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Open Source as a Tool for Communal Technology Development: Using Appropriate Technology Criteria to Determine the Impact of Open Source Technologies on Communities as Delivered Through the Massachusetts Institute of Technology Fab Lab Projects.

A dissertation submitted to the Faculty of the Arts, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Arts.

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Abstract

This paper aims to determine whether open source technologies are able to address community-specific needs more appropriately than proprietary equivalents and are therefore more relevant to the needs of the communities that create them.

To this end, the paper argues that open source initiatives are not solely bound to the realm of software creation. An example of this is provided through a study of the Massachusetts Institute of Technology's Fabrications Laboratories, or Fab Labs. Two studies of Fab Lab projects are used to determine the role that open source plays in the developing of appropriate technologies. Criteria for appropriate technologies are therefore discussed and the case studies are unpacked accordingly.

To answer the central research question, this paper explores written theory, includes an analysis of the case studies, and presents personal interviews with team leaders that have conducted Fab Lab projects.

It was found that an open source framework does indeed contribute towards effective appropriate technologies, and that the term open source may be applied to non-software specific technology creation.

Because this paper has identified that open source is applicable to non-software situations, more research is necessary to explore this varied fields, especially in the development sphere.

DECLARATION

I declare that this dissertation/thesis is my own unaided work. It is submitted for the degree of Interactive Design in the University of the Witwatersrand, Johannesburg. It has not been submitted for any other degree in any other university.

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(name of candidate)

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This paper is dedicated to all of those who seek to better their communities by giving their time and expertise.

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Introduction

Outlining a Definition of Open Source and the Problems Faced When Locating Non-Software Development in an Open Source Context

The overarching aim of this research paper is to argue that projects that adopt open source principles are culturally more relevant to the communities that create them, when compared to projects of a propriety nature. I have chosen an open source context to frame this argument, because open source projects entail a communal developing of technologies that seem appropriate to relevant community technology development.

The application of open source technology development may apply to a diverse range of communities. For example, many artists who work in the digital domain are involved in the creation of software technologies that are used for art installations. Many of these artists work within the open source domain, because they have access to a range of software components which are relevant to their practice. Such artists may therefore belong to a community that requires specific technologies for artistic application. An open source system is useful for communities such as artists because it allows them to gather and contribute to a growing library of software code that is specific to artists' needs. Other communities however, may require a technology that is not software-specific, yet the process of knowledge creation and contribution encouraged by an open source framework may be useful in the generation of non-software specific technology creation.

The problem is that the definition of open source, according to Richard Stallman[1] in his article entitled *On 'Free Hardware'*, applies to software development only. Chapter one of this paper therefore argues that the principles or the development methodology[2], to use Richard Stallman's term, of open source may apply outside of software creation. The

1 Richard Stallman is an evangelist for the open source movement and founder of the Free Software foundation (Open Source Software Development: An Overview. 33)

2 "Open source is a development methodology; free software is a social movement." Stallman, Richard (2007). "Why Open Source Misses the Point of Free Software".

application of this to hardware is therefore used as a means of identifying 'open' thinking outside of the software environment.

Open hardware initiatives[3] have advocated for recognition under the open source definition, but according to Stallman the copyright legalities in and around the manufacture and costs of hardware manufacture make this impossible (Stallman, *On 'Free Hardware'*). This paper does not intend to argue that the hardware manufacture of technology should be open sourced under licence, but rather argues that the principles of open source, or an open source framework, applies to non-software technology development.

In chapter two, the Massachusetts Institute for Technologies Fabrication Laboratories or Fab Labs are used as an example of agencies that employ an open source framework to construct technologies that are not necessarily software specific. Fab Labs are merely used as an example of such a facility as they provide ready examples of projects that are created within an open source framework. A chapter about these facilities is relevant because the central case studies, used in this paper to present non-software specific hardware development that employs an open source framework, are provided through a study of projects created in Fab Labs. These examples are used to explore open source as a communal or collaborative means to develop technologies that address the specific needs of communities.

The following case study demonstrates how proprietary technologies are often inaccessible to the end-user, and as a result, aids the argument for non-software specific open source development.

In 2006 the BBC headlined a *New Straw to Kill Disease as you Drink*[4]. It was reported that a Danish design team invented a product called the *LifeStraw* which was designed for people in developing countries. The report stated that for a purchase price of

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[3] Stallman refers to such initiatives as enthusiasts of open or free hardware design (On 'Free Hardware').
[4] "New straw to kill disease as you drink." BBCnews 4 May 2006. http://news.bbc.co.uk/1/hi/world/africa/4967452.stm.

$3.50, people in developing countries could drink clean filtrated water from polluted water sources. The design is unique and potentially provides millions of people with access to clean drinkable water. Yet the designers failed to anticipate a few issues. Generally, according to the BBC report, people in such countries cannot afford to pay US$3.50 for a *LifeStraw*. In addition to this, the reason that the inhabitants of such countries often do not have access to drinkable water is because they live a fair distance away from water sources and not because the water is polluted. In this case, it can be concluded that one must take into account the cultural environment in which the proprietary product is to be introduced. The *LifeStraw example* illustrates that the developers of proprietary products may make cultural presumptions which may lead to a cultural ineffectiveness due to a lack of contextual understanding. It is within this context that I make the case that communities are able to address their own needs more appropriately, given a development platform that suits communally based technology growth.

Chapters three and four present Fab Lab case studies which describe the contexts of specific communities that required and developed their own technologies which address their specific needs within an open source environment. These technologies are unpacked in accordance to a list of criteria outlined by W. C. Wicklein that measure the effectiveness of appropriate technologies. Appropriate technology, according to Anthony Akubue in his paper *Appropriate Technology for Socioeconomic Development in Third World Countries* for the Journal of Technology Studies, is a term used to describe a developmental approach concerned with technology creation that addresses community specific problems (Akubue 1). The technologies addressed in chapters three and four are compared to Wicklein's criteria so that the relevance of the technologies to the communities that made them may be studied.

It is important to note that this paper does not intend to argue that all Fab Lab projects are open source, or that all open source projects are effective appropriate technologies. The case studies are merely used as a study of non-software specific technology creation that occurs within the open source sphere and to gauge such projects efficacy as appropriate technologies. Additionally the paper does not intend to argue that

Fab Lab facilities are necessary to develop appropriate or open source technologies. Open source projects can be developed in any context or environment as long as it adheres to the requirements of open source development. The paper does set out to determine whether such open source projects are appropriate technologies.

The findings of the case studies are presented in chapter five, which describe the issues that pertain to non-software specific open source technology development. These suggest the conditions under which non-software specific technology creation should occur to reinforce the idea that many communities require technologies that relate to their specific needs.

Chapter One

The Open Source Tradition and its Application to Non-Software Technology Situations

This chapter provides a definition and example of open source and its organisational structure so that a concrete motivation for the application of an open source framework for non-software specific use may be gained. This is significant as this framework supports the communal developing of technologies. I will explore concerns regarding open source development; aiming to reject a blind evangelising of the nature of open source without fully understanding the limitations of open source development. This is additionally intended to provide a backdrop that may highlight the potential failures of hardware development in an open source context.

Towards a Definition of Open Source

The term 'open source' has seemingly become misconstrued, appropriated and appended to a varied range of situations. There are various definitions for open source; the most important of which states that the term 'open source' may be used in the context of software creation only.

On the home page of *The Open Source Initiative*[5], a web site that proclaims to officially define open source, Eric Raymond, advocate for the open source movement and co-founder of the open source initiative, suggests that open source is:

> […] a development method for software that harnesses the power of distributed peer review and transparency of process. The promise of open source is better quality, higher reliability, more flexibility, lower cost, and an end to predatory vendor lock-in (Raymond).

The transparency of process mentioned by Raymond may seem to afford the freedom for software developers to peruse, learn, apply and evolve implemented processes for their own benefit. This freedom underpins open source development and ironically, seems to

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[5] *The Open Source Initiative.* 13 March 2007. http://www.opensource.org

contribute to the widely misconstrued use of the term ‘open source’ which has become synonymous with free software or software that is obtainable at no financial cost. In his article *Why ’Open Source’ misses the point of Free Software*, published on the GNU Operating System website in 2007[6], Stallman clarifies this misconception by referring to ‘free’ in terms of “freedom of speech, not free beer” (Stallman, *Why ’Open Source’ misses the point)*.

Felix Stalder’s paper *On the Differences between Open Source and Open Culture* for the 2005 Open Congress[7] points to the freedoms which underpin the practice of software creation as outlined in the Open Source Initiative’s General Public Licence (GPL). These freedoms, he observes, must allow for:

1. The freedom to duplicate the software
2. The freedom to modify the software
3. The freedom to duplicate the modification
4. The obligation to pass on these rights.

The GPL, is a licence which serves to protect the freedom of open source software. Unlike most software licences, which aim to deny individuals the freedom to copy and modify software projects, the GPL is intended to guarantee this freedom. The GPL, as stated on the GPL page of the GNU website[8], therefore provides legal permission to copy and modify software (The GNU General Public License).

The preamble to the GNU GPL further states that the software (firmware) that is embedded in the microprocessors that govern hardware is often inaccessible to modification. The preamble states: “Some devices are designed to deny users access to install and run modified versions of the software inside them, although the manufacturers can do so. This is fundamentally incompatible with the aim of protecting users’ freedom to change software” (The GNU General Public License).

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[6] GNU Operating System. 2007. http://www.gnu.org/philosophy/open-source-misses-the-point.html
[7] Open Congress for Node, delivered in London at the Tate Britain on 1 October 2005. http://publication.nodel.org/On-the-Differences
[8] GNU Operating System. 2007. http://www.gnu.org/licenses/gpl.html

Many open hardware projects, such as Arduino, allow the firmware to be altered. In such a case, the firmware of a hardware artefact could be protected by a GPL.

Although these freedoms are to be protected by the General Public Licence, Joseph Feller and Brian Fitzgerald, who further unpack the open source definition in their book *Understanding Open Source Software Development* written in 2001, suggest the following; “Open source definition is not a licence in itself, rather it is a specification against which a software products’ terms and conditions can be measured” (12-18). It suggests that the open source definition is used to gauge the open sourceness of software projects and not the legalities of licensing. This in turn implies that the open source definition is a framework that enforces the rules of open source practice.

To consider the freedoms that open source software projects enjoy as applied to open hardware projects would be ideal. The fact is that the tangleblness of hardware provides a plethora of legal loopholes in the copywriting of such projects. John Ackermann, who led the first draft version of the TAPR’s Open Hardware Licence, states on the TAPR website, that the legal concepts that work for software, do not conceptually apply to hardware products, or the documentation that is required to copy or change them (Ackermann). As a result, TAPR has contributed to the Open Hardware Licence (OHL), which, unlike the GPL, is not a copyright licence. A copyright, the OHL preamble states, protects documentation from unauthorised copying, modification and distribution, but has little to do the right to make, copy or distribute artefacts that are based on that documentation. The OHL licence may contribute to the freedom of making, but it does not cover an open project firmware or software (ibid).

The definitions mentioned in this chapter allude to a set of characteristics that outline a framework which define the principles within which open source software is developed. It is this framework, I propose, that allows non-software specific artefacts to be developed in an open source manner. If these definitions support principles that relate to the transparency of process, distributed peer review, the freedom to distribute and modify the process for the purpose of evolving open products or software artefacts; and is not a licence but a system for measuring the terms and conditions of these principles, then it can be said that the definitions of open source can support processes that are not software specific. For the purpose of this paper, I therefore define open source as a communal or collaborative developing of technology:

a) That is not software specific
b) Where the process or 'blueprints' are made freely accessible or open for peer review,
c) Where the products of process such as ideas and executions may be modified, improved or expanded on, and
d) That use the term 'open' in the context that open source developers create works in principle and not in the context of open source software creation and in particular, open source licensing.

The Organisational Structure of Open Source

The open source definition provides a framework for the communal creation of technologies. Arguably, a system for proprietary software development could do the same, but one must consider the conditions under which the development occurs.

Raymond provides an important analogy which demonstrates the differences between commercial and open source software development platforms in his paper titled *The Cathedral and the Bazaar* published in 1998. He compares the development of commercial software to the building of a cathedral, and suggests that commercial software is constructed as if by wizards and mages, who work in seclusion, behind closed doors and who do not reveal their work until it is complete (Raymond, *The Cathedral and the Bazaar*). Raymond states that open source developers produce systems in an environment which he describes as "bazaar-like", an anarchistic system for development, which he believes, produces uncannily efficient results. The bazaar-like environment to which he compares open source development, Raymond believes, is rich and diverse in approach and agenda; attributes which he sees to produce reliable products (Ibid).

The processes employed by open source and proprietary software developers might be similar in nature, but it is apparent that the agendas, and the end products are designed to meet very different needs. Open source software must adhere to the four freedoms enshrined in the General Public Licence; its process of development must be transparent and available for peer review. However, proprietary software development and processes are purposefully secret, to safeguard the intellectual property of the pay-for product's developers or owners. It is imperative that the differences between these two systems be understood, so that an argument for the applicability of open source systems for the creation of more relevant or appropriate technologies for communities may be established. The attributes of the bazaar, I believe, support the development of community specific technologies. Members of the bazaar are able to determine the most appropriate approach and agenda for technology creation that will best suit the nature of their group. A Cathedral-like system is more concerned with the building of the cathedral, or the product, than with the communities and cultures for which the cathedral is intended to service. Bazaar-like systems, on the other hand, are more concerned about the needs of the people in the bazaar.

The difference between Microsoft's Windows operating system and Linux, the open source equivalent, provides a good example of Raymond's analogy. The cathedral-like Windows system is developed, owned and sold by Microsoft. Microsoft alone reserves the right to add to, change or adapt their software. The bazaar-like Linux operating system is programmed by a community of software engineers who develop components of the system for their own specific needs. The qualities of the bazaar were evident at the inception of Linux. According to Ragib Hasan from the University of Illinois, on his *History of Linux* webpage, Bill Gates purchased the DOS operating system. In its cathedral-like environment, Microsoft's wizards and mages constructed the Windows platform which was marketed aggressively (Hasan). As a result, Gates gained the monopoly on affordable personal computing operating systems. Alternative operating systems, such as the Macintosh's OS and UNIX were too expensive for the average computing enthusiast. Unsatisfied with the functionality and cost of proprietary operating systems, Linus Torvalds, built a crude operating system based on Andrew Tanenbaum's MINIX in 1991 (Ibid). He posted an invitation to the MINIX news group appealing to its members to contribute to the development of his new operating system. The bazaar-like MINIX user group responded with a great deal of enthusiasm and sought to develop an operating system that was free, customisable and serviced the needs of the MINIX community (Ibid). Currently, anyone can add to, change or adapt the software. This operating system is regularly updated; the source code is easily obtainable and is owned by no one and everyone. In comparison, Windows, or any other proprietary products is owned by the company that developed the end product. As stated on the Broadband Glossary website; users of proprietary software must purchase a license to be able to use the software. Users have no right to access or modify the source code. This means that proprietary technologies are developed and owned by individuals or companies who therefore exclusively own the rights to the end product as well as the intellectual property associated to its development.

