

Investigating social manufacturing business model elements to support local suppliers



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DECLARATION

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ABSTRACT - ENGLISH

Manufacturing systems change constantly and a new theory towards value creation is emerging. It is believed that the next industrial revolution is upon us. This is emphasised by recent manufacturing strategies that have been initiated on national level such as the Catapult (UK), NNMI (US), SIP (Japan) and Industrie 4.0 (Germany) to create value in the manufacturing industry through a concept known as the ‘Internet of Things’.

In the last decade we have witnessed some new emerging approaches to technology creation and transfer. Social manufacturing will use co-creation where the innovation process is totally open to global communities in which everybody can participate through online platforms. Everybody can access and use existing design solutions and tools on these platforms and co-create even more solutions.

This report investigates the changes in the different manufacturing paradigms and to what the manufacturing industry is moving towards. Thereby, focusing on social manufacturing and supplying local suppliers with tools, through business model elements, to incorporate social manufacturing within their business models. This can enable start-up- and current manufacturing businesses to have an advantage in the future by providing better products and services to their clients by using the available technology.

ABSTRACT - AFRIKAANS

Vervaardiging stelsels verander voortdurend en 'n nuwe teorie teenoor produk of dienste waardeskepping is besig om te ontwikkel. Daar word geglo dat die volgende industriële revolusie om die draai is. Dit word beklemtoon deur die onlangse produksie strategieë wat reeds begin het op nasionale vlak soos die Catapult (UK), NNMI (VSA), SIP (Japan) en Industrie 4.0 (Duitsland) om waarde in die vervaardigingsbedryf te skep deur middel van 'n konsep bekend as die 'Internet of Things'.

In die afgelope dekade het ons 'n paar nuwe konsepte tot tegnologie skepping en die oordrag daarvan gesien. 'Social manufacturing' gebruik 'co-creation' waar die innovasieproses heeltemal oop is vir die wêreld gemeenskap waarin almal kan deelneem op aanlyn platforms. Almal kry toegang tot bestaande ontwerp oplossings, gebruik die oplossings en gereedskap op hierdie aanlyn platforms en 'co-create' selfs meer oplossings.

Hierdie verslag ondersoek die veranderinge in die verskillende produksie paradigmas en waarna die vervaardigingsbedryf oppad is. Daarom is die fokus op 'Social manufacturing' en om die plaaslike verskaffers of besighede met gereedskap deur middel van besigheidsmodel elemente van 'Social manufacturing', te verskaf. Dit sal plaaslike besighede help om 'Social manufacturing' te inkorporeer in hulle besigheidsplan. Dit kan nuwe- en huidige produksie besighede in staat stel om 'n voordeel in die toekoms te hê. Die besighede sal beter produkte en dienste aan hulle kliënte kan bied deur gebruik te maak van tegnologie wat reeds beskikbaar is.

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NOMENCLATURE

ACS	Autonomously Controlled Sub-Systems
AI	Artificial Intelligence
BBfA	Bamboo Bikes for Africa
BMC	Business Model Canvas
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CBC	Customer Buying Cycle
CIM	Computer Integrated Manufacturing
CNC	Computer Numerical Control
CPS	Cyber-Physical-Systems
EDP	Engineering Design Process
IIoT	Industrial Internet of Things
IoT	Internet of Things
IC	Industrial Cluster
IP	Intellectual Property
ISO	International Standard Organization
OAC	Open Architecture Control
OAP	Open Architecture Product
OSI	Open Systems Interconnection
OSS	Open Source Software
OWC	One Week Challenge
PDL	Product Development Lifecycle

STC-LAM	Stellenbosch Technology Centre Laboratory for Advanced Manufacturing
UK	United Kingdom
US	United States

GLOSSARY

Business Model Canvas – ‘Practical tools to help you understand customers, design better value propositions, and find the right business model’ [1].

Co-creation – ‘A business strategy focusing on customer experience and interactive relationships. Co-creation allows and encourages a more active involvement from the customer to create a value rich experience’ [2].

Crowd Companies – ‘The crowd is becoming a company unto itself - it is backed by powerful technologies, like mobile devices and social networks, and it is self-organising. Companies are changing their business models to partner with the crowd, fulfilment, changing innovation, manufacturing, and customer relations’ [3].

Cyber-Physical-Systems – ‘Cyber-Physical Systems (CPS) are integrations of computation, networking, and physical processes. Embedded computers, network monitors and control the physical processes, with feedback loops where physical processes affect computations and vice versa’ [4].

Industrial Cluster (IC) – ‘...groups of interrelated industries that drive wealth creation in a region, primarily through export of goods and services’ [5]. Another term closely related to an IC is Industry Clusters and is described as: ‘Industry clusters are groups of similar and related firms in a defined geographic area that share common markets, technologies, worker skill needs, and which are often linked by buyer-seller relationships’ [6]. However, in this study the IC is the group of people the experiment is focused around (Closely related to the target market).

Industrial Internet of Things – ‘The Industrial Internet of Things (IIoT) is the use of Internet of Things (IoT) technologies in manufacturing’ [7].

Industrie 4.0 – Is a German government strategic initiative name for the fourth industrial revolution that includes the internet of things, cyber-physical systems and cloud computing [8].

Internet of Things – ‘The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided

with identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction' [9].

Manufacturing Paradigm – A manufacturing pattern or model used by the manufacturing industry of a specific time period.

Power Law – ‘A power law is a relationship in which a relative change in one quantity gives rise to a proportional relative change in the other quantity, independent of the initial size of those quantities’ [10].

Product Development Lifecycle – Is the cycle through which every product goes through from introduction (planning) to withdrawal or support [11].

Social Manufacturing – The consumer changes his role into a consumer with development competence or in other words, a prosumer [12]. This enables co-creation on online platforms where the crowd community can be used to contribute to the entire manufacturing process. This concept links directly to Industrie 4.0, Internet of Things and Cyber-Physical Systems.

Traditional manufacturing – Is defined in this study as the current manufacturing process, where the manufacturer and the consumer are separated and is called mass customisation and personalisation.

1. INTRODUCTION

Manufacturing is a fundamental aspect to enhance national development and prosperity. It contributes to the growth of wealth for a nation, the quality of life of individuals and the power and position of a state [13]. Manufacturing has guided nations to development, Germany, USA and the Netherlands in the 17th century, England in the 19th century, Japan in the 20th century and the modern day China, Taiwan and Korea. A strong manufacturing sector is significant to a society or community because manufacturing stimulates all the other sectors in the economy.

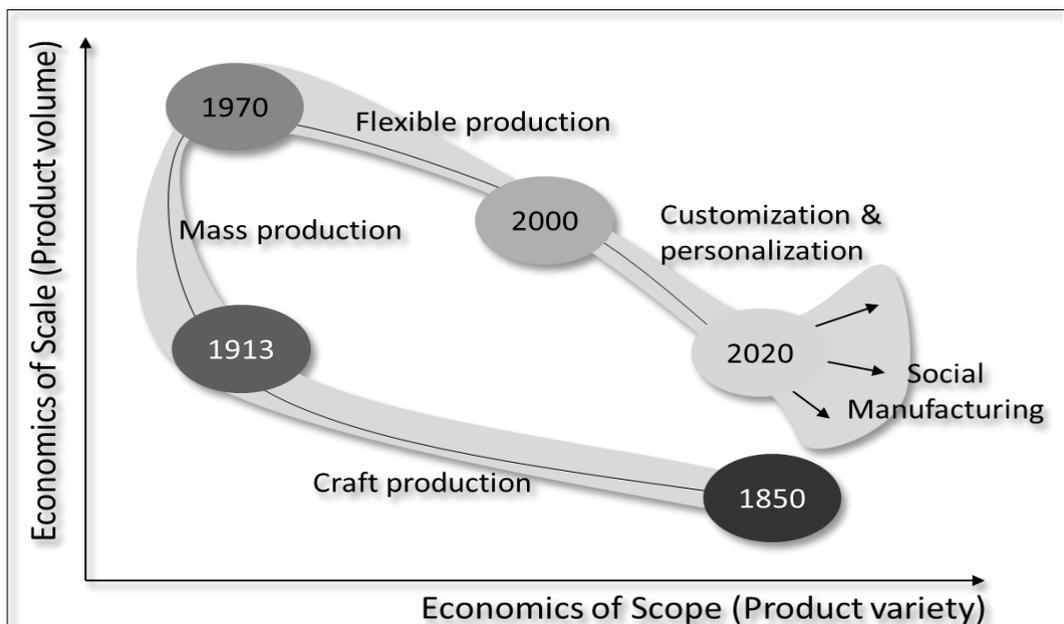


Figure 1-1: Effect of revolutionary changes on manufacturing economics of scope and scale [14]

To ensure prosperity, better life and sustainable development, manufacturing needs strong and continued endeavour of all actors in a modern society. The manufacturing industry has had many revolutionary changes throughout the years as shown in Figure 1-1. According to Koren *et al.* [15] development of new enabling technologies, changes in societal and market imperatives, cause the change in the manufacturing paradigms.

The craft production revolution forced society to focus more on the product volume or economics of scale. The invention of assembly lines supported craft production. This introduced mass production and saturated the market with specific products. Around the

1970s, society demanded a greater variety of products, which meant we went into an era of customisation and personalisation. Connectivity, however, was an issue in the early days of computer networking.

The ISO (International Standard Organization) recognised that a standard was required for communication among different systems in a network and started work on the OSI (Open Systems Interconnection). The term “open” according to Day *et al.* [16] was chosen to emphasise that by conforming to the OSI standards, a system anywhere in the world would be open to communication with other systems, obeying the same standards. The ISO 7498 standard (accepted in 1983) then initiated a way to integrate systems such as CAD (Computer-Aided Design)/CAM (Computer-Aided Manufacturing) and CIM (Computer Integrated Manufacturing).

The start of the nineties introduced a new open initiative in manufacturing. The machine tool controllers (CNC) were identified as a target for being opened up e.g. LinuxCNC. Only a few vendors offered CNC controllers at that time and they were closed systems. These closed systems blocked further development and did not allow for any adaptation from the initial product. A solution to this situation was OAC (Open Architecture Control) and was proposed as a concept for easy integration and implementation of customer-specific controls by using configuration methods and open interfaces in a vendor neutral, standardised environment [17].

Open architecture was recently expanded to a different idea called OAP (Open Architecture Products) – this is a new class of products consisting of a fixed platform and modules that can be swapped and added. According to Koren *et al.* [18], customers can change and adapt OAP’s to their required needs by integrating their modules into the platform. Manufacturers will produce these social manufacturing platforms, while customers and new small companies will develop new modules using open design platforms.

The latest trend or industrial revolution is the Internet of Things (IoT) [19] [20] which has ignited several manufacturing strategies on national level such as the Catapult (UK), Industrie 4.0 (Germany), NNMI (US) [21-23] and SIP from Japan. Kagermann *et al.* [24] describe this new industrial revolution as the convergence of the virtual world (cyberspace) and the physical world into the form of Cyber-Physical-Systems (CPS). This new era will

bring changes in customer expectations, production methods and value creation. Due to these changes, Burmeister *et al.* [19] stated that the focus should shift from product and service innovation to business model innovation.

