomee, H (eds). (1979) The shaping of South African Society, 1652-1820. Cape Town: Longman.

Emery, S; Ali, N; Veldman, B; McCutcheon, RT and van Huyssteen, S. (1993) Labour Enhanced Construction for Bituminous Surfacings, Manual 11. Roggebaai: South African Bitumen and Tar Association (SABITA).

Emery, S; Ali, N; Veldman, B; McCutcheon, RT and van Huyssteen, S. (1993) Methods and Procedures, Manual 12. Roggebaai: South African Bitumen and Tar Association (SABITA).

Emery, S. (2003) “Design and construction of hot-mixed asphalt surfacings for employment-intensive construction.” In: McCutcheon, RT and Taylor Parkins, FLM (editors). (2003) Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

Employment Task Force (C. Mthombeni, Co-ordinator). (1996) "The labour-intensive upgrading of the Schoonoord-Apel Road : Phase II Baseline Document." (Pilot Project, Northern Province). Johannesburg: National Rural Development Forum.

Esterhuizen, A. (2005) “The Government of Malawi/European Union Public Works Programme (Gom/Eu Pwp) - A Multi-Tier Approach to Poverty Reduction and Food Security.” In WORK2005: Second International Conference for Employment Creation in Development. Johannesburg: University of the Witwatersrand.

Faber, C. (1963) Candela the shell builder. New York: Reinhold.

Farstad, H. (2001) “Growing Entrepreneurs and improving SME sustainability: conditions, resources and approaches.” In McCutcheon, RT and Taylor

Parkins, FLM (eds) Conference proceedings of WORK2001: First International Conference on Employment Creation in Development. Johannesburg: University of the Witwatersrand.

Fathy, H. (1976) Architecture for the Poor. Chicago: University of Chicago Press.

Feinstein, CH. (2005) An Economic History of South Africa: Conquest, Discrimination and Development. Cambridge: Cambridge University Press.

Fitchett, A. (2001) Low income housing in Alexandra, Johannesburg: Empowerment, Skills Development and Job Creation. Johannesburg: University of the Witwatersrand. (MSc Project Management, unpublished)

Fitchett, A. (2005) Transcripts of discussions. WORK2005: Second International Conference for Employment in Development. University of the Witwatersrand, Johannesburg.

Fitchett, A and McCutcheon, RT. (2005) "Training Vocational and Entrepreneurial Skills: Shared Concerns of South Africa and Europe." WORK2005: Second International Conference for Employment in Development. University of the Witwatersrand, Johannesburg.

Geddes, R. "Zambézia Feeder Roads Project." In McCutcheon, R and Taylor Parkins, F (2001) WORK 2001 First International Conference on Employment Creation in Development: Conference Proceedings. Johannesburg: Research Centre for Employment Creation in Construction.

Gélinas, JB. (trans. 1998) Freedom from Debt: the reappropriation of development through financial self-reliance. London: Zed Books (Orig. 1994).

Gertzen, DM., Nevin, G., and McCutcheon, R.T. (1997) "Labour-based urban residential street construction: An evaluation of the Soweto experience 1992-1996", Proceedings of the SAICE 8th Annual Congress: Magnum Opus, Eskom Conference Centre, Midrand, 17-18 April. Johannesburg: SAICE.

Gertzen, D; Nevin, G and McCutcheon, R. (2003) "Employment-intensive urban residential street construction – an evaluation of the Soweto experience 1992-1996." In: McCutcheon, RT and Taylor Parkins, FLM (editors). (2003) Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

Giliomee, H and Schlemmer, L (eds). (1985) Up against the fences: Poverty, passes and privilege in South Africa. Cape Town: David Philip.

Gulati, A., et al. 1996. “Reaching the Poorest of the Poor? An Evaluation of the Community Employment Programme. Draft.” Johannesburg: Community Agency for Social Engineering (CASE), August.

Hagen, S. 1985. “Rural Access Roads Programme, Kenya: Analysis of Costs and Productivities.” CTP No 84. Geneva: ILO.

Harris, R. (1998) “A crank’s fate and the feting of a visionary: reflections on the history of aided self-help housing.” Third World Planning Review. Vol 20; 3.

Hattingh, J. and Potgieter, C.J. 1999. “Evaluation of the Labour-Intensive Macadam Construction Technique.” 7th Conference on Asphalt Pavements for Southern Africa (CAPSA). Zimbabwe: CAPSA.

Hattingh, J. 2003. “Evaluation of the Labour-intensive Macadam Construction Technique with special reference to franchising.” In McCutcheon, RT and Taylor Parkins, FLM. Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

Hattingh, J. and McCutcheon, R.T. (2005) “Labour-Based Macadam Black top Surfacing.” 11th Regional Seminar for Labour-based Construction. Geneva: ILO.

Hattingh, J; McCutcheon, R and Richardson, A. (2007) “Practical implementation of a philosophy towards increased job creation for the construction industry as a whole.” 12th Regional Seminar on Labour Intensive Practices. Durban: ILO.

Heeks, R. (2003) eGovernment for Development: Success and Failure Rates of eGovernment in Developing/Transitional Countries. Manchester: IDPM, University of Manchester.

Hefer, A., Moloisane, R., McCutcheon, R.T., Horak, E. and Van Wijk, A.J. 2003. “Performance of waterbound macadam pavements: case study in Johannesburg.” In McCutcheon, RT and Taylor Parkins, FLM. Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

Henriod, E (editor). (1984) The Construction Industry: Issues and Strategies in Developing Countries. Washington, D C: World Bank.

Hirsch, ED; Kett, JF and Trefil, J. (eds) (2002) New Dictionary of Cultural Literacy, Third Edition. Houghton Mifflin.

History of Freemasonry. Sourced from http://www.angelfire.com/ August 2004.

Holti, R; Nicolini, D and Smalley, M. (1999) "Building Down Barriers": Prime Contractor Handbook of Supply Chain Management: Sections 1 & 2. Crown Copyright.

Huchzermeyer, M (2001) “Housing for the poor? Negotiated housing policy in South Africa.” Habitat International Volume 25, Issue 3 (September). Elsevier.

Huerta, S. (2003) “The Mechanics of Timbrel Vaults: A Historical Outline.” In: Becchi, A et al. (2003) Essays on the History of Mechanics. Birkhauser.

IBRD (International Bank for Reconstruction and Development: The World Bank). (1974) “The Study of the Substitution of Labour and Equipment in Civil Construction. Phase 11- Final Report.” Staff Working Paper No. 172. Washington: IBRD.

IBRD (1986) The Study of the Substitution of Labour and Equipment in Civil Construction: A Research and Implementation Project Completion Report. Washington: IBRD.

IBRD (1990) World Development Report 1990: Poverty. New York: Oxford University Press.

IBRD (1994) World Development Report. Infrastructure for Development. World Bank, Oxford University Press.

Iliffe, J. (1987) The African Poor: A History. Cambridge: Cambridge University Press.

ILO (1999) Investing in Jobs for Development: The ILO’s Employment-Intensive Programme. Geneva: International Labour Organisation.

ILO (2001) The construction industry in the twenty-first century: Its image, employment prospects and skill requirements: Tripartite Meeting on the Construction Industry in the Twenty-first Century. Geneva: International Labour Office.

ILO (2005) World Employment Report 2004-2005. Geneva; International Labour Office.

ILO (2005) “Global Employment Trends: Brief.” www.ilo.org/trends Accessed February 2005.

ILO (2008) “Lesotho.” http://www2.ilo.org/public/spanish/employment/recon/eiip/countries/africa/lesotho.htm Accessed May 2008

IT Transport. (1998) Cost comparison between labour-based methods for road works: A case study from Ghana. Abingdon: IT Transport for DFID.

Keynes, JM. (1936) The General Theory of Employment, Interest and Money. Macmillan and Cambridge University Press, for Royal Economic Society.

King, LW. (trans) (1910) Hooker, R (ed). Code of Hammurabi. Sourced from http://www.wsu.edu August 2004.

Kirmani, SS. (1988) The Construction Industry in Development: Issues and Options; Report INU 10. Washington: The World Bank; Infrastructure and Urban Development Department.

Koenigsberger, OH et al. (1974) Manual of Tropical Housing and Building. Longman.

Lal, D. (1974) Methods Of Project Analysis. Baltimore: Johns Hopkins University Press.

Lal, D. (1978) Men or machines : a study of labour-capital substitution in road construction in the Philippines. Geneva: International Labour Office.

Leibbrandt, HCV. (1897) Riebeeck's Journal, etc. Part1: Dec 1651-Dec 1655. Cape Town.

Leitch, J. (2001) "WORK2001: First International Conference on Employment Creation in Development: World experts call for large-scale national programmes." IMESA: Journal of the Institution of Municipal Engineering of Southern Africa, Vol. 26, No. 6.

Lewis, DH and Ngoasheng, MM. (1996) Restructuring the South African Labour Market: Report of the Commission to Investigate the Development of a Comprehensive Labour Market Policy RP83/2996. Cape Town: Department of Labour.

Ligthelm, A and Van Niekerk, K. (1990) "Unemployment: The Role of the Public Sector in Increasing the Labour Absorption Capacity of the South African Economy." Development Southern Africa; Vol. 7, No. 4.

Lieuw Kie Song, MRE; Phillips, SD and McCutcheon, RT. (2003) "Theoretical and laboratory research into waterbound macadam basecourses." In McCutcheon, RT and Taylor Parkins, FLM. Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

Loosemore, M; Dainty, A and Lingard, H. (2003) Human resource management in construction projects: strategic and operational approaches. London: Spon Press.

Luthuli, A. (1958) “A Message to Every Voter from the African National Congress, April 1958” Cited in http://www.anc.org.za/ancdocs/history/lutuli/art60.html

Maasdorp, GG. (1994) Public Works Programmes in South Africa: A key element in Employment Policy. Johannesburg: Urban Foundation.

Majeres, J. (2003) “Employment Intensive Investment and Poverty Reduction: The Wider Policy Framework.” ILO ASIST Bulletin, No. 15.

Majoe, T M. (2003) Research on the registered CETA learnerships. Johannesburg: University of the Witwatersrand, unpublished project report.

Malepfana, N and Mokoena, E. (2007) Double-vaulted structure using cement-stabilized earth tiles. Unpublished research report, BSc (Eng). Johannesburg: University of the Witwatersrand.

Mark, R (ed). (1993) Architectural Technology up to the Scientific Revolution. Cambridge: MIT Press.

Mark, R. (1982) Experiments In Gothic Structure. Cambridge, Mass.: MIT.

Master Builders Association. (2003) Master Builders Pricing Guide 2002/2003. Midrand: Master Builders Association.

MBSA. (previously BIFSA) (2007) Annual Report 2007. http://www.mbsa.org.za/

MBSA. (2008) Annual Report 2008. http://www.mbsa.org.za/

Mathéy, K (ed). (1992) Beyond Self-help Housing. London: Mansell.

McCutcheon, RT. (1985) “The use of donkey-drawn carts in labour-intensive road construction in Botswana.” CTP 42 (Feb). Geneva: ILO.

McCutcheon, R.T. (1983) “The Pilot Project of Labour Intensive Road Construction and Maintenance.” Gaborone: MLGL

McCutcheon, RT. (1989) "A strategy for increasing the use of local resources in the DBSA programme with particular emphasis upon the potential for productive employment creation." Halfway House: Development Bank of Southern Africa.

McCutcheon, RT. (1990) "Labour-intensive road construction and maintenance in Africa: an introduction." The Civil Engineer in South Africa, Vol. 32, No. 11.

McCutcheon, R.T. (1991) “The main findings of the district pilot project of labour road construction and Maintenance in Botswana and the implications for similar projects in South Africa.” Development Southern Africa. Vol. 8, No. 2.

McCutcheon, RT. (1992) “Botswana: A description of the District Roads Labour-intensive Improvement and Maintenance Programme.” Development Southern Africa. Vol 9.

McCutcheon, RT; Croswell, JA; Meyer, D; van Zyl, C and Watermeyer, R. (1993) Interim Guidelines for Appropriate Contract Procedures and Documentation for Labour-based Construction. Construction and Development Series Number 2. Halfway House: Development Bank of Southern Africa.

McCutcheon, RT. (1995) "Employment Creation in Public Works: Labour-intensive Construction in Sub-Saharan Africa - the Implications for South Africa." Habitat International, Vol.19, No. 3.

McCutcheon, RT and Marshall, J. (1996) Labour-intensive construction and maintenance of rural roads: Guidelines for the training of road builders. Halfway House: Development Bank of Southern Africa.

McCutcheon, RT. (1998) Institution, Organisation and Management For Large-Scale, Employment-Intensive Road Construction And Maintenance Programmes. Halfway House: Development Bank of Southern Africa.

McCutcheon, RT and Taylor Parkins, FLM (editors). (2001) Conference proceedings of WORK2001: First International Conference on Employment Creation in Development. Johannesburg: University of the Witwatersrand.

McCutcheon, RT. (2001) “An Introduction to Employment Creation in Development and Lessons Learned from Employment Creation in Construction.” Urban Forum Vol. 12, No.4.

McCutcheon, R. (2002) “Public Works: Potential for job creation.” NALEDI: Policy Bulletin, Vol 5, No 3. (Edited version of: McCutcheon, R. (2002) Employment and Public Works. Johannesburg: University of the Witwatersrand, WORK Research Centre for Employment Creation in Construction.)

McCutcheon, R and Fitchett, A. (2003) “BEE in the Construction Sector breeds disillusionment.” NALEDI: Policy Bulletin, Vol 5, No 3. (Edited version of: McCutcheon, R and Fitchett, A. (2003) Black Economic Empowerment in

the Construction Sector. Johannesburg: University of the Witwatersrand, WORK Research Centre for Employment Creation in Construction.)

McCutcheon, RT and Taylor Parkins, FLM (editors). (2003) Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

McCutcheon, RT and Croswell, JA. (2003) "Group Tasks and Group Balancing." In McCutcheon, RT and Taylor Parkins, FLM. Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

McCutcheon, RT and Taylor Parkins, FLM. (2003) "Choice of Technique Analysis and Applications to High Cost, High Standard Infrastructure." In McCutcheon, RT and Taylor Parkins, FLM. Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

McCutcheon, RT and van Steenderen, WPC. (2003) "Employment-intensive aspects of the rehabilitation of the Great North Road: N1-28 Matoks to Louis Trichardt, South Africa." In McCutcheon, RT and Taylor Parkins, FLM. Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

McCutcheon, R; Fitchett, A; Lieuw Kie Song, M and Quainoo, H. (2004) An Overview of the South African Construction Sector in 2003. Johannesburg: NALEDI.