The example above illustrates the difference in agenda that occurs between open source and proprietary systems. If proprietary software requires that licences must be purchased so that the software may be used, then its agenda focuses on the financial reward that the product may bring to the owner. A proprietary system's focus is therefore product specific. Tim O'Reilly's online article *Lessons from Open Source Development*, for the Communications of the ACM written in 1999, states that open source products are, on the other hand, often designed as a solution to a particular problem (O'Reilly). If like minded developers within an open source community develop software applications in answer to a specific problem, then one may conclude that the software solution offers a service to its respective community. It may therefore be said that open source systems are service orientated while proprietary systems are product orientated.

Additionally, the freedom that permits public access to the source code allows developers to receive the benefit of response by like-minded developers, who contribute to the increased functionality of the product. O'Reilly goes on to state that it is this communal-user development of technology, not the product itself, which may be the key to a product's success (O'Reilly). Furthermore, he states that open source product development, in contrast to proprietary product development, relies on the social contract that occurs between developers and users in which both parties agree to co-operate under certain rules that are beneficial to both parties (Ibid). It is therefore apparent that collaboration between developers and users or developer-users is necessary in open source environments.

It is important to note, however, that although collaboration occurs in both open and proprietary software development systems, the agendas of individual participation in the two systems differ. In the context of the cathedral model, collaboration occurs behind closed doors for the benefit of the end product, whereas the bazaar context employs open collaboration on public networks for the benefit of the group or open source community. An example of such collaboration exists in artist communities, where contributors work in the open source *Processing* environment, a software programme used to creative interactive situations. Here, discipline-specific libraries are developed, documented and maintained by the communities that created them. Such libraries cater to the needs of artists who work with mediums such as video, typography or sound (Fry and Casey).

In his journal article *Self or Group? Cultural Effects of Training on Self-Efficacy and Performance* for the Administrative Science Quarterly Journal published in 1994, Christopher P. Earley describes the role of participants in individualistic and collectivistic environments. Earley states:

> […] people base their self-understanding on the reactions of important others around them in a collectivistic culture. A worker from an individualistic culture strives to improve work performance because of the recognition he or she may receive, whereas a worker from a collectivistic culture seeks improvement because of the gains his or her group may receive. (89)

Earley's study discusses the agendas of collectivistic and individualistic systems. In Earley's terms, we can define developers in a proprietary context as individualistic and open source developers as collectivistic.

The transparency of process described by Stalder enables software to be developed in the public domain and the collectivistic working culture, described by Early, alludes to an open source work ethic that supports collectivistic communities by delivering usable technology at little or no cost. The transparency of process as prescribed by an open source framework and defined by Stalder, stipulates that the technology and the means to add to the technology must be provided openly so that the technology can be built upon. In so doing, the technology can be improved to cater to the specific needs of the collectivistic group. If open source communities build upon existing technologies and contribute by adding to an existing body of knowledge, then it follows that communities support the development of such technologies. As a result open source particularly supports collectivistic culture or the principle that a body of people collectively takes ownership of a development undertaking.

If a community is able to address their needs by collectively contributing to the development of a technology, and the end-user is an active participant in the process of technology creation, then one could assume that the technology would be loaded with values and ideals pertinent to the group.

The importance of a collective culture is illustrated in Lyn Henderson's article entitled *Instructional Design of Interactive Multimedia: A cultural critique*, published in1996. The article suggests that Abstract Instructional Design is socially and culturally constructed. She proposes that instructional design is loaded with values, ideologies and images which act in the interest of particular cultural groups (1). While instructional design is primarily concerned with the creation of instruction or educational materials, I find that software creation is similarly loaded with values, ideologies and images. Therefore, by using Henderson's example as an analogy to describe the process by which technologies are created: proprietary software development involves the loading of values, ideals and images which are aimed at a particular cultural group. However, open source development is concerned with the loading of values, ideologies and images that are determined by a particular cultural group. This suggests that end-users who engage with a proprietary product must become conversant in the developers language and use of metaphor before they can become proficient in the use of the technology. In contrast, open source developers, the members of public or communities who contribute to an open product, are conversant with the ideologies and values and images that are integrated in the final product because they were involved in the developing process.

Henderson suggests that instructional design should include collaboration between developers and end-users and that the end-user must be an active participant and take responsibility in the learning-teaching paradigm (1). In the context of technology creation, I use Henderson's example to illustrate how a development process that utilises collaboration, where the end-user is an active participant, within an open source framework may be used to avoid cultural irrelevance when communities pursue the development of technologies that address their specific needs. This development process is discussed in depth in chapter two.

The open source framework promotes a process that is transparent, encourages distributed peer review, supports the freedoms that enforce the ability to copy, modify and distribute the end product, supports a style of collaboration that is collectivistic, and is particularly end-user focused. Because open source is collectivistic and the process of creation is open to free distribution and modification, I believe that the open source framework is an appropriate system for the communal development of technologies which are able to meet the requirements and the specific needs of communities.

Open Source as a Framework for Non-Software Specific Situations

It is the transparency of process, discussed in Raymond's definition of open source, which provides the promise of better service and the end to vendor lock-in that makes the open source framework valuable to the collective development of community specific technologies. It is therefore unfortunate that this framework is allowed to officially apply to software contexts only. Throughout this chapter, I have argued that this framework may apply to non-software situations. While this argument may seem plausible in theory, I have included three instances to substantiate my argument where an open source context could be applied to non-software specific instances in practice.

Knowledge as Open Source

Friedrich Kittler discusses academia in relation to open source software development in his paper entitled *Science as Open Source Process*. He states that in universities "[…] the knowledge generated and passed on must be able to circulate without the protection of patents and copyrights, unlike in closed or even secret research organisations and industries" (177). Kittler makes his argument by stating that in Athenian times, the process of documenting, archiving and spreading knowledge was open and free. After the invention of the Gutenberg press, universities became less 'open' as knowledge became locked in the system of books and publishing activity (Kittler 178). Kittler's reasoning suggests that open source is primarily concerned with the freedom of access to knowledge, which establishes open source in a non-software specific context. If knowledge is freely accessible; is allowed to be distributed, modified and the modifications distributed, and the information that pertains to the knowledge is distributed for peer review; and is transparent, then knowledge in its freely accessible context, may then support the definition of open source. This suggests that open source may be applied to a situation that is not software specific.

Furthermore, it is understood that the term source, as referred to by programmers, signifies the source of the code required to produce software application programmes. Consider code to be a language that is used to determine a set of instructions that must be performed by a computer. Typically, these instructions are delivered in a computer language that programmers are able to understand. Stalder says that one of the four freedoms employed in open source projects states that source code must be supplied in a format that is humanly comprehendible (Stalder). If code is a language that must be comprehendible, then it follows that literature is code, and can therefore be open source. If code is a set of instructions, then instructions or instructable materials can be open source, providing that the instructions are comprehendible, are allowed to be duplicated, modified and made publicly available. If one were to substitute the term 'software' with 'technology', one could envision an open culture applied to the general development of technologies. If the author or authors of a technology provide open and public access to their source code, files, documentation or the instructions pertinent to the making of their particular technology (albeit software or hardware), one may assume with reason, that the technology may be duplicated or remade and used in any way that the user may see fit. If the author allows a user to modify the project to suit their needs, and in return is obliged to produce a new set of documentation so that others may remake or modify the duplication or modification, then the process would support an open culture similar to that of open source software communities.

Documentation, however, cannot be protected by the GNU GPL. It may, according to the Free Software Foundation, as stated on their Free Documentation Licence webpage[9], be protected by the GNU Free Documentation Licence, which serves to ensure the freedom of content in documents such as “manuals, textbooks, or other functional and useful documents” (GNU Free Documentation Licence).

Social Interaction as Open Source

In 2006, Jill Coffin, a doctoral student at the Institut fur Elektronik, Eidgenossische Technische Hochscule, provided an *Analysis of Open Source Principles in Diverse Collaborative Communities*[10]. Her paper discusses the core principles of open source software development and maps these to non-software specific situations. One of these situations include the Burning Man’s *Black Rock City* project, which is an annual open collaborative project in which thousands of participants congregate in the Nevada desert. Here participants gather for a week to create a temporary metropolis which is dedicated to community, art and self expression (Coffin). It is a post-modern Woodstock, favouring expression and open accessibility to that expression. According to Coffin, *Black Rock City* follows an organisational framework that closely mimics that of a successful open source software community (Coffin).

The following table provides a comparison between Coffin’s descriptions of the organisational properties of *Black Rock City* that she feels relate to the basic fundamental properties of an open source framework and the properties of open source culture as defined by Stalder in his paper entitled *On the Differences between Open Source and Open Culture*.

Properties of *Black Rock City*	Open Source Framework
Black Rock City has an open and distributed membership which is based solely upon participation and involvement.	Open source projects or initiatives encourage a user base which is based on voluntary contribution and participation (Stalder).

[9] GNU Operating System. 2007. http://www.gnu.org/licenses/fdl.html
[10] http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1342/1262

Black Rock City is a convincing foundational artifact from which organised participation can be build upon. Participants of *Black Rock City* are self managed and contribute to the project on their own terms.	Contribution to open source project revolves around the foundational artefact (software), and participation is based on the value and the quality of programming that the potential participant is able to offer (Stalder).
Black Rock City has a benevolent dictator or compassionate project manager who understands the service that is required of the product and the needs of the community.	The benevolent dictator, according to Raymond, is a project leader who is at service to his community. Stalder states that the benevolent dictator is determined by a voluntary hierarchy, of which the hierarchy of authority is determined by an individual's responsibility (Stalder).
Foundational developers and early adopters who, along with the benevolent dictator, set the project ethos.	All projects have a leader, or a group of leaders (organisers), who determine the overall direction of an open source project and determine which contributions made by the community are included in the project (Stalder).

Coffin demonstrates that the framework employed by a team of open source software developers can be applied to a non-software specific situation. *Black Rock City*, although a social event, appears to conform to the fundamental principles of open source, Coffin states that the organisers of the city do not conform to transparency and peer review. However, Coffin states, in 2004 members of *Black Rock City*, unsatisfied with the authoritive control and the power of the established hierarchy, inspired a revolt. Larry Harvey, the benevolent dictator, upheld the right to fork, or rather allowed the divided members the right to establish a modification of *Black Rock Cit*y (Coffin). This is significant, because it suggests that the benevolent dictator not only supported the freedoms enshrined in what is reflected in the open source General Public Licence by allowing participants to duplicate and modify the artefact, he conformed to peer review which resulted in the fork.

While Black Rock City does not conform to transparency of process, the city does adopt the fundamental principles and the freedoms that reflect those of open source development. Should the benevolent dictator publish the processes required to host such an event, and organise the event around the suggestions and contributions of participants, then *Black Rock City* could, in the context of human social interaction, support the definition of open source through its publication. This is significant because *Black Rock City* situates communal activity within an open source context.

Hardware as Open Source

Gershenfeld, Massachusetts Institute for Technology (MIT) Professor and Director for the Center of Bits and Atoms, writes that personal fabrication will do for hardware development what open source has done for software development. In his book entitled *Fab: The Coming Revolution on Your Desktop-from Personal Computers to Personal Fabrication,* printed in 2005, Gershenfeld states:

> In a world of open source software, ownership of neither computers nor code alone provides the basis for a proprietary business model; what's left is the value added to them by creating content and delivering services. […] Similarly, possession of the means for industrial production has long been the dividing line between workers and owners. But if those means are easily acquired, and the designs freely shared, then hardware is likely to follow the evolution of software. (Gershenfeld 15)

Open source, according to Gershenfeld, should therefore be concerned with content creation and its service delivery. If it is possible for the content of hardware creation, in the context of personal fabrication, to be distributed, modified and the modifications distributed then it could be possible that hardware supports the definition of open source. But this sentiment can be strengthened if one were to consider that open hardware projects content must be open to peer review, the process for describing the creation of hardware must be transparent, and the function of the hardware must meet developer-users' specific needs.

According to Stallman's definition of open source, neither Gershenfeld's, Kittler's or Coffin's arguments may claim licensing under the open source initiative, yet these examples provide evidence that systems, organisations and communities can in fact operate under principles that reflect (or adhere) to what we understand to be 'principles' of open source.

Concerns Regarding Open Source

While this paper may seem to evangelise the nature of open source, it does not intend to. It rather aims to highlight its potential. Open source development does however have limitations, which must be understood – the flaws in open source development in a software context provide a backdrop to the potential failures in an open hardware context.

Michelle Levesque is a seasoned open source developer, who in her 2004 paper entitled *Fundamental Issues with Open Source Software Development* for the online First Monday Journal, discusses the potential flaws in open source development. She believes that "the general public continue to feel that Open Source software is inaccessible to them" (Levesque). Levesque's paper lists the possible reasons to why this may be so. Her reasons are included here to suggest a way forward for non-software specific open source development:

- **User Interface Design**: Levesque states that "programming geeks value integrity over beauty". As a result the user interface becomes less intuitive and more difficult to use by the end-user than a programmer. She suggests that programmers should realise that the general public will "never know that they [the programmers] happened to invent a particularly clever algorithm". This is also plausible in non-software specific situations, where it is possible that technology creators develop artefacts that are hard to use or understand. Technology developers must therefore develop technology artefacts that are accessible to the end-user.
- **Documentation**: Levesque suggests that open source projects seem to lack proper documentation. "Because [programmers] don't have any contractual responsibility…", the documentation is seen as a general handbook, rather than a comprehensive document that provides enough evidence for the furthering of development by other programmers. Documentation or instruction materials are

crucial for the development of an open project. One of the benefits of open source initiatives is that future users are able to remake or evolve technology artefacts. Insufficient documentation can therefore potentially hamstring the longevity and sustainability of communally developed technologies.

- **Feature-centric development**: In the course of her studies, Levesque was led to believe that “the best software tools are small programs that do one thing well, and interface cleanly with other tools”. Here, she believes that open source developers are occasionally guilty of ‘feature creep’, the notion that individual programmers try to gain ‘street credibility’ by continually adding arbitrary details to prove their skills. It is possible that feature-centric development may jeopardise the relevance of community specific technologies. Community specific technology artefacts should be designed to cater for the specific needs of its community. If functionality is added to a community specific technology by an individual for personal benefit, then the technology artefact as a whole becomes less relevant to the community.
- **Programming for the Self**: It would seem that programmers write code for their immediate programming community, without taking cognizance of the broader community for which the end-product is intended. Levesque states:

> Open source projects are made by programmers for programmers, who then can’t understand why the general public would bother with proprietary software when this open source tool is working for *them*. Meanwhile, the rest of the world begins to associate ‘Opens Source’ with software that is only accessible to the technocratic elite” (Levesque).

A community specific technology must be accessible to its community. If the broader community is unable to implement the technology because they are unable to understand its value, then the technology is irrelevant to them. It is therefore important that the intended purpose of the artefact is clear.