Most software developers and producers consider source code as valuable intellectual property (IP) and make it unavailable to the public. The concept of open source software (OSS) IP is different, because OSS programs give any interested party (e.g. the public and other businesses), access to the source code leading to a distributed innovation platform in which any user can actively participate in the product's development, thus, enabling co-creation of value [25].

These open hardware and open source concepts are today known as one concept referred to as *Social Manufacturing*. Social manufacturing type of initiatives can be divided into projects (e.g. Wikispeed, OpenStructures and SketchChair), toolkits (e.g. Autodesk 123D, Cloud3DVIA), enterprises (e.g. Arduino, Bug Labs and Local Motors) and learning and education (e.g. Tinkercad). Social manufacturing theories and concepts are also evident in China's growing motorcycle manufacturing industry. The approach of social manufacturing has been so successful that motorcycle production has quadrupled from 5 million to over 20 million motorcycles a year since the mid-1990s, giving China about 50% of the global market share [26].

Value creation within social manufacturing cannot be described as a traditional process, where the producer and the consumer are separated from one another. Instead the consumer changes his role into a consumer with development competence or in other words, a prosumer [12]. The open design principle for value creation follows a bottom-up approach [27] from where different types of patterns start to emerge. The underlying theory in this process is called Emerging Synthesis [25].

1.1 Problem Statement

Starting a new business can be difficult, however, there are numerous online crowd-based platforms that can support start-up manufacturing businesses. These business owners do not necessary understand the benefits of these online platforms and how to use them. Therefore, the problem is to develop business model elements for any type of local supplier to incorporate social manufacturing within their manufacturing business.

1.2 Project Scope

The study will include the comparison of business elements, reducing product development pattern times and to investigate the trends of these business elements with regards to social manufacturing. A generic business model can then be developed to support local suppliers to understand the benefits, challenges and concepts behind social manufacturing.

1.3 Research Objectives

From the problem statement and project scope the following research questions were identified:

- What are the business elements of social manufacturing?
- How does social manufacturing compare to traditional manufacturing?
- How can social manufacturing be incorporated in the current industry?
- Can a business model for social manufacturing be developed?
- Is this business model valid?

1.4 Research Objectives

From the research questions the following three research objectives were identified in order for local suppliers to have a tool to incorporate social manufacturing in their current business model:

1. Identify different business elements of social manufacturing in comparison with traditional manufacturing with the business model canvas as foundation;
2. Develop a generic social manufacturing business model and process to support start-up local manufacturing suppliers;
3. Validate the business model and process with own experimental projects.

1.5 Report Layout

A summary of the different chapters of this report will follow below with a short description of each chapter:

- Chapter 2 – Literature Review chapter is used to understand the concepts for social manufacturing to establish requirements to achieve the research objectives.
- Chapter 3 – Research Methodology chapter is used to describe the methods that are used in the research study in order to achieve the required results.
- Chapter 4 – Experimental Setup and Design chapter is used to describe the different experimental project setups that are used in this study.
- Chapter 5 – Results and Discussion chapter is used to describe the results obtained from the experimental projects.
- Chapter 6 – Conclusion and Recommendations chapter is used to describe possible future research work and the conclusion of this research study.

2. LITERATURE REVIEW

This chapter will review current literature to understand what is required to achieve the research objectives and will be used in the research methodology. The literature review will be divided into the manufacturing paradigms, Crowd Companies, business model canvas (BMC), complexity in manufacturing systems and social manufacturing systems.

2.1 Manufacturing Paradigms

As societal imperatives and the market changed, new enabling technologies emerged for each manufacturing paradigm as defined by Jovane *et al.* [28]. The basic elements [15] of a manufacturing paradigm include developing the product (design), manufacturing (make), assemble and sale. The sequence of these basic elements differs for each paradigm due to the changes in their respective societal needs.

2.1.1 Craft Production

Craft production requires highly skilled workers to manufacture each product by hand [28], [29]. Examples of craft production workers include silversmiths, masons and carpenters. Craft production started when craftsmen made flint knives and weaved baskets [29], [30]; the peak of this paradigm was reached with the production of automobiles. Each individual part was produced using general purpose machine tools (die and tool sector) and then manually assembled.

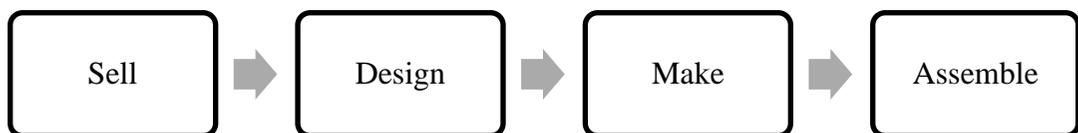


Figure 2-1: Pull system for the craft production paradigm (Adapted from [31])

Craft production was introduced around the year 1850. The business model was based on a pull system (sale-develop-produce-assemble) as illustrated in Figure 2-1 and Table 2-1. Society demanded individual products in small batches. The craftsmen will only design and manufacture the product once the customer has paid for the product.

Table 2-1: Craft production business model is based on a pull system with the manufacturing of individual products

Paradigm	Craft production
Paradigm begin	1850
Societal Needs	Individual products
Market	Small demand
Business Model	Pull (sale-produce-assemble)
Enabling Technology	Electricity
Key technology	Machine tools
Information & knowledge processing	Skills of individuals

The key technology for paradigm was machine tools and the enabling technology was electricity. Information and knowledge processing was measured on the skills of the individuals.

2.1.2 Mass Production

Mass production was introduced around the year 1913 when Henry Ford realised that the prices of automobiles were too high and needed to decrease in order to make it more affordable for the majority of the population. To accommodate for the change in society needs (population), he invented the moving assembly line for automobiles which significantly lowered production costs [15].

Mass production is described as producing a high number of identical products [28]. The mass production paradigm started around the year, 1913. The business model was based on a push system (develop-produce-assemble-sale) as illustrated in Figure 2-2 and Table 2-2. Society demanded a reduction in product cost that meant higher productivity was required.

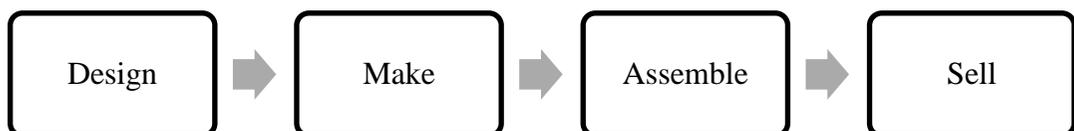


Figure 2-2: Push system for the mass production paradigm (Adapted from [31])

The enabling technology for mass production was interchangeable parts and the key technology, assembly lines. The introduction of interchangeable parts made the production process less complex which meant that highly skilled workers were no longer needed and labour costs were reduced.

Table 2-2: Mass production business model is based on a push system to lower product price with high productivity rates

Paradigm	Mass production
Paradigm begin	1913
Societal Needs	Price, productivity
Market	High demand- high batches
Business Model	Push (develop-produce-assemble-sale)
Enabling Technology	Interchangeable parts
Key technology	Assembly line
Information & knowledge processing	Scientific management

The decreasing production costs allowed the product price to be reduced. Information and knowledge processing was based on scientific management.

2.1.3 Flexible Production

Mass produced products started saturating the market and people no longer wanted basic products; they consequently demanded a greater variety of products. In order to satisfy customers' needs, lot sizes were decreased and flexible production was introduced [28]. In this context, Duguay *et al.* [32] defined flexible as “the capacity to deploy or redeploy production resources efficiently as required by changes in the environment”.

Flexible production was introduced around the year 1970. The business model was based on a push-pull system (develop-produce-sale-assemble) as illustrated in Figure 2-3 and Table 2-3. Society demanded a greater variety of products. The enabling technology was digital computers and the key technology, flexible manufacturing systems.

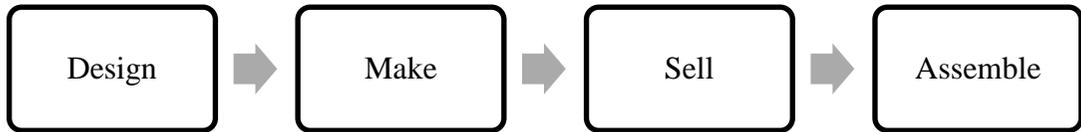


Figure 2-3: Push-Pull system for the flexible production paradigm (Adapted from [31])

Information and knowledge processing was based on data storage/retrieval information processing. Flexible production resources include cost, quality and time. The company had to be flexible with regards to product volume as the quantities that customers demanded had significant fluctuations.

Table 2-3: Flexible production business model is based on a push/pull system with the manufacturing of a variety of products

Paradigm	Flexible production
Paradigm begin	1970
Societal Needs	Variability of products
Market	Reduction of batch sizes
Business Model	Push/pull (develop-produce-sale-assemble)
Enabling Technology	Digital computers
Key technology	Flexible manufacturing systems
Information & knowledge processing	Data storage/retrieval information processing

With flexible production, the parts are manufactured on a similar basis as with mass production, however, the final product is only assembled once the customer has bought the product [28].

2.1.4 Mass Customisation and Personalisation

The change to mass customisation and personalisation is predominantly due to societal needs changing from a greater variety of products, to optional features and customisable products [15], [33]. To satisfy these societal needs, manufacturing companies made changes to the way they run their businesses.

Manufacturers design standard products to manufacture and give the customer a variety of optional extras to add to the standard product. This enables co-creation of the product that is within the company's manufacturing capabilities. Mass customisation and personalisation was introduced around the year 2000. The business model is based on a pull system (develop-sale-produce-assemble) as illustrated in Figure 2-4 and Table 2-4.

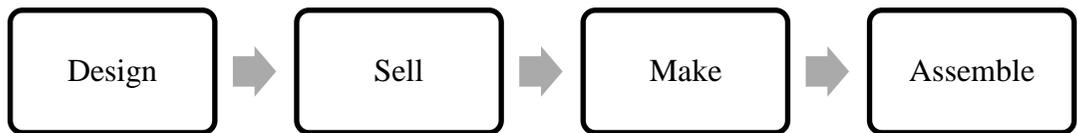


Figure 2-4: Pull system for the mass customisation and personalisation and paradigm (Adapted from [31])

Societal needs demands customised products and are environmentally conscious. The standard product is still mass produced by means of flexible automation manufacturing, to reduce production costs. Once the customer has paid and selected the extras of their choice, the manufacturing of the product will be completed [2].

Table 2-4: Mass customisation and personalisation business model is based on a pull system with the manufacturing of customised, environmentally conscious products

Paradigm	Mass customisation and personalisation
Paradigm begin	2000
Societal Needs	Customised products- Environmentally conscious
Market	Global production- demand fluctuation
Business Model	Pull (sale-produce- assemble)
Enabling Technology	Information technology
Key technology	Reconfigurable manufacturing systems
Information & knowledge processing	Knowledge management

The enabling technology for mass customisation and personalisation, is information technologies and the key technology reconfigurable manufacturing systems. Information and knowledge processing was based on knowledge management. The next manufacturing paradigm is social manufacturing, which will be discussed in section 2.5.