McCutcheon, RT and Fitchett, A. (2005a) "The Critical Importance of the Hands-on Site Supervisor." In WORK2005: Second International Conference for Employment in Development. Johannesburg: University of the Witwatersrand.

McCutcheon, R and Fitchett, A. (2005b) "Skills, Training and Education for Employment and Development." In: WORK2005: Second International Conference for Employment in Development. Johannesburg: University of the Witwatersrand.

McCutcheon, RT and Fitchett, A. (eds.). (2005c) WORK 2005: Proceedings of the Second International Conference on Employment and Development: Skills, Training and Education. Johannesburg: University of the Witwatersrand, Research Centre for Employment Creation in Construction.

McCutcheon, RT; Croswell, JA; Fitchett, A and Taylor Parkins, FLM. (2005) "The South African National Public Works Programme, and the Expanded Public Works Programme with particular reference to its Infrastructure component."

Second International Conference for Employment in Development. Johannesburg: University of the Witwatersrand.

McCutcheon, RT; Croswell, JA and Taylor Parkins, FLM. (2005) "The South African National Public Works Programme and Expanded Public Works Programme with particular reference to the Infrastructure component." In WORK2005: Second International Conference for Employment in Development. Johannesburg: University of the Witwatersrand.

McCutcheon, RT; Croswell, JA and Taylor Parkins, FLM. (2005) "Skills and Employment Generation at Mohlaletse, Sekhukhune, Limpopo Province, South Africa: A case study with implications for employment creation and skills development in general and the South African Expanded Public Works Programme in particular." WORK2005: Second International Conference for Employment in Development. (Discussion document.) Johannesburg: University of the Witwatersrand.

McCutcheon, RT; Croswell, JA and Hattingh, J. (2006) "Re-Engineering Construction for Employment and Development: Labour-intensive construction of access and high-standard roads in the Expanded Public Works Programme." 3rd IRF/SARF Regional Conference for Africa: Roads for the African Renaissance: Durban.

Merrifield, A. (2000) "the role of the construction industry in the delivery of infrastructures in South Africa." In Khose, M (ed). Infrastructure: Mandates for change. Pretoria: HSRC Publishers.

Mitchell, M and Bevan, A. (1992) Culture, Cash and Housing. London: VSO/IT Publications.

Mkhize, MM. (1994) An evaluation of a small labour-based contractor development programme in Soweto. Johannesburg: University of the Witwatersrand, Unpublished MSc (Civil Engineering).

Mthombeni, C. (1995) A critical analysis of the Community-Based Public Works . Johannesburg: University of the Witwatersrand, unpublished MSc(Eng) dissertation.

Muatjetjetja, M. (2005) "Labour Intensive Work in Botswana: An Evaluation of Six Programmes." In: WORK2005: Second International Conference for Employment in Development. Johannesburg: University of the Witwatersrand.

Murison, H S and Lea J P (eds). (1978) Housing in Third World Countries: Perspectives on Policy and Practice. London: Macmillan.

Murray, BK. (1982) Wits, the early years: a history of the University of the Witwatersrand, Johannesburg and its precursors 1896-1938. Johannesburg: Witwatersrand University Press.

National Public Works Programme (NPWP). (1994) National Public Works Programme. What is it? How does it work? A guide for communities, trade unions, government departments, contractors and NGO's. Pretoria: Department of Public Works.

National Public Works Programme (NPWP). (1994) A brief introduction to The National Public Works Programme. Pretoria: Department of Public Works.

National Committee for Labour-intensive Construction (NCLIC); Congress of South African Trade Unions (COSATU) and South African National Civic Organisation (SANCO). (1993) The Framework Agreement for Public Works Projects Using Labour Intensive Construction Systems. Johannesburg: NCLIC-COSATU-SANCO.

NEFTC. (1994) National Employment Creation Programme for the Provision of Public Infrastructure Using Labour Intensive Methods (National Public Works Programme) Pre-Investment Investigation: Final Report: A framework for the implementation of a National Public Works Programme adopted by the NEF. Johannesburg: National Economic Forum.

Norton, J. (1986) Building with Earth: A Handbook. Rugby: IT Publications.

NPWP Task Team. (1994) National Public Works Programme Third Draft. Pretoria: Department of Public Works.

NPWP Task Team. (1994) National Community Based Public Works Programme. Pretoria: Department of Public Works.

NPWP Task Team. (1995) Report of the National Public Works Programme Presentation to Cabinet. Pretoria: Department of Public Works.

NPWP Task Team. (1995) National Public Works Programme Annual Report 1994/95. Pretoria: Department of Public Works.

Ntoi, L. (2000) Managing the development of small-scale labour-based road contractors: with particular reference to Lesotho. Unpublished MSc (Eng), Johannesburg: University of the Witwatersrand.

Ochsendorf, JA; Hernando, JI and Huerta, S. (2004) “Collapse of Masonry Buttresses.” Journal of Architectural Engineering, 10(3).

Ochsendorf, J. (2004) "Eladio Dieste as Structural Artist." In: Anderson, S (ed) Eladio Dieste: Innovation in Structural Art. Princeton Architectural Press.

OECD. (1994) The OECD Job Study. Paris: OECD.

Pahad, M. (1997) Assessment and the National Qualifications Framework: a guide for teachers. Sandton: Heinemann.

Pama, MC. (1992) Productive employment creation in road construction and maintenance in Lesotho: the critical importance and nature of training. Unpublished MSc (Eng), Johannesburg: University of the Witwatersrand.

Parker, HW and Oglesby, CH. (1972) Methods improvement for construction managers. New York: McGraw-Hill.

Pedreschi, R. (2000) Eladio Dieste. London: Telford.

Penguin (1972) Penguin Dictionary of Economics. Harmondsworth: Penguin Books Ltd.

Perold, H and Jooste, P (eds). (2006) Employment and Unemployment in South Africa: A brief description. Johannesburg: Business Trust.

Pevsner, N. (1951) An Outline of European Architecture. Harmondsworth: Penguin (first published 1943).

Philip, R. (2004) “Skills shortage means foreigners will get SA jobs.” Johannesburg: Sunday Times, 10-08-2004.

Phillips, S D. (1992) The Viability Of Reintroducing Waterbound Macadam As A Base Course For Roads In South Africa Using Labour-Based Construction Methods. Johannesburg: University of the Witwatersrand, Unpublished MSc.

Phillips, SD; McCutcheon RT and Meyer, D. (1993) "The use of waterbound macadam basecourses for the labour-based construction of medium and heavily trafficked roads in developing areas." 12th International Road Federation World Highways Conference: Madrid.

Phillips, S D. (1994) Theoretical Analysis of Labour-Intensive Construction of Waterbound Macadam Roads. Johannesburg: University of the Witwatersrand, Unpublished PhD.

Phillips, SD; Mackay, A; Smit, J; Damstra, G; MacLeod, D and Mthombeni, C. (1995) Summary Report of the Quality of Assets Team, First Draft Report

for the NPWP Task Team and for the CEP (Community Employment Programme). Pretoria: Department of Public Works.

Phillips, SD; McCutcheon, RT; Emery, SJ; Little, R and Kwesiga, MB. (1995) "Technical analysis of the employment creation potential of a National Public Works Programme." Journal of the South African Institution of Civil Engineers, Vol. 37, No. 3.

Phillips, S D. (2004) "Expanding employment in public works in South Africa." ASIST Bulletin No. 18. September 2004. ILO/ASIST.

Radebe, J. (1994) National Public Works Programme. Pretoria: Department of Public Works.

Republic of South Africa. (1998) The building has begun! Government's Report to the Nation '98. Pretoria: Office of the President.

Republic of South Africa. (2002) "No. R63: Basic Conditions of Employment Act, 1997. Ministerial Determination No: 3: Special Public Works Programmes." Government Gazette No 23035. Pretoria: Government Printer.

Republic of South Africa. (2002) "No. R64: Basic Conditions of Employment Act, 1997. Code of Good Practice for employment and conditions of work for Special Public Works Programmes." Government Gazette No 23035. Pretoria: Government Printer.

Republic of South Africa (2004) Division of Revenue Act No 5, 2004. Government Gazette.

Rich B.R.P. (1991) The Architecture Of The Southern Ndebele. University of the Witwatersrand: Unpublished M Arch Thesis.

Rodwin, L. (1987) Shelter, settlement, and development. Boston: Allen & Unwin.

Sabnis, GM. (1983) Structural Modelling and Experimental Techniques. Englewood Cliffs: Prentice-Hall.

SAQA (2004) The National Qualifications Framework: An Overview. South African Qualifications Authority. Sourced from http://www.saqa.org.za 07-11-2007.

Singer, H. (1992) Research of the World Employment Programme: Future Practices and Selective Assessment. Geneva: ILO.

Smallwood, J and Haupt, T. (2005) "The need for construction health and safety (H&S) and the Construction Regulations: engineers' perceptions." Journal of the South African Institution of Civil Engineering. Vol 47; No 2.

Society of Genealogists and Origins. (2000) London Apprenticeship Abstracts 1442-1850. Sourced from http://www.englishorigins.com August 2004.

South African Revenue (DORA) (2000) Act No. 16: Division of Revenue Act. Government Gazette.

South African Revenue (DORA) (2002) Act No. 5: Division of Revenue Act. Government Gazette.

Spence, R J S and Cook, D J. (1983) Building Materials in Developing Countries. Chichester: John Wiley & Sons.

Spence, R J S. (1993) Jobs from Housing: Employment, Building Materials, and Enabling Strategies for Urban Development. London: IT Publications.

Stamp, P. (1989) Technology, Gender, and Power in Africa. Ottawa: International Development Research Centre.

Stewart, F. (1977) Technology and Underdevelopment. London: Macmillan.

Stiglitz, JE. (2002) "Employment, social justice and societal well-being." International Labour Review, Vol. 141: 1-2. Geneva: International labour Office.

Strassman, W P and Wells, J. (1988) The Global Construction Industry: Strategies For Entry, Growth And Survival. London: Unwin Hyman.

Tariq Ali, Z (2003) The Potential for Employment Creation and Small Contractor development in the Construction of the Constitution Hill Project, Johannesburg, South Africa. Unpublished research report, MSc (Eng). Johannesburg: University of the Witwatersrand.

Thomas, HR; Horman, MJ; de Sousa, UEL and Zavrski, I. (2002) Benchmarking of Labor-Intensive Construction Activities: Lean Construction and Fundamental Principles of Workforce Management. Rotterdam: International Council for Research and Innovation in Building and Construction.

Thwala, WD and McCutcheon, RT. (1999) "A Critical Evaluation of Large Scale Development Projects and Programmes in South Africa," in Forging the links between historical research and the policy process. Johannesburg: University of the Witwatersrand, History Workshop.

Thwala, WD. (2000) A critical evaluation of large scale public work projects and programmes in South Africa 1980 to 1997. Johannesburg: University of the Witwatersrand, unpublished MSc(Eng) Dissertation.

Tipple, G. (2000) Extending themselves: User-initiated transformations of government-built housing in developing countries. Liverpool: Liverpool University Press.

Turner, JFC and Fichter, R (eds). (1972) Freedom to Build. New York: Macmillan.

UNDP. (2004) South Africa Human Development Report 2003: The Challenge of Sustainable Development in South Africa: Unlocking People's Creativity. Oxford: Oxford University Press for United Nations Development Programme (Asghar Adelzadeh - Principal Author and Coordinator).

United Nations (2000) Millennium Declaration http://www.un.org/millennium/declaration/ares552e.htm (accessed 2006/09/03)

Ural, O (ed). (1979) Housing, Financing, Construction. New York: Pergamon.

Van Steenderen, WPC and McCutcheon, RT. (2000) "New challenges in development: a case study in Sekhukhuneland, South Africa." ILO 8th Regional Seminar for Labour Based Practitioners. Cairo.

Van Steenderen, WPC and McCutcheon, RT. (2003) "The Use of Sulphonated Petroleum Product Stabilisers in Employment- Intensive Road Construction." In McCutcheon, RT and Taylor Parkins, FLM. Employment and High-Standard Infrastructure. Johannesburg: WORK Research Centre for Employment Creation in Construction.

Van Staden, M A. (2005) An investigation into the use of stocklam timber for housing in South Africa. Johannesburg: University of the Witwatersrand, Unpublished BSc Building dissertation.

Van Wyk, L. (2003) A Review of the South African Construction Industry. Part 1: Economic, Regulatory and Public Sector Capacity Influences on the Construction Industry. Pretoria: CSIR Boutek.

Van Zyl, J; Kirsten, J and Binswanger, HP (eds). (1996) Agricultural land reform in South Africa : policies, markets and mechanisms. Cape Town : Oxford University Press.

Vahrenkamp, R. (2006) “Roads without Cars: The HAFRABA Association and the Autobahn Project 1933-1943 in Germany.” University of Kassel, Faculty of Economics and Management. www.ibwl.uni-kassel.de/vahrenkamp

Wagner, W F. (ed.) (1976) “Human Settlements - The Winning Designs” Architectural Record. May. Bonn: McGraw-Hill.

Wells, J. (1986) The Construction Industry In Developing Countries : Alternative Strategies For Development. London: Croom Helm.

Wells, J and Wall, D. (2001) “The role of structural adjustment policies in the expansion of employment in the building construction sector in Kenya and Tanzania.” In McCutcheon, RT and Taylor Parkins, FLM (eds) (2001) WORK2001: First International Conference on Employment Creation in Development. Johannesburg: WORK Research Centre for Employment Creation in Construction, University of the Witwatersrand.

World Bank. (2001) World Development Report 2000/2001: Attacking Poverty. New York: Oxford University Press.

The following internet sites have been accessed regularly between 2003 and 2009:

http://www.ceta.org.za/

http://www.epwp.gov.za/Downloads/technical_legalguidelines.pdf

http://www.egyptarch.com/egyptarchitect1/hasanfathi/ngourna/main_gschool.htm

http://archnet.org/library/images/

http://hrdwarehouse.hsrc.ac.za

APPENDIX 1: TRAINING

Studies in employment-intensive construction of rural roads as well as high-standard infrastructure have shown that training is essential at all levels for effective delivery (McCutcheon and Taylor Parkins 2003). This is of critical importance for the construction sector in South Africa at present, with significant impact on the country's economy as a whole. To cite one of many media articles highlighting this issue: "One report by the Human Sciences Research Council … showed technical skills to be the country's greatest labour scarcity …" attributed to "… a chronic decline in apprenticeships – including a slide from 29 800 in 1986 to 16 500 in 1998 – little vocational guidance at schools, and "ineffective" technical colleges," (Philip: 2004).