- **Religious Blindness**: Lastly, she suggests that open source developers do not recognise important technology development in proprietary circles, and refuse to believe that much can be learnt from proprietary development. She argues that the failure

> to acknowledge the weaknesses in the open source position, so that these weaknesses can be resolved, is a key problem among open source developers (Ibid). Indeed, as the Fab Labs will show in chapter two, much communal developing of technology occurs through precedent. Personal fabrication, for example, is not concerned with original invention more than it is concerned with the appropriating of knowledge for the development and refining of technologies so that specific needs may be met.

It is clear that open source is not without its limitations. Accessibility, clear documentation, solution specific design, clear product output and the ability to understand and apply appropriate precedent when needed may contribute to open source projects' success. Moreover, these parameters relate to the requirements of non-software specific design. A technology that employs an open source development framework must supply instruction or documentation that is comprehendible, the function of the artefact must be made clear and should meet the specific requirements of the group or community for which the artefact is developed.

Chapter Conclusion

This paper does not intend to sanction open source or degrade the means by which proprietary technologies are developed. Open source supports a collectivistic culture, which appears to support the development of free, relevant and communally specific technologies and is therefore used as an appropriate framework in which the development of communally specific technology development can be studied.

It is apparent that open source is an official term that defines a particular framework applicable to the development of software only. It is also apparent, however, that this term may unofficially be applied to a range of non-software situations, where these situations allow for:

- The transparency of process,
- Distributed peer review,
- The freedom to distribute and modify processes for the purpose of evolving the situation, and

- A system for measuring the terms and conditions of the principles under which this system is applied.

It is therefore evident, according to Gershenfeld, Kittler and Coffin, that open source organisational principles or framework can be conceptually applied to a range of non-software specific instances, such as knowledge distribution, community based social events and hardware development. However, these instances must adhere to the four freedoms as described by Stalder as these freedoms underpin the principles of the open source software movement. It is evident that the physical properties of hardware require a different kind of licence to that of software. However, it is possible for firmware to licensed under the GNU GPL, for documentation or instruction to be licensed under the GNU Free Documentation Licence, and for the physical hardware to be licensed under the TAPR Open Hardware Licence. Furthermore, it evident that open source is not without its shortcomings and that individuals or communities who wish to use an open source framework to develop technologies that cater for their specific needs must address these issues in order for the technologies to be accessible, sustainable and re-make-able.

Chapter Two

<u>Fab Labs: Their relation to Open Source and Their Impact in Communities</u>

It has been established that it is possible for non-software specific situations to adhere to an open source framework. I will use Fab Lab projects as an example of non-software specific open source technology creation to study the relevance that such technologies have in the communities that develop them.

Fab Labs are communally based laboratories that employ an open culture for technology creation. These technologies are not software specific and the labs provide a useful platform for arguing that open methods are also applicable to non-software specific technology creation. Apart from providing a brief contextual history of Fab Labs, this chapter provides a study of the framework employed by Fab Labs. These include its working structure and open culture so that the core attributes of Fab Lab process, that position Fab Lab projects in an open source context, may be determined. To unpack the relevance of open culture development on communities, the Fab Labs' shared core capabilities, and services to its communities, are also discussed.

Fab Labs: A Brief History

In 1998, Gershenfeld, held a series of semester workshops called *How to Make (Almost) Anything*. The workshops were designed for advanced Physical Sciences students in the throes of their research and promised to provide much needed experience on the kinds of high-tech fabrication tools used to make, according to Gershenfeld, "[…] just about anything" (Gershenfeld 4-5).

Surprisingly, students with little or no technical experience enrolled for these workshops and soon began to make and assist in the making of complex technology artefacts. These artefacts were created as a result of personal whims, which fulfilled no real value other than the students' personal needs, as Gershenfeld states: "None of the students needed to convince anyone else of the value of their ideas; they just created them [for] themselves" (Gershenfeld 9). It is plausible that proprietary products that fulfil such personal needs do not exist. Relying on proprietary technologies, students would have had to compromise on satisfying their whims, settling for a product that would have ‘almost’ met their specific requirements, or provided more functionality than was required by the individual. Students were therefore not relying on proprietary technologies to satisfy their wants, but using this forum for technology creation to develop technological artefacts that were specific to their personalised wants and/or needs.

Drawing from his experience with the students, Gershenfeld considered the application of these workshops on communities that do not readily have access to technology manufacturing equipment. He believed that communities could theoretically create technological artefacts that are specific to their needs or wants. The success of his semester workshop therefore inspired the global implementation of Fab Labs by the Massachusetts Institute for Technology’s Center for Bits and Atoms. Gershenfeld describes a Fab Lab as an initiative dedicated to making both access to fabrications technology and the manufacture of technological artefacts openly accessible to the public. He states “Instead of bringing information technology (IT) to the masses, Fab Labs show that it’s possible to bring the tools for IT development, in order to develop and produce local technological solutions to local problems,” (Gershenfeld 13).
He goes on to state that:

> Life without the infrastructure we take for granted today required invention as a matter of survival rather than as a specialised profession. The design, production, and use of engineered artefacts – agricultural implements, housewares, weapons and armour – all took place locally. The purpose of bringing tool making back into the home is not to recreate the hardships of frontier living, just as it’s not to run personal […] production lines out of the family room. Rather, it’s to put control of the creation of technology back into the hands of its users (Gershenfeld 8).

By 2002, the first field Fab Labs (labs not based at MIT but in communities) were set up in India, Costa Rica, Norway, Boston (USA) and Ghana (Gershenfeld 12). The value of these labs to communities is evident in their rapid global distribution. In a

January 2009 entry on the Fab Lab page of the Wikipedia website, Amy Sun, MIT graduate and Fab Lab field specialist states that the current Fab Lab footprint has extended to twenty four registered Fab Labs in various countries including Kenya, Afghanistan, Iceland, the Netherlands, Spain and South Africa. Each invites individuals from their respective communities to develop and build innovative technology artefacts, either for themselves or for their communities. This growth suggests a direct need for independent technology development.

The Fab Lab Framework

The history of the Fab Lab appears to uncover a need for the production of technology artefacts that satisfy individuals' needs. So much so, that it is believed that the Fab Lab model may meet the specific needs of broader communities. If it is possible for personal fabrication to meet the specific needs of communities, then it is important to understand how the working model for personal fabrication in Fab Labs supports such technology creation, and how its framework fits within an open source context.

Fab Labs: A System of Open Process and Working Methods

In *Personal Communication Fabrication in the Lyngen Alps*, a paper delivered by Neil Gershenfeld and Manu Prakash in 2004 for the 3rd edition of Telektronikk, the authors state that the labs use an education model that is project based, and supports peer-to-peer training. Users of the lab create instruction materials while they work, and the resulting documentation of this is shared online. They suggest that this is an open source approach to soft- and hardware development. (Gershenfeld and Prakash 23)

The open sharing of ideas is at the core of the open source framework which is reflected in the freedoms defined by the open source General Public Licence (Stalder). If one were to consider comparing the raw material or software code of open source to instruction materials or documentation, then the history of the Fab Labs shows that Fab Lab projects support the freedom to distribute and the obligation to share the source of the code or instruction materials. These freedoms are encapsulated by the transparency of process, which specify that access to the documentation must be permitted and allowed to be modified and duplicated. Additionally, the rights to use, modify or duplicate the documentation must be passed on (Stalder).

An investigation of the open frameworks employed by Fab Labs was conducted during field research at the Soshanguve Fab Lab situated in Pretoria, South Africa. Moses Mogotlane, a co-ordinator for the South African Fab Lab initiative and member of the Advanced Manufacturing Technology Strategy (AMTS) project implementation team, reiterates these points in an interview, stating that it is the sharing of knowledge and the open access to project documentation which makes it possible to copy, re-make and or improve upon Fab Lab projects (Mogotlane Interview 7, 12).

The tradition of knowledge sharing originating in Gershenfeld's semester workshop is integral to Fab Lab culture. Gershenfeld states the following about the students that enrolled for his course:

> [They employed an] intellectual pyramid scheme. Just as a typical working engineer would not have the design and manufacturing skills to personally produce [such] projects, no single curriculum or teacher could cover the needs for such a heterogeneous group of people and machines. Instead, the learning process was driven by the demand for, rather than the supply of, knowledge. Once students mastered a new capacity […], they had a near-evangelical interest in showing others how to use it. As students needed new skills for their projects they would learn them from their peers and then in turn pass them on. Along the way, they would leave behind extensive tutorial material that they assembled as they worked (7).

Although it does not appear that the original Fab Lab deliberately adopted the characteristics of open source communities from the outset, the peer-to-peer intellectual relay system that evolved from Gershenfeld's semester course seemed to transpire naturally and proved to be an effective learning model.

In *Science as Open Source Process,* Kittler suggested that historically, learning institutions represented a means to open material distribution (Kittler 177). The Fab Labs are reminiscent of this: they provide open access to tutorial materials and project documentation which facilitates free and accessible knowledge.

If Fab Lab project documentation is compared to source code, and the information or the knowledge embedded in the documentation is freely accessible so that a technology artefact may be freely duplicated, modified or manipulated to suit the requirements of other users, and the other users are obligated to contribute to the documentation of new knowledge, then it would appear that the working structure of Fab Labs conform to an open source framework.

The Fab Labs as an Open Source Culture

If instruction materials or documentation are perceived as the equivalent of a software programmer's source code, it can be said that Fab Labs apply an open source framework as an effective method for producing non-software specific technology artefacts. The open documentation or instruction materials that are developed by Fab Lab users enable projects to conform to this framework. Elements of the open source definition are evident in the Fab Charter. The *Fab Charter*, as defined on the central Fab Lab website, not only serves to enforce the principles that define the Fab Lab culture and practice, but also alludes to some of the principles that conform to open source process:

The Fab Lab Charter is presented below:

> **Mission**: Fab Labs are a global network of local labs, enabling invention by providing access for individuals to tools for digital fabrication.
>
> **Access**: You can use the Fab Lab to make almost anything (that doesn't hurt anyone); you must learn to do it yourself, and you must share the use of the lab with other users.
>
> **Education**: Training in the Fab Lab is based on doing projects and learning from peers; you're expected to contribute to documentation and instruction.
>
> **Responsibility**: You're responsible for:
>
> **Safety**: knowing how to work without hurting people or machines,

> **Cleaning up**: leaving the lab cleaner than you found it,
> **Operations**: assisting with maintaining, repairing, and reporting on tools, supplies, and incidents.
> **Secrecy**: Designs and processes developed in Fab Labs must remain available for individual use although intellectual property can be protected however you choose.
> **Business**: Commercial activities can be incubated in Fab Labs but they must not conflict with open access, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success (The Fab Charter).

Because the Fab Charter endorses open access and stipulates that users must contribute to the process of documentation, it ensures that users of Fab Labs adhere to the open source principles endorsed by the labs, and continues the culture of knowledge sharing that was evident in Gershenfeld's semester workshop. It also aims to ensure that this culture is maintained as common practice in all field labs.

When describing the Fab Lab as an open source community, one could compare it to Coffin's persuasive argument for the *Black Rock City* infrastructure as an open source culture and practice. The labs, according to Bongani Mdluli, the operation manager for the Soshanguve Fab Lab, are open and accessible to the public (Mdluli Interview 7). According to Sun, who stated that there are a growing number of international Fab Labs, these labs are globally distributed which determines a widespread membership (Sun). Fab Lab members must, according to the Fab Charter, contribute in return for its services, which suggest that the labs widespread membership is based on user participation (The Fab Charter). Mogotlane states that the Fab Labs are a network of collaborators which use forums to hold collective discussions in which decisions are made (Mogotlane Interview 11). Fab Labs, according to Mogotlane, inspire project leaders or innovators (Mogotlane Interview 3), who are typically the trusted benevolent dictators. The Fab Labs, says Mogotlane are centered on the needs of their respective communities (Mogotlane Interview 10). The Fab Labs, as the foundational developers, and project leaders, as benevolent dictators, set the Fab Lab project ethos. In comparison to *Black*

Rock City, it is plausible that the projects created in Fab Labs, provided they are documented and freely accessible, meet the requirements of an open source framework.

Having discussed that the term open source officially refers to a platform for software development, it is evident that the model on which open culture and practice is based is not software specific, and that the open source model can be successfully applied to a range of situations. Its also appears that an open approach to problem solving is an efficient vehicle for culturally or community specific technology creation that is relevant to the needs of the creators.

Fab Labs: The Sharing of Core Capabilities

Each Fab Lab hosts a variety of facilities and skills that enable users to produce technology artefacts. The 2008 update of the Fab Foundation's *Fab FAQ* webpage states that "Fab Labs share core capabilities, so that people and projects can be shared across them" (Fab FAQ). This is made possible by the tools that are common to all Fab Labs. A shared inventory ensures that knowledge about the operation of machinery is common to all Fab Labs. The global Fab Lab network and its common technical expertise ensure a broad trouble shooting platform when technical difficulties arise. The shared inventory also caters for global file-data compatibility which means that projects that are created in Ghana, for example, can be fabricated at a lab in Boston, US. Provided that the tutorial material and the documentation of a project are comprehensive enough, it is possible that a project conceived in a Ghana lab can be re-made in Boston by a community and modified to suit its needs.

These core capabilities and tools allow users to create a variety of technologies, which range from the printing of sophisticated two-dimensional circuit boards to three-dimensional structures (Gershenfeld 25). The Fab Foundation website, describes the fabrication tools that are common to all Fab Labs:

- A computer-controlled laser cutter for creating 3 dimensional objects that are cut from 2 dimensional pieces,
- A large four by eight inch milling machine for making furniture and house-sized parts,

- A smaller precision milling machine for making 3 dimensional moulds,
- A sign or vinyl cutter for printing masks, flexible circuits and antennas,
- Open source programming tools for programming processors and interfacing with machinery. (Fab FAQ)

Mogotlane stated in an interview that Fab Labs employ or intern an electronics engineer and a programmer or IT specialist to assist users in the operation of machinery. These supporting members guide and show users how different machines may be used in combination to create specialised artefacts (Mogotlane Interview 4). Each lab has:

- One permanent manager
- An assistant manager
- At least two interns with a BTech degree or equivalent diploma.

The Labs adopt what Mogotlane calls a “learn while you teach, and teach while you learn” approach to attracting interns and in so doing promote peer to peer learning (Mogotlane Interview 4).

Like open source software engineers, who are networked, share a common programming language and the skills required to produce software applications, Fab Labs are networked, share core capabilities and skills. Shared core capabilities therefore imply that the distributed network between Fab Labs and open source developers are similar.