2.2 Crowd Companies

The next manufacturing paradigm is predicted to be social manufacturing. There are numerous companies that currently implement social manufacturing elements in the manufacturing industry and through using online platforms within other industries. These companies are called Crowd Companies that are defined as ‘...The crowd is becoming a company unto itself - it’s backed by powerful technologies, like mobile devices and social networks, and it is self-organizing. Companies are changing their business models to partner with the crowd, fulfilment, changing innovation, manufacturing, and customer relations’ [3].

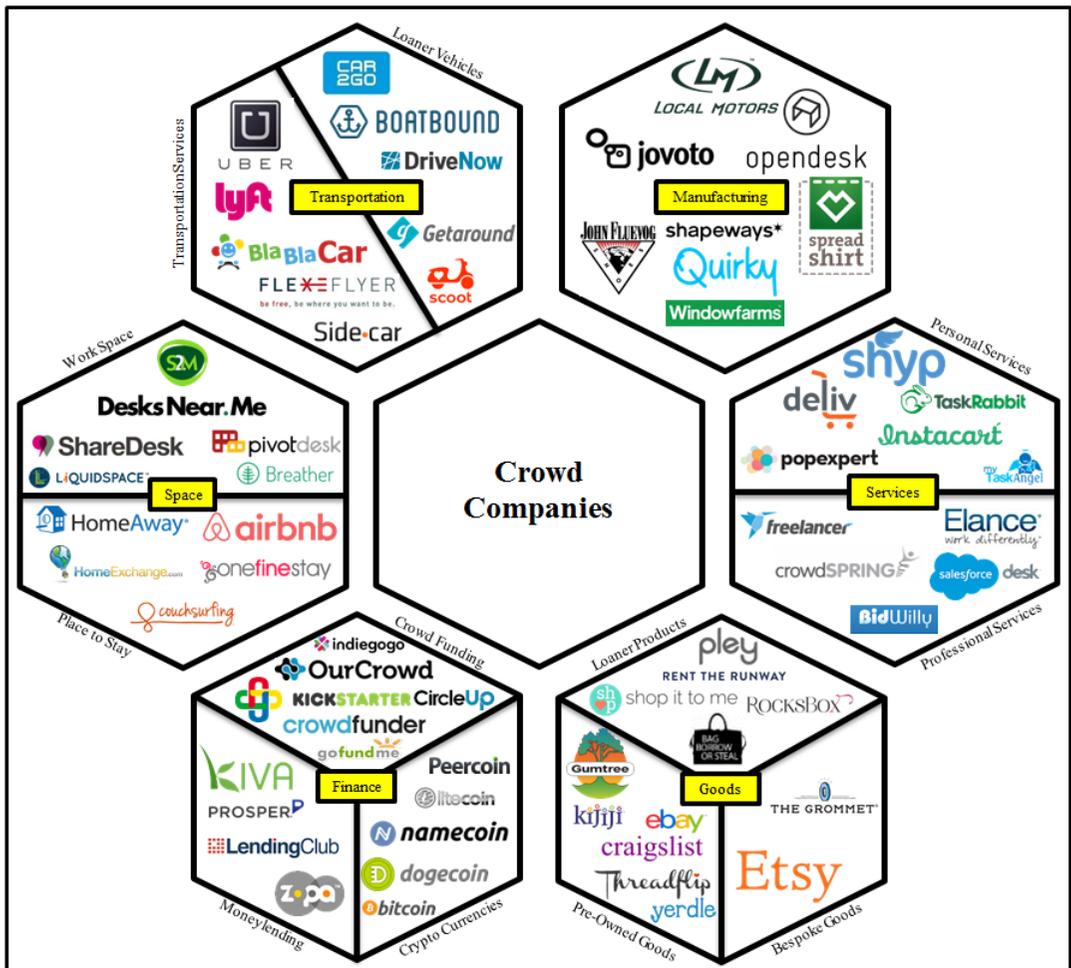


Figure 2-5: Crowd Companies currently using social manufacturing elements in their business models (Adapted from [34]) [35-104]

These industries include transportation, work and living space, personal and professional services, financial services, and goods. Each of these industries, along with manufacturing, is summarised in Figure 2-5 in a honeycomb structure. Figure 2-5 shows each industry is divided into individual honeycombs and each honeycomb, has sub-industries. A brief discussion on each industry will follow below.

The transportation industry is divided into sub-industries called transportation services and loaner vehicles. This industry include companies e.g. Uber [36], Lyft [37], Scoot [38], etc. (more examples can be found in Figure 2-6).

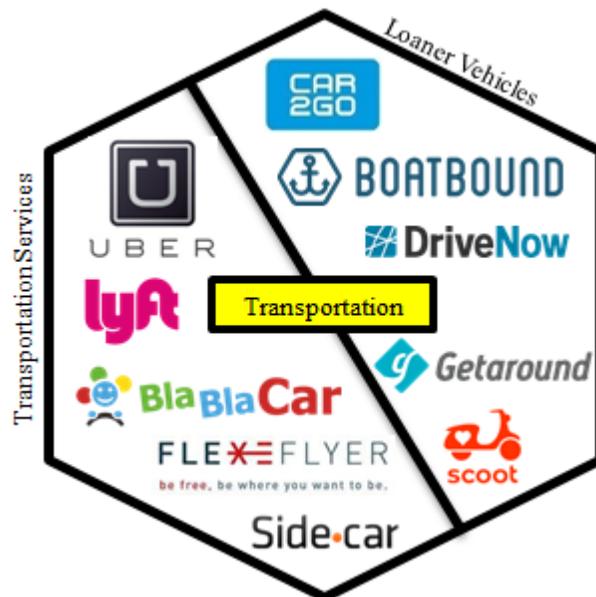


Figure 2-6: Crowd Companies currently in the transportation industry magnified from Figure 2-5

For an example, Uber [36] changed the entire transportation industry using the latest mobile phone technology through an application. The problem is that in urban areas there are many taxis and many potential passengers, however, there is no means of communication or connecting the two parties. The Uber application links willing taxi drivers (who use their own cars, therefore Uber owns no vehicles), to potential passenger fares using the latest smartphone technology.

Therefore, this application links two crowds through an online platform that without this application, would not have been possible. The entire transaction is cashless and paid using a credit card through the online platform. The taxi fare is calculated according to the

distance and the time of the fare and is therefore more accurate than traditionally taxi methods.

The financial industry is divided into sub-industries called crowd funding, moneylending and crypto currencies. This industry include companies e.g. Jumpstarter [35], Kickstarter [39], Bitcoin [40], Zopa [41], etc. (more examples can be found in Figure 2-7).



Figure 2-7: Crowd Companies currently in the finance industry magnified from Figure 2-5

For an example, Kickstarter [39] and Jumpstarter [35] are crowd funding mechanisms that run through an online platform. These websites enables entrepreneurs to get funding for ideas. The problem with becoming an entrepreneur or starting a new business, is finding a funder to take on the risk of the proposed new business idea.

The reason why this is difficult, is that the funder is not willing to take a risk on something that the market does not necessarily demand and does not want to take this risk alone. Kickstarter (Jumpstarter) solves both these problems as the online platform decides whether the product or idea is fundable. This means that the market, which in this case is the online community, decides if they want to fund your product or idea by investing with small contributions for small rewards or incentives.

A goal is set for the required funds and users on the online platform give small contributions to try and reach the goal of the required funds. This enables new companies or ideas to start a business and supplies to a need that the online community requires.

The space industry is divided into sub-industries called work space and places to stay. This industry include companies e.g. Airbnb [60], Couchsurfing [63], DesksNear.Me [54], ShareDesk [58], etc. (more examples can be found in Figure 2-8).



Figure 2-8: Crowd Companies currently in the space industry magnified from Figure 2-5

For an example, Airbnb [60] changed the entire accommodation industry using the latest smartphone technology through an application. The problem is that hotel accommodation has become expensive and there is a significant amount of people that have open rooms or houses of their own that they are willing to rent out. There are people that are willing to pay less and stay in an open room of somebody's residence, however, they don't know of each other.

The Airbnb application links potential accommodation (who use their own houses, therefore Airbnb owns no property) to potential renters. The two crowds are linked through an online platform that without this application would not have been possible. The entire transaction is cashless and is paid using a credit card through the online platform.

The services industry is divided into sub-industries called personal- and professional services. This industry include companies e.g. Freelancer [74], CrowdSpring [73], Popexpert [76], Taskrabbit [81], etc. (more examples can be found in Figure 2-9).



Figure 2-9: Crowd Companies currently in the services industry magnified from Figure 2-5

For an example, Freelancer [74] is an application that provides willing experts to do freelance work in their field of expertise for people that require work for a specific job. Therefore, this application links people that are willing to do freelance work to potential work opportunities through the online platform. The two crowds are linked through an online platform that without this application would not have been possible. The entire transaction is cashless and is paid using a credit card through the online platform.

The goods industry is divided into sub-industries called pre-owned goods, loaner products and bespoke goods. This industry include companies e.g. Gumtree [103], eBay [90], Shop it to me [87], Etsy [83], etc. (more examples can be found in Figure 2-10). For an example, Gumtree [103] is an online platform that provides users with goods to sell or buy. This can be second hand goods or new products. This removes the retailer and provides users that have unwanted goods, to find willing buyers.



Figure 2-10: Crowd Companies currently in the goods industry magnified from Figure 2-5

This platform provides the opportunity for buyers to find better prices for products than retailers offer. Therefore, the two crowds (Buyers and Sellers) are linked through an online platform that without this application would not have been possible.

The manufacturing industry is starting to move into a more social paradigm from mass customisation and personalisation. Therefore, evidence of this should be found through manufacturing companies starting to incorporate social manufacturing concepts within their business.

Manufacturing companies currently using social manufacturing include: Local Motors [104], Shapeways [100], Quirky [99], Opendesk [94], Windowfarms [102], etc. (more examples can be found in Figure 2-11). All the above mentioned examples incorporate co-creation platforms for their design process.



Figure 2-11: Crowd Companies currently in the manufacturing industry magnified from Figure 2-5

Local Motors use the community, not only as designers, but in the entire manufacturing process. The community is the core value of their business model and as stated on the Local Motors website: ‘Community is a core value at Local Motors. Engaging the community to facilitate innovation and empower the maker community drives everything we do [105].’ Figure 2-12 is adapted from the Local Motors website and describes their community involvement with regards to the different business elements of the company.

Co-creation is described by Local Motors as: ‘Co-creation is an essential element of vehicle innovation at Local Motors. Micro-factories bring the Local Motors team, the physical community, and the virtual community, together to make this concept a reality. Using the Local Motors website, engineers, designers, enthusiasts and fabricators can submit their own ideas, receive helpful feedback, and develop their designs [105].’