Throughout the main body of the present thesis, the significance of training has been highlighted as a critical component to achieving economy and efficiency that allows employment-intensive construction to compete with other methods in terms of cost, time and quality. Specifically, the integration of training into the programme of construction is discussed in section 8.1.2.

This appendix provides background and a more detailed discussion of the challenges facing the South African and broader global construction sector in relation to education and training. It is set predominantly in the South African context with its unique historical background as a preface to discussion on the new education and training framework. Training for technical competence is investigated, from the perspective of conventional approaches and more innovative ones. Principles for a training model in the specific context of the study area are posited, based on this research.

A1.1 OVERVIEW OF SKILLS TRAINING IN THE BUILDING INDUSTRY

A number of interrelated challenges pertaining to skills training in the construction sector have been identified as being of concern both to the developing and

developed world. An ILO document (ILO 2001) emanating from the "Tripartite Meeting on the Construction Industry in the Twenty-first Century, Geneva 2001" presents the major issues from a global perspective as being:

- The high and growing percentage of workers in the informal sector and in 'labour only' subcontracting;
- The need for these 'casualized' workers to spend their time between projects engaged in 'jobbing' and seeking work, rather than spending this down-time in training programmes;
- The fact that many of the people attracted to the construction sector lack formal education, and thus find it difficult to progress beyond the more menial activities[106];
- The gap between the informal and formal components of the sector in relation to productivity and quality of workmanship, making the transition into the formal sector difficult.

The increase in numbers of workers in the informal sector brings with it serious implications for training in the industry. People engaged by a contractor or public body for a significant time can gain skills incrementally on an informal apprenticeship system, and are more likely to be sponsored or supported in other ways in furthering their training through formal channels, in that the employer will be the immediate beneficiary of improved quality and productivity. In both ways (in the workplace and through training), and ideally in combination, the employee can achieve a level of skill that can be measured, either through formal accreditation or through less formal means, such as evidence of completed work and letters of recommendation. In the informal sector, all of this becomes tenuous[107], thus leaving the employees of informal contractors extremely vulnerable from the perspective of improving their employability.

---

[106] "Construction as a sector … employs the fourth highest number of persons having no education … (and) also has the fourth smallest percentage of employed persons with a higher education qualification, behind households, agriculture and mining," (Van Wyk 2003: 1). Figures derived from the South African census 2001.

[107] The ILO document (ILO 2001) and other sources identify that the shift to casualization is precisely because of the cyclic and volatile nature of construction work, and that casual labour is

Moreover, where mechanisms are put in place by authorities to encourage workplace and 'lifelong' training, the informal employer is often (understandably) reticent about involvement in training programmes. There is a perception that in subscribing to one formal structure, questions will be asked about other practices, such as tax evasion, and lack of compliance with occupational health and safety regulations, building codes and other statutory requirements. The miniscule profit margins in the construction sector and the volatile nature of the industry are arguably the greatest factors producing the high attrition of emerging building contracting firms. Once locked into formal sector structures, these regular levies and expenditure can be the difference between the survival and failure of the small entrepreneur during economic downswings.[108]

In the developing world, low levels of formal education exacerbate the problems of 'unemployability' within the mainstream economy, and put an increased burden on the construction sector through its ability to "absorb the excluded" (de Souza 2000). It is regarded as "the only significant alternative to farm labour[109] for those who do not have any particular skill" (ILO 2001). The converse of this is that conventional skills training and education need to be refashioned to attain acceptable success rates of trainees, for example by including basic literacy and numeracy courses along with the vocational subjects. At the upper end of the skills ladder, construction (and its related professional disciplines) is increasingly regarded as an inferior field of endeavour for those who have a choice of career. This has particular importance for employment-intensive construction, where the

---

employed only for the duration that their labour is required. On leaving the job, they return to the labour pool, and any improvement in their skills becomes potentially to the benefit of a competing contractor.

[108] In Europe the vulnerability of small enterprises in all sectors is high, for example, loans granted to small and medium enterprises "… are provided with an expected annual loss of 25% …" (Farstad 2001:351), and research in UK indicates a failure rate of small businesses to range between 30 and 50% in a three year period. Volatility, competitive tendering and project dynamics all contribute to a higher statistic in construction, and within this sector Merrifield (2000) has assessed that, within the South African business environment, an even higher statistic can be expected. In the formal construction sector in South Africa, 1 400 companies were liquidated in the period 2000 to 2002. (Van Wyk 2003:2)

[109] Water shortage and land degradation resulting from rural overcrowding in apartheid 'homelands' in many parts of South Africa has made subsistence agriculture impossible, and organised farming expensive to initiate, whether using labour or machine intensive methods.

highest calibre of professional, technical and managerial people is required because of the commitment, depth of knowledge and creativity that is demanded to ensure successful programmes and projects (Geddes 2001).

Commentators (ILO 2001) note the diminishing role played by public bodies as direct providers of construction services, preferring to subcontract out almost all of the building work, including maintenance of public facilities. This exacerbates the situation outlined above, in that public sector employers do not have the same concern about 'head hunting' of their trained staff, and traditionally (eg in South Africa) the public authorities have been significant providers of bursaries for students in professional and high-level technical studies.

In South Africa, as with the rest of the world, the other substantial employers in the construction sector were traditionally the large contracting companies. Increasingly the trend is for these to move to management subcontracting, shedding their craftsmen as well as their less skilled workers. The scale of their operations allowed on-site training to take place, as there were enough skilled artisans to support the apprentices. With subcontracting, the influential companies no longer have a vested interest in any training except for their highly qualified in-house management staff.[110]

It is generally acknowledged that there is a direct correlation between skills levels and productivity (Chan, et al. 2001).[111] What is less obvious is the effect of health and safety (or their lack) on the output of individuals and the building site as a whole (Thomas 2002:136). A good training programme has, at its heart, good practice with regard to use of tools, awareness of other workers on the site, and

[110] There has been a concerted effort by most of these large companies in South Africa to engage in mentorship programmes with their subcontractors, with incentives provided by government. However, most of the training and skills transfer has been directed towards management, no doubt to improve the interface between subcontractor and management contractor. The burden of quality and productivity remains with the subcontractor.

[111] "A recent international productivity survey found that South African businesses used only 59% of their time productively, with poor planning and inadequate management still the key reason for time wasted." (Van Wyk 2003:2)

issues relating to personal health. The construction sector in South Africa has one of the worst Occupational Health and Safety records (Smallwood and Haupt 2005:3). The shift to employment-intensive methods may decrease the severity of accidents in comparison with those involving machines, but the sheer number of people working on the site puts great emphasis both on individual workers and on management (see Fig A1-1).



Fig A1-1: Rural Access Roads Programme, Kenya. (Photo: RT McCutcheon)



Fig A1-2: Quarry, Rural Access Roads Programme, Kenya. (Photo: RT McCutcheon)

The cyclic and volatile character of the building industry has a number of negative influences on training, including:

- The argument from contractors that the demand for skilled labour is unpredictable in both type and quantity,[112] thus not justifying the cost and time required by training;
- The skills shortages that result from this attitude result in increased use of machines to achieve the required quality and productivity levels;
- Once a contractor has moved to mechanised methods, especially where the machines have been purchased, he/she seldom returns to the more labour orientated techniques.[113]

The cost of training to the employer/contractor and the individual worker (whether in actual outlay, down time or disruption in the flow of work) is often cited as a primary reason for the lack of interest: "…the real cost of upgrading their skills … are high and the rewards uncertain," (ILO 2001). What is not generally aired is the cost (to individual, to contractor and to society) of NOT training. The health and safety issue is but one aspect, but other factors include the lack of sustainability of low-skilled jobs, and the lack of competitiveness of both the worker and the contractor.

In countries where skills levies are in place, the shift to casualization of labour and subcontracting by informal operatives has diminished this resource base, allowing the cost of training either to government or other sectors of the economy, or leaving the training programmes to stultify and collapse. While this is has not been a problem in South Africa, in that more revenue has been coming in from established contractors than is being used for training, CETA has already identified this as a problem area, especially as the Expanded Public Works Programme is rolled out.[114]

---

[112] The complexity of building (in comparison with most civil engineering construction) serves to exacerbate this problem, especially where the more skilled operatives have not reached full artisan capacity with the attendant abilities to adapt their skills to new circumstances.
[113] This creates a downward spiral, where there is less demand from contractors for skilled artisans, and professional and client expectations are lowered in terms of craftsmanship.
[114] The Skills Development Levies Act of 1999 exempts small businesses, defined in the Act by the annual expenditure on wages and salaries. This is essential, given their vulnerability, but where established contractors increasingly shed their direct labour force and move to

For the individual worker, time, money and disruption resulting from engaging in training must be seen to have value. Researchers and commentators have pointed to the importance of certification of training programmes, and individual courses within them, so that the results of training are immediate and measurable (ILO 2001).

The building industry suffers from an additional barrier to effective training of site personnel through the conventional division of design and construct. This was the major criticism of the building industry in a report in the 1960s in the United Kingdom,[115] the home of contractual practices used throughout the English-speaking world. Professionals are not trained to design, detail and specify for the skills that are available, to facilitate on-site skills development, or to consider efficient processes and use of materials that would contribute to the productivity and quality of the work. Where artisan and managerial skills are scarce, this contributes to a general lowering of expectations and an excuse to move to machinery to meet demands from the professional team for quality and time performance.

The factors outlined in this section show fundamental problems facing the construction sector as a whole, and the building industry in particular. Most of these characterise the building industry throughout the world, but have a more severe impact in developing countries, where poverty, inadequate basic education and lack of infrastructure compound the problems.

A1.2 TRADITIONAL METHODS OF TRAINING

The training of building craftsman through the medium of apprenticeship is indicated as early as 4 100BP in the Mesopotamian Code of Hammurabi.[116] The

---

subcontracting, the funds from the levy must necessarily decrease.

[115] Banwell, H. (1964) *The placing and management of contracts for building and civil engineering work.* London; HMSO.

[116] Hammurabi's Code also prescribed minimum wages for day labourers and skilled artisans (273-274), and stringent remedies for bad workmanship on the 'eye-for-an-eye' principle (229-233) (King 1910).

importance of transferring the craftsman's skills to the apprentice is enshrined thus: "If an artisan has undertaken to rear a child and teaches him his craft, he cannot be demanded back (188). If he has not taught him his craft, this adopted son may return to his father's house (189)," (King 1910). An explanation for the development of this method in the Middle Ages, in contrast with parents passing down their own skills is that, "as tools became more complex, and the knowledge and skills to use them became more specialized, parents … could no longer teach their children everything. Children were apprenticed to craftspersons or artisans who had the specialized skills and tools for a particular trade" (Clark 1999). What is noteworthy here is the emphasis on tools to meet high levels of craft: no longer is the 'standard builder's toolbox' sufficient when the craftsman is required to produce work of exceptional quality and technical complexity.

The organisation of the building industry from within was linked to the evolution of guilds that "… were an important part in apprenticeship as they established the quality standards for the product and practice,"(Clark 1999). The guilds, in return, ensured that their apprentice members were protected in terms of hours of work and wages.

In the Near Eastern, Western and Anglophone colonial world, the tradition of apprenticeship has continued unbroken to the present, adapting to the major changes brought about by the Industrial Revolution. In parts of Africa, a similar model has evolved (Blier 1987), unsurprising given the clear advantages of learning by example and through observation. The complexity of tasks and the need to adapt them to specific contexts are often best served in a one-to-one learning environment, where the 'master' is highly skilled and experienced.

A1.2.1 The apprenticeship system

In Britain, before the Industrial Revolution, most people[117] began their apprenticeship between the ages of 14 and 19 (not younger than 11) and

[117] "… there was a significant number of girl apprentices, though much fewer than boys …" with

"generally lasted seven years" although usually longer "if the apprentice was younger than normal when indentured," (Society of Genealogists 2000). In this 'traditional' format, the apprentice would gain all practical and theoretical skills and knowledge from his 'master' and through working alongside more experienced apprentices and journeymen. It was thus entirely dependant on the abilities of the master, both in his expertise, and his ability to transmit it to the apprentice. Where the system was overseen by a guild, measures were in place to ensure quality and consistency, as well as to establish conditions of the relationship between master and apprentice. On completion of the apprenticeship, the individual would become a journeyman for a few years, moving from site to site to gain additional experience to equip him to become a master in his own right.

In its mature form "… education for work was organized in such a way that basic knowledge could be developed in a classroom setting and applied skills could be developed on-the-job," (Society of Genealogists 2000). This form of training is still prevalent, where the learner has blocks of classroom and simulated hands-on experience in a training yard, alternating with site work for a contractor. In this way some of the variables of a pure apprenticeship are minimised, in that the more theoretical aspects are addressed in a fairly controlled environment.

A1.2.2 Advantages of apprenticeship

The advantages of the apprenticeship system of training in the building industry can be summarised as follows:

1. the apprentice learns by example and in a productive environment, thus contextualising knowledge and skills;
2. no extra equipment is required other than what is required to do the job;

---

the proportion of girls depending on the craft; "… girls could be apprenticed, and so become masters. There are, however, relatively few records of women masters," (Society of Genealogists 2000). These records of the London Livery Companies appear to have had close parallels with other European cities and countries. The scarcity of female 'masters' needs to be interpreted both in the context of the society's norms, and because the woman's potentially most productive years from a work point of view are also when she would be bearing and raising children.

3. training is holistic – physical and cognitive skills are fully integrated, management tasks (eg care of tools, safety, orderliness, material quantities and interfacing with the rest of the workforce) become habitual;
4. because it is a one-on-one process, the 'master' constantly evaluates the artisan in terms of passing on to more complex or diverse activities;
5. from a site management perspective, it is easy to organise in that the 'master' takes full responsibility for the trainee.[118]

However, where there is a shortage of skilled and experienced artisans, and/or where training needs are great (both of which characterise the South African building industry at present), the time required to train the apprentice effectively and the reduction in the 'master's' productivity mean that other methods need to be explored. For example, during World War II, "Job Instruction Training" was developed in which supervisors in defence plants were trained to instruct their workers on a much shorter timeframe. In the same decade, Hassan Fathy developed a training model to maximise the effectiveness of skilled craftsmen as teachers and to prevent the abuse of the apprenticeship system where the artisan slows down the training to prevent excessive competition in his field of expertise (see Chapter 5.3).