Fab Labs as a Support Service for Communities: A South African Case Study

Mogotlane states that the geographical placements of the communities that house Fab Labs determine their needs and focus, thus confirming the potential diversity of the globally distributed Fab Lab network (Mogotlane Interview 10). Even within the South African context there is a disparate difference between labs. According to Mogotlane, the Kimberley Fab Lab, for example, is centred on mining, education and agriculture, because the lab is situated in a farming and mining district. The Soshanguve Lab situated on the outskirts of Pretoria, on the other hand, is located near schools, technikons and clinics and therefore pivots around the needs of university students and school learners in the Soshanguve area. The lab at the Innovation Hub, situated in the central business district of Pretoria caters for small business (Ibid 10). The same is evident in international labs. The Barcelona lab in Spain focuses on architecture, because the city has an architectural history, while the Norwegian lab caters for its farming community. Mogotlane goes on to add that the culture of a community determines the culture of a lab. He states that there is a need for innovation at the Soshanguve lab and its primary users are school children. It is therefore accessible during the week and over weekends so children may have access to the facilities after school. Similarly, the lab at the Innovation Hub caters for small businesses and maintains regular office hours as a result (Mogotlane Interview 10). It is therefore apparent that all Fab Labs cater to the needs of their respective communities.

The original field Fab Labs were established to empower communities through technology creation and to use such technologies to create solutions to specific problems faced in communities. The Fab Labs in South Africa however were additionally introduced to increase a technology skills base and to transfer these skills to industry. The AMTS, according to Mogotlane, is a cabinet approved strategy of the South African Department of Science and Technology (DST) that manages technology manufacturing strategies. In an interview conducted on the 24th of May 2008, Mogotlane stated that the Fab Labs are what the AMTS refer to as "a vehicle for transfer" that provides communities with equipped laboratories that are designed to develop and transfer skills to industry (Mogotlane Interview 1). The Fab Labs, in a local context, are designed to incubate technologies that address local needs. And the innovators of these technologies are the groups or individuals that experience the need for such technologies directly. The AMTS hoped to capitalise on the knowledge sharing capabilities of the Fab Labs' open process, so that new skills may be transferred to industry.

In addition to resolving community specific needs, Mogotlane stated that Fab Labs are also used to realise certain national objectives. In an *Address by Deputy Minister Derek Hanekom* (South Africa's deputy minister for Science and Technology) in 2007, at the Launch of the Fabrication Business Laboratories, published on the Department of Science and Technology website, he stated that the Fab Labs are intended to solve communal needs locally. This includes the facilitation of appropriate skills development, the provision of facilities for entrepreneurs so that they are able to build and test technology artefacts, and to increase the diffusion and adoption of technology. The Labs are intended to increase research and development in the technology sphere and provide access to the infrastructure required to create small batches of niche products (Ibid). This in turn, Hanekom suggested will create job opportunities, build a high value-add manufacturing focus in the localities, develop human-resources, build cross-cutting skills, facilitate the development of 'smart-industries' by encouraging joint research and community interaction and provide an enabling infrastructure for innovators (Ibid).

The Fab Labs are seen to realise the objectives of the DST as a result of the labs' encouragement of technology empowerment through project specific and open training. Fab Lab personnel actively participate in project problem-solving processes, and provide the necessary training during the prototyping phase of projects. Additionally, Fab Labs' provide support during the mass-manufacturing phase of the project when needed, which is realised through the aiding of the patenting process, facilitation of relationships between innovators and industrial designers and the provision of networking opportunities between innovators and potential investors. In so doing, Fab Lab's assist users in the creation of employment opportunities for the benefit of the users' community. To further community involvement; the AMTS currently incenitivise community based projects by providing funds of up to R30 000[11] for community based initiatives (Mogotlane Interview 5).

Although this section deals with the South African government's response to Fab Lab implementation, the material provides some good examples of how agencies such as Fab Labs might contribute to communities in general. The Fab Labs were developed as free-to-use micro-manufactories which provide individuals with public access to fabrication equipment, manufacturing tools and the knowledge with which to use them (Gershenfeld 13-14). Fab Labs are therefore able to equip users with the tools required to conceptualise and produce functional contemporary technology artefacts. I therefore believe that when Fab Labs are successfully introduced and maintain an open source framework in under-serviced communities, where individuals or communities are able to

[11] US$ 3293

fabricate advanced technologies to resolve their specific needs, that technology growth will benefit the most.

Chapter Conclusion

Fab Lab project documentation is transparent, up for peer review, may be distributed, modified and redistributed. The Fab Lab maintains a system for measuring the terms and conditions of access to documentation through a carefully constructed charter, which promotes an open source framework. It is therefore evident that the documentation process required of Fab Lab projects support an open source framework.

Gershenfeld's semester workshop and the ongoing implementation of the Fab Labs provide evidence that it is possible for Fab Lab users to create sophisticated technology solutions to cater to their specific needs, regardless of their technical proficiency. The instruction or documentation materials that follow as a result from the Fab Charter allow Fab Lab projects to fulfil Stalder's four freedoms.

Fab Labs act as a globally networked hub of technology innovation in much the same way that team members of open source initiatives do, which enables users to share core capabilities and maintain open channels of communication. The shared core capabilities enable the global network to share information, data and instruction materials regardless of their geographical location. This is suggestive of the Fab Lab's distributed network which enables a platform for distributed peer review.

It is evident that Fab Labs adopt an open source approach. This approach is aimed at non-software specific technology development where technologies developed and manufactured are specific to the needs of the user. It is also evident from the diverse lab 'cultures' that the labs support their respective communities and their users directly in doing so. As a result, Fab Labs support an open framework, and a framework for technology development that is specifically relevant to the needs of the community.

Chapter Three

The *Electronic Shepherd*: A Norwegian Case Study of a Community Specific Technology Developed Within an Open Source Framework

It has become evident that Fab Labs employ an open source framework from which community specific technologies may be developed. This chapter provides a study of the *Electronic Shepherd*, a technology that was developed within the Fab Lab's open source framework and caters to a specific community's needs.

The study determines the suitability or appropriateness of the case study for the community for which it was intended. *Appropriate technology* is a term used to describe the suitability of a technology artefact. To this end, I map the development of the *Electronic Shepherd* to criteria that are used to determine the effectiveness of appropriate technologies, as described by R.C. Wicklein in his paper *Designing for Appropriate Technology in Developing Counties* for the journal Technology in Society, published in 1998.

I include a brief history of the case study to contextualise this project's development, as well as a background to Wicklein's appropriate technologies criteria, so that the relevance of the criteria used to gauge the effectiveness of this case study for its intended community may be established.

Background to the *Electronic Shepherd*

The *Electronic Shepherd*, the Fab Lab project used for this study, originated in the Lyngen Alps, Norway, high above the Arctic belt (Gershenfeld 187). The geographical location of the Lyngen Alps results in extremely harsh winter conditions, during which livestock move into the more treacherous regions of the Alps and often do not return. Locating and managing livestock during this season is therefore hazardous to the shepherds that work and live in this area (Thorstensen et al 245).

During the spring of 2001, Norwegian shepherd Haakon Karlsen noticed that satellites field the horizon, an observation that led to him to consider the potential for tracking his flocks by satellite (Gershenfeld 187). Although conventional satellite tracking operators do not typically provide satellite tracking services for shepherding purposes in the Lyngen area, Bjørn Thorstensen from Telenor, a telecommunications company partnered with Karlsen to develop a satellite tracking system that could service the local shepherding community (Gershenfeld 189). Seeking further assistance, Karlsen and Thorstensen presented the idea to MIT in 2002, which led to the installation of a field Fab Lab on Karlsen's farm in 2003 (Gershenfeld 189). This facility was used to refine and develop the *Electronic Shepherd* project and realise Karlsen's vision (Gershenfeld 189). As a solution to this specific geographically-based shepherding problem, Karlsen and Thorstensen based their technology around the flock behaviour of sheep (Thorstensen et al 245). The *Electronic Shepherd* team devised a series of radio tags that were fitted to livestock. The radio tags transmitted location data to a series of antenna via a wireless node-hopping or mesh-network system which relayed flock information to a shepherd (Gershenfeld 189).

While the Electronic Shepherd project was designed to resolve the hazards of shepherding in treacherous winter conditions, and therefore meet the needs of the shepherding community specifically, the Lyngen Fab Lab appears to have had an impact on the broader Lyngen industry. According to Arne Gjengedal in his paper *Industrial clusters and establishment of MIT FabLab at Furuflaten, Norway* delivered at the 9th International Conference on Engineering Education held in San Juan in 2006, the Norwegian Fab Lab is now a primary resource for technology development in the Lyngen area. This lab has partnered with business, government and other research institutions for technology research, development and the prototyping of new technology products (Gjengedal). Through projects similar to the *Electronic Shepherd*, the MIT-Norway Fab Lab aims to provide support at all levels through research projects and the development and testing of prototypes as well as to provide product development for the local business community. In a PowerPoint presentation[12], Haakon Karlsen, director of the Lyngen Fab Lab and co team leader of the *Electronic Shepherd* states that the facility also aims to provide a network between other globally based Fab Labs and access to professional

[12] Karlsen, Haakon Jr. "a Creative Arena.". PowerPoint Presentation. Norway. 10 May 2006. <http://www.cba.mit.edu/events/05.07.Norway/presentations/Norway.ppt>

assistance, technical equipment for fabricating and testing. All of this aims to contribute to increased research in important areas for Norway (Karlsen).

The Significance of Appropriate Technology in Relation to Community Technology Development

The *Electronic Shepherd* project is a technology that attends to the specific needs of the Lyngen shepherding community. The process of development is therefore inclusive of the social and cultural dimensions of the Lyngen shepherding community. Thus the innovation is a result of a social and cultural need. It is under these circumstances that I believe that the *Electronic Shepherd* is classified as an 'appropriate technology'.

Appropriate technology, according to Anthony Akubue's paper for The Journal of Technology Studies entitled *Appropriate Technology for Socioeconomic Development in Third World Countries*, is a term that dates back to the 1930s and is used to describe the appropriateness of technologies in 3rd world or developing countries (Akubue 33). Appropriate technologies are perceived to be different from current or modern technologies and are specifically defined as a system for technology development which harnesses local labour and resources for manufacture to benefit third world countries economically (Ibid 33). If the development and manufacture of a technology utilises local labour (community) and resources, then it may be assumed that the benefits of technology development will reach further than the developer's economy. Provided that the local labour is directly involved in the development phase, it follows that the local labour will also receive a broader skills or knowledge base.

Although appropriate technologies are seen to benefit countries or communities economically, they have also come to be viewed as a system for development which addresses community-specific issues. Akubue states that over the years, "[appropriate technology] has evolved into a development approach that is aimed at tackling community development problems" (Akubue 37). Because appropriate technologies address community development problems within the technology sphere, and because appropriate technologies are a development model, it may be deduced that appropriate technologies are inclusive of the social and cultural dimensions of innovation (Akubue 37).

Robert Wicklein's paper *Designing for Appropriate Technology in Developing Counties* for the Technology in Society journal provides seven criteria on which the effectiveness of appropriate technologies for communities can be measured. These criteria are:

- A technology's systems independence,
- Its image of modernity,
- The need for an individual or collective technology,
- Cost,
- Risk factor,
- Capacity to evolve, and
- The need for single or multipurpose technologies. (Wicklein 372-374)

It is important to note that these criteria do not have to be met in full to meet the requirements of appropriate technologies but simply outline a system whereby the effectiveness of an appropriate technology may be measured. The following case study is therefore unpacked in accordance to these criteria so that the appropriateness of personal fabrication, or open source technology development, within a specific community context may be determined.

If appropriate technologies are inclusive of the cultural and social dimensions of innovation, and it is a development approach to resolving community problems, then it would appear that appropriate technology is a suitable description for community based Fab Lab projects. That is not to say that all Fab Lab projects may be deemed appropriate technologies. In some instances it may be assumed that Fab Lab projects do not meet any of Wicklein's criteria. A system for measuring the effectiveness of appropriate technologies in a Fab Lab context is therefore necessary, and will establish the appropriateness of technology artefacts that have been designed within an established open source framework for communities. The following Fab Lab project provides sufficient documentation with which to gauge its effectiveness as an appropriate technology. The criteria are therefore used to study the *Electronic Shepherds* capacity to harness local labour and resources to produce a potentially innovative technology that is able to solve a community's specific needs.

Criterion 1: Systems Independence

Systems independence refers to the degree to which a technology artefact may operate independently of other technology systems or facilities (Wicklein 372). If a technology requires labour, financial or technical support which a community is unable to offer, then its capacity to function as an appropriate technology is minimised. It should therefore not require peripheral technology systems to ensure its efficient functioning.

Gershenfeld and Prakash suggest that the Lyngen Fab Lab is committed to "demonstrating and developing applications that are driven by the needs of individuals instead of industries" (Gershenfeld and Prakash 25). The commitment to an independently developed artefact was achieved when Karlsen envisaged a technology solution that catered to the needs of the Lyngen shepherding community and was not supported by an existing technology service. The development of the *Electronic Shepherd* was made possible by the open source framework used by Fab Labs which ensures a localised support structure as is encouraged by the Fab Charter. The Charter provides an approach to independent technology development that requires research and development that is user-based as opposed to industry-based. If users are able to research and fabricate personal technologies under the conditions stipulated by the Fab Charter then it follows that the technologies will be less reliant on external technical or financial support.

The commercial satellite tracking services in the Lyngen area could not accommodate shepherds' needs. The *Electronic Shepherd* therefore became inherently independent of commercial systems. Karlsen was therefore obligated to develop the *Electronic Shepherd* technology independently and the Fab Lab provided the means to do so. As a result, the project was largely fabricated in the Lyngen Fab Lab. Circuit boards, antennae and software were built and written in the Fab Lab, which suggests that the lab, as a facility, supports systems independence to some degree. As a result, Karlsen's project fashioned its own service, which mimicked the existing systems made available by Telenor's mobile service. Karlsen's system could be extended by the contribution of other shepherds: the more fixed antennae that neighbouring shepherds installed, the larger the network grid and therefore the service would become (Gershenfeld 189).

The *Electronic Shepherd* provided a service to the shepherding community that was not available commercially. As a result its components where fabricated in-house and all research was carried out via the Fab Lab network. The team did not require any peripheral technology systems to ensure the projects functioning, nor did it require extensive labour, external technical expertise or financing that inhibited the development of the technology. Because the *Electronic Shepherd* project was developed within an open source framework, which was supported by the Fab Charter, the *Electronic Shepherd* project team was able to build and refine a technology system that effectively utilised their local labour and resources. It may therefore be concluded that the *Electronic Shepherd* project meets Wicklein's systems independence criteria towards an effective appropriate technology.

Criterion 2: Image of Modernity

According to Wicklein, the Image of Modernity suggests that people of developing counties prefer to be perceived as modern and progressive; Wicklein states:

> An example of this phenomenon is [evident in] the development of an inexpensive high protein instant food sold throughout Latin America. In several countries this new cereal has met with success, but in one country it was a complete failure. After careful investigation concerning the products failure, researchers found that many citizens of that country perceived it as 'poor people's' food. This was not an image that people wanted to be connected with, even though they could benefit from this product. (Wicklein 372)

When Wicklein refers to a technology's image of modernity, he refers to how contemporary and desirable the technology may be perceived by a community. It is important, Wicklein believes, that an appropriate technology is not patronising. He states that an appropriate technology should appeal to a group or communities sense of dignity and pride (Wicklein 372). Out of date or cheap-looking technologies will therefore not contribute to the effectiveness of an appropriate technology.