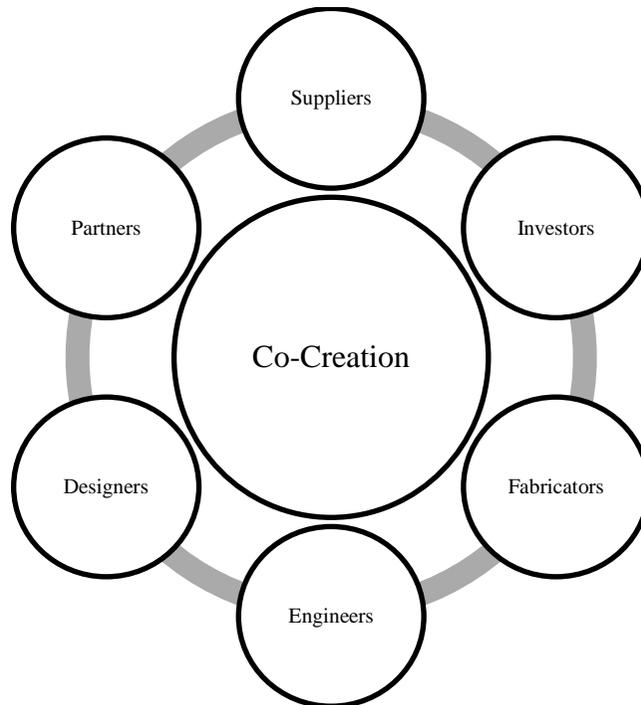


Figure 2-12: Co-creation conceptual framework from current social manufacturing projects (Adapted from [105])

The co-creation designers are used to source and filter design ideas in order to find the solution for a design problem. Therefore, Local Motors is a suitable example of a social manufacturing driven company; it is important to ensure that their proven concepts and business elements are taken into consideration in this study.

2.3 Business Model Canvas

The business model canvas (BMC) was chosen as it summarises the business model using the nine building blocks. The BMC is described as: 'Practical tools to help you understand customers, design better value propositions, and find the right business model' [1]. In order to develop a BMC for a more social paradigm, an analysis is required on the basic structure of the BMC. The nine building blocks of the BMC are shown in Figure 2-13 and these building blocks are: Key partners (Partnership network), Key activities (Value configuration), Key resources (Capability), Value propositions, Customer relationships, Channels, Customer segments, Cost structure and Revenue streams (Revenue model).

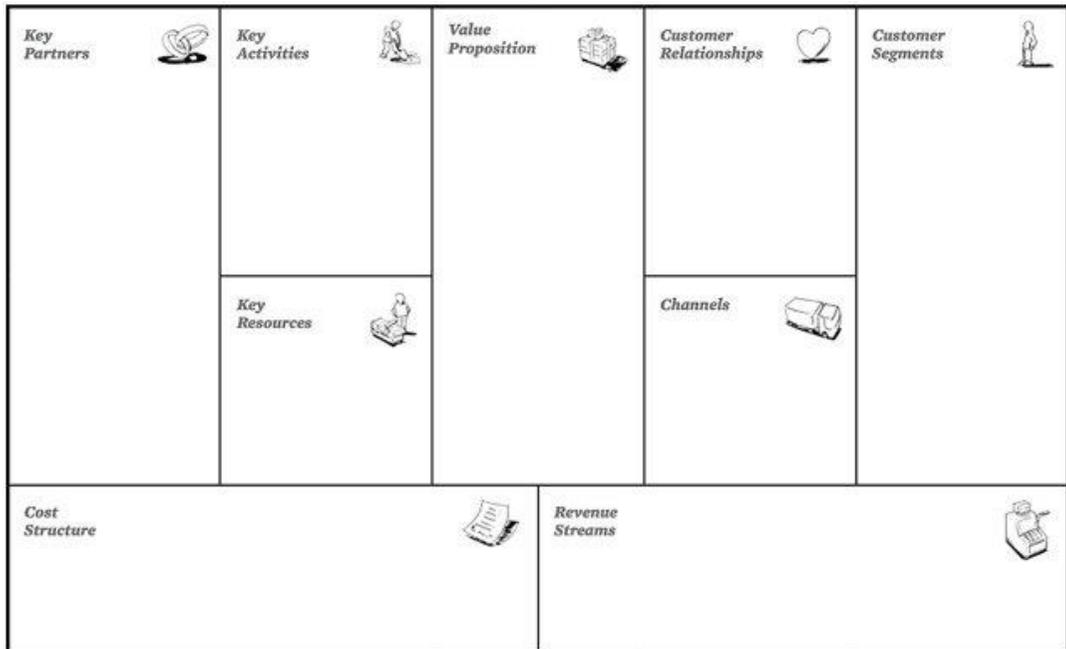


Figure 2-13: The nine building blocks from the basic business model canvas (BMC) structure [106]

This section will be divided into the nine building blocks and discussed individually. This section is based on Osterwalder's [107] business model ontology and the report handed by Botes [31] as a final project at the Industrial Engineering Department of Stellenbosch University.

2.3.1 Key Partners

Key partners are also described as partnership networks. In order for companies to enhance their competitive stance in the market, an alliance is formed between two or more companies and is called key partners. For these partnerships to exist, an agreement is used to establish conditions and reasons for the partnership.

An example of an agreement and its different attributes are shown in Figure 2-14. A brief discussion of each of these attributes will follow below to establish the exact meaning of these partnerships agreements.

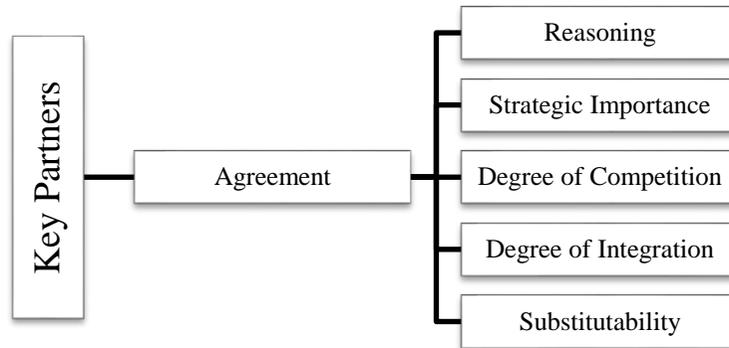


Figure 2-14: Key partners structure on holding an agreement of the business model canvas (Adapted from [31])

- The three reasons for companies to form an alliance are: Acquire resources, reduction of uncertainty or risk and for economics of scale and optimisation.
- The strategic importance is rated on a scale from 0 to 5. A rating of 5 indicates a high strategic relevance and 0 is strategically irrelevant.
- The degree of competition is rated on a scale from 0 to 5. A rating of 5 indicates the partnering company is considered as a big competitor and 0 indicates the partnering company is considered as a small competitor.
- The degree of integration is rated on a scale from 0 to 5. This rating is measured as the link between the companies. A rating of 5 indicates the companies are considered to have an integrated supply network and 0 indicates the companies are independent.
- The substitutability is rated on a scale from 0 to 5. A rating of 5 indicates the partnering company is easily replaceable with a different company and 0 indicates the partnering company is difficult to replace.

2.3.2 Key Activities

Key activities are also described as value configuration. The configuration of activities and processes creates value; therefore, the value configuration can be divided into activities. An example of the structure of the key activities and its different attributes are shown in Figure 2-15. A brief discussion of each of these attributes will follow below to establish the exact meaning of the activities attributes.

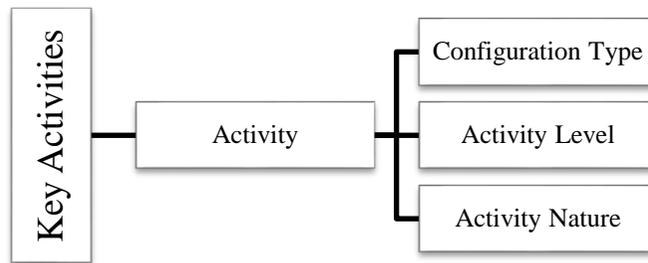


Figure 2-15: Key activities structure of the business model canvas (Adapted from [31])

- The three configuration types are: value network, value shop and value chain. The value network is formed when customers are liked and focus on providing the correct services, operations, promoting the network, etc. The focus point of a value shop is the customer and the feedback received from the customer. The value shop uses the following activities: providing solutions, evaluation and implementation. Value chains transform resources into products and use the following activities: marketing, sales, deliveries and service.
- The two types of activities are primary and support activities. Support activities are procurement and management.
- The activity nature is described as each configuration type having its own primary activities. These primary activities are known as the activity nature and are shown in Figure 2-16.

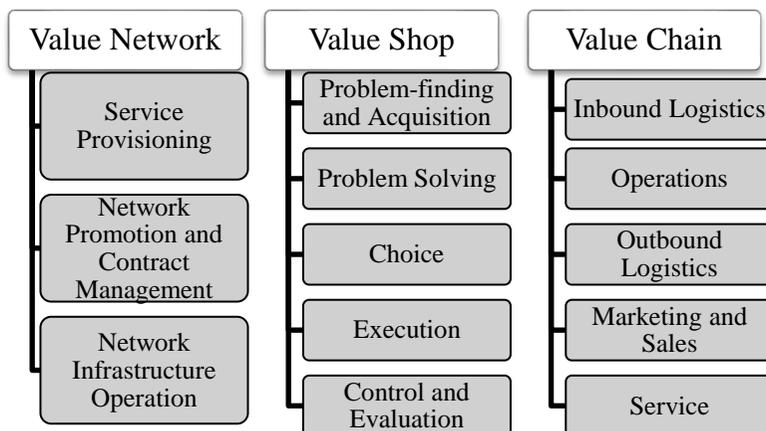


Figure 2-16: Activity nature of the key activities block of the business model canvas (Adapted from [31])

2.3.3 Key Resources

Key resources are also described as capability. A variety of resources are used by any company to continuously create its products and/or services, therefore, the capability of the company is broken down into the various resources. These resources are for the most part obtained from outsourcing and are described as actors. The key resource structure and its attributes, are shown in Figure 2-17. A brief discussion of each of these attributes will follow below to establish the exact meaning of the key resources.

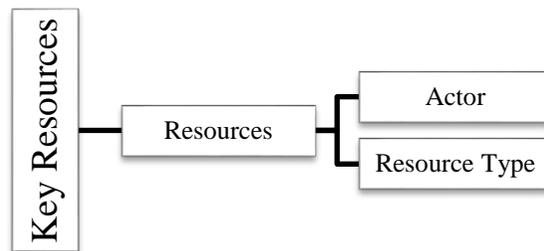


Figure 2-17: Key resources structure of the business model canvas (Adapted from [31])

- The actor is the outsourcing company or organisation and is given a name and description.
- The three types of resources are human-, tangible- and intangible resources. Human resources are the work force of the company. The tangible resources are the physical resources of the company (e.g. equipment, building and vehicles) and intangible resources are the brand names, patents, etc.

2.3.4 Value Propositions

Value propositions satisfy customer needs and add value to customer segments [108]. Value propositions include the products, after sale customer care and services. Value propositions are the products/services that make the company unique compared to the competitors.

Shown in Figure 2-18 are the attributes and structure of the value propositions. A brief discussion of each of these attributes will follow below to establish the exact meaning of the value propositions, which is also known as an offering (as shown in Figure 2-18).