A1.2.3 The collapse of the apprenticeship system

A number of interlinked factors can be attributed to the worldwide decline in apprenticeship as the principal method of training tradesmen in the building industry. These include:

- For the apprenticeship system to work efficiently, there needs to be continuity of work to support the apprentice's learning process. The demand for any specific trade in the industry, but especially the more highly skilled work, is unpredictable (ILO 2001);

[118] A good 'master' will also instruct the apprentice on body movements, handling of tools, efficient placement of tools and materials, and even nutrition and appropriate clothing. All of these aspects are difficult to teach in a classroom or training yard with several learners, and each contributes significantly to productivity and quality.

- The effect of training on the productivity of the artisan or master craftsman – at the extreme, "OJT (on-the-job training) takes the trainer and materials out of production for the duration of the training time" (Clark 1999);
- It demands sufficient numbers of skilled and experienced artisans to do the training, and there is a limitation on the number of apprentices that any one artisan can supervise at a time;
- A low level of skill and/or limited experience of the artisan limits the effectiveness of the training unless a rigorous process of assessment (both of the artisan and the apprentice) is in place, with appropriate back-up;
- There are limitations to the system in the context of rapidly developing technological change, unless the artisan or master craftsman is also engaged in ongoing training;
- The training experience is restricted to the particular conditions present in the work being undertaken through the period of apprenticeship (hence the 7 years in Medieval times). At present, this is even more of a problem in terms of the range of skills and applications required, type of work undertaken by the artisan, and the artisan's own abilities because of specialization;
- A good artisan or craftsman is not necessarily a good teacher and it is difficult to find people who have both a good mix of skill, knowledge, experience, and the ability to transfer these to the learner[119];
- There is often resistance to expediting the training process because of an unwillingness to flood the market and produce more (and possibly better) competition;
- It is regarded as an inefficient method of training, especially when suitable 'masters' are in short supply for direct production, even before contemplating the reduction in their performance through taking on a training role.

[119] Personal communication, Elizabeth Beard, 2003.

In South Africa, additional factors have to be taken into account due to its 'split economy' and to the legacy of colonial and apartheid rule. The events that have led to the situation inherited by the democratic government in 1994 are outlined below.

A1.3 SOUTH AFRICA UNDER APARTHEID

A number of issues deserve consideration in an analysis of the present skills and training situation in South Africa. Crippling skills shortage, coupled with the breakdown in traditional modes of training, has become an increasingly disturbing inhibitor of the country's ability to meet its own development targets. Reports from government driven research have become frontline news,[120] highlighting the construction sector's inability to provide the technical skills necessary for planned and approved capital projects.

A brief outline of the legislation that undermined technological capacity, and response by opposition forces to this, gives an insight into the particular factors that have produced a post-colonial scenario in its most extreme form. Even before the Nationalist (apartheid) government came to power in 1942 legislation had been promulgated to protect white workers from competition of other race groups. For example, in 1924, the "Industrial Conciliation Act" stated that any 'worker whose contract of service or labour (was) regulated by any Native Pass Laws and Regulations' was not to be considered an 'employee'," for the purposes of any kind of legitimised industrial action. It followed the 'Native Affairs Act' of 1920 that introduced job reservation on the basis of race and the 'Apprenticeship Act' that favoured whites over blacks. Several Acts were promulgated in the 1920s that were intended to protect white workers, of whatever level of skill, from competition from blacks or Asians. For example, in an effort to encourage the employment of whites by white employers, a minimum

[120] One of many articles includes, for example: "One report by the Human Sciences Research Council, using figures from 2000, showed technical skills to be the country's greatest labour scarcity…. Meanwhile, a much broader HSRC report … blames a chronic decline in apprenticeships …" (Philip 2004).

wage was legislated by means of which "the government hoped that the act would tend to price black workers out of jobs," (Luli 2004).[121] Restriction of blacks into urban areas through the 'Native Urban Areas Act' of 1923 has particular significance for the building industry in that blacks were debarred from seeking work in urban areas, thereby preventing 'jobbing artisans' from operating, and encouraging white contractors (with other legislation, as outlined above) to confine their permanent workforce to whites.

This, and similar pre-apartheid legislation, speaks of societal racism favouring whites, but it took the Nationalist (apartheid) government to institute a web of laws that prevented blacks from operating in any capacity beyond that of menial worker. Restrictions on places of residence, the ability to seek work, and reservation of skilled work all existed in some form before 1942, but the contrast lies in favouring one population group over the rest, versus active legislation debarring some inhabitants from engaging in social, economic and intellectual aspects of life. The individual pieces of apartheid legislation are too numerous to cite here, but almost every one can be shown to have inhibited anybody but whites from becoming active members of the socio-economic environment in which they lived.

The most significant of these laws to this study, in the sequence that they were promulgated, were:

- The "Black Building Workers Act No 27 of 1951" that prohibited blacks from performing skilled work in white urban areas (Feinstein 2005:157);
- The "Native Laws Amendment Act No 54 of 1952" that gave the authorities the power (among other draconian measures) to remove 'idle' blacks from white urban areas, even if they were there legally. This effectively prevented people from seeking work from formal sector (white) contractors, or jobbing as independent contractors;

[121] The effectiveness of this strategy is proved in the awarding of the contract for the William Cullen Library, University of the Witwatersrand, where the winning tenderer submitted two tenders, the more expensive using white labour only being the one accepted (Murray 1982).

- The "Bantu Education Act No 47 of 1953" formalised the segregation of black education, to result in the medium of instruction being either indigenous languages, for which there were no text books, or Afrikaans, the overt cause of the 1976 schools protests. Of particular importance here was the elimination of maths and science from the high-school syllabus, thereby leading to generations of the majority of the population being debarred from technically or professionally orientated careers;
- A labour relations act of 1953 prevented blacks from being members of registered trade unions, later (in 1956) to be amended to entrench job reservation on racial lines by excluding blacks from the definition of 'employee', thus tightening up the 'Industrial Conciliation Act' of 1924;
- To prevent the few blacks who had been able to complete their schooling from entering the professional world, the "Extension of University Education" Act of 1959 prohibited blacks from entering the Universities of Cape Town and the Witwatersrand and restricting them to 'black' tertiary institutions where professional and technical courses were not offered.

Chief Albert Luthuli[122] summed up the effects of the combination of these pieces of statute in 1958: "Every door through which we might have sought advancement, culture and a higher civilization has been slammed in our faces. Our schools are being turned into schools for ignorance, tribalism and servitude. The universities are being closed to us. Any sphere of employment other than ill-paid unskilled labour is being closed to us." It is against this background that the democratic government of 1994 began the process of re-evaluating the education system and the massive skills incapacity of the country from basic literacy and numeracy, to professional and managerial levels that had been depleted by the exodus of highly educated people during apartheid rule.[123] Problems confronting the construction sector globally, and more severely in

[122] Luthuli was the Nobel Peace Prize winner in 1961 and president of the ANC.
[123] Several were exiled because of their political affiliations, but many left because of army conscription, ethical reasons or because of the distorted social and economic environment that was a direct consequence of apartheid.

countries emerging from colonialism, are compounded in South Africa by the blatantly skewed educational, social and economic frameworks honed over the 40 years of apartheid power.

A1.4 POST-APARTHEID SOUTH AFRICA

In 1992, during the transitional phase to South Africa's democracy, the government, through the Department of Manpower, finally responded to trade union pressure for training and legislation reform. Not only was access to formal training barred to the majority of the population, but the formal method of apprenticeship training itself had lost favour, with registration for apprenticeships dwindling alarmingly from the 1970s to 1995, by 80% (Bird 2001:2). In 1995, as a result of the collaborative efforts of the Departments of Education and Labour, the South African Qualifications Authority Act (No. 58 of 1995) was passed into law, heralding a fundamentally different approach to education and training countrywide.

All education and training, in whatever format it is delivered or acquired, now falls under the National Qualifications Framework (NQF). Two of the major principles governing the NQF are:

1. the acknowledgement of the inequitable access to formal learning under apartheid, responded to through the process of Recognition of Prior Learning (RPL) that forms the basis from which individuals '…have the opportunity to progress further in learning…" (Bird 2001: 3) through a structured career path with nationally certified qualifications[124]; and
2. the integration of theory and practice, structured around outcomes based syllabus frameworks, education methods and methods of assessment.

The emphasis on 'outcomes based' education and assessment is primarily in response to the need for a more responsive workforce, as well as empowering

[124] Two primary objectives are embodies in RPL, the "need to accelerate the redress of past unfair discrimination in education, training and employment opportunities," and "to recognise the learning that has taken place outside traditional learning contexts," (SAQA 2004).

individuals to take charge of their own careers. In the words of SAQA: “The shift in thinking is from education for employment – developing the ability to do a specific job – to education for employability – developing the ability to adapt acquired skills to new working environments,” (SAQA 2004).

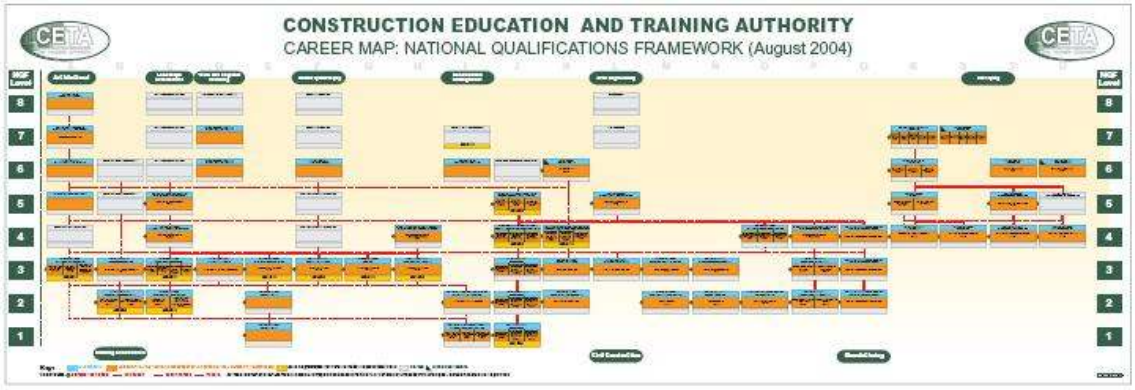


Fig A1-3: CETA Career Map. (CETA 2004)

The South African Qualifications Authority (SAQA), comprises members appointed by the Departments of Education and Labour on consultation with stakeholders involved in education and training. Its two primary functions are:

- to formulate policies and criteria for the registration and accreditation of bodies responsible for establishing education and training standards, and monitoring and auditing performance in terms of these standards;
- to oversee the implementation of the National Qualifications Framework (SAQA 2004).

Several bodies are directly accountable to SAQA, the most important of which, to this study, is the Construction Education and Training Authority (CETA). It is one of several sector authorities (SETAs) representing all areas of economic activity.

The five objectives of the National Skills Development Strategy that emanate from the National Qualifications Framework are:

- To develop a culture of high quality lifelong learning;
- To foster skills development in the formal economy for productivity and employability;
- To stimulate and support skills development in small business;

- To promote skills development for employability and sustainable livelihoods through social development initiatives; and
- To assist new entrants into employment. (Dept of Labour 2001)

NQF level	Band	Qualification type
8 7 6 5	Higher Education and Training	Post-doctoral research degrees Doctorates Masters degrees Professional qualifications Honours degrees National first degrees Higher diplomas National diplomas National certificates
Further Education and Training Certificate (FETC)		
4 3 2	Further Education and Training	National certificates
General Education and Training Certificate (GETC)		
1	General Education and Training	Grade 9 national certificate and Adult Basic Education and Training Level 4

Table A1-1: NQF Framework. (SAQA 2004:6)

As an all-encompassing framework, the NQF is structured around eight levels. (See Table A1-1) In this system, artisan training in the construction sector is through learnerships at level 3, with expected duration of 12 to 18 months. The apprenticeship system has been replaced entirely. A learnership is “a planned combination of learning outcomes which has a defined purpose and which is intended to provide qualifying learners with applied competence and a basis for further learning,” (SAQA 2004:5). In the case of most qualifications administered by CETA, it combines classroom and workplace learning, and is intended to equip learners with ‘knowledge, skills and values” (SAQA 2004:2), thus integrating the previously separated ‘education’ and ‘training’ in the past systems.

The Skills Development Act No.97 of 1998 and the Skills Development Levies Act No.9 of 1999 have been put in place to provide funding for skills training. The levy grant scheme aims to expand the knowledge and competencies of the

labour force resulting in improvements in employability and productivity. The intention is to stimulate skills development by enabling employers to reclaim some expenditure on skills enhancement initiatives. Levies are paid by employers into the National Skills Fund through the South African Revenue Services, from which Sectoral Education and Training Authorities pay levy-grants to qualifying employers.

The most commonly voiced criticisms of the CETA learnerships and especially its skills programmes, are that they are of such short duration that the skills acquired do not lead to sustainable employment opportunities. A sample of skills programmes registered in the second half of 2004 range from two to six month training periods, linked to specific projects (CETA 2004). A trainee exits the programme with quite specific skills, but there is no guarantee that she or he will have the opportunity to proceed on a career path that will fill out a well-rounded qualification. In the words of a public servant in local government: "What we need is a class of entrepreneurial artisans," (Chainee 2004).[125] Given the lack of mobility of most workers at the bottom end of the skills hierarchy, and the requirement of many publicly funded projects for employment from the immediate community, the CETA career paths are arguably too idealistic. This has been identified as a particular problem where a number of members of a community have been exposed to short, project specific, skills programmes with no opportunity of progressing to a higher level, thus creating a saturation of low level skills (Fitchett 2001). Hampering the attainment of craftsmanship equivalent to full apprenticeship training is the lack of 'bedding in' time in which to develop high levels of productivity and quality. Similarly, exposure to site and team management skills is limited, thus hampering the ability to set up as an independent subcontractor. These challenges have been acknowledged by CETA, and are mitigated to some extent by ensuring that the workplace components of qualifications are guaranteed, but there is considerable scope for enhancing this aspect of the training process.

[125] Personal communication. Mr Chainee is an official in the Ekhuruleni Local Authority.