Wicklein's argument is true when one considers a technology that is imposed upon a community. It stands to reason that if one were to pay for a technology artefact, then it must appear modern or desirable. Open source projects on the other hand, are generally not imposed, but are self created innovations that are developed and driven by a group. It is therefore reasonable to assume that a community which develops its own technology will find it desirable. Open source projects may therefore be perceived as modern, an attribute which increases its efficacy as an appropriate technology.

The *Electronic Shepherd* project was developed under the rules defined by the Fab Charter, and may therefore be deemed open source. As discussed, the nature of open source projects may contribute to its image of modernity criterion. The *Electronic Shepherd* project may therefore be perceived as modern by the project team. The *Electronic Shepherd* project was however, intended for the broader Lyngen shepherding community (Thorstensen, Programme for Fab Lab Research Seminar). It therefore constitutes a technology that was imposed upon a broader community of shepherds. Its image of modernity as perceived by other shepherds in the Lyngen community must therefore be considered.

The *Electronic Shepherd* can be perceived to be modern because it comprises modern technologies. In a presentation, Thorstensen describes some of the contemporary technologies evident in the electronic shepherd project. Lead sheep or flock leaders are fitted with Global Positioning Systems (GPS) which gather information about their flock and relay the data to base stations. The herd is equipped with electronic ear tags which transmit the carrier's data to the flock leader. This data includes information relating to the carrier's blood volume, pulse, temperature and the state of the *Electronic Shepherd's* sensors. Later or more modernised versions of the *Electronic Shepherd* project promise lower frequencies embedded Internet Protocol (IP) and integrated GPS communications systems (Thorstensen. *Programme* for Fab Lab Research Seminar). This suggests that the

Electronic Shepherd team revises and upgrades components where new technologies are able to improve the project.

It can be deduced that the *Electronic Shepherd* project applies sophisticated contemporary technologies to address the concerns realised by a traditional shepherding activity. Since this project considers the electronic automation of shepherding activities by using modern tools such as laptops, radio frequency devices and global satellite positioning technologies, one may consider that the *Electronic Shepherd* shows evidence of an image of modernity in sharp contrast to traditional shepherding implements such as shepherd crooks, sheepdogs and bells.

In conclusion, it may be argued that an image of modernity is irrelevant to a community that develops technologies within an open source framework. The product of an open source project will be desirable because it is created to address a specific need. Because it was created by a community its perceived image of modernity will be relevant to the group. An image of modernity does, however, apply when considered in a proprietary context, or when a technology is imposed upon a community. If one should pay for a technology, then it must appear to be modern because the individual or group will have this expectation of the product.

Criterion 3: Individual vs. Collective

This criterion relates to the collaborative structure which supports the development of an appropriate technology. According to Wicklein;

> Some cultures advocate a strong commitment to group process, where the benefit of the whole is held in higher esteem than individual accomplishment. In contrast, other cultures place a high priority on individual responsibility and accomplishment. These factors must be considered in detail when designing appropriate technology, because they will contribute to the success or failure of any given device or strategy. (Wicklein 372-373).

This criterion does not prefer a collective over an individual system to determine the success of an appropriate technology. Rather, as Wicklein states, the success of an appropriate technology hinges on the nature of a specific community. If a community, for example, is committed as a group, then a collective technology will benefit the group where "the benefit of the whole [group] is held in higher esteem than individual accomplishment" (Wicklein 372). Conversely, if independent individuals determine the makeup of a group, then an individual technology would be more appropriate.

The Fab Lab tradition is based on an open culture, which, as it has been established, is collectivistic. Fab Labs therefore promote a group effort, where the outcomes of technology development benefit the group of developers as opposed to the individual. In addition to the internal collaborative culture inherent in all Fab Lab projects, the Norwegian Fab Lab sought to provide a much needed collaborative research platform for the academic and industrial sectors of Norway (Karlsen). It is therefore apparent that the *Electronic Shepherd* also aims to benefit the broader industrial and research sectors of Lyngen through collaboration. A collaborative research effort was evident in the Haakon and Thorstensen partnership which spanned the shepherding and telecommunications industry, resulting in the development of the components required to realise the *Electronic Shepherd* project in the MIT-provided lab facilities.

The nature of the mesh-network technologies developed by Haakon and Thorstensen are additionally dependent on communal involvement: the more repeaters that are installed by farmers in this area expand the wireless network which results in a more efficient network (Gershenfeld. 189). End-user participation was therefore important to the Electronic Shepherd project's success. The shepherding hazards experienced in the area are common to all Lyngen shepherds, and shepherding predicaments are thus communal.

The advantages experienced by the Lyngen shepherds could benefit many more groups and individuals concerned with the sheep farming industry in Norway. These include government, abattoirs and consumers. The project has since evolved to cater to the needs of those involved in the peripheral farming industry which suggests that the evolution of this project is dependent on the greater Lyngen farming community (Thorstensen. *The Electronic Shepherd*). A later version of the *Electronic Shepherd* project should be able to provide consumers with a detailed report on the activities of livestock.

The scale of the ad-hoc mesh network employed by the *Electronic Shepherd* project relies on the participation of the Lyngen shepherding community – the more repeaters that are installed on neighbouring farms, the greater the network becomes (Gershenfeld 189). The development of the *Electronic Shepherd* project therefore requires a collectivistic approach to its design, because it has to cater to a broader shepherding community. The system also services the greater farming community, which consists of farmers, abattoirs, government agencies and consumers (Thorstensen et al 251). The community therefore expands beyond the parameters of the Fab Lab community that developed the project. It stands to reason that collaboration between the developers and the greater farming community is imperative and that the *Electronic Shepherd* project requires a collectivistic approach to its design in order to succeed as an appropriate technology.

Criterion 4: Cost

Wicklein states that the cost of the technology must be affordable for the communities for which the artefact is intended. If the target market is unable to purchase the artefact, then the technology is inappropriate (Wicklein 373).

The Thorstensen, Syversen, Bjørnvold and Walseth 2004 report *Electronic Shepherd – A Low Cost, Low-Bandwidth Wireless Network System*, explains that the project intends to bring low-cost but high technology network and tracking services to shepherds and herders. Haakon and Thorstensen understood that the *Electronic Shepherd* project had to be affordable for shepherds.

To minimise costs, the *Electronic Shepherd* team considered a prototyping and manufacturing process that could compete with the cost of purchasing a proprietary equivalent. Gershenfeld and Prakash state that the installation of many fixed antennae and antennae types are required to negotiate the rough Lyngen terrain and to improve the radio signals line-of-site. The installation of these by commercial vendors would represent serious cost implications to the Lyngen shepherding community. To remedy this, the Lyngen Fab Lab began a subsidiary project with the intention of developing and perfecting customisable antennae that could be produced locally at a reduced cost. These antennae are fabricated from low cost copper roll stock and cut to size using a low cost sign cutter, using the free software engineered by the MIT for Fab Labs. The circuit boards are produced in the Lyngen Fab Lab on a small milling machine. It is possible to fabricate an antenna in the Fab Lab at a cost of US$1, while its commercial equivalent would cost between US$100 and US$200. Additionally, the lab provides a level of flexibility: antennae can be adjusted in size and shape to best suit their geographical placement, whereas commercial antennae are standard in size, or vary in brand, product, range and cost (Gershenfeld and Prakash 22). In addition to the cost savings returned on customisable antennae, the team sought to cut costs on other electronic components:

> Production cost for one access point is around $300. […] the weight of the radio tag is only 16 grams and the size is 32x41mm. For small batches, the production cost is about $20 (Thorstensen et al 254).

If the *Electronic Shepherd* project is able to produce cheaper and more customisable components than commercial alternatives, then it is evident that the *Electronic Shepherd* project is reasonably cost effective.

Criterion 5: Risk Factor

This criterion refers to two types of possible risks faced when developing appropriate technologies. Internal risks, Wicklein states, relate to the systems that are required to ensure that support during the production, or in the case of the *Electronic Shepherd* project, the prototyping phase is available (Wicklein 373). In the context of this case study, these risks may include the availability of raw materials, labour, skills and research resources.

External risks, Wicklein states, define the systems that are required to ensure the ongoing functioning of a project once it is completed (Wicklein 373). In the case of this study, these systems include technical support and support from the target audience, governments and key industries.

Internal Risks: The *Electronic Shepherd* Project and its Production Support System

Internal risks will be addressed by discussing the *Electronic Shepherd* project's harnessing of local materials and the sharing of knowledge.

Harnessing Local Materials

The Fab Lab provides all of the necessary materials required when prototyping new technologies. Access to available resources ensures that cost efficient antennae and components may be produced (Gershenfeld and Prakash. 25). This ensures that risks pertaining to excessive costs are managed. In addition to the low cost copper roll stock, the lab provides a wide range of the electronic components needed to produce the circuitry required to run the project, and the interns provide the technical support that is needed to ensure that components are fabricated correctly and that the correct electronic components are used. This means that the Lyngen Fab Lab provides the raw materials and skills required to ensure that the internal risks pertaining to available materials and local skills are managed. The Lyngen Fab Lab therefore helps to lower the internal risk profile of this project. That is not to say that all open source or appropriate technology projects require Fab Labs to curb their internal risks; Fab Labs are merely a facility that supports an open source framework. If a project is able to adhere to the freedoms required of an open source initiative, then it is possible for the project to be open source. Similarly, if a project is able to manage its internal risks without Fab Lab facilities, then it is able to contribute to its effectiveness as an appropriate technology.

Sharing of Knowledge

Telenor, a commercial service supplier, provided some of the expertise required for the development of the *Electronic Shepherd* project (Gershenfeld189), which indicates that a local industry's provision of labour may contribute to the management of a project such as the *Electronic Shepherd*'s internal risk.

Furthermore, the Fab Lab as discussed in chapter two, is dedicated to the advancement of the knowledge required to develop technologies through personal fabrication. The Fab Charter stipulates that users of a Fab Lab must contribute to documentation: “Training in the Fab Lab is based on doing projects and learning from peers; you're expected to contribute to documentation and instruction.” (Fab Charter) This provides production support by exposing Fab Lab users to a global network of instructors and an international database of documentation. Additionally, Fab Labs employ interns that specialise in IT and electronics, who are dedicated to helping Fab Lab users realise their objectives (Mogotlane Interview 4). During the development of the *Electronic Shepherd* project, the Norwegian lab and the MIT were in constant communication, and Haakon’s farm became host to one of the first International Fab Lab Symposiums where international delegates were able to discuss Fab Lab projects and processes when developing technologies and project leaders were able to present status reports on their projects (Symposium on Digital Fabrication).

External Risks: The Electronic Shepherd and its Running Support System

Apart from providing access to fabrication equipment and the support mechanisms required to man the machinery, Fab Labs are prepared to help users commercialise and, at the user’s request, develop business plans, marketing strategies and patent their designs (Khutso Interview 4). Once projects are prototyped, users may be introduced to a team of product designers, who will help advance the commercialisation process or the mass production of the project. Thorstensen recognises that Fab Lab projects require further support from industry. He states that the project must provide an available infrastructure and the overall project must draw commitment from all parties involved in the production chain (Thorstensen, Programme for Fab Lab Research Seminar). In Lyngen, this service is supported by FabDesign AS, which is an industrial design company established in close cooperation with the MIT Fab Lab. FabDesign AS has been involved in the furthering of the design of antennae for the Lyngen Fab Labs (Gjengedal 3), which suggests that project developers receive further support from industry.

The capacity to design and develop cheap and customisable antennae, affordable electronic ear tags and mobile base stations, suggests that the project is adaptable and can be altered to work effectively under specific local conditions. The lab fosters additional support from local learning institutions, government and industry, which creates a wide support network that contributes to the improvement of local research output.

The Lyngen Fab Lab supports local business development through technology skills transfer to industry and works in collaboration with key Lyngen industries and academic institutions: as the lab stakeholders are jointly comprised of government, schools and industries, businesses have a vested interest in the success rate of the lab (Gjengedal. 2). A sustainable use of local resources for technologies as developed by the labs is therefore fundamental to the growth of industry in Lyngen. The systems required to ensure that the margin for internal and external risks are marginalised are therefore evident in the Norwegian lab.

Criterion 6: Single/Multi Purpose Technology

Since some developing countries experience extreme poverty, Wicklein suggests that appropriate technologies may often be required to fulfil more than one particular function, or "provide for a variety of applications" (Wicklein. 374). The criterion for Individual or Collective Technologies criterion does not prefer an individual over a collective technology. Similarly, this criterion does not prefer a single purpose technology over a multipurpose technology. It is the specific need of the community that determines the need for technology that may fulfil one or more purposes. This section therefore discusses the *Electronic Shepherd* project in terms of the of the Lyngen communities need for a single or multipurpose technology.

Although designed to track livestock the *Electronic Shepherd* project has progressed to deliver additional functionality within the shepherding community. The project also relays data relating to the carriers' body temperatures, blood volumes and pulse rates, which allow shepherds to monitor the wellbeing of livestock and their geographical location. Additionally, the project team has made this shepherding-specific data accessible to groups who may benefit from its use. Such groups may include veterinarians, slaughterhouses and consumers who are now able to access data relating to the lifespan, health, breeding, and birth, identity tagging, grazing and other aspects of livestock lifecycles appropriate to the food production chain. (Thorstensen, Programme for Fab Lab Research Seminar). The *Electronic Shepherd* therefore serves a dual purpose: it provides data relating to an animal's whereabouts, as well as its wellbeing.

That the *Electronic Shepherd* provides varied data to the shepherding community, the farming industry and consumers requires that the technology perform multiple functions. That the project is able to do so successfully contributes to its effectiveness as an appropriate technology.

Criterion 7: Evolutionary Capacity

Wicklein states that an appropriate technology should "grow with the society it benefits, and not exist as a relatively short-lived solution" (Wicklein. 373). This criterion, according to Wicklein, refers to the capacity for which a technology may expand or be reconfigured to suit growth and to which improved production processes can be measured. An appropriate technology should therefore evolve so that it may develop with the pace of technological advancements. If a technology is unable to keep up to the pace of technological advancements, then it stands to reason that it will serve as an appropriate technology for a short period of time. It is also critical that local production processes be able to meet the requirements of an evolving appropriate technology.

The documentation that is intrinsic to the Fab Lab culture cultivates a platform from which technologies may evolve. Much documentation on the development of this project exists online. Thorstensen et al's report on the *Electronic Shepherd – A Low-Cost, Low-Bandwidth, Wireless Network System* provides comprehensive and detailed descriptions of the components, the installation setup and the theory which may be used to remake the *Electronic Shepherd* project. Access to such documentation has made possible the re-development or evolution of stable of ad-hoc mesh-network and tracking systems available for the benefit of a community of fishermen (Tapscott, D. Williams, A). It is therefore evident that open source projects such as the *Electronic Shepherd* has an evolutionary capacity. As discussed in chapter one, Stalder suggests that an open source project must allow for duplication, modification, where the modification might evolve to suit the developer's requirements. It is therefore, in the nature of an open source project to evolve.

