Candidate's Declaration

I hereby solemnly declare that this dissertation is my own unaided work. It is being submitted to the Degree of Master of Science to the University of the Witwatersrand, Johannesburg.

This dissertation, or any version thereof, has not been submitted before for any degree or examination to any other University.

Thus signed in Johannesburg, on the _____ day of _______________ 2016

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Signed by:

Abstract

Project management put the U.S. astronaut Neil Armstrong on the moon and has made possible the realisation of some of mankind's wildest dreams. Recent project management trends would indicate that the discipline has not only departed from the traditional practice of delivering projects based on an engineering design (with appended cost and schedule estimates), but that project scope, scale and complexity have drastically increased as well.

It would however transpire from the numerous and recurrent unsatisfactory outcomes of Large Infrastructure Projects (LIPs) that traditional project management has not necessarily kept pace with such new developments – especially their ever-increasing complexity. Massive costs and schedule overruns on such projects attest to the severity of this problem. Similarly, instances of substantial changes to the initial project scope will suggest that modern project management approaches would still require enhancements.

Project management is defined as "*the application of knowledge, skills, tools, and techniques to project activities in order to meet project requirements*" (PMBoK Ver. 5) – Hence, to improve project delivery performance, a particular attention should be given to managing requirements throughout the project lifecycle, which constitutes the essence of System Engineering (SE).

Systems Engineering, as a discipline and as a way of thinking, is gaining popularity and acceptance in its applications to Large Infrastructure Projects (LIPs) due to the benefits emerging from its ability to manage escalating complexity, particularly in large and complex infrastructure projects such as transportation (e.g. railways, ports), energy, and water infrastructure projects. These LIPs drive economic growth, through both their construction phase (e.g., job creation) and their successful outcomes (e.g., better services).

This study has considered Systems Engineering principles and concepts for incorporation by way of enhancements into a holistic project lifecycle model that improves delivery effectiveness – which shall then result in substantially reduced cost and schedule overruns on Large Infrastructure Projects (LIPs).

Dedication

"But it is the Spirit in a man, the breath of the Almighty,
that gives him understanding." [Job 32:8]

To my God-given wife and children, and

To the Project Management community across the African continent,

I humbly dedicate this work ...

Acknowledgements

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- My Research Supervisor, Ms Bernadette Sunjka, for the guidance and sympathetic support throughout the development of this work, the quality of which shall reflect the scope and intensity of her academic supervision;
- Transnet SOC, my previous employer, where I headed up the Project Management Centre of Excellence (PMCoE) for many years, affording one the most generous opportunity to understand the challenges around delivery of large infrastructure projects and to gather insight, information, data, and lessons-learned – all of which have not only prompted this very research, but have also ultimately sustained its successful completion;
- Transnet Centre for Systems Engineering (TCSE) at the University of Witwatersrand for their backing and support toward this research, and for affording me an open knowledge-sharing platform from which one could safely step into this fascinating world of Systems Engineering; and,
- Colleagues and friends in the industry (that are too many to mention on this page) whom, through discussing Project Management topics/issues, have assisted in enriching and crystallising one's own thoughts and insights around the effective delivery of capital and infrastructure projects.

"My heart is not proud, O Lord, my eyes are not haughty;
I do not concern myself with great matters or things too wonderful for me.
But I have stilled and quieted my soul; like a weaned child with its mother,
like a weaned child is my soul within me. I have put my hope in the Lord,
both now and for evermore." [Psalm 131:1-3]

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Symbols are not reflected in the body of this dissertation as no equation is included therein, other than those in-built in Excel spreadsheets used to analyse survey responses.

Nomenclature / List of Acronyms

Capex	Capital Expenditure
CASoS	Complex Adaptive System-of-Systems
CLIOS	Complex, Large-scale, Integrated, and Open Systems
DoD	Department of Defence [USA]
DP	Deployment Package
EC	European Commission
ELLP	East London Line Project [UK]
EPCM	Engineering Procurement and Construction Management
EU	European Union
FEL	Front End Loading
GDP	Gross Domestic Product
GR	Gate Review
H&S	Health and Safety
ICT	Information and Communication Technology
INCOSE	International Council on Systems Engineering
IPA	International Project Analysts
ISO	International Standard Organisation
ITS	Intelligent Transportation System
LIP	Large Infrastructure Project
MCMA	Mexico City Metropolitan Area
NASA	National Aeronautics and Space Administration
NETLIPSE	NETwork for the dissemination of knowledge on the management and organisation of Large Infrastructure ProjectS in Europe
NPV	Net Present Value
ORP	Operational Readiness Plan
ORS	Owner Requirements Specification
PESTLE	Political, Economic, Social, Technological, Legal, and Environmental [Analysis]
PICC	Presidential Infrastructure Coordinating Committee
PIR	Post Implementation Review
PLD	Problem-Literature-Data
PLM	Project Lifecycle Methodology
PM	Project Management

PMBoK	Project Management Body of Knowledge
PMI	Project Management Institute
PWW	[Dutch] Public Works and Water Management
ROI	Return on Investment
RSA	Republic of South Africa
SA	System Analysis
SE	Systems Engineering
SEBoK	Systems Engineering Body of Knowledge
SECoE	Systems Engineering Centre of Excellence
SEH v3	Systems Engineering Handbook version 3
SE in CES	[Dutch] Guideline for SE within the Civil Engineering Sector
SE for ITS	Manual on Systems Engineering for Intelligent Transportation Systems
SE for PWW	[Dutch] Guideline Systems Engineering for Public Works and Water Management
SIPs	Strategic Infrastructure Projects
SM	Stakeholder Management
SME	Subject Matter Expert
SMT	Systems Measurement Triangle
SoI	Systems-of-Interest
SoS	System-of-Systems
SoSE	System-of-Systems Engineering
SSA	Sub-Saharan Africa
SSM	Soft Systems Methodology
ST	Systems Thinking
STD DEV	Standard Deviation
S-TEAM	Systems Techniques-, Engineering-, Approaches-, and Methodologies
SWOT	Strengths-Weaknesses-Opportunities-Threats [Analysis]
TA	Thematic Analysis
UK	United Kingdom
US	United States
US DoS	United States Department of State
USA	United States of America
USAF	United States Air Force [USA]

V	Vee [for V Model]
V&V	Verification and Validation
VSM	Viable Systems Model
VTVT	Verification-Tailoring-Validation Triangle
YTD	Year-to-Date