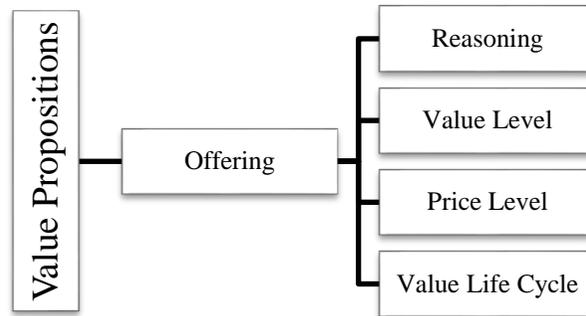


Figure 2-18: Value propositions structure of the business model canvas (Adapted from [31])

- The reasoning attribute is described by three ways to add value to a customer. These three values are: Product/service, reduce customer risk (e.g. Insurance) and reduce customer effort (Increase customer convenience e.g. online shopping).
- The four types of value level can be described by the scaled flow diagram shown in Figure 2-19. The first type, Me-Too, is when you deliver the same product/service as your competitors. The second type, Innovative Imitation, is when you have added innovation to a competitor's product or service. The third type, Excellence, is when you sell a high-end/high-quality product or service. The last type, Innovation, is when the product or service is disruptive technology that is brand new and changes the industry.

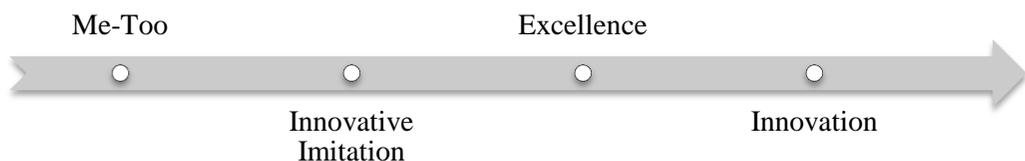


Figure 2-19: Value proposition scale level of the business model canvas (Adapted from [31])

- The price level is divided into four levels of ascending order: free, economy, market and high-end.
- The value life cycle is divided into five stages and it is important to understand at what stage the product/service starts to add value. The five stages are: Value creation, value purchase, value use, value renewal and value transfer.

2.3.5 Customer Relationships

The company has to maintain a good relationship with its current and future customers in order to ensure the company has a constant profit stream. However, it is important for the company to decide what type of customer relationship the company will have with its customers. It is therefore important to look at the customer relationship structure as shown in Figure 2-20 and its attributes.

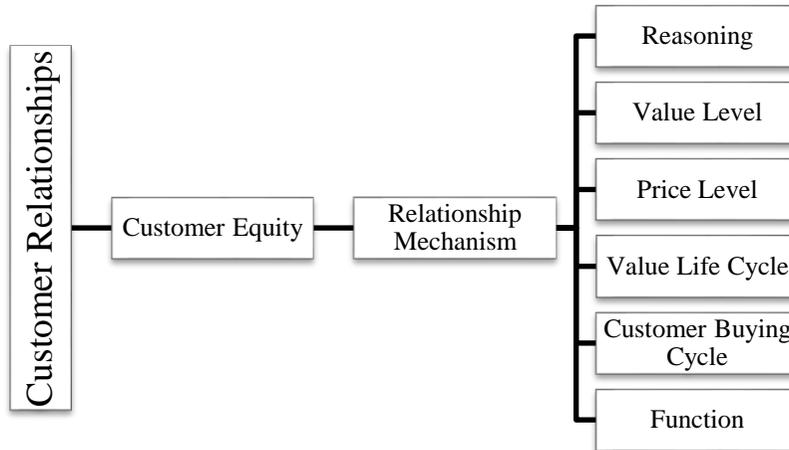


Figure 2-20: Customer relationships structure of the business model canvas (Adapted from [31])

A brief discussion of each of these attributes will follow below to establish the exact meaning of customer relationships.

- The customer equity has three goals, namely acquisition, retention and add-on selling. These three goals are important to consider maintaining and growing the company's customer relationships. Customer-acquisition is the relationship with new customers. Customer-retention is to maintain the customer by keeping the customer satisfied. Add-on selling is important to insure extra products and services that will increase profits.
- To find the discussion on reasoning, value level, price level and value life cycle, see section 2.3.4.
- To find the discussion on CBC (customer buying cycle), see section 2.3.6.
- The three functions for a customer relationship are: personalised, create trust and enhance brand building.

2.3.6 Channels

Channels are the distribution channels to deliver products or services to specific customer segments. The distribution channel is connected by links and these links represent the different tasks to deliver the products or services to the customer. The channels structure is shown in Figure 2-21 along with the different attributes for the structure.

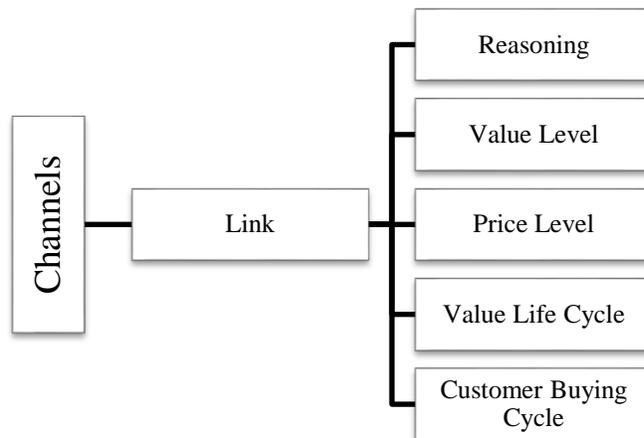


Figure 2-21: Channels structure of the business model canvas (Adapted from [31])

A brief discussion of each of these attributes will follow below to establish the exact meaning of distribution channels.

- The discussion of reasoning, value level, price level and value life cycle can be found in section 2.3.4.
- CBC is divided into four phases and is shown in Figure 2-22. The first phase of the CBC is awareness. This phase is used to attract the customer to the product through advertising or promotions. The second phase is evaluation. In this phase the customer needs all the necessary information from the company as the customer is interested in the product. The third phase is purchase and this might be negotiable if it is a business-to-business transaction otherwise it will be a fixed amount that the customer is willing to pay. The fourth phase is after sales. It is important to provide efficient after sales service (e.g. maintenance and troubleshooting) to ensure that customers will want to buy products or services from the company in the future.



Figure 2-22: Customer Buying Cycle of the channels block of the business model canvas (Adapted from [31])

2.3.7 Customer Segments

Customer segments are the customers or consumers that the company identifies as the group the company wants to sell products or services to. Customer segments are important as this can shape the way the product/service are designed, manufactured and presented to appeal towards the customer or consumer.

2.3.8 Cost Structure

The cost structure is the individual expenses for all the different accounts that the company must pay in order to supply products and services from production, delivery and maintenance. The cost structure is shown in Figure 2-23 along with the different attributes. Each of these accounts has a sum attribute that is simply the monetary value for the account. The percentage is the attribute that measures the contribution of a specific cost stream to the cost structure.

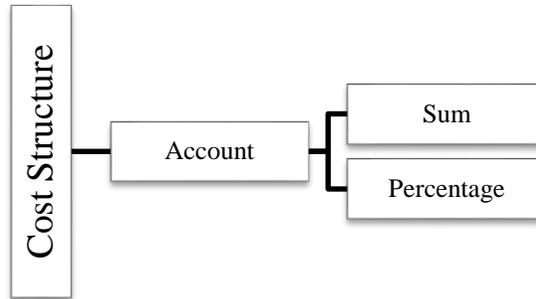


Figure 2-23: Cost structure of the business model canvas (Adapted from [31])

2.3.9 Revenue Streams

Revenue streams or revenue model is measured on the company's ability to convert the value proposition into a sustainable income. The revenue model is divided into the revenue streams and pricing which describes a stream from an offering. These elements have attributes and this revenue model structure is shown in Figure 2-24.



Figure 2-24: Revenue model structure of the business model canvas (Adapted from [31])

A brief discussion of each of these attributes will follow below to establish the exact meaning of revenue streams.

- The five stream types are: Lending, selling, licensing, advertising and transaction cut.
- Percentage is discussed in section 2.3.8.
- The three types of pricing are: Market pricing, differential pricing and fixed pricing. Market pricing will depend and vary according to the current market trends. Differential pricing depends on the volume of products and customer preference. Fixed pricing does not depend on market trends and will remain on a fixed rate.

2.4 Complexity in Manufacturing Systems

This section is divided into complexity of systems and the power law. Although these concepts are different, they are used together in this study to prove the power law. Proving the power law will indicate that the study does follow a natural phenomenon; it will ensure that this study used a natural population and that the population was not forced to participate or change their natural behaviour. This section will be based on Vrabic's study on 'Discovering autonomous structures within complex networks of work systems' [109].

2.4.1 Complexity of Systems

Social manufacturing is a complex system/network, however, it is a controlled system and there are some similar patterns that can be identified to simplify these networks. Later in this study, ACS (autonomously controlled subsystems), will be used to develop a simplified network for social manufacturing.

Autonomous means having power for self-government [110]. Autonomous controllers have the ability and power for self-governance in the performance of control functions [110]. Intelligent ACS use similar techniques from AI (artificial intelligence) to achieve this autonomy. These control systems evolved from conventional control systems by incorporating intelligent components [110]. In the case of social manufacturing, the crowd will control the entire process and therefore it will be an ACS.

ACS existed since the flexible manufacturing paradigm in the 1970s and Saab (Car manufacturer) divided their workers into autonomous teams which increased the quality and productivity of the workers [111]. The ACS's success was short-lived due to serial production. However, current manufacturing trends such as the personalisation of products and the decrease in lot sizes, have created the opportunity of ACS to resurface [28].

To consider complex manufacturing systems, the system structure needs to be improved and for that reason divided into subsystems. According to Vrabic [109], if a subsystem is to be autonomous, the subsystem must be able to self-organise and the information flow within the system must exceed the information flow between the surroundings and the subsystem. If this is true and the internal connections of the system are strong compared to the surroundings, then the possibility exists to use complex network analysis to identify ACS.

According to Vrabic [109], to identify an ACS can be divided into three steps, namely network modelling, network analysis and community detection. A brief discussion on the three steps will follow below.

- Network modelling of complex networks display the connectivity patterns between the different elements of the network. The values of the variables associated with these networks are distributed over several orders of magnitude. These distributions conform to the power law and describe a wide range of social and natural phenomena. Examples of these distributions are social networks, internet and biological systems [112].
- Network analysis will be done using the power law which is described in section 2.4.2.
- Community detection is described as strongly connected clusters or sub-networks. The purpose of identifying these communities is to understand the functional and structural properties of these complex networks [113].

2.4.2 Power Law

The power law will serve as the network analysis from the previous section 2.4.1. The power law can be described as: ‘A power law is a relationship in which a relative change in one quantity gives rise to a proportional relative change in the other quantity, independent of the initial size of those quantities’ [10].

Examples of power law functions are Stefan-Boltzmann law [114], Steven’s power law [115], Square-cube law [116], Kleiber’s law [117], Zipf’s law [118] and Gutenberg-Richter law [119]. In order to prove that the power law exists in a study the data must follow the power law curve and the log curve shown in Figure 2-25.