The primary challenge to effective skills development in South Africa is in addressing the poor quality of basic and general education (both in the past and currently) for the majority of its people as disparities between rural and urban, rich and poor schools are incrementally addressed. The consequences of this translate into jobless growth and, where skills demands cannot be met, vindicating the use of machine intensive processes. Further up the skills ladder, gaps in literacy and numeracy are revealed when learners progress to levels demanding higher-level cognitive skills, such as those required for management functions.

On balance, CETA's approach to training is an appropriate vehicle to accommodate the complexities of the South African skills void at present and in the near future. More valid than proposing another radical change to the training system, with consequences on research and implementation time and cost, burdens created through change in legislation, and further confusion for all parties operating within the industry, this thesis proposes that the CETA method be enhanced. In the longer term, when the skills void has been addressed to some extent, and when the education system is operating effectively, then would be the time to revisit vocational training to arrive at a system that addresses the criticisms, if in fact they are found to be valid when the system reaches maturity.

Thus a two-pronged approach to artisan training is put forward here – where professionals and other decision makers adapt their designs and specifications to the skills that *are* available, and that they structure projects and programmes to assist in the *development* of the skills base.

A1.5 THE MODEL AS A VEHICLE FOR TRAINING

In developing the design and specification for employment-intensive construction where artisan training is a key objective, the professional team should work closely with experienced site operatives (contractors, site supervisors and

artisans) during the phases from feasibility to contract documentation to determine local skills levels and types, productivity rates and quality expectations. These should be revisited with the specific workers on site and be part of an ongoing process of monitoring and evaluation. What is proposed here is a generic example, worked in collaboration with construction managers, as an example of the kind of training structure that would result from such a process.

A1.5.1 Artisan training

Some fundamental principles of artisan training can be defined that are essential for effective employment-intensive construction. On the one hand, these would be considered to be good practice for every method of construction, but take on special significance where the labour force is the primary consideration. These include greater attention to productivity, quality, and health and safety, to ensure that each project can compare favourably with more machine intensive techniques. By ensuring that these principles are entrenched, the learner's competitiveness in the open market is improved.

Of specific importance to employment-intensive construction are: an emphasis on using materials and methods that have a high local labour content; training for more people on site, such as orderliness and not crossing other activity paths; encouraging capacity to train or mentor on site without lowering quality or productivity; teaching management functions at all skills levels, including the theory and rationale of these processes. The latter would include, at artisan level: calculation of daily quantities of materials, pre-empting materials shortages on site, self-motivation, motivation of less skilled members of a team, and taking initiative.

The professional and contracts management team can facilitate these principles in the following ways:

a) Productivity can be enhanced through greater buildability and planning for efficient use and minimal wastage of materials;

b) Sequencing of work from basic to more complex tasks;
c) Assisting the contractor in developing task-based or output-based methods of evaluation as a means of restoring productivity to that current in the 1970s. (This could require the defining of rates for each task – eg foundation walling, taking up corners, reveals, sills, lintels, ring beams, beam fill for masonry, etc. or could work on a baseline output, discounted where more complex work is needed.)
d) Training for quality should leave room within the design and specification for increasing levels of sophistication, eg plaster thickness, that is consistent with the process of construction;
e) Design should be robust to accommodate low entry skills so that the building is satisfactory, even with coarse detailing. The sequence of work should be planned so that the detailing becomes more refined to satisfy the different uses of parts of the building.

There should be scope for the last activities in each trade to demonstrate the trainees' achievement, with aesthetic freedom to produce an equivalent to the Medieval craftsman's masterpiece.[126] Not only does this encourage pride in workmanship, but it reinforces the value of employment-intensive construction as being 'hand-crafted' and not just a means of generating jobs.

Fig A1-4 shows the stages of construction of a typical public building, here shown as a road camp that would be converted to a primary school after the road is complete. The building itself maps out the training process, moving from simpler to more complex activities, in keeping with the various functions accommodated in each part. These are designated from the lowest skills requirements (in red) through the spectrum to the most challenging, highly serviced parts (in purple). In remote areas, a single team of workers could build the entire project, progressing to the higher skills levels as they complete each part, but ideally, at least two teams starting at different levels should be deployed. This allows for more

[126] In West Africa, the craftsmen have an equivalent 'signature' on each building they construct, adding pride to their work, and thereby greater status to the industry as a whole. (Blier 1987)

efficient completion of the building, but more important to the training process is that the less skilled people will benefit from working alongside more experienced artisans, and the more highly skilled can be encouraged to share their learning with the rest of the workforce.

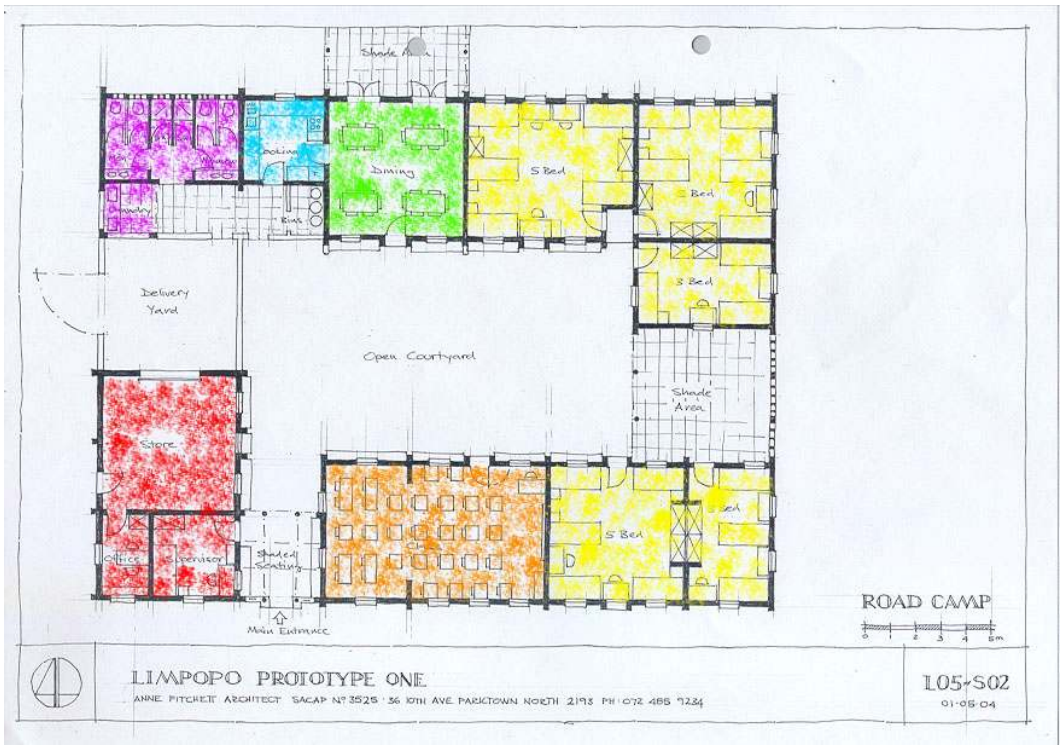


Fig A1-4: Road Camp/primary school showing sequencing for different skills levels.

In a hypothetical project, the part shown in red that comprises the materials store and supervisor's accommodation would have elementary detailing, such as rubble stone foundations, stretcher bond brickwork, bagged plaster to the interior of the store and rough one-coat plaster for the rest. Windows would be fixed-section, with separate fixed timber louvers for ventilation. The large door to the store could either be installed later in the construction process, or could be done by an external subcontractor. Floors would be wood floated, with carpet or matting to the supervisor's room. Roofing would follow a clockwise sequence of construction so that the smallest span (over the ablutions and kitchen) would be built first, and all the roofing would commence after the walling is complete.

The classroom (shown in orange) would be a 'trial run' for the bedrooms in that the same materials and detailing are used for both parts, but a higher level of quality would be expected in the yellow parts. Flemish-bond brickwork would be introduced, with two-coat plaster. The floors would be steel float concrete. Casement windows would be used, with the addition of separate pivoting louvres. Built-in timber furniture would be specified, increasing in complexity for each section of these two parts.

Greater refinement of detailing is required for the dining hall (in green), as a public space. Increasing complexity of brick bonding and carpentry would be introduced, including pivot-hung windows with timber sills, double-leaf glazed doors and loose furniture.

The kitchen (in blue) and the ablutions (shown in purple), would be detailed to accommodate tiling and water-resistant flooring. Problems of plumbing and water reticulation are introduced, and more advanced electrical work for the stove and distribution box is needed. On completion of the superstructure, the roofing would commence, requiring the co-ordination of carpenter and mason for the profile boards for the vaulting. Plastering of the roofs will require the greatest attention to ensure that they are waterproof and have a smooth finish.

The building is completed with the external works and the entrance structure. For these, an open brief is given to the artisans to encourage creativity and pride in workmanship, ideally reflecting the highest quality of skill that they have mastered.[127]

When the building is no longer required as a road camp and training facility, it is planned in such a way that it can be converted easily into either a school or a Multi-purpose Community Centre. The detailing and specification lends itself to

[127] This has been used to excellent effect for over 100 years in the *Sagrada Familia*, in Barcelona, by Antonio Gaudi. The result is a dynamic interaction of the architectural and artistic programme, a worthy successor to the great cathedrals of the Medieval period.

this, in that the initial phases of the building work can be upgraded easily for their new uses.

In this way, the building design, specification and detailing not only facilitates the training process, but serves as a visual demonstration of the levels of skill achieved by the trainees. In this way, employment-intensive practices can be showcased, with the concomitant importance of training for this method of construction.

A1.5.2 Management training

The experience of employment-intensive civil engineering works, such as the Kenyan Rural Access Roads Programme shows the critical importance of management capacity at all levels. There is also a widely held contention that small operatives are likely to generate more employment per unit of expenditure than large companies that have a tendency towards highly mechanised methods. Hattingh, moreover, has shown that the low levels of capital needed to establish a contracting company that focuses on employment-intensive processes facilitate the development of small contractors. (Hattingh, McCutcheon and Richardson 2007:7) However, the experience in nurturing inexperienced contractors to the point where they can be competitive with formal sector tenderers has not been consistently successful. Egbeonu (2006), for example, has shown the problems experienced with mentorship, a framework used extensively in South Africa.

It is the contention of this thesis that other methods need to be devised to support the formal training of small manufacturers, contractors, site supervisors and artisans in acquiring both technical and managerial expertise. The Supply Chain management system described in Chapter 7 is a synthesis of this system as used in the United Kingdom, the contractor development programme used in Soweto (Mkhize 1992; Table 4-3) and the artisan training programme developed by Fathy (1973) at New Gourna (Table 5-9).

The features of the proposed system can be summarized as follows:

a) Repetition of module in each building
b) Repeat public buildings until the Supply Chain network has enough experience and skill to be autonomous
c) PWD as mentor thereafter, then lead supplier
d) Ethos of continuous improvement through construction and through formal (lifelong) learning

This is embedded in the South African government's commitment to supporting education and training initiatives, particularly through Recognition of Prior Learning and the philosophy of lifelong learning as the fundamental mechanisms for addressing a legacy of colonial and apartheid exclusion from formal learning for the majority of its citizens. This thesis offers another approach by looking beyond the methods currently used to achieve these objectives

APPENDIX 2: STABILIZED EARTH TILE MANUFACTURE

As part of the technical studies in this thesis (see 6.4.3), an innovative application of the hand-operated block-press was developed to manufacture 20mm thick tiles from stabilised earth. This method had immediate application in the tile production for the Mapungubwe Visitors Centre in Limpopo Province. Because this was part of a larger poverty relief programme administered by the client, the South African Parks (SANParks) department, it was necessary to determine productivity levels through work studies. It became apparent that the daily output was linked to various supervisor and higher management activities, as is outlined below.

This appendix therefore serves as an indication of the level of detail required in research and development if the re-engineering contemplated in this thesis is to compete with other methods of construction in terms of efficiency, economy and quality. The outcome of work studies such as this is to facilitate the equitable determination of an output (task) based daily wage, defined here by the number of tiles produced by each team of three people. It must be emphasised that this level of production, indeed the task-based wage method itself, depends on management's being exemplary, otherwise both the output and the credibility of the process is undermined.

A2.1 STRATEGIC MANAGEMENT

The supply of materials and equipment must be ensured:

- Quarry sand must be from an approved source, with the requisite testing on a regular basis;
- Cement or other stabiliser needs to be from an approved source and of a predefined standard;
- Water supply must be tested regularly if it is not of drinking quality.

Stabilized earth construction is highly sensitive to the type of soil, particularly when used for vaulting, as the compressive strength is a critical factor. Before

any manufacture takes place, a full set of soil tests must be carried out, followed by some experimentation to establish the optimal ratio of stabiliser, as this is the one material that drains money from the targeted community. Soil testing should be repeated whenever a new source is used, as well as when the sand changes colour or texture. Experience shows that soil from a single quarry will not have the range of particles that give both cohesion (clay and silt) and strength (larger particle sizes), so some experimentation is needed to derive the best ratio of soils from two or more sources.

Productivity is sensitive to the quality and regular maintenance of the equipment (McCutcheon and Marshall 1998). The block press is robust and easily maintained, but should be adequately protected from moisture to prevent rusting, and moving parts checked and repaired on a regular basis. While the checking should be one of the responsibilities of the supervisor, management needs to ensure that there are procedures for repairs and a stock of spares to minimise down-time. Other equipment includes: pallets sufficient for the daily output, with stocks to replace those damaged from wear-and-tear; plastic for covering and curing the tiles; hosepipe or watering can for curing.

A2.2 SUPERVISOR TASKS

Manufacturing should be under the direction of a supervisor where more than one block-press is used, or where the block-making is integral with the construction work on the same site. The responsibilities of the supervisor are similar to that of the ‘hands-on site supervisor’ in labour-intensive road building, described in Chapter 4. Where tiles and blocks are manufactured on the construction site, the programming should be carefully considered to avoid delays in brick and tile laying, and to ensure that curing times are observed.

The location of the block-yard ideally is close enough to the building operations to allow for manual transporting from the stacking areas, thereby avoiding double-handling. This said, manufacture should be carried out in a dedicated

area, with sufficient clear space around each of the presses to ensure safety. Only the two operators, one assistant and the wheelbarrow with the current batch should be permitted in this space. The experience at Mapungubwe was that when more people were present, the productivity and quality fell significantly. (Fig A2-1) A daily laying-out space should be designated for each of the two teams using one block-press, immediately adjacent to the workspace. Tiles are transferred from here to the curing area on a daily basis when they are removed from the pallets. The curing space should be arranged so that each day's output is clearly marked to assist in the quality control (through compression testing), as well as for monitoring productivity.