Thorstensen states that the *Electronic Shepherd* project may be adapted for home and office use or where ubiquitous computing may be necessary, such as the monitoring and tracking of the deployment of firemen and policemen. Thorstensen and his team are currently implementing military-based field trials for the monitoring of soldier deployment. *Telemedicine*, another possible application of the *Electronic Shepherd* project, allows patients to be remotely monitored from the comfort of their homes, while curbing hospitalisation costs and alleviating hospital resources for those in real need (Thorstensen et al. 254). These examples provide evidence that it is possible that projects such as the *Electronic Shepherd* have the capacity to evolve or be modified to suit the requirements of other communities.

The capacity for evolution is also evident in the *Electronic Shepherd's* development process. The project received regular component upgrades during its development, which suggests that the project evolved technologically. The original system migrated from a General Packet Radio Service (GPRS), a system that remits data though the transmitting of data packets, to accommodate Global Positioning Systems (GPS) integration. Other efficient tracking technologies such as customisable antennae are constantly being improved to accommodate flexible positioning and stable WIFI communications systems (Gershenfeld and Prakash.23-25). This project's evolutionary capacity is made possible by the support structures that curb its internal risks, such as the support supplied by the Thorstensen, the Fab Lab staff and Lyngen industries through the sharing of knowledge. It therefore appears that the evolution of the *Electronic Shepherd* project parallels the evolution of mainstream technology development and that it receives periodic upgrades as and when applicable technologies become available.

In his paper entitled *Electronic shepherd – a low-cost, low-bandwidth, wireless network system*, Thorstensen describes additional features that contribute to the evolution of the *Electronic Shepherd*. These features are discussed with reference to weight, cost and power longevity. He also discusses the importance of the design of relevant graphic user interfaces so that farmers are able to understand and process the data streams as they come in from the field which includes a navigational map system so that farmers can visualise their flock locations at any given time and locate them in times of need (Thorstensen et al. 246). The *Electronic Shepherd* team continually evolve the project to meet the growing requirements of an expanding community.

In alignment with the freedoms inherent in open source projects, the driving technology behind the *Electronic Shepherd* is being appropriated, adapted and modified to suit the needs of additional communities. Additionally, the design of the *Electronic Shepherd* constantly evolves to maximise the potential of newer technologies and user interfaces. Evidence of the *Electronic Shepherd* capacity to evolve is therefore apparent, a contribution to the projects value as an appropriate technology.

Chapter Conclusion

From an understanding of Wicklein's criteria for effective appropriate technologies, we can conclude that the *Electronic Shepherd* project fulfils the following criteria for an effective appropriate technology:

It is a technology system that is able to function independently of other proprietary technologies. It is possible that the *Electronic Shepherd* project may be manufactured in a Fab Lab using the labour, technical expertise and materials at hand. Projects such as these, which are incubated in environments such as Fab Labs which implement open source frameworks and collaboration, may therefore be considered a systems independent technology.

The technologies that were employed in the make up of the *Electronic Shepherd* project may, by today's standards, are perceived as modern. The project itself provides a modern solution to traditional shepherding activities. Additionally, the collaborative nature of the open source community determines its perception of the project's modernity. In other words, the community that created the technology will perceive it as modern because they created it. The project may therefore be perceived as modern, and as such contributes to the projects effectiveness as an appropriate technology.

The *Electronic Shepherd* project services broad shepherding and peripheral farming communities. It must therefore cater for a collective audience. To fulfil its requirement as an appropriate technology, the *Electronic Shepherd* project should therefore lean towards a collective technology. The participation of neighbouring shepherds – which improves the scope of the ad-hoc network – suggests that this project is a collective technology, as participation not only improves the effectiveness of the project, but also gives ownership to the community. The development processes employed by the Fab Lab team require a collective commitment also: the collaboration that occurred between key industries, the development team and the open source environment provided by the Fab Lab network allowed for the project's successful implementation. As a result, the collective nature of the *Electronic Shepherd* project contributes to its effectiveness as an appropriate technology.

The *Electronic Shepherd* project team was able to produce project components that were more affordable and more customisable than a proprietary equivalent. The project is therefore comparatively affordable which contributes to its success as an appropriate technology. As an open source project, the collaboration that takes place between members of the community can be used to negotiate appropriate costs for the project.

The Fab Lab provided facilities, structures and access to a distributed globally networked knowledge bank that ensured the successful development of the project, as well as its ongoing functioning. Such resources reduced the risks of the project's development and implementation, which adds to the project's effectiveness as an appropriate technology.

Because the *Electronic Shepherd* project caters to the requirements of the local shepherding community, as well as a broader farming and consumer community, the project is required to fulfil more than one purpose. While the project is used to track the whereabouts of livestock by providing data pertinent to shepherds, it is also able to provide a range a data specific to the animal's wellbeing, or data pertinent to veterinarians and slaughterhouses. It is the project's ability to provide a variety of data which may be used to various ends that enables the project to function as a multifunctional technology. The projects' ability to perform multiple functions increases its effectiveness as an appropriate technology. It cannot be sated that an open source process will contribute to the success of this criterion, because an open source platform is not necessarily concerned with multi-functioning technologies.

As a Fab Lab project, the *Electronic Shepherd* was developed within an open source framework, in line with the Fab Charter. Open source projects, by nature, evolve. That a community of fishermen have successfully appropriated and evolved the *Electronic Shepherd* project to suit their specific needs indicates that the project has the capacity to evolve, which contributes to its effectiveness as an appropriate technology.

By situating the project in Wicklein's criteria, it is apparent that the *Electronic Shepherd* project is a good example of an effective appropriate technology that is able to provide a meaningful and appropriate solution to a specific shepherding problem. Furthermore, that the *Electronic Shepherd* could be borrowed and adapted to suit the needs of other communities suggests that this project adheres to the four freedoms outlined by Stalder: the *Electronic Shepherd* team was obliged to pass the right to the documentation of their technology development on to the members of a team who wished to modify and evolve the project. This establishes the *Electronic Shepherd* project as an open source initiative which could only have been achieved if a transparency of process was evident, or if the documentation was comprehensive enough to understand.

The collaborative dialogue that occurs during open source projects supports the processes of effective appropriate technology development. One would expect, for example, that communities involved in technology creation would provide an open dialogue about their projects. Such dialogue might include consensus regarding the financial impact that the proposed artefact might have on the community. The nature of an open source framework and the nature of communal activity would imply that the project would require a collective effort and therefore a collective technology. The nature of the globally distributed networks apparent in open source projects would contribute to minimising of internal and external risks. The technology would always appear to be modern because the artefact would be born out of communal necessity, and developed and produced by the community. The community would collectively decide the need for a single or multipurpose technology, and in so doing, decide its appropriateness. The freedoms inherent in open source projects, which allow further groups or communities to develop and evolve projects, ensures an evolutionary capacity. It therefore justifiable that an open source framework supports the creation of effective appropriate technologies.

Additionally, an open source framework provides a platform which is inclusive of a group's cultural dimensions and therefore needs. This is justified by the fact that the end-users are directly involved in the creation process, and therefore have at hand, the varied social and technical requirements required to resolve their specific problems. As was evident in the creation of the Life Straw, mentioned in chapter one, proprietary technology solutions do not always cater to these needs. Yet it appears that there are similarities between the agenda for open source creation and effective appropriate technologies. As Akubue states:

> Appropriate technology is not about taking a stand against technology, but about technology being a heterogeneous collection of social and technical options rather than a homogeneous phenomenon. From this collection, the best choices are then made based on the objectives to be accomplished and possible human and environmental effects. (Akubue 39)

If appropriate technology is concerned with the catering of collective social and technical options that best conform to the needs of a specific community, then it would appear that open source is an appropriate development model for the creation of effective appropriate technologies.

Chapter Four

The Solar Powered Streetlight: A South African Case Study and Report of Findings

The case study discussed in the previous chapter described a Fab Lab initiative that in most respects fulfilled the qualities of an effective ‘appropriate technology’ which was developed within an open source framework. This chapter presents the *Solar Powered Streetlight*, a South African Fab Lab case study which is also developed within an open source framework. While the data obtained for chapter three comprised an analysis of documentation and conference proceedings, this case study utilises data from field research and interviews. The findings are unpacked according to Wicklein’s criteria for the development of effective appropriate technologies as a means to determine the success of the project and as a framework in which to compare it to the previous cases study. The information obtained for this study is used to substantiate the argument that open source projects are contextually more relevant and appropriate to the communities that create them than proprietary equivalents. Wicklein’s criteria are used to establish the effectiveness of this case study as an appropriate technology for the community for which it is intended.

Background to the Solar Powered Streetlight

In recent years, South Africa has experienced a high demand for electricity which has led to the rising costs of commercial power supply, frequent power shortages and load shedding[13]. According to Eskom’s 2009 Annual Report, in its *Summary of the Findings of the Load Shedding Case Study*, load shedding has had a significant social impact on South Africans. The report states that lower income groups are the most affected due to load shedding’s effect on public services such as public transport and lighting systems. It also states that safety became a major concern for all income groups as security systems which are reliant on the national power grid are not able to function reliably. For income groups that do not have access to security systems, it may be deduced that public lighting systems, which may act as a deterrent for criminal behaviour, affect the safety of individuals in these groups.

[13] Load shedding refers to the regulation of the supply of electricity due to the inability for power stations to cope with the demand for electricity. As a result, power stations reduce the demand for electricity by scheduling power-cuts over their network grid (Eskom).

These issues prompted S'khumbuzo Ndlovu, an electrical engineering student at the Tshwane Institute for Technology, resident of Soshanguve and intern at the Soshanguve Fab Lab, to start considering alternative energy sources as possible solutions to the electricity problems in his community in 2005 (Ndlovu Interview 10). In an interview held at the Soshanguve Fab Lab on the 19th of June in 2008, Ndlovu stated that load shedding negatively impacted areas in his community that are in critical need of an uninterrupted power supply. Schools and clinics, which are unable to render their public services as a result of unreliable energy services, are examples of such areas (Ndlovu Interview 11). To this end, Ndlovu initiated the *Solar Powered Streetlight* project.

The project's main aims, he stated, were to reduce public electricity consumption in Soshanguve by substituting commercial power with a solar-based source of energy, thereby decreasing the demand for commercial energy and the need for load shedding (Ndlovu Interview 11).

The project may, however, also have other social benefits. As Ndlovu promises, the project not only provides a public lighting system that contributes to the national power grid, but as a result will also provide public services with a more reliable access to a constant supply of electricity. Furthermore, the project could create employment opportunities and encourage knowledge and skills sharing if Ndlovu makes use of local labour.

Streetlights play a significant role in the curbing of criminal activity. In an article entitled *Lack of Streetlights Sees Rise in Crime*[14], published in 2008 for IOL, Thandi Mthethwa states that police report an increase in crime where streetlights are out of service (Mthethwa). In 2005, BuaNews, a government news website reported in an article titled *Today's Feature: Villagers Rescued from Jaws of Crime*[15] that the crime rate in a village in Rustenburg was significantly reduced when streetlights were installed in the area (*Today's Feature*). It may therefore be assumed that criminal activity may rise in

[14] http://www.iol.co.za/index.php?set_id=1&click_id=13&art_id=vn20080902103953608C657175
[15] http://www.buanews.gov.za/view.php?ID=05071309151001&coll=buanew05

public areas where streetlights fail as a result of load shedding. As a project that is powered independently of Eskom, the *Solar Powered Streetlight* appears address this issue.

The Soshanguve Fab Lab, one of five in South Africa, provided the framework, tools and materials required of Ndlovu to develop the Solar Powered Streetlight project. Bongani Mdluli, the Operations Manager for the Soshanguve Fab Lab, stated in an interview on the 19th of June 2008, that the decision to situate a Fab Lab in Soshanguve was jointly made by the MIT, DST and the Centre for Scientific and Industrial Research (CSIR). After the inception of the Soshanguve Fab Lab, the Soshanguve community has been involved in projects such as a low cost housing development plan and the *Thinner Client*, an international Fab Lab collaborative project which aims to re-invent the internet and provide free web access to under-serviced communities (Mdluli Interview 1). The Soshanguve community's involvement in the Fab Lab indicates a desire to create low-cost innovative technology projects that address their community's needs. The *Solar Powered Streetlight* is an example of such a project.

To determine whether the *Solar Powered Streetlight* project is an appropriate technology, its process of development is mapped according to Wicklein's criteria described on page 47. The criteria function as a means to measure the effectiveness of the *Solar Powered Streetlight* as an appropriate technology.

Criteria 1: Systems Independence

The *Solar Powered Streetlight* project, according to Ndlovu, proposes a public street lighting system that is independent of the currently installed pay-for variety. He states that a solar powered alternative will alleviate public commercial power consumption and allow Eskom to redirect saved power to facilities such as hospitals, clinics and schools that are in need of a stable supply of electricity (Ndlovu Interview 11). Using solar charged battery power, the *Solar Powered Streetlight* could provide a continuous light source for up to sixteen hours daily without the aid of any supporting technologies, states Ndlovu (Ndlovu Interview 11).

Ndlovu states that conventional streetlights require the replacing of components every one or two years and their power source is reliant on a commercial electricity provider's service. Ndlovu states that the rechargeable battery which is used in his project may last for up to twenty years before it requires replacing, and that the solar panel will last indefinitely. Light Emitting Diodes (LED's), are used in the design of the light source, which according to Joliet, a manufacturer of LED lighting systems, are designed to last for up to 50 000 hours (Joliet Technology). Presuming that a *Solar Powered Streetlight* would provide twelve hours of light daily, the system would run independently for eleven years before a routine maintenance check would be required. The *Solar Powered Streetlight* is therefore independent to the extent that it is able to provide sufficient power during load shedding. The *Solar Powered Streetlight's* systems independence is further emphasised by its low maintenance requirements.

Although Ndlovu claims that his project, once completed and installed, is able to function independently of other technologies, it must rely on some form of system; whether it is the commercial power grid which it supports, or a constant and uninterrupted source of sunlight. To this end, the *Solar Powered Streetlight* is somewhat systems independent, but not wholly.

If the *Solar Powered Streetlight* is able to produce its own power and requires little maintenance, the system may be considered more self sufficient and therefore more systems independent than the current equivalent pay-for system. The *Solar Powered Streetlight* project is therefore more systems independent than its commercial equivalent. While the project is dependant on some systems, it does appear to be technologically independent, a factor which contributes to its effectiveness as an appropriate technology.

Criteria 2: Image of Modernity

According to Ndlovu, members of his community are curious about and interested in the development of a public lighting system that is self sufficient and free to use (Ndlovu Interview 16). In contrast to the conventional public street lighting systems to which his community has been exposed to for years, the *Solar Powered Streetlight* offers what may be perceived as a technological advancement, or modern implementation of a street lighting system. It may therefore be deduced that the *Solar Powered Streetlight* has provided a platform from which to inform Ndlovu's immediate community's understanding of solar and alternative energies contributes to his projects image of modernity.