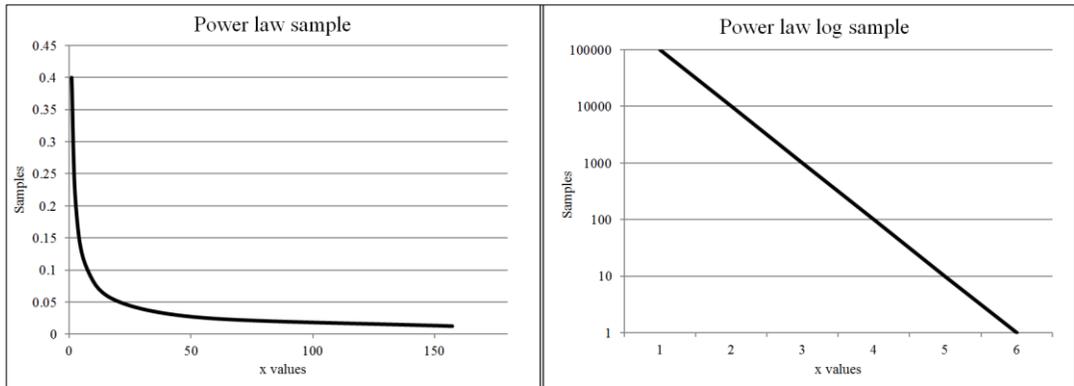


Figure 2-25: Power Law example of the power curve and the log log curve (Adapted from [109], [112])

Scale-free networks are complex and uniquely characterised by power laws. Therefore, these networks are easily identified using a power law. The power law as shown in Figure 2-25 will be explained using equations (1)-(5) from Vrabic's study [109].

Probability distribution of complex networks in node degrees follows a power law equation (Eq. (1)), where α is the exponent and C is constant:

$$p(x) = C \times x^{-\alpha} \quad (1)$$

This network is scale-free because the distribution is the same for any scale of observation, excluding an overall multiplicative constant. This means that if a network can be designed to be scale-free, it will be able to scale to any size population and will have the same results. Figure 2-26 shows the difference between a scale-free network (Figure 2-26 a) and a random network (Figure 2-26 b). The scale-free network distribution is generated through Barabasi-Albert model [120] and in the scale-free network hubs emerge as shown in Figure 2-26 a).

From Eq. (1) $p(x)$ diverges as x approaches 0, therefore the power law can only hold from a x_{min} value onwards (Bigger value) and α is assumed to be positive. Using these assumptions Eq. (1) is normalised to Eq. (2):

$$1 = \int_{x_{min}}^{\infty} p(x) dx = C \times \int_{x_{min}}^{\infty} x^{-\alpha} dx = \frac{C}{1-\alpha} \times [x^{1-\alpha}]_{x_{min}}^{\infty} \quad (2)$$

Using Eq. (2), if $\alpha > 1$ then C can converge and is calculated using Eq. (3):

$$C = (\alpha - 1) \times x_{min}^{\alpha-1} \quad (3)$$

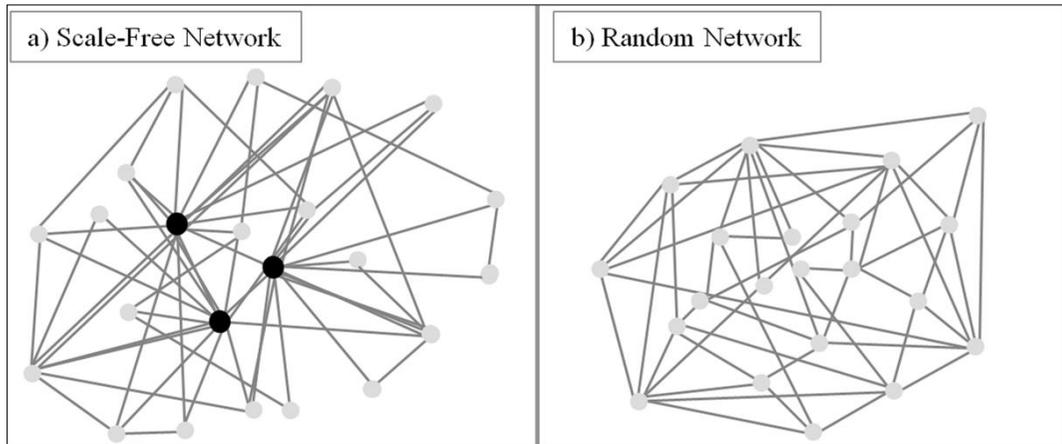


Figure 2-26: Different complex networks: a) Scale-free network compared to b) Random network (Adapted from [109])

Using Eq. (1) and the normalised Eq. (3) the power law distribution follows Eq. (4):

$$p(x) = \frac{\alpha-1}{x_{min}} \times \left(\frac{x}{x_{min}}\right)^{-\alpha} \quad (4)$$

Example of Eq. (4) plotted on a graph is shown in Figure 2-25 a) and the corresponding log-log graph is shown in Figure 2-25 b). In order to obtain the value of α Eq. (5) can be used, where x_i are the observed values of x . For more literature on the mathematics of the power law refer to [112].

$$\alpha = 1 + n \times \left[\sum_{i=1}^n \frac{x_i}{x_{min}} \right]^{-1} \quad (5)$$

2.5 Social Manufacturing Systems

Social manufacturing relies on the basis that personal and social networking ties and relationships provide value to organisations in a network by allowing them to tap into the resources embedded within the network for their own benefit [15]. Zhang *et al.* [121] define social manufacturing as a new kind of networked based manufacturing mode which integrates distributed socialised manufacturing resources and aggregates enterprises into manufacturing communities through initial self-organisation and clustering.

Vukovic *et al.* [122] believe that web 2.0 technologies are the enabler of crowd sourced manufacturing or social manufacturing. It is used for collecting mass data and problem solving. There are three drivers that caused a growth in crowd sourced manufacturing [123]. Real economic value is created out of these new principles due to concurrent, mass

collaboration where people are living, experiencing and expressing gradually more within digitally enabled social- and peer networks. The idea of open design systems is to change the method we use to construct knowledge around manufacturing itself, as the ability to generate new knowledge can play a significant role to stay competitive [16]. This way leads to new methods for solving problems and accelerate the process of co-creation [24].

Social manufacturing is predicted to start in the year 2020. The business model will be based on a pull system (sale-produce-assemble) as illustrated in Figure 2-4 and in Table 2-5. Society will demand personalised products on demand and will be sustainable conscious across the entire value chain. The enabling technology for social manufacturing will be the IoT and the key technology might be self-organising systems. Information and knowledge processing will be CPS.

Table 2-5: Social manufacturing business model is based on a pull system with the manufacturing of personalised products

Paradigm	Social Manufacturing	Existing Social Manufacturing companies
Paradigm begin	Predicted to start by 2020	Local Motors
Societal Needs	Personalised products on demand –Sustainability conscious	Opendesk
Market	Global production – demand fluctuation	Quirky
Business Model	Pull (sale-produce-assemble)	Shapeways – 3D printing
Enabling Technology	Internet of things	WindowFarms
Key technology	Self-organising systems	Blender
Information & knowledge processing	Cyber-physical systems	OpenStructures

Local Motors (social manufacturing company) is the first disruptive entrant in the US automotive manufacturing industry in decades. The company helps solve local problems, through open-source principles, by making transportation more sustainable globally with the use of local suppliers and utilises innovative distributed manufacturing to co-create vehicles and components with its virtual community of role-players around the world.

The company uses an online crowd (community) on open design platforms to design the vehicle and the local community to manufacture the vehicle. This social manufacturing company [104] uses a mobile factory (with rapid product development technology) on the back of a transport vehicle (truck), to transport the factory to the customer's location and manufacture the product at the delivery location.

This will mean that distribution costs will be reduced significantly and this enables Local Motors to produce vehicles faster at lower costs with more human resources than their competitors. This indicates a clear difference between conventional manufacturing and social manufacturing companies. The difference being that anyone with internet access can create and share their product designs or ideas online in an open design database. The shared designs and ideas are then open to other people to contribute to the design by either making improvements or suggestions.

Using more crowd-sourcing and customer immersion service platforms in social manufacturing to identify patterns from emerging synthesis, will shorten the design period [124]. This will ensure faster identification of the required patterns and will help to develop customer demanded products. The second major difference of social manufacturing is that the manufacturing is done by the user/market and the manufacturing capability is embedded within the online community platform database [124].

Traditional manufacturing is defined in this study as the current manufacturing process, where the manufacturer and the consumer are separated and is called mass customisation and personalisation. To illustrate the comparison between social manufacturing and traditional manufacturing companies, a comparison is required with regards to the design cycle (Rate), prototype cost, prototyping rate and human resources as shown in Figure 2-27.

This indicates that social manufacturing will enable companies to increase the design, cycle- and prototyping rate, have access to more human resources at a lower cost and have a decrease in prototyping cost than their traditional competitors.

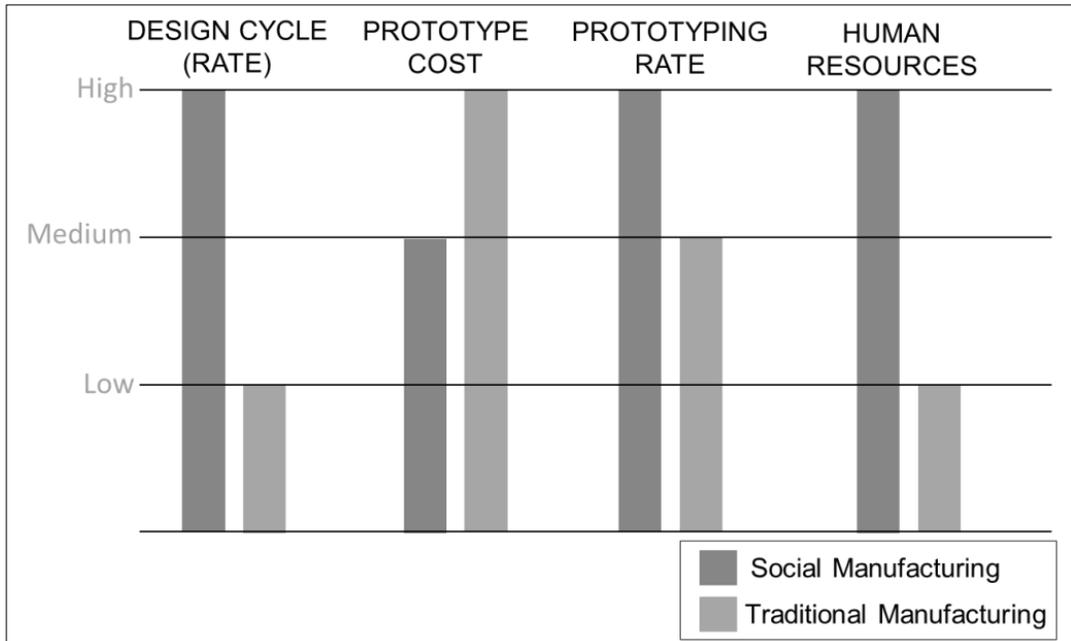


Figure 2-27: Comparing efficient utilisation of traditional- and social manufacturing methodologies (Figure is not to scale- only use for illustrative purposes) [124]

Social manufacturing is made possible by the rapid development of Social Media, devices e.g. tablets and smart phones, technology, and the creation of apps [123]. Therefore, the enabling technology for social manufacturing, is the IoT which allows the company to instantly communicate an issue to a large crowd of people online and allows the crowd to respond instantly.

This creates opportunities for internal related work or with corporate partners to have seamless access to transfer relevant information, share documents and to automate manual tasks that can lead to accelerated processing- and decision making methods.