Fig A2-1: Reduced productivity through excessive number of workers (F Prinsloo)

Payment should be based on output per team of three people. Work studies have shown that each press should have a capacity of 750-800 tiles per eight hour working day, as given in the diagram (Fig A2-2) below. Teams that work more efficiently than this should not increase the batch size, but rather have a slightly shorter cycle. This will tend to improve the efficiency of the partner team, as their mixing and rest times will be shortened. An important responsibility of the supervisor is to monitor the rate of output so that the tasks are balanced as shown in Fig A2-2.

mix	press		Mix	press		mix	press	etc
cure & stack	mix	Press		mix	press		mix	etc

Fig A2-2: Optimal cycle for tile manufacture (10 min rest periods shown shaded)

It is the responsibility of the two tile-makers in each team to ensure the correct mix, tile thickness and lack of damage to the tiles. Low quality tiles are often distinguished by cracking, crumbling corners and inconsistent colour.

A2.3 TILE-MAKER TASKS

Once tile-makers have been trained, they should be able to work with a minimum of supervision. This is facilitated if the mixing is done by volume, as multiples of a standardised container. Sand (often a combination from two sources to optimise particle size) and cement should be mixed dry, and only enough water added to achieve cohesion, as excess water reduces the strength of the tile. This is the reason that the size of a batch must be limited, especially in a hot-dry climate with high evaporation. Because the tiles are carried from the press on individual pallets, many of the problems of consistency found in the manufacture of blocks are avoided. If the mixture is not sufficiently wet, the lever arm of the press gives too much resistance. The mix should be sprinkled loosely into the press in exact quantities – again using a container of the correct volume that can be struck off with a straight-edge before placing in the press.

A2.4 THE ASSISTANT

The assistant has three main tasks:

- Removing the tile from the press and placing in the daily stacking area;
- Stacking the previous day's batch in the curing area, removing and cleaning the pallets;
- Curing the tiles for seven days, after which they are stacked for use.

Throughout the curing time, the tiles must be protected from evaporation, placed on an impervious surface and wrapped in plastic sheeting. Curing can be done with a watering-can or hosepipe. While the daily cycle given in Fig A2-2 shows the stacking being done by one team, for quality control it could be preferable for the assistant of the lead team to start work earlier so that each team stacks its own output.

A2.6 CONCLUSIONS

As can be seen from the above description, there needs to be great attention to detail to achieve a level of productivity. Site experience has shown that the greatest hindrance to this is through excessive numbers of people standing around the press (typically found in labour-extensive work). This also impacts on the health and safety of the labour force.

APPENDIX 3: DETAILED COST ANALYSIS OF CASE STUDIES

A3.1 DPW SCHOOL DETAILED COST BREAKDOWN

The analysis of the Department of Public Works standard school is based on four documents from the Limpopo Department. These are: drawings of the classroom block; itemised invoice for materials from the nominated building supplier, Builders Market; labour estimates by DPW Limpopo; and a summary by trade of the Bill of Quantities, replicated below.

Code	Trade	Cost per trade
A1	Preliminaries	17 000
A2	Foundations	42 089
A3	Concrete work	26 296
A4	Masonry	70 466
A5	Waterproofing	2 904
A6	Roof covering	21 984
A7	Carpentry & joinery	28 796
A8	Ceilings	21 100
A9	Ironmongery	23 248
A10	Metalwork	16 292
A11	Plastering	6 400
A12	Plumbing & drainage	3 400
A13	Electrical	18 285
A14	Glazing	7 084
A15	Painting	9 789
	Subtotal	**315 133**
	Contingency	5 000
	Value Added Tax	44 818
	TOTAL	**364 951**

Table A3-1: Bill of Quantities, trade summaries (DPW Limpopo)

Code	trade	item	classrooms	toilets	trade total
	concrete	USB green	1306.44		
		cement	5745.60		
		softboard	590.52		
B1	**total**		**7642.56**		**7642.56**
	brickwork	brickforce	426.13	64.98	
		door frame	1078.44	879.9	

		windows	11365.80		
		galvanised wire ties	112.69		
		cement	5825.40	4104	
		Brickgrip DPC	256.82	69.05	
		grille blocks		648.37	
B2	**total**		**19065.28**	**5766.3**	**24831.58**
	waterproofing	ridge piece	776.34		
		facia board	1261.98		
		facia joiner	30.1		
		bargeboard	492.02		
		bargeboard joiner	15.73		
		rainwater shoe		990.07	
B3	**Total**		**2576.17**	**990.07**	**3566.24**
	roof covering	roof sheeting	16758	1326.96	
		roofing screws	369.36	25.65	
		galvanised wire	167.12	40.83	
		air vent		9.12	
B4	**Total**		**17294.48**	**1402.56**	**18697.04**
	carpentry	roof truss	9405.00		
		38x114 SA pine	478.12	179.55	
		50x76 SA pine	4329.31	102.43	
		38x114 SA pine	765.51		
		38x76 SA pine	714.10		
		poles		228.00	
		wire nails	179.55		
		carbolinium	201.78		
B5		**Subtotal roof**			**16381.57**
		skirting	1922.32		
		quadrant	839.32		
		steel nails	182.40		
		doors	2578.68	1210.73	
		door stops	6.84	6.84	
B6		**Subtotal general**			**6948.91**
B7	**Total**		**21602.93**	**1727.55**	**23330.48**
	ceilings	ceiling board	3972.13		
		38x38 SA pine	1960.23		
		trap door	248.52		
		clout nails	261.63		
		wire nails	89.77		
		cover strip	802.33		
B8	**Total**		**7334.61**		**7334.61**
	ironmongery	locksets	273.37	243.32	
		brass screws	36.48		
		pinboards	4924.80		
		chalkboards	13078.08		
		cabinets	4035.60		

		rawl bolts	191.52		
		fire extinguishers	1819.44		
B9	**Total**		**24359.29**	**243.32**	**24602.61**
	metalwork	security gates	3078	1585.74	
		cabin hooks	105.11		
		weldmesh		302.1	
B10	**Total**		**3183.11**	**1887.84**	**5070.95**
	plastering	cement	5825.40		
B11	**Total**		**5825.40**		**5825.40**
	plumbing	PVC pipe		111.47	
		toilet roll holder		126.08	
		pit pedestal		1048.57	
		wash trough		627.68	
B12	**Total**			**1913.8**	**1913.8**
	Electrical	lights	3080.63		
		fittings	1032		
		D/B	2532.24		
		reticulation	6253.07		
B13	**Total**		**12897.94**		**12897.94**
	Glazing	glass	8094		
		dow corning silicone	194.43		
B14	**Total**		**8288.43**		**8288.43**
	Painting	gloss enamel	560.88		
		undercoat	517.56		
		PVA	1256.28		
		varnish	411.31		
B15	**Total**		**2746.03**		**2746.03**
B16	**TOTAL FROM SUPPLIER**				**146747.67**

Table A3-2: Materials from building supplier, VAT included (DPW Limpopo)

Grade	**Trade**	**Number***		**Days**	**Total**	**Rate/day**	**Cost****
Unskilled		3+9	12	10	120	35	4 200
Semi-skilled	Brickwork	4+4	8	24	192	45	8 640
	Carpentry	1+1	2	14	28	35	980
	Electrical	0+1	1	14	14	35	490
	Plumbing	0+1	1	7	7	35	245
Skilled	Brickwork	7+0	7	24	168	95	15 960
	Carpentry	1+0	1	14	14	90	1 260
	Electrical	1+0	1	14	14	90	1 260
	Plumbing	1+0	1	7	7	90	630
Supervisor		1+0	1	90	90	65	5 850
Clerk		0+1	1	90	90	65	5 850
Targeted labour							**55 365**
Manager		1+0	1	90	90	200	18 000
Professional		0+1	1	20	20	200	4 000
Total							**67 365**

Table A3-3: Labour quantities and rates (DPW Limpopo)

No information was provided on the cost of materials sourced from quarries or directly from the brick manufacturers, so this information was taken from the Master Builders Pricing Guide (MBA2003)

Materials from source		
Quarry	coarse sand	876.00
	plaster sand	216.00
	stone	4810.00
	Waste (20%)	1180.00
	total	**6082.00**
Bricks	stocks	15400.00
	facers	14065.00
	waste	737.00
	transport	450.00
	total	**30652.00**
Total from source		36734.00

Table A3-4: Materials direct from quarry/manufacturer (MBA 2003)

		materials	mat total	labour	lab total	overhead	BoQ	Tot BoQ
P&G					11000	5000		17000
	Concrete	7642					68385	
	brickwork	24831					70466	
	Plaster	5825					6400	
	Quarry	6082						
	Bricks	30652						
	Glazing	8288					7084	
	Painting	2746					9789	
wet trades			86068		28200	47856		162124
	gen carpentry	6948					12670	
	ironmongery	24602					23248	
	metalwork	5070					16292	
gen carpent			36622	1120		14468	52210	
	roof carpentry	16381					16126	
	Sheeting	18697					21984	
	waterproofing	3566					2904*	
	Ceilings	7334					21100	
roof carpent			45979	1120		15015	62114	
tot carpent		82601			2240	29482		114324
Plumbing			1913		875	611		3400
Electrical			12897		1750	3637	18285	18285
			183481		44065	87586		315133

Table A3-5: Cost breakdown, separating general carpentry from roof carpentry. (Note: BoQ item exceeds materials quote form supplier)

The total cost for the roofing is derived from the material costs, the pro rata allocation of labour (50-50 split with general carpentry) and a pro rata allocation for overheads, based on the ratio of material costs as the most reliable and consistent data.

A3.2 NEW GOURNA SCHOOL DETAILED COST BREAKDOWN

This section provides data drawn from Fathy's (1976) *Architecture for the Poor*, in which he gives a comprehensive costing for the masonry components of the entire project, including manufacture of bricks and the cost of labour employed within the project. This is accompanied by an equivalent set of values drawn largely from the LITE project discussed in section 5.4. As has been noted, comparisons over such distance and time should be treated with caution, as economic, social, climatic and managerial factors have a significant influence on the type of design that would best meet the project objectives. An example is the wage rates: in section 5.4 the rates for the LITE house were adjusted to match the Department of Public Works wages for the purpose of comparison, despite both projects being costed in the same year and both being located in South Africa's Limpopo Province.

The quantities for the New Gourna School have been scaled from plan and section, with reference to the photograph (Fathy 1976: Figs 99 -101), giving the following figures (Table A3-6):

Description	**Quantity**
< 0.7m thick rubble foundation	137m
> 0.7m thick rubble walling	379m
Walls to cill height	406m
Walls above cill	423m
Arches 3m span	14
Arches 1.5m span	14
Domes 3m diameter	6
Domes 4m diameter	7
Vaults 2.5m span	82m
Vaults 2m span	63m
Vaults 1.5m span	26m

Table A3-6: New Gourna School quantities for masonry work

The following detailed breakdown of costs is derived directly from Fathy's published data, with the 2003 South African equivalents taken from the LITE project as detailed in section C3.3 below and from the *Master Builders Pricing Guide 2002/2003* (MBA 2003):

BULK MATERIALS

1. **EARTH BRICKS** (per 1 000 bricks) Note: Four teams produce 3 000 bricks per day per team.

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
1.1 Earth and sand transport from site to dump @ $5m^3$ earth and $2m^2$ sand per day in hand tipping trucks, giving 3 000 bricks per day 2 labourers @ 10pt/day	6.70pt	Nil		
1.2 Straw (cost assumed to include labour from outside project)	Nil	15.00pt		
1.3 Sand from quarry to site (labour from outside)	Nil	11.00pt		
1.4 Water – petrol driven pump for bricks and trees (per 12 000 bricks) Mechanic @ 35pt/day for $^1/_5$ day 1 labourer @ 10pt/day	1.10pt	16.60pt		
1.5 Brick making 2 brickmakers @ 25pt/day 2 labourers @ 10pt/day	25.00pt	Nil		
1.6 Brick stacking 1 labourer @ 10pt/day for ½ day	1.60pt	Nil		
1.7 Supervision (per 4 teams) 1 supervisor @ 15pt/day	1.20pt	Nil		
1.8 Railway (for 24 000 bricks) 1 supervisor @ 15pt/day 1 labourer @ 10pt/day	2.00pt	Nil		
Carry to construction	37.60pt	42.60pt	R890.00	R880.00

1.1 EXTRA FOR FIRED BRICKS

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
1.9 Stacking, firing and unloading 1 mason @ 30pt/5 000 bricks 1 assistant @ 17pt/5 000 bricks 1 firer @ 15pt/10 000 bricks 6 labourers @ 10pt/5 000 bricks 8 unloaders @ 10pt/10 000 bricks	31.00pt	102.00pt		
Carry to construction	31.00pt	102.00pt		

2. STONE (per m^3; output $40m^3$ per day128)

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
2.1 Explosives	Nil	4.00pt		
2.2 Transport (fuel & depreciation) Driver @ 63pt/day ($20m^3$/day) 5 porters @ 15pt/day	5.30pt	6.85pt		
2.3 Tool maintenance 1 blacksmith @ 35pt/day 1 assistant @ 15pt/day 1 apprentice @ 8pt/day	1.45pt	1.25pt		
2.4 General labour (30m3/day) 4 workmen @ 10pt/day 1 foreman @ 45pt/day 1 ganger @ 15pt/day 2 watchmen @ 18pt/day mechanic @ 35pt/day, ¾ share assistant @ 15pt/day, ¾ share	6.00pt	Nil		
2.5 Removal of soft strata unskilled labour	1.37pt	Nil		
2.6 Quarrying 4 quarrymen + 4 assistants @ 15pt/m3 4 workers @ 10pt/day	16.33pt	Nil		
2.7 Sorting and stacking unskilled labour	1.00pt	Nil		
Carry to construction	31.45pt	12.10pt		

3. MORTAR

3.1 SAND (per m^3; $17.5m^3$ per truck per day)

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
3.1 Fuel and depreciation	Nil	8.40pt		
3.2 Labour 1 driver @ 63pt/day 5 porters @ 15pt/day 1 guard @ 18pt/day share of mechanic's wage =	12.00pt	Nil		
3.3 Gravel removal unskilled labour	2.00pt	Nil		
Carry to construction	14.00pt	8.40pt		

3.2 LIME (per m^3; output $6m^3$ per day)

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
3.4 Fuel (solar oil)	Nil	85.00pt		
3.5 Labour 1 stacker @ 30pt/day 5 workmen @ 10pt/day 1 firer @ 15pt/day	36.50pt	Nil		

128 Fathy (1976) is inconsistent on the output, in places stating that this is $30m^3$ per day, but the figure of $40m^3$ is more frequently used.