When asked about his view on the concept of an *image of modernity*, Ndlovu believes that it, in the context of local technology development, is entrenched in the Fab Lab concept. This entails the provision of access to the advanced tools and skills required to solve local problems technologically. These problems may differ between communities; the image of modernity is therefore inherent in the technological solutions that are realised by the specific communities who are empowered through access to these facilities. Ndlovu believes that these technological solutions are indicative of innovative problem solving, which are played out on the world stage: "My solar powered project shows [the world] how we solve our own problems. This is a good thing; it makes Soshanguve look technologically capable. The presence of the lab and the projects that come out of it allow Soshanguve to compete internationally with other labs" (Ndlovu Interview 23). Ndlovu therefore believes that his project allows the world and his community to perceive how modern technologies are able to solve his community's needs, and in so doing, what his community is technologically capable of.

If the *Solar Powered Streetlight* project introduces advanced technologies into a community that is not accustomed to such technologies and inspires discussion regarding the further potential applications of such technologies then it is plausible that the project adheres to Wicklein's criterion for an image of modernity. Furthermore, if Ndlovu and his community believe that the project is able to show the world that they are capable of competing technologically at a global level, then it is evident that they perceive its image of modernity.

Criteria 3: Individual vs. Collective

It must be remembered that this criterion does not prefer an individual over a collectively developed technology, but rather prefers a system of development that will benefit the community the most.

Collaborative efforts were evident in Haakon and Thorstensen's *Electronic Shepherd* project. It appears that collaboration is an important factor that appears in all Fab field labs. When users do not have experience in the creation of technologies, they are able to rely on Fab Lab interns, other users and the Fab Lab network (Ndlovu. Interview 18, 21).

According to Ndlovu, correspondence between the South African Labs occurs regularly. He states that the transpiring dialogue that occurs between labs is used to trouble shoot issues which pertain to the operations of the labs and the technical concerns faced by individual project creators (Ndlovu Interview 21). The following instance frames an example of the collaborative efforts that take place between Fab Labs. In consultation with interns from other Fab Labs, Ndlovu found that it would be advantageous to design a custom energy efficient LED lighting system instead of employing the use of conventional energy efficient light bulbs (Ndlovu Interview 21).Ndlovu states that he was inefficiently skilled to develop the specialised lighting components required to improve his project and as a result, drew upon the expertise of those in his community. Ndlovu consulted Ruben Shongwe, a lecturer at the Tshwane University for Technology with experience in heavy current engineering. Various collaborative efforts are therefore evident during the development of the *Solar Powered Streetlight* project. Collaboration occurred over the Fab Lab network, as well as between the project leader and a local Soshanguve skills base.

Ndlovu states that his collaboration with Shongwe is beneficial to both parties. When the new lighting system is complete, Ruben will use the developed technology for his own purposes, while Ndlovu will incorporate the finished product into his project. Furthermore, Ndlovu will be able to assist other users remake this component for inclusion in their projects, thereby increasing the local knowledge base in this particular area of expertise (Ndlovu Interview 21).

Since collaboration is a necessary component in the development of Fab Lab and other open source projects, collective approach to this project is required. As Ndlovu works in collaboration with members from TUT and other Fab Labs, and may use his project and research to contribute to the growth of the local knowledge base, an effective collective approach to this project's development is apparent. That the *Solar Powered Streetlight* requires a collaborative approach to its creation, and that its development approach accomplishes this, puts the project a step closer to fulfilling its effectiveness as an appropriate technology.

Criteria 4: Cost Factor

This section outlines the cost implications incurred during the development of the *Solar Powered Streetlight* to ascertain the degree to which this project may be deemed financially appropriate to the Soshanguve community.

According to Ndlovu, access to, and use of the Fab Labs facilities, staff and materials are provided free of charge (Ndlovu Interview 22). Ndlovu used the Soshanguve Fab Lab's facilities to fabricate most of the components required for the development of his prototype. The majority of the materials needed to complete his project are supplied by the lab. These materials include the copper boards, which Ndlovu used to create the custom circuitry required for his project. He used the open source software supplied by the MIT to mill these boards on a 3D milling machine. The lab supplied a wide range of circuitry components, such as the micro-controllers, resistors, capacitors and transformers that Ndlovu needed to regulate the clean voltage that is supplied by the solar panels for battery recharging and efficient light emission (Ndlovu Interview 22).

Additionally, Mdluli states that the lab makes extensive use of free and open source software (Mdluli Interview 1). A key open source software component that is used by Fab Labs to render fabricated artefacts is a Computer Aided Design (CAD) software package that was developed by MIT which provides an interface between most of the software applications and all of the hardware that are used in the labs. (Mdluli Interview 1). This permits users to print artefacts that range from two-dimensional signage and circuit boards to three-dimensional structures (Gershenfeld 25). Instead of using expensive proprietary software to model and fabricate circuit boards, or outsource the printing of circuitry, Ndlovu manufactured the custom circuitry required for his project for free.

The development of the *Solar Powered Streetlight* project did incur costs when materials and components, such as the solar panel and battery were not available at the lab (Ndlovu Interview 22). However, since the project proposes to serve the needs of Soshanguve community, states Khutso, the project team was able to apply for and have received government funding, granted by the AMTS for the sum of R30 000[16] (Khutso Interview 3). The funding covered the costs of the components and materials that the Fab Lab was unable to supply (Ndlovu Interview 20). To date, the *Solar Powered Streetlight* project team has spent approximately R6 000 of its funding, 20% of their net budget, which illustrates how much the use of the lab reduces prototyping costs (Ndlovu Interview 20).

The cost of the installation of a single *Solar Powered Streetlight* is currently undeterminable as the project is in its development phase. Ndlovu, however, believes that the *Solar Powered Streetlight* will benefit his community financially. He states that conventional streetlights will be cheaper to install than his solar charged alternative in the short term, although he predicts that conventional streetlights will be more expensive to run in the long term as costs for energy consumption and maintenance are incurred. He goes on to state that the light bulbs used in conventional streetlight are fragile and contain poisonous gasses. Frequent pay-for services are therefore necessary so that defective bulbs may be replaced and poisonous gas leakage may be tested. Conventional streetlights are therefore expensive because costs are incurred for their running as well as frequent maintenance.

Ndlovu states that the rechargeable batteries which are used in the *Solar Powered Streetlight* have a life span of 20 years, the LED bulbs are able to provide an uninterrupted light source for eleven years and the solar panels, provided they are suitably protected, will last indefinitely (Ibid). According to Ndlovu's calculations, it would appear that the project has minimal servicing costs.

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The Soshanguve Fab Lab provides the facilities which include machinery; the knowledge support infrastructure and the components that Ndlovu needs to develop his technology for free. Additionally, the development of the *Solar Powered Streetlight* promises to benefit their broader community: although Ndlovu predicts that the initial setup of his system will incur more costs than traditional streetlight systems, the free electricity that the *Solar Powered Streetlight* provides will financially benefit his community in the long run. It can therefore be deduced that this case study is, in the long term, financially appropriate to the needs of the Soshanguve community. That these cost factors are met, increase the *Solar Powered Streetlight's* effectiveness as an appropriate technology.

Criteria 5: Risk Factor

Internal risks, according to Wicklein, pertain to the systems that are required to ensure the successful development of a project (Wicklein 373). The successful development of the *Solar Powered Streetlight* requires an availability of local materials so that the project may be physically produced. Its success also requires support from the Fab Lab network, as well as support from the Soshanguve community through its local skills base. The lab is able to supply much of the raw material required to create the product. Additionally, the Fab Lab network is able to provide a broad platform from which the Fab Lab community may offer technical advice or contribute to the process of development. The Soshanguve local skills base can be drawn upon to offer expertise in areas of project development.

External risks pertain to the support mechanisms required to ensure the successful and ongoing functioning of the project after its implementation. The ongoing functioning of the *Solar Powered Streetlight* relies on successful community engagement, networking opportunities with key members of local municipalities, opportunities to work with local industrial design agencies, so that the prototype may be refined for implementation, and the development of business strategies.

Internal Risks

Without the support from a local skills base, the project is unable profit from the knowledge its community may offer, and without a broad knowledge base from which to draw, the project is unable to progress. Additionally, the project requires a harnessing of local materials in order for the project to develop. These are the kinds of issues which determine this projects internal risk. The internal risks for the *Solar Powered Streetlight* are therefore addressed through the availability of local materials, knowledge sharing capabilities and local skills trade-offs that are made available to the project.

Harnessing Local Materials

Ndlovu states that the majority of the materials that are required to construct his project are made available locally through the Fab Lab for free (Ndlovu Interview 22). He goes on to state that the printing and creating of one's own electronic components works out to a fraction of the cost of a purchased equivalent. This ensures that the financial risks that may hinder the development of the project are curbed. Additionally, he states, self made components are beneficial because the creator has a better understanding of "what is going-on on the circuit board" (Ibid 22). It stands to reason therefore, that users who develop their own technologies have more control over the potential risks faced during development than over purchased components, because the creator has a better understanding of what their work entails. All of the circuitry required for the *Solar Powered Streetlight* is printed and assembled in the lab except for the solar panel and the batteries which are not made locally (Ibid 22). That such a large portion of the project is not locally available has serious implications on the management of the project's internal risk. Should Ndlovu develop a solar panel and battery system in the lab using local materials, the margin for internal risk will be greatly reduced.

Sharing of Knowledge

In the context of the *Solar Powered Streetlight*, knowledge sharing is attributed to the Fab Lab global network and not the Soshanguve community. An example of the utilisation of the Fab Lab's network knowledge base was evident in the *Solar Powered Streetlight project* when interns at the Potchefstroom Fab Lab suggested that Ndlovu investigate LEDs as a cheaper and more energy efficient alternative to conventional energy saving light bulbs.

The contribution supplied by the local skills base relies on the Soshanguve community and the skills that members from the community are able to offer. It may therefore be said that the local skills base may contribute to the project and therefore contribute the minimising of the projects internal risks. The local researching, learning and sharing of information also means that the local knowledge base is able to expand which in turn, supports the local skills base. The outsourcing of skills from a local knowledge base was applied when Ndlovu and Shongwe collaborated on the redesign of the projects new LED light bulb. In this instance, it is apparent that an effective use of local skills has contributed to the production of the *Solar Powered Streetlight project*, which provides an example of the support structures that are available which ensure that internal risks in the project are curbed.

As an institution, Fab Labs encourages knowledge sharing and development, which may contribute to curbing of other projects internal risks. Mdluli states that the Soshanguve Fab Lab wants their community to benefit from the knowledge that the Fab Lab staff has gained (Mdluli Interview 8). Although users of the lab are encouraged to do a lot of their own web based research, interns and users occasionally perform research together. The interns add value to the research process where they can, but are in no way allowed to interfere with the users' ideas or intended goals. Ndlovu states that a one-way flow of communication occurs between the intern and the user when users do not know enough about the technologies that are required to make a particular project, but knowledge is shared when users become more experienced.

Ndlovu aims to employ members of his community to mass produce and install his proposed lighting system, which will contribute to Soshanguve's local production system and thereby control further internal risks.

Fab Lab users are afforded access to trouble shooting forums and networks, which allow technology artefacts to be refined. The lab provides additional support by providing in-house expertise and skills. It is apparent that the *Solar Powered Streetlight* requires less maintenance than the currently implemented streetlight system and has the capacity to support a local production system. As mentioned, Ndlovu plans to employ members of his local community, thereby contributing to the skills development and the production system of the Soshanguve community. These provisions ensure that Soshanguve Fab Lab and the *Solar Powered Streetlight* project offer the support systems required to minimise potential internal risks.

External Risks

External risks are addressed through commercialisation and community employment opportunities. If the project is unable to function on a long term basis, then its external risks have not been managed. This section therefore provides a study of the facilities made available and the plans that the *Solar Powered Streetlight* team propose to ensure the sustainable running of their project.

In addition to the free materials, access to lab equipment and staff expertise, the Soshanguve lab provide access to the skills required to further the Solar Powered Streetlight and prepare the artefacts for mass production. Khutso sates that "the labs put innovators in touch with the right people". To date, Khutso states, he has put the implementation of Ndlovu's *Solar Powered Streetlight* project forward to the Soshanguve municipal authorities and has received positive feedback from them, and is confident that this will result in large scale implementation.

The labs also facilitate professional product designing and marketing. According to Khutso, this is made possible through an industrial design company called Redimade, which provides input on the industrial design of the prototyped artefact and helps to further its commercial value. To ensure that an artefact such as the *Solar Powered Streetlight* is commercially viable, agencies such as Redimade refine the prototype so that it is commercially sustainable. The labs therefore assist users in the development of projects that are able to function after the completion of the prototype. Furthermore, he states that the lab provides assistance in the development of business plans, marketing strategies and networking opportunities to provincial governments and access to innovation funds (Khutso Interview). These processes offer evidence that the lab provides the support infrastructure required to alleviate the potential external risks that may have hampered the development of the *Solar Powered Streetlight* project.

Ndlovu has stated that he aims to employ members of the community to mass manufacture the poles, print the circuit boards and install and service the streetlight system once the project reaches its implementation phase (Ndlovu Interview 20). This would require skills transfer, an aim that complements the DST's agenda, and ensures the effective running of the *Solar Powered Streetlight* project after its implementation.

Additionally, the project has been designed to support itself for approximately 20 years. Hardy solar panels and long lasting batteries ensure this (Ndlovu Interview 26). The design of the product has catered for the long term and sustainable running of the project.

The Soshanguve Fab Lab supports local innovators and encourages the growth of the local skills base by providing access to funds and networks for technology development on behalf of local government. Additionally, the lab works in collaboration with local academic institutions such as TUT and schools to refine research output, as well as industry agencies such as Redimade, which refine technology artefacts for the market. Local skills transfer is made possible by this collaboration, and because collaboration exists to the extent that it does, suggests that the parties involved value the importance of the lab. These provisions ensure the Soshanguve Fab provides the support systems required to minimise potential external risks. The study of the solar powered streetlight project suggests that systems to minimise potential problems during the prototyping phase are in place. It is therefore evident that the project's Internal Risks are successfully managed. Although systems to ensure the sustainable running of the project after completion are in place, the effectiveness of the Solar Powered Streetlight's external risks may only be measured once the project has been implemented.

Criterion 6: Single/Multi Purpose Technology

In countries where extreme poverty and lack of financial capital inhibit the development of new technologies, Wicklein states that a single technology that performs more than one function may be more beneficial to the communities that create them. Settlements such as Soshanguve, which may experience high unemployment, or low income margins may therefore often fail to receive the contemporary or high technologies that wealthier local settlements do. It may therefore be said that the *Solar Powered Streetlight*, as a multipurpose technology would contribute to the projects success as an effective appropriate technology.