3. RESEARCH METHODOLOGY

The research methodology process is described and summarised by the flow diagram illustrated in Figure 3-1. This process is divided into the problem statement and research objectives followed by the four phases that will be described individually in this chapter.

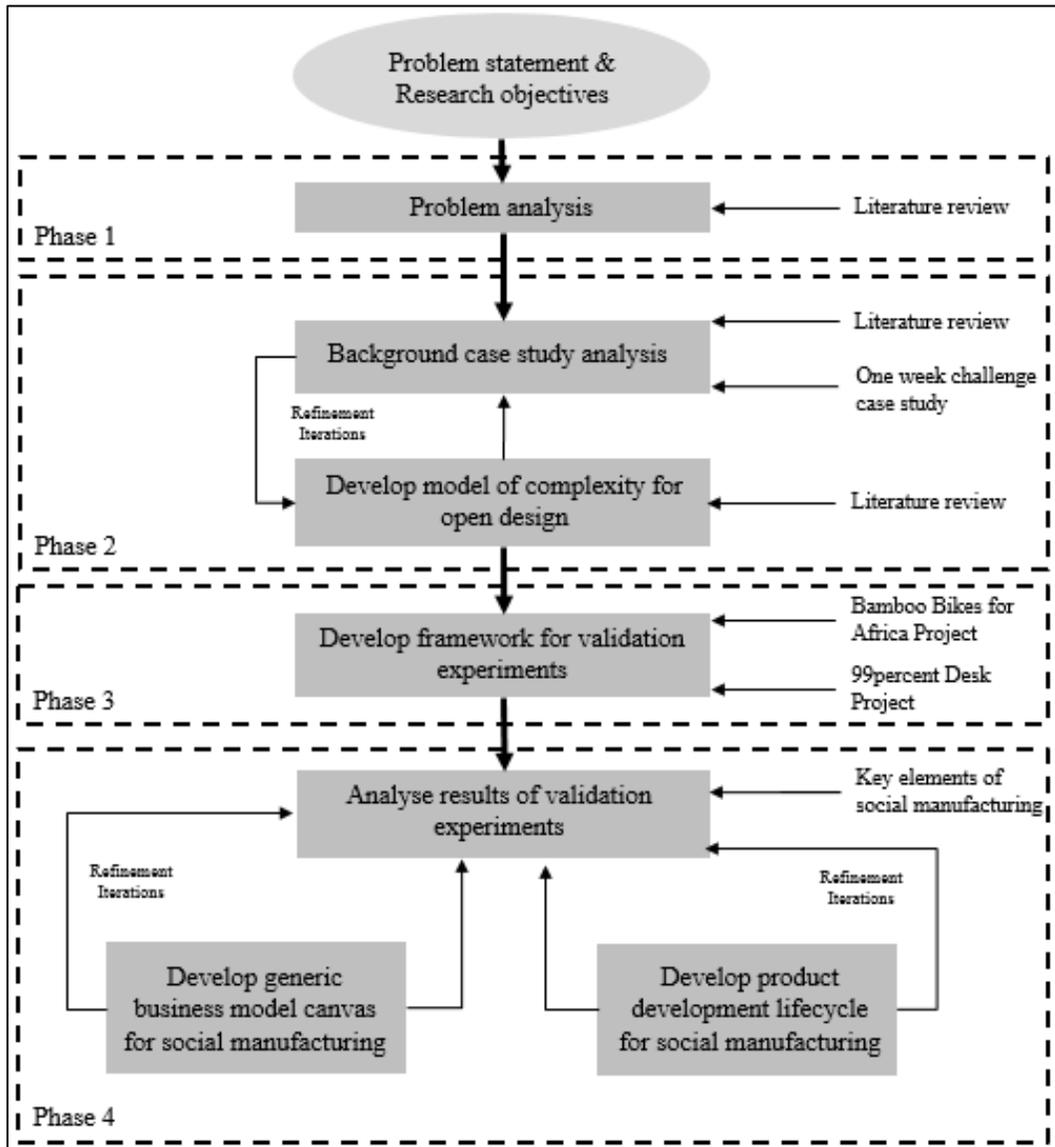


Figure 3-1: Research methodology process for social manufacturing business model elements

The final phase of the research methodology process will be used to develop a BMC and a PDL for social manufacturing that is shown in Figure 5-21 and Figure 5-20, respectively.

In order to develop the BMC and the PDL from phase four of the research methodology, the first three phases must be completed. The problem statement and research objectives can be found in chapter 1.

Phase 1 of the research methodology will be discussed in this chapter and will be conducted by providing a summary of the literature review. The problem analysis is discussed in section 1.1 through the project scope and the research objectives. The literature review is used in the problem analysis and is discussed in the sub-sections of chapter 2.

Chapter 2 discussed the change in the manufacturing industry (manufacturing paradigms) from the 1850s to the predicted future of social manufacturing. Analysing these different manufacturing paradigms, a trend is identified in customer demand and technology.

Customers demand unique or personalised products / services, however, this is difficult to achieve as designing, manufacturing and delivering these products to the masses, is a difficult task without technology. Social manufacturing can be the solution to this problem because incorporating social manufacturing technology (Table 2-5) into the business model of this industry will transform the industry.

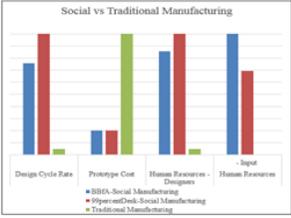
Section 2.2 discussed the current Crowd Companies in manufacturing- and other industries. This gives an indication that current industries are changing through the use of co-creation and online platforms in their business models to improve the products or services provided to customers.

Section 2.3 discussed the nine building blocks of Osterwalder's [107] BMC. The BMC will be used to develop a social manufacturing BMC. This along with the PDL can then be used as a guideline or tool by local suppliers to use for the implementation of social manufacturing in their manufacturing business.

Section 2.4 discussed the complexity of manufacturing systems and the power law. The complexity of manufacturing systems and the One Week Challenge (OWC) background case study will be used in phase 2 of the research methodology to develop a network model for complexity for open design in section 4.2. The power law will be used to validate the experiment's results in order to prove that the experiment is a scale-free network and, therefore, a natural phenomenon. This proves the system and population used

in the validation experiment was not forced or manipulated through the experiment in section 5.2.1.

Table 3-1: Breakdown of how research objectives will be validated

	Research objective	Result used to validate research objective	Research objective used in these phases of the methodology
1	Identify different business elements of social manufacturing in comparison with traditional manufacturing.		Phases 1, 2, 3
2	Develop generic social manufacturing business model and process to support start-up local manufacturing suppliers.		Phases 3, 4
3	Validate business model and process with own experimental projects.		Phases 3, 4

Phase 3 and 4 of the research methodology is divided into two experiments; the Bamboo Bikes for Africa (BBfA) experiment and the 99percentDesk validation experiment. The BBfA experiment will be used to develop the BMC and the PDL. The 99percentDesk will be used to validate the BMC and the PDL through the results remaining relatively constant for both experiments.

Table 3-1 describes the results that will be used to validate the three research objectives along with the relevant phases of the research methodology. The first research objective will be validated using a comparison between social manufacturing and traditional

manufacturing for both BBFA and 99percentDesk experiments. The second research objective will be validated by the BBfA experiment through developing the BMC and the PDL. The third research objective will be validated by the 99percentDesk experiment through validating the BMC and PDL.

4. EXPERIMENTAL SETUP AND DESIGN

This chapter will be used to describe the process of the experimental setup and design of the three experimental projects of this study. The three experimental projects are the One Week Challenge, Bamboo Bikes for Africa and the 99percentDesk.

4.1 Background Case Study: One Week Challenge

In order to understand the business elements and concepts of social manufacturing, a background case study is required. This study must simulate a manufacturing business from customer demand analysis, concept generation, the design process and the manufacturing of the final product.

The background case study is called the OWC (One Week Challenge) and the problem statement is to complete the entire design and manufacturing process of a unique product within one week using co-creation with open design platforms through Social Media. This section will describe the experimental setup and design for the OWC.

4.1.1 Engineering Design Process

To understand how to implement a study using social manufacturing in the design process with Social Media, a brief overview of a standard EDP (engineering design process) is required. Figure 4-1 shows a flow chart of the required steps of an EDP and to understand these steps, a brief description is listed below of each step [125].

- Define the Problem (Problem statement)

In order to define the problem the questions have to be asked: ‘Who is the problem for?’, ‘What is the problem for?’ and/or ‘Why is the problem important?’ [125].

- Do Background Research

Do research on previous solutions or failures to this problem or similar problems. This will be used to avoid previous mistakes of other engineers and save time by not focusing on solutions that will fail. As a result, background research must be done in two areas, namely users or customers and existing solutions [125].

- Specify Design Requirements

The design requirements must summarise the important characteristics of what the solution must meet to be successful. Analysing the key features of a concrete similar solution can be used to identify design requirements [125].

- Brainstorm Solutions

Most design problems have many different solutions and it is important to brainstorm all the possible solutions in order for the best solution to appear with the current knowledge of the problem [125].

- Choose the Best Solution

To find the best solution, an analysis of each solution is required to check whether the solution meets all the design requirements. All solutions that do not meet all the requirements must be rejected. Consequently, the best solution can be selected from the remaining solutions [125].

- Do Development Work

Constant development work must be done throughout the design process to improve and refine the solution, even after the product is shipped to the customer [125].

- Build a Prototype

A prototype is described as an operating version of a solution. A prototype is generally not as well rounded and polished as the final version. The prototype is a key step to develop the final solution as it allows the designer to test the feasibility of the solution [125].

- Test and Redesign

To find the best possible solution, the design process will have multiple iterations and redesigns to establish the final product. After each design process iteration, the solution will be tested and new problems will be found. Changes are made to avoid the new problems and then test the new solution. This process will continue until a final solution is found [125].

- Communicate Results

To complete the project, the results must be communicated to others through a report and/or a display board. This is important as the solutions must be documented in order to manufacture and support the products [125].