3 helpers @ 8pt/day I supervisor @ 10pt/day				
Carry to construction	36.50pt	85.00pt		

CONSTRUCTION

4. RUBBLE MASONRY FOUNDATIONS >0.7m WIDE

Assume width 0.8m x depth 0.8m x 137m (from plan) = 88m^3 stone
Assume mortar is 20% of volume = 17.6m^3 mortar
Labour calculated at 8m^3 per day = 11 days

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
4.1 Stone	2 650pt	1065pt	R1 467	R2 200
4.2 Mortar	156pt	109pt		R4 668
4.3 Masonry labour 2 masons @ 40pt/day 2 assistants @ 10pt/day 4 helpers @ 8pt/day 1 stone dresser @ 10pt/day 1 mortar mixer @ 10pt/day 1 apprentice @ 10pt/day 1 foreman @ 10pt/day	1 738pt	Nil	R3 740	
4.4 Water @ 2pt/day	Nil	22pt		
Carry to collection	4 544pt	1 196pt	R5 207	R6 868

5. RUBBLE MASONRY FOUNDATIONS <0.7M WIDE

Assume width 0.5m x depth 0.8m x 379m (from plan) = 151m3 stone
Assume mortar is 20% of volume = 30.2m^3 mortar
Labour calculated at 4m^2 per day = 38 days

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
5.1 Stone	4 548pt	3 627pt	R2 517	R3 775
5.2 Mortar	3 020pt	318pt		R8 009
5.3 Masonry labour 2 masons @ 40pt/day 2 assistants @ 10pt/day 4 helpers @ 8pt/day 1 stone dresser @ 10pt/day 1 mortar mixer @ 10pt/day 1 apprentice @ 10pt/day 1 foreman @ 10pt/day	5 111pt	Nil	R12 920	
4.4 Water @ 2pt/day	Nil	76pt		
Carry to collection	12 679pt	4 021pt	R15 437	R11 784

6. WALLS TO CILL HEIGHT

Assume walls average 0.5m thick (from plan) x 1.2m high x 406m (from plan) = 244m3
1 000 bricks unfired for 5.56m3
44 batches of 1 000 bricks required (43 885 bricks 300x150x100)
Mortar @ 15% of volume = 36.6m3
Labour output average 800 bricks per team per day = 55 days

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
6.1 Bricks	1 615pt	1 874pt	R39 160	R38 619
6.2 Mortar	512pt	307pt	Nil	R9 706
6.3 Brickwork 2 masons @ 40pt/day 2 workmen @ 10pt/day 2 helpers @ 8pt/day 1 trainee @ 10pt/day railway $^{1}/_{15}$ of 20pt/day 2 stackers @10pt/day mortar mixer @ 10pt/day for ½ day	8 305pt	Nil	R10 450	Nil
Carry to collection	10 432pt	2 181pt	R49 610	R48 325

7. WALLS FROM CILL TO TOP

Assume walls average 0.5m thick (from plan) x 3m high x 423m (from plan) = 634.5m3
115 batches of 1 000 unfired bricks (114 119 bricks)
Mortar @ 15% of volume = 95m3
Labour output average 800 bricks per team per day = 143 days

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
7.1 Bricks	4 324pt	4 899pt	R 102 350	R100 425
7.2 Mortar	1 330pt	798pt	Nil	R25 194
7.3 Brickwork 2 masons @ 40pt/day 2 workmen @ 10pt/day 2 helpers @ 8pt/day 1 trainee @ 10pt/day railway $^{1}/_{15}$ of 20pt/day 2 stackers @10pt/day mortar mixer @ 10pt/day for ½ day 1 scaffolder $^{1}/_{5}$ of 20pt/day 3 helpers, $^{1}/_{5}$ of 10pt/day	23 023pt	Nil	R30 316	
Carry to collection	28 677pt	5 697pt	R 132 666	R125 619

8. ROOFING

All arches, vaults and domes assumed to be of fired brick with lime mortar

Arches	14 x 1.5m span x 360 bricks	5 040
	14 x 3.0m span x 540 bricks	7 560
	Labour 14 days	
Vaults	26m x 1.5m span x 153 bricks/m	3 978
	63m x 2.0m span x 204 bricks/m	12 825
	82m x 2.5m span x 272 bricks/m	22 304
	Labour 45 days	
Domes	6 x 3.0m diameter x 8 400 bricks	
	7 x 4.0m diameter x 14 000 bricks	
	Labour 14 days	
Total bricks	186m3 (75 batches of 1 000)	74 107
Mortar @ 15% volume	27.9m3	
Total labour	73 days	

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
8.1 Bricks (fired)	5 145.00pt	10845.00pt		R82 500
8.2 Mortar	1 408.95pt	2605.86pt		R7 400
8.3 Brickwork 2 masons @ 40pt/day 1 workman @ 10pt/day 2 helpers @ 8pt/day Railway $^{1}/_{15}$ of 20pt/day 1 stacker @ 10pt/day Mortar mixer @ 10pt/day for ½ day	8 930.09pt	Nil	R15 695	
Carry to collection	15484.09pt	13450.86pt	R15 695	R89 900

9. FLOORS

Assume 100mm thick slab x 747m^2 = 75m^3
Labour assumed at 5m^3 per day = 15 days

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
9.1 Stone	2 358.75pt	907.50pt		
9.2 Mortar	568.13pt	1 001.25pt		
9.3 Transport	Nil	3.50pt		
9.4 Construction labour 2 placers @ 20pt/day 3 workmen @ 10pt/day 1 mortar mixer @ 10pt/day	1 200.00pt	Nil		
Carry to collection	4 126.88pt	1 908.75pt	R2 550	R22 515

TOTAL CONSTRUCTION COSTS

	Egypt 1940s		South Africa 2003	
Item	**Labour**	**Material**	**Labour**	**Material**
4. Foundations > 0.7m wide	4 544pt	1 196pt	R5 207	R6 868
5. Foundations < 0.7m wide	12 679pt	4 021pt	R15 437	R11 784
6. Walls to cill height	10 432pt	2 181pt	R49 610	R48 325
7. Walls cill to top	28 677pt	5 697pt	R132 666	R125 619
8. Roofs	15 485pt	13 450pt	R15 695	R89 900
9. Floors	4 127pt	1 908pt	R2 550	R22 515
	75 944pt	28 453pt	R221 165	R305 011

Table A3-7: Detailed labour and material cost breakdown, New Gourna School, with equivalent South African costs (2003 values)

Labour as % of direct masonry costs:

Egypt 1940s: 72.7%

South African 2003: 42.0%

This difference in the labour ratio is largely attributable to the change in circumstances of place and time. At New Gourna, lime burning and brick firing could take place on site, using local labour, whereas this was not feasible in the

LITE projects because of cost of fuel and the small scale of production. This highlights the need to make thorough evaluation of all the factors of production for a particular place and time when proposing employment-intensive construction.

A3.3 LITE HOUSE DETAILED COST BREAKDOWN

The following data is transcribed from LITE project records, omitting carports and a gate that have no bearing on this cost comparison:

Material	**Characteristics**			**Cost in R** per unit	**Cost in R** per m^3
	Activities	Amount	Unit		
Building sand	Dig and deliver	4.0	m^3	160.00	**40.00**
Cement	N/a	40.0	litre	36.50	**912.50**
Water	Deliver	200.0	litre	6.00	**30.00**
Crushed stone	Collect rock	1.5	m^3/md	25.00	16.67
	Transport	1.0	m^3	25.00	25.00
	Crush stone	1.2	m^3/3md	75.00	62.50
					94.26

Material	**Mixture (batch)**			**Costs in R** per mixture
	Amount	Litres	Cost per m^3	
Building sand	3 buckets	36	40.00	1.44
Cement	1 bucket	12	912.50	10.95
Water	1 bucket	12	30.00	0.36
Crushed stone	2 bucket	24	94.26	2.26
Total material cost per mixture (batch)				15.01
Total material cost per m^3 concrete				**300.20**

Material	**Mixture (batch)**			**Costs in R** per mixture
	Amount	Litres	Cost per m^3	
Building sand	3 buckets	36	40.00	1.44
Cement	1 bucket	12	912.50	10.95
Water	1 bucket	12	30.00	0.36
Total material cost per mixture (batch)				12.75
Total material cost per m^3 mortar				**265.20**

Table A3-8: Concrete and mortar cost per m^3, LITE house (LITE 2003)

Material	**Characteristics**			**Cost in R** per unit	**Cost in R** per m^3
	Activities	Amount	Unit		
Red soil	Dig and deliver	10.00	m^3/d	145.00	14.50
	Sieving	1.00	m^3/d	25.00	25.00
	Tractor hire	10.00	m^3/d	100.00	10.00
	Fuel	20.00	litre	75.00	7.50
					57.00
Clay	Dig and deliver	6.00	m^3/d	145.00	14.50
	Crumbling	0.75	m^3/d	25.00	33.33
	Sieving	1.50	m^3/d	25.00	16.67

	Tractor hire Fuel	6.00 20.00	m^3/d litre	100.00 75.00	16.67 12.50 **93.67**
Bitumen	N/a	200.00	litre	600.00	**3 000.00**
Cement	N/a	40.00	litre	36.50	**912.50**
Water	N/a	100.00	litre	nil	**nil**

Material	**Mixture (batch)**			**Costs in R** per mixture
	Amount	Litres	Cost per m^3	
Building sand	3 buckets	36	40.00	1.44
Cement	1 bucket	12	912.50	10.95
Water	1 bucket	12	30.00	0.36
Total material cost per mixture (batch)				12.75
Total material cost per m^3 mortar				**265.20**
Material	**Mixture (batch)**			**Costs in R** per mixture
	Amount	Litres	Cost per m^3	
Red soil	3 buckets	36.0	57.00	2.05
Clay	1 bucket	12.0	93.67	1.12
Bitumen	2% of dry mix	1.0	3 000.00	3.00
Cement	2% of dry mix	1.0	912.50	0.88
Water	5% of dry mix	2.4	0.00	0.00
Total material cost for 8 earth bricks				7.05
Total material cost per brick				**0.88**

Table A3-9: Stabilized earth brick cost (material only), LITE house (LITE 2003)

Code	Description	Material	R/unit	Unit	Amount	Total
LA	Site preparation					
LA1	Clear and grub	-	-	-	-	0.00
LA2	Levelling	-	-	-	-	0.00
LB	Foundations					
LB1	Set out excavation	-	-	-	-	0.00
LB2	Excavate	-	-	-	-	0.00
LB3	Compact	-	-	-	-	0.00
LB4	Mix and place concrete	Concrete	293.00	m^3	12.5	3 662.50
LB5	Cure concrete	-	-	-	-	0.00
LB6	Set out foundation walls	-	-	-	-	0.00
LB7	Build foundation walls	Mortar Rocks	257.71 41.67	m^3 m^3	10.00 20.00	2 577.10 833.40
LB8	Cure mortar	-	-	-	-	0.00
LB9	Backfill and compaction	Soil	0.00	m^3	30.0	0.00
LC	Floor					
LC1	Level, backfill and compact	Soil	0.00	m^3	95.40	0.00
LC2	Lay damp proof membrane	Dpm	100.00	Roll	3.00	300.00
LC3	Lay damp proof course (dpc)	Dpc	10.99	Roll	3.00	32.97
LC4	Cast concrete slab	Concrete	293.00	m^3	7.60	2 226.80
LC5	Cure concrete	-	-	-	-	0.00
LC6	Cast screed	Mortar	257.71	m^3	1.90	489.65
LC7	Cure screed	-	-	-	-	0.00
LD	Walls					
LD1	Place poles and fish line	-	-	-	-	0.00
LD2	Position door frames	Door frame	100.00	each	7	700.00

LD3	Build up walls to cills	Mortar	257.71	m^3	3.09	796.32
		Bricks	0.88	each	1932	1 700.16
		Brickforce	11.99	13.5m	14	167.86
LD4	Position window frames	Window	200.00	E1	1	200.00
		frames	240.00	C2	10	2 400.00
			526.00	C4	9	4 734.00
LD5	Build walls to door head	Mortar	257.71	m^3	3.53	909.72
		Bricks	0.88	each	2209	1 943.92
		Brickforce	11.99	13.5m	14	167.86
LD6	Place window cills	Mortar	257.71	m^3	0.1	25.77
		Cills	4.99	each	99	494.01
LD7	Place lintels	Mortar	257.71	m^3	0.1	25.77
		Lintels	30.00	each	27	810.00
LD8	Build up walls	Mortar	257.71	m^3	0.9	231.94
		Bricks	0.88	each	550	484.00
LD9	Build in roof ties		257.71	m^3	0.1	25.77
			0.88	each	275	242.00
LD10	Build up walls		257.71	m^3	0.5	128.86
			0.88	each	275	242.00
LE	Roof and ceilings					
LE1	Treat roof timbers	Carbolinium	4.32	litre	30	129.60
LE2	Fix wall plates	Wall plates	24.96	each	20	499.20
LE3	Place trusses	Truss	1173.90	type1	8	9 391.20
			195.65	type2	12	2 347.80
LE4	Place temporary junctions	Planks	15.13	each	10	151.30
LE5	Place purlins	Purlin	40.00	each	30	1 200.00
LE6	Place bracing	Planks	15.13	each	10	151.30
LE7	Place sheeting	Sheeting	47.74	each	40	1 909.60
LE8	Place gutters, down pipes	Gutter	12.50	m	48.8	610.00
	and fascia boards	Down pipe	70.00	each	4	280.00
		Fascia	75.60	4.8m	11	831.60
LE9	Finish roof	Valley cap	130.91	2m	15	1 963.65
		PVA paint	49.60	5l	5	248.00
LE10	Place insulation	Insulation	17.00	m^2	114.5	1 946.50
LE11	Place brandering	Brandering	12.03	each	50	601.50
LE12	Place ceiling	Boards	35.62	m^2	114.5	4 078.49
		Cornice	3.50	m	110	385.00
LE13	Paint ceiling	PVA paint	49.60	5l	3	148.80
LE14	Place plinths	Plinth	2.50	3m	41	102.50
		PVA paint	49.60	5l	1	49.60
LF	Interior					
LF1	Place burglar bars	subcontract	-	-	-	0.00
LF2	Paint metalwork	PVA paint	49.60	5l	2	99.20
LF3	Glazing	Glass	16.00	E1	1	16.00
			16.00	C2	10	160.00
			72.00	C4	9	648.00
LF4	Plaster walls	Mortar	257.71	m^3	4.5	1 159.70
LF5	Electrical installation	Subcontract	-	-	-	1 500.00
LF6	Hang doors	Doors	673.00	each	7	4 711.00
LF7	Paint walls	Limewash	59.99	25kg	6	359.94
LF8	Plumbing	WC	200.00	each	1	200.00
		Shower	50.00	each	1	50.00
		Curtain	75.00	each	1	75.00
LH	Veranda					