According to Ndlovu, the *Solar Powered Streetlight* project was designed to alleviate the growing demand and rising costs of pay-for electricity, and to redirect commercial power to critical areas that may need it more. It therefore fulfils multiple functions; that of financial alleviation and the relaxing of power failures to areas in the Soshanguve community that require uninterrupted power supply.

Additionally, Ndlovu states, the individual components used in the *Solar Powered Streetlight* may be used for additional applications. The LED array, for example, could be used to develop low cost, energy efficient torches, and the solar panel and battery pack could be used to power household appliances, such as geysers and lights (Ndlovu Interview 27).

As Wicklein suggests, effective appropriate technologies should provide more value to under serviced communities by fulfilling more than one function. The Solar Powered Streetlight is capable of increasing cost savings as well as the reliability of uninterrupted power supply for critical facilities such as schools and clinics. It is also possible that components of the project could be used for other applications. This indicates that the project fulfils more than one function and is therefore effective as a multi purpose appropriate technology.

Criteria 7: Evolutionary Capacity

Wicklein states that an appropriate technology should have the capacity to evolve in time. This is to ensure the longevity of the artefact, so that it does not become outdated and therefore obsolete.

The *Solar Powered Streetlight* system is comprised of individual modular components. These components include a chargeable battery, a solar panel, an energy efficient light bulb and the necessary circuitry. It is possible that these components may be replaced without interfering with the system as a whole. This indicates an opportunity for the updating or replacing of individual components as newer technologies become available, thus ensuring the project's capacity to evolve.

The ability for the *Solar Powered Streetlight* to evolve and adapt to newer and more efficient technologies was evident when Ndlovu opted to replace conventional energy efficient light bulbs with a more energy efficient LED array system that did not require the redesign of the entire project. This suggests that newer lighting technologies may interface with the project as they are developed, or that the system may evolve to accommodate more efficient renewable energy sources in the future without interfering with the overall design of the artefact.

The necessary documentation required to situate the project within an open source framework is lacking. This is possibly due to the fact that the project is currently uncompleted. Yet documentation must be available to allow for the project's duplication and modification for it to be evolved by communities who require solar technologies. Because no documentation yet exists, it is impossible to foresee future modification which will ensure the project's evolution.

If the *Solar Powered Streetlight* project is able to interface future lighting technologies, then, to some degree, it has the capacity to evolve. However, the lack of documentation hinders the project's evolutionary capacity by communities. This factor minimises the project's effectiveness as an appropriate technology.

Chapter Conclusion

The *Solar Powered Streetlight* is in the final stages of development and project team are adding to, but have not yet completed, or made their documentation publicly available. However, in accordance with the Fab Charter and the open source tradition, the documentation or instructions required to remake the *Solar Powered Streetlight* or its components must be made available to other Fab Lab users. As a participant observer, it was apparent that other Fab Lab users developed an interest in alternative and specifically solar energy uses as a result of the *Solar Powered Streetlight* project. If Ndlovu is able to successfully transfer the skills that he obtained during the development of the *Solar Powered Streetlight*, the freedom to modify the documentation for the implementation of this project to other situations would be ensured. The Fab Charter insists that the documentation created during the modification of the *Solar Powered Streetlight* be made available for distribution within the Fab Lab context. Based on this fact, the *Solar Powered Streetlight* is not an open source technology. It was however created in an open source environment, and relied partly on open source practice through distributed networks and collaborative efforts.

Although the *Solar Powered Streetlight* may require supporting systems, it appears to function more independently than the conventional street lighting systems that are currently in use, and is therefore more of an effective appropriate technology than its proprietary equivalent.

It is a technology that utilises modern electronic components and contributes to its community's understanding of modern technologies. It is also capable of informing the world of Soshanguve's ability to produce current and competitive technology applications. The *Solar Powered Streetlight's* image of modernity therefore increases its effectiveness as an appropriate technology. As in the *Electronic Shepherd* project, the image of modernity is defined by the community. In other words, the project will appear to be modern to the community, because they created it.

A collaborative effort was required to develop and refine the system. Furthermore, a collaborative community effort will be required to install and maintain the project which may ensure the furthering of skills transfer and job creation. It is therefore evident that the project is a collective technology. That it benefited from a collaborative effort contributes to the projects effectiveness as an appropriate technology. Open source, which relies on a distributed network and collaboration, supports this criterion inherently.

The local Fab Lab network and the sharing of skills that was evident in the development phase of the *Solar Powered Streetlight* ensured that internal risks were curbed, while the support the Fab Lab offers to ensure the successful commercialisation or mass implementation of the project minimises the external risks. The curbing of these risks adds to the projects effectiveness as an appropriate technology. However, that the project team was unable to effectively harness and manage its local resources, for example, to develop major components such as its own solar panels and batteries, decreases the project's ability to function as an appropriate technology. If documentation is made available, it is plausible that other communities can develop their own solar powered streetlights. Furthermore, the documentation should allude to the problems encountered which could suggest that solar panels, for example, can be developed and manufactured locally. The failure to apply open source process here may influence the project's effectiveness as an appropriate technology.

The *Solar Powered Streetlight* offers a source of electricity that may reduce the Soshanguve community's financial costs. The long term implementation of this project increases the project's effectiveness as an appropriate technology. The collaborative nature of open source communities allows for the discussion and negotiation of appropriate and applicable financial costs of open source projects.

The modular design of the product also allows the project to evolve and adapt to new technologies that may offer improved functionality in the future. The capacity to evolve increases the project's effectiveness as an appropriate technology. Yet for this project to be able to evolve by future users, and adapt to future technology innovations, substantial documentation, as required by an open source framework, is necessary.

Should the *Solar Powered Streetlight* project provide the documentation required of open source projects, and harness its local materials more effectively, it is possible that the *Solar Powered Streetlight* project may be considered an appropriate technology that caters to the needs of the Soshanguve community that would be developed within an open source framework.

Chapter Five

<u>The Problems Encountered that Hinder the Open Source Process</u>

This paper argues that open source technologies are more relevant and advantageous to the communities that build them than equivalent commercial technologies. Effective appropriate technologies are concerned with communities' social and technical requirements. It therefore follows that the nature of the open source framework complements the creation of effective appropriate technologies, by ensuring open dialogue and collaboration pertinent to social and technical needs of communities.

While the Fab Lab concept has been discussed as facility which supports open source practice, we cannot assume that all Fab Lab projects adhere to the Fab Charter in support of an open source framework.

Both of the case studies relied heavily on the facilities and materials supplied by the Fab Labs. This is not to say that the creation of all non-software specific technologies require Fab Labs. The Fab Labs cater to an open source environment because the Fab Charter supports the freedoms of the open source framework. If the projects discussed in the case studies were to be created outside of the Fab Lab framework, the projects would probably not be open source, and therefore probably not appropriate because the labs are agencies for open source development. This does not mean that communities cannot collaborate in an open source manner, or that they cannot adhere to the requirements of effective appropriate technologies in an open source fashion.

The Fab Lab Charter states that Fab Lab users must learn from peers, as well as contribute to documentation and instruction. The documentation of non-software specific technology, manufactured within an open source framework, ensures that future users are able to remake and evolve the rendered artefact. This was evident in the *Electronic Shepherd* because other communities were able to modify and adapt the final artefact. However, this was not evident in the *Solar Powered Streetlight*. One is assured that comprehensive documentation and instruction materials for Fab Lab related projects are locally available at the Fab Lab facilities. Yet publicly available versions of documentation pertaining to the *Solar Powered Streetlight* are not yet available, which questions the ability to situate this project within an open source context.

Problematic areas pertaining to publicly available documentation for the South African case study are included in this chapter so that they may be examined in terms of their importance to open source manufacture, as well as to identify the reasons that comprehensive documentation was absent.

Mdluli stated that contribution to the documentation process that is emphasised in Gershenfeld's semester course is not a tradition at the Soshanguve Fab Lab (Mdluli Interview 10). When asked how easily users are able to remake projects, Ndlovu stated that projects are usually re-learned or re-created from inception, and users typically have to rely on the interns' experience and knowledge with such projects instead of hard-copy documentation. The Soshanguve Fab Lab's biggest downfall is its inability to re-make projects due to poor documentation processes (Khutso Interview 1). This is an issue that was raised by Levesque, which pertains to the potential flaws of open source development.

Other Fab Labs seem to share the Soshanguve Fab Lab's view on the archiving of documentation. Most Fab Labs exhibit their projects, but do not provide evidence that documentation pertaining to the projects exist. To ensure that all Fab Lab users have access to documented projects, and are able to contribute to the documentation of projects, Fab Labs have reportedly developed online repositories that archive the documentation process. However, virtual repositories such as Think-cycle.org, a web initiative dedicated to the housing of all Fab Lab project documentation no longer exist. While individual Fab Labs own web space, few of them make use of this medium as an online communication tool or documentation repository. This is true for both case studies. Even though the *Electronic Shepherd* provides sufficient publicly accessible documentation, it is not housed on the Lyngen Fab Lab website. This suggests that only users of the lab have access to required documentation, which reserves the creation of Norwegian Fab Lab technologies to those that reside in Lyngen.

It is possible that most Fab Labs do not provide public access to their documentation intentionally. This may ensure that non-users do not abuse the principles that are stipulated in the Fab Lab Charter by failing to contribute to documentation and instruction in return for the information gathered from Fab Lab web pages.

However, it is plausible that issues pertaining to the recreation of projects, and or instruction, are addressed through the global Fab Lab network. Mogotlane states:

> “The labs create their own problem solving forums on both a national and global basis. Internal problem areas are dealt with on a communal Fab Lab level – all labs pull together to sort issues and problem areas out”. (Mogotlane Interview 11)

While this statement is not a pretext for the lack of required documentation, it does provide evidence that knowledge sharing through collaboration and open dialogue does occur. In addition to inter-lab correspondence, the reports on the *Electronic Shepherd* and the *Solar Powered Streetlight* provide evidence that a public sharing of knowledge occurs through collaboration between local universities and key industries. It is indeed in the best interests of local governments, schools and industries to support Fab Labs so that they may prosper from the technology transfer that result from such collaboration.

Although the open source model does encourage public participation, open source communities are selective in terms of their collaborators. While any member of the public is free to propose contribution, not all public contributions are accepted (Stalder). This selection process manages the quality of material supplied in the creation of an open source project. In comparison, this could suggest that Fab Labs offer documentation and tutorial material when needed, to trusted members of the Fab Lab community. I found this to be true in my capacity as an observer at the Soshanguve Fab Lab. Although I was not involved in the development of community specific projects, users of the lab freely provided details about the development of their projects, which suggests that users do work in the spirit of open source development even though they do not contribute to written documentation.

My findings therefore conclude that the *Electronic Shepherd* project is an effective Appropriate Technology that was created within an open source framework that meets the specific needs of the community that helped to develop it. In addition, the findings indicate that an open source framework directly contributed to the *Electronic Shepherd* project's effectiveness as an appropriate technology.

The *Solar Powered Streetlight* is a less effective Appropriate Technology because it does not address its internal risks with regard to managing its local resources, and is not wholly systems independent. Due to its lack of documentation, it does not adhere to the freedoms determined by the open source movement, and therefore fails to meet the principles of an open source project. The findings indicate that an open source process, of which appropriate documentation is necessary, may contribute to the project's increased effectiveness as an appropriate technology in the long term, because the project will be able to be modified, improved and evolved.

Chapter Six

Conclusion

This paper argues that open source technologies are able to address community-specific needs more appropriately than a proprietary equivalent and are therefore more relevant to the needs of the communities that create them.

The methods used to obtain the data required for this paper included qualitative and empirical research. This is comprised of material sourced from journal articles, news reports, books and online documentation pertaining to the case studies. Interviews with the Fab Lab Manager, operations director, interns and the Solar Powered Streetlight project leader were conducted on location at the Soshanguve Fab Lab. Interviews with members from the AMTS were also conducted.

One of the problems posed by the research question is that open source is a term reserved for the development of software products only. In tackling this problem, I was required to study the definition of open source and position the principles of the open source framework in non-software specific situations.

The Fab Labs provided a good working example of a non-software specific situation that successfully employed the principles of open source development. Additionally, Gershenfeld's semester class demonstrated that users who made projects in the Fab Lab created artefacts that addressed their personal wants or needs, and the Fab Charter confirmed that it is possible for individuals and communities to create technology artefacts that answer to their specific needs within an open source environment. Fab Labs therefore provide a backdrop from which the impact of open culture on the relevance of communally based technology projects may be studied. The Fab Lab example is important for the reason that it contextualises the development of technologies in communities, and establishes the relevance of technologies to the communities that create them. In the context of this paper, Fab Lab communities represent the potential that open and collaborative technology development may have for broader communities and may be used to set the stage for the development of technologies that may service very specific communities, such as a community of artists.

Two Fab Lab projects were selected as case studies, because the paper assumed that they would follow an open source framework. During the course of the study, it was found that the *Electronic Shepherd* adhered to open source principles, while the *Solar Powered Streetlight* did not. It was also found that the open source framework employed by the *Electronic Shepherd* project contributed to its effectiveness as an appropriate technology. In the case of the *Solar Powered Streetlight*, it was found that although it was developed within an open source environment, it could not be referred to as an open source project because it lacked the required documentation. This also contributed to it being a lesser appropriate technology, which is evident through its inability to be evolved by other parties. This was compounded by the fact that it did not utilise its local resources efficiently, and was not entirely systems independent.

The research used in this paper proved that an open source approach to technology creation is able to address the needs of a community and that an open source model contributes to successful and effective appropriate technology creation. This is because open source initiatives address the criteria required of appropriate technology development, and because the collaborators or communities involved in open source technology creation determine the outcomes required for their specific needs.

Furthermore, the research suggests that the principles of open source creation may apply to non-software specific situations. This is significant because the term has traditionally been associated with software development only. The fact that open source can apply to non-software situations means that we can further our understanding of community technology development, and the impact that this has on communities. The case studies in this paper demonstrate that an open source framework does indeed have an impact on the communities involved. That other communities are able to freely duplicate, modify and adapt projects to suit their own needs, as seen in the *Electronic Shepherd* case study, is indicative of this.

During the course of my research, I found that although an open source framework is able to contribute to the creation of effective appropriate technologies, certain conditions must be met. The processes required to recreate projects must be made publicly available, otherwise the project does not adhere to the principles and freedoms of open source. Furthermore, collaboration and open dialogue must occur between members of the development team and the broader community for which the technology is intended.

In justifying the situation of open source practice outside of software development, this paper contributes to a broader understanding of the potential application of open source. While this paper has shown the application of open source to hardware, it can be argued that its framework can be applied to any instance where documentation, or instruction, may be allowed to be duplicated, modified and distributed.

Through case studies, this paper provides a reference to the development of appropriate technologies. The criteria for which, may be used by developers of open source and appropriate technologies to gauge the success rate of their products as well as fully understand the communities for which their product is intended. Additionally, it allows developers of appropriate technologies to understand the benefits that open source practice may have on their projects. That collaboration, transparent dialogue, and the freedom to pass one’s solution to a particular problem on to others will not only provide others with solutions to problems, but create a platform for exponential technology development.

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