LH1	Level and compact	Soil	0.00	m^3	35.4	-
LH2	Place concrete	Concrete	293.00	m^3	2.8	820.40
LH3	Cure concrete	-	-	-	-	-
LJ	Work floor					
LJ1	Clear and grub	-	-	-	-	-
LJ2	Excavate	-	-	-	-	-
LJ3	Compact	-	-	-	-	-
LJ4	Build walls	Mortar Bricks	257.71 0.88	m^3 each	0.3 152	77.31 133.76
LJ5	Place concrete	Concrete	257.71	m^3	2.2	566.96
LJ6	Cure concrete	-	-	-	-	-
LK	Finish					
LK1	Clean buildings	PVA paint Limewash	49.60 59.99	5l 25kg	1 1	49.60 59.99
LK2	Clean site	-	-	-	-	-
LK3	Put in inventory	-	-	-	-	-
Total material cost						64 264.88
Plus 5% contingency						67 478.12

Table A3-10: Material costs, LITE house (LITE 2003)

Code	Description	Days	Team leader	Builder	Labour	Man days	Cost
LA	Site preparation						
LA1	Clear and grub	1	-	-	1	1	25.00
LA2	Levelling	1	-	-	2	2	50.00
LB	Foundations						
LB1	Set out excavation	0.5	-	-	1	0.5	12.50
LB2	Excavate	3	-	-	7	21	525.00
LB3	Compact	0.5	-	-	1	0.5	12.50
LB4	Mix and place concrete	6	1	2	3	36	1140.00
LB5	Cure concrete	-	-	-	-	-	-
LB6	Set out foundation walls	0.5	-	1	1	1	30.00
LB7	Build foundation walls	8	-	2	4	48	1360.00
LB8	Cure mortar	-	-	-	-	-	-
LB9	Backfill and compaction	2	-	-	5	10	250.00
LC	Floor						
LC1	Level, backfill and compact	2	-	-	5	10	125.00
LC2	Lay damp proof membrane	0.1	-	1	1	0.2	12.00
LC3	Lay damp proof (dpc)	0.1	-	1	1	0.2	12.00
LC4	Cast concrete slab	3.5	1	2	3	21	665.00
LC5	Cure concrete	-	-	-	-	-	-
LC6	Cast screed	1	-	2	4	6	170.00
LC7	Cure screed	-	-	-	-	-	-
LD	Walls						
LD1	Place poles and fish line	0.2	-	2	2	0.8	24.00
LD2	Position door frames	2	-	2	4	12	340.00
LD3	Build up walls to cills	6	-	2	4	36	1020.00
LD4	Position window frames	2.5	-	2	4	15	425.00
LD5	Build walls to door head	7	-	2	4	42	1190.00
LD6	Place window cills	2.5	-	2	2	10	300.00
LD7	Place lintels	1	-	2	2	4	120.00
LD8	Build up walls	2	-	2	4	12	340.00
LD9	Build in roof ties	4	-	2	6	32	880.00

LD10	Build up walls	1	-	2	4	6	170.00
LE	Roof and ceilings						
LE1	Treat roof timbers	3	-	2	-	6	210.00
LE2	Fix wall plates	0.1	-	1	1	0.2	6.00
LE3	Place trusses	2	1	1	3	10	310.00
LE4	Place temporary junctions	2	1	1	2	8	260.00
LE5	Place purlins	3	1	1	2	12	390.00
LE6	Place bracing	0.5	1	1	2	2	65.00
LE7	Place sheeting	3	1	1	3	15	465.00
LE8	Rainwater goods & fascias	2	1	2	1	8	280.00
LE9	Finish roof	0.5	-	1	1	1	30.00
LE10	Place insulation	0.5	-	1	2	1.5	42.50
LE11	Place brandering	0.5	-	1	2	1.5	42.50
LE12	Place ceiling	6	-	1	2	18	510.00
LE13	Paint ceiling	1	-	1	6	7	150.00
LE14	Place plinths	1	-	1	1	2	60.00
LF	Interior						
LF1	Place burglar bars	2.5	subcontract				-
LF2	Paint metalwork	2	-	1	3	8	220.00
LF3	Glazing	2.5	1	1	3	12.5	387.50
LF4	Plaster walls	2.2	-	2	2	8.8	264.00
LF5	Electrical installation	3	-	-	1	3	75.00
LF6	Hang doors	1.5	-	1	1	3	90.00
LF7	Paint walls	2.5	-	-	5	12.5	312.50
LF8	Plumbing	2	-	-	1	2	50.00
LH	Veranda						
LH1	Level and compact	2	-	-	2	4	100.00
LH2	Place concrete	1.5	1	2	3	9	285.00
LH3	Cure concrete	-	-	-	-	-	-
LJ	Work floor						
LJ1	Clear and grub	0.2	-	-	1	0.2	5.00
LJ2	Excavate	1	-	-	1	1	25.00
LJ3	Compact	0.2	-	-	1	0.2	5.00
LJ4	Build walls	1	-	1	2	3	85.00
LJ5	Place concrete	1	1	2	3	6	190.00
LJ6	Cure concrete	-	-	-	-	-	-
LK	Finish						
LK1	Clean buildings	1	-	-	5	5	125.00
LK2	Clean site	0.5	-	-	5	2.5	62.50
LK3	Put in inventory	1	1	-	2	3	95.00
LM	Earth brick manufacture						
LM1	Manufacture	20	2	-	6	160	4800.00
Total direct labour costs							**19318.50**

Table A3-11: Direct labour costs, LITE house (LITE 2003)

Position	**Salary (R)**	**Cost/day**	**Participation**	**Days**	**Total (R)**
Supervisor	2700.00	122.73	65	59.8	7339.25
Site manager	14250.00	647.73	5	4.6	2979.56
Assistant	4200.00	190.91	20	18.4	3512.74
Engineer	14000.00	636.36	10	9.2	5854.51
					19686.06

Table A3-12: Site management costs, LITE house (LITE 2003)

Equipment	Cost/day (R)	Duration	Total (R)
Trailer, 3 tonne	28.90	2	57.80
Rock crusher 8-35mm stone	18.04	31	559.24
Terrabric machine 290x154x115	5.76	20	115.20
Terrabric machine 290x154x108	5.76	20	115.20
Concrete hand mixer 65l	5.05	46	232.30
Sieve	0.67	46	30.82
Plate compactor	20.27	4	81.08
DCP	3.29	1	3.29
Theodolite	21.87	2	43.74
Generator	10.79	6	64.74
Drill	3.71	3.5	12.99
Light Delivery Vehicle	75.15	46	3456.90
Large equipment cost			4773.30
20% extra for hand tools			954.66
Total equipment cost			5727.96

Table A3-13: Equipment costs, LITE house (LITE 2003)

Code	Description	Unit	Quantity	Rate	Amount
LA	Site preparation				
LA1	Clear and grub	m^2	150	0.91	136.38
LA2	Levelling	m^2	150	1.38	206.99
LB	Foundations				
LB1	Set out excavation			111.50	111.50
LB2	Excavate	m^3	59.9	23.53	1409.66
LB3	Compact	m^2	62.4	1.68	104.55
LB4	Mix and place concrete	m^3	12.5	621.74	7771.77
LB5	Cure concrete			72.72	72.72
LB6	Set out foundation walls			16.06	156.06
LB7	Build foundation walls	m^3	30.0	263.11	7893.27
LB8	Cure mortar			72.72	72.72
LB9	Backfill and compaction	m^3	30.0	23.65	709.36
LC	Floor				
LC1	Level, backfill and compact	m^2	95.4	8.09	772.01
LC2	Lay damp proof membrane	m^2	95.4	4.92	469.28
LC3	Lay damp proof course (dpc)	m	88.6	1.47	129.90
LC4	Cast concrete slab	m^3	7.6	623.35	4737.47
LC5	Cure concrete			72.72	72.72
LC6	Cast screed	m^3	1.9	605.61	1150.66
LC7	Cure screed			72.72	72.72
LD	Walls				
LD1	Place poles and fish line		19	7.41	140.78
LD2	Position door frames		8	228.53	1828.20
LD3	Build up walls to cills	m^2	87.8	69.24	6079.12
LD4	Position window frames		19	551.37	10476.07
LD5	Build walls to door head	m^2	100.4	69.38	6965.96
LD6	Place window cills		99	15.12	1497.29
LD7	Place lintels		27	53.35	1440.52
LD8	Build up walls	m^2	25.0	69.76	1744.08
LD9	Build in roof ties		120	22.12	2654.00
LD10	Build up walls	m^2	12.5	79.97	999.68
LE	Roof and ceilings				

LE1	Treat roof timbers			772.21	772.21
LE2	Fix wall plates	m	74.8	9.66	722.45
LE3	Place trusses		22	717.35	15781.71
LE4	Place temporary junctions		4	231.78	927.11
LE5	Place purlins		30	86.37	2591.00
LE6	Place bracing		28	15.38	430.54
LE7	Place sheeting	m^2	137.3	26.83	3683.85
LE8	Place gutters, down pipes and fascias	m	48.8	60.94	2973.80
LE9	Finish roof			2959.95	2959.95
LE10	Place insulation	m^2	114.5	23.19	2654.83
LE11	Place brandering	m	240.4	3.93	945.42
LE12	Place ceiling	m^2	114.5	61.52	7044.28
LE13	Paint ceiling	m^2	229.0	2.81	643.82
LE14	Place plinths	m	120.5	3.48	418.82
LF	Interior				
LF1	Place burglar bars		19	232.60	4419.33
LF2	Paint metalwork		27	28.11	759.04
LF3	Glazing		19	110.88	2106.76
LF4	Plaster walls	m^2	446.8	4.97	2218.92
LF5	Electrical installation			2170.12	2170.12
LF6	Hang doors		8	786.16	6289.31
LF7	Paint walls	m^2	993.6	1.33	1325.98
LF8	Plumbing			1219.80	1219.80
LH	Veranda				
LH1	Level and compact	m^2	35.4	10.90	385.85
LH2	Place concrete	m^3	2.8	707.98	1982.33
LH3	Cure concrete			72.72	72.72
LJ	Work floor				
LJ1	Clear and grub	m^2	28.0	3.05	85.45
LJ2	Excavate	m^3	2.8	48.71	136.38
LJ3	Compact	m^2	28.0	3.05	85.45
LJ4	Build walls	m^2	6.9	80.79	557.43
LJ5	Place concrete	m^3	2.2	644.68	1418.31
LJ6	Cure concrete			72.72	72.72
LK	Finish				
LK1	Clean buildings			530.32	530.32
LK2	Clean site			231.88	231.88
LK3	Put in inventory			314.64	314.64
LM	Earth brick manufacture				
LM1	Manufacture		5605	2.26	12685.13
TOTAL COST					**150615.58**

Table A3-14: Bill of Quantities, LITE house (LITE 2003)

A3.4 LIGHTWEIGHT STEEL SYSTEM DETAILED COST BREAKDOWN

The data for this case study is taken from two sources: Vela steel building systems provided a quote (October 2007) for materials and in-house labour for the steel building system for a block of five classrooms, while the conventional building work was costed with information provided by Dr Alfred Taluchaba of the

School of Construction Economics and Management, University of the Witwatersrand.

Description	Quantity	Unit cost	Total (R)
600mm Standard panel (L1)	7	645.00	415.00
1200mm Standard panel (L2)	60	1 045.00	63.240.00
1200mm Window panel (L3)	40	1 220.00	48 800.00
1200mm Door panel (L4)	5	1 040.00	5 200.00
Truss	37	465.34	17 217.58
Battens and auxiliaries	96	59.56	5 717.76
Bracing	1 block	1 735.64	1 735.64
Ceiling battens	1 block	6 914.88	6 914.88
Posts and beams, including shoes and caps	1 block	9 381.70	9 381.70
Total excluding VAT			**162 722.56**
VAT			22 781.16
9.1 Total			**R185 503.72**

Table A3-15: Vela quotation for Lightweight Steel System school (Vela 2007)

Code	Description	Unit	Quantity	Rate	Amount (R)
1.1	Site clearance	m^2	300.00	5.65	1 695.00
1.2	Excavation	m^3	33.00	40.95	1 351.35
1.3	Compaction	m^2	277.00	5.85	1 620.45
2.1	Raft foundation (see Fig A3-1)	m^3	32.46	843.75	27 388.13
3.1	Superstructure (see Table A3-15)	item			163 446.15
4.1	Roof sheeting	m^2	350.00	97.40	34 090.00
4.2	Waterproofing	m	143.00	42.18	6 031.74
4.3	Ceilings & insulation	m^2	277.00	167.41	46 372.00
5.1	Glazing	ea	40	342.00	13 680.00
5.2	Doors	ea	5	663.56	3 317.80
5.3	Painting	m^2	268.86	60.16	16 175.00

Table A3-16: Summary Bill of Quantities, Lightweight Steel System school (2007 SA Rands)

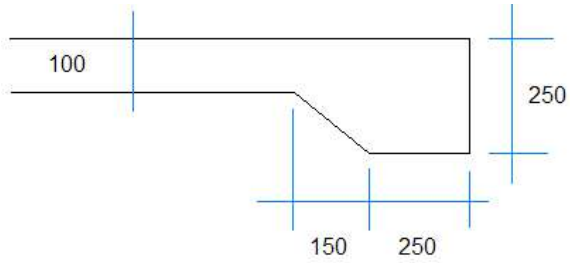


Fig A3-1: Raft foundation dimensions, Lightweight Steel System school

These values have not been taken to 2003 prices as the Lightweight Steel system was not in existence in South Africa at the date.