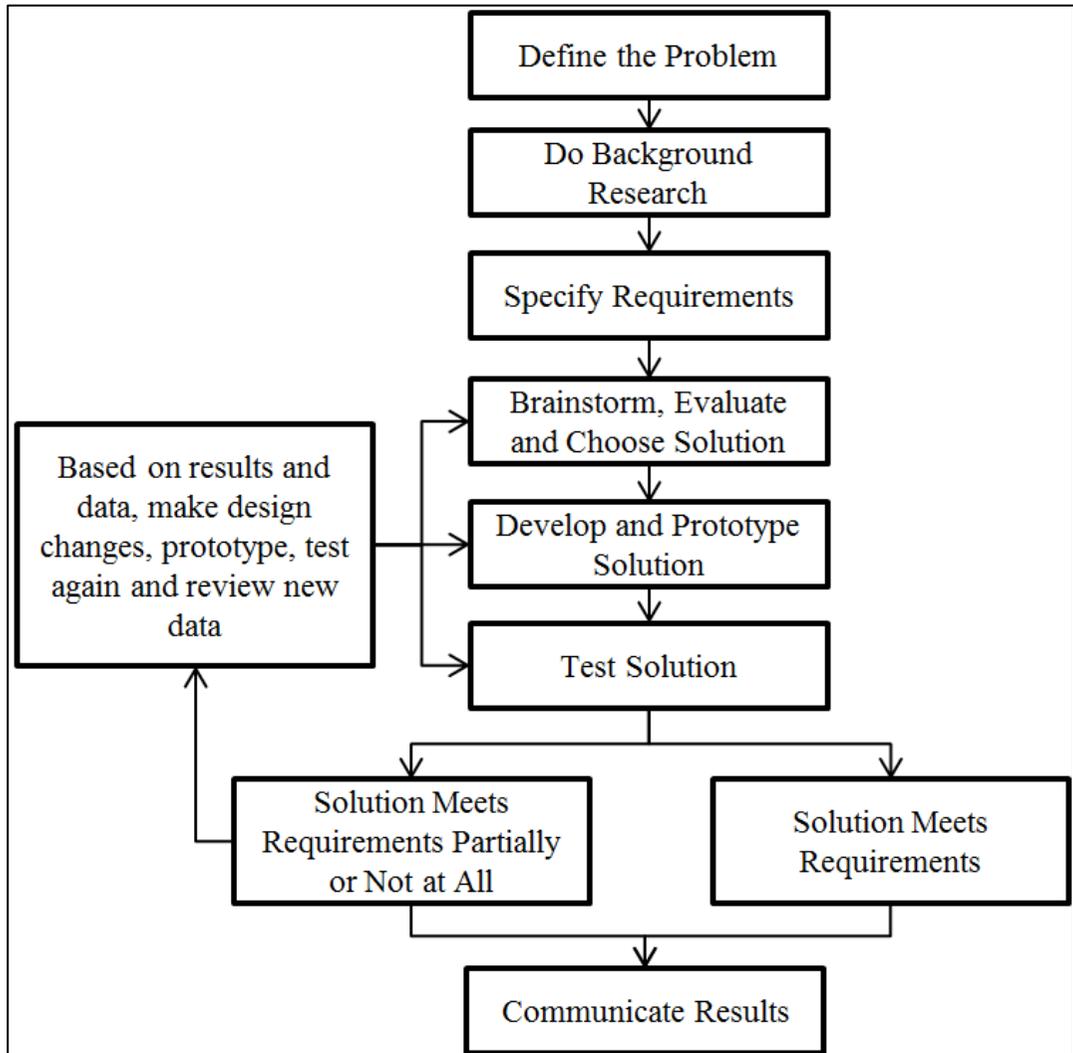


Figure 4-1: The engineering design process (Adapted from [125])

4.1.2 The One Week Challenge Experimental Setup

The OWC must simulate the use of social manufacturing in order to be relative to this study. Therefore, to incorporate social manufacturing and Social Media within the OWC, the EDP shown in Figure 4-1, must be used to develop the OWC experimental process.

Another factor that must be taken into consideration for the OWC process, is the effect of open design on the design process within product development. The effect of open design can cause patterns to be identified faster and this will shorten the research and concept design phases as illustrated in Figure 4-2. This effect ensures faster identification of customer- and market requirements that will produce the final design faster, through decreasing the product manufacturing time.

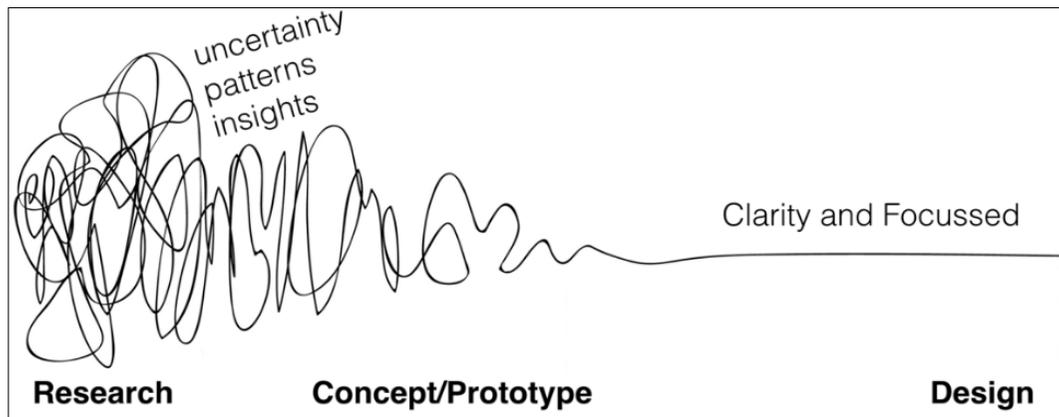


Figure 4-2: The effect of open design (social manufacturing) on the design process during product development [126]

It is important to remember the OWC goal is to manufacture/produce one product within a week using social manufacturing concepts through Social Media. This is done by gathering data using an IC (industrial cluster) with social manufacturing.

An IC is described as: ‘...groups of interrelated industries that drive wealth creation in a region, primarily through export of goods and services’ [5]. Another term closely related to an IC is Industry Clusters and is described as: ‘Industry clusters are groups of similar and related firms in a defined geographic area that share common markets, technologies, worker skill needs, and which are often linked by buyer-seller relationships’ [6].

However, in this study, the IC is the group of people the experiment is focused around (closely related to the target market) and this IC is the Industrial Engineering Department of Stellenbosch. Therefore, using the concepts from Figure 4-1, Figure 4-2 and the IC, an experimental process was developed for the OWC as illustrated in Figure 4-3.

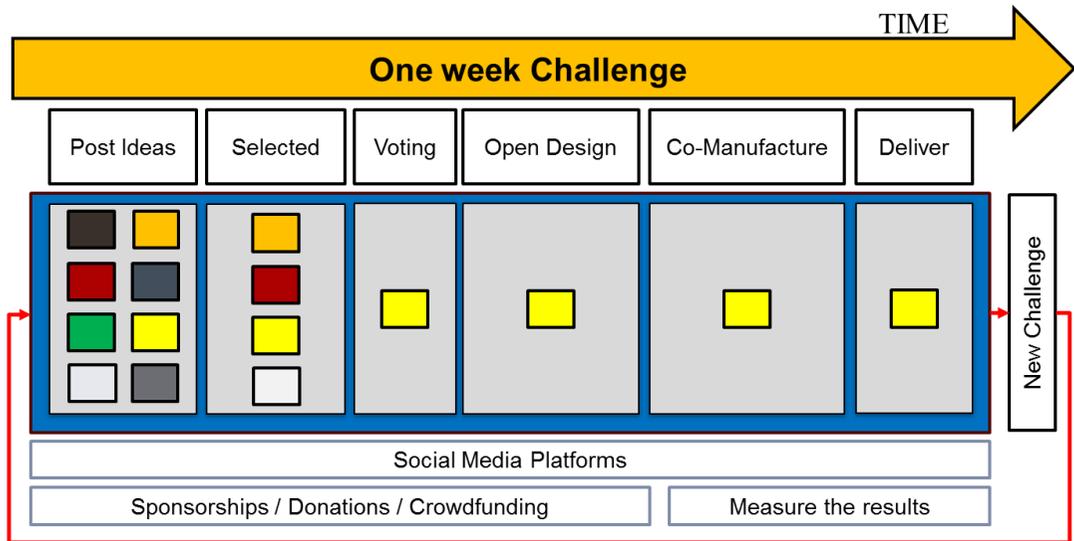


Figure 4-3: OWC process illustrating the steps for community contribution and selection, open design (co-creation) and co-manufacturing [124]

The OWC starts by posting a problem on Social Media (e.g. Facebook and Instagram) for people to be able to see the problem. This problem can be any type of product for any specific situation where the product is something unique that has to be designed and manufactured. The next step is to start crowd-sourcing ideas through people using social media platforms, to post ideas for possible solutions to the problem.

After a day, the best ideas are used in a voting pole where the crowd can submit their votes on social media to determine the best solution. The chosen solution from the voting pole is then the product that needs to be manufactured. This design and manufacturing process happens in one week from the initial idea crowd-sourcing to the final product delivery as illustrated in Figure 4-3. After the final product is delivered, a new problem is posted on the social media platforms to rerun the process.

In order for the OWC experiment to be successful, a few requirements and constraints need to be set:

1. The product functionality must be simple
2. To ensure product manufacturing is accurate and to increase manufacturing speed, 3D-printing technology must be used in the manufacturing process.

3. Use social media to crowd source, select and develop the final concept and specifications of the product.
4. Try to limit resource usage and use crowd funding models for manufacturing costs.
5. The product must be delivered within the allocated one week time period.

4.1.3 The One Week Challenge Process Description

A short description of each day in the OWC proceedings for will follow below:

- Monday: Setup of Social Media Platforms

The first day is used to do Social Media platform setup on Facebook and Instagram. It is important to create and display content on these platforms that the IC can relate to. To attract participation from the IC, the Facebook and Instagram accounts are used to exchange information with the crowd.

The project description is described in detail on the home pages of the Facebook and Instagram accounts, however, short videos, photos and graphics are used to amplify the idea of the OWC. It is important to establish a connection with the IC and to encourage engagement, hence, the project description and layout of the Facebook and Instagram pages are significant.

The Facebook page has a button to contribute with funding in order to use crowd funding for all the resources required to manufacture and deliver the product. This initial setup of the OWC is a challenging task and could be a crucial task for a social manufacturing project.

- Tuesday: Product Specifications

The second day is assigned to understand what the IC needs are and how these needs can be fulfilled. To identify the needs, solutions to the problem are posted on the Social Media platforms by the administrators. Evaluating the crowd input on these solutions gives a perspective of the IC and can be used to guide the IC to produce higher quality solutions.

This evaluation process is dependent on the reach and followers gained on the Social Media platforms. Where the goal of the first day is to acquire followers on the Instagram and Facebook platforms, the goal of the second day is to force feedback or engagement from the crowd. This is achieved through advertising and promoting the Facebook page

content by using the Facebook promotion function. This is a function where an administrator can pay to promote a specific event, post or page in order to increase exposure on Social Media.

To enhance the promotion, a Facebook event is created where subscribers could publish and vote for the product that would eventually be designed and manufactured. This event and some of the page content is promoted by the page users itself (without payment), through user interest in the page or page content and user self-expression. To establish which solutions will be used in the event to vote for the final product, a list of potential products was comprised of suggested products that were 'liked' the most by the subscribers.

- Wednesday: Specific Product Design

At this stage of the OWC, the project is established with regards to Social Media platforms and the followers are steadily increasing over both of the Social Media platforms. The final product was chosen through the IC using a voting pole on the Facebook event. The design can now be generated for the product that can be manufactured.

The demo model or prototype was printed on a 3D printer as shown Figure 4-4 in provided by the Industrial Department's STC-LAM (Stellenbosch Technology Centre Laboratory for Advanced Manufacturing). The first printed product was a rough manufactured product to enable further improvement on finishing and quality. This will be used for quality assurance in the final product design.

- Thursday: Quality Assurance and Manufacturing

The final product design is improved and manufactured on the 3D printer shown in Figure 4-4, however, the improved design will ensure better tolerance for a higher quality product. The delivery of the product is scheduled for the next day by using knowledge gained from the prototype manufacturing process. This is important to ensure the final product is manufactured at the correct quality before the scheduled delivery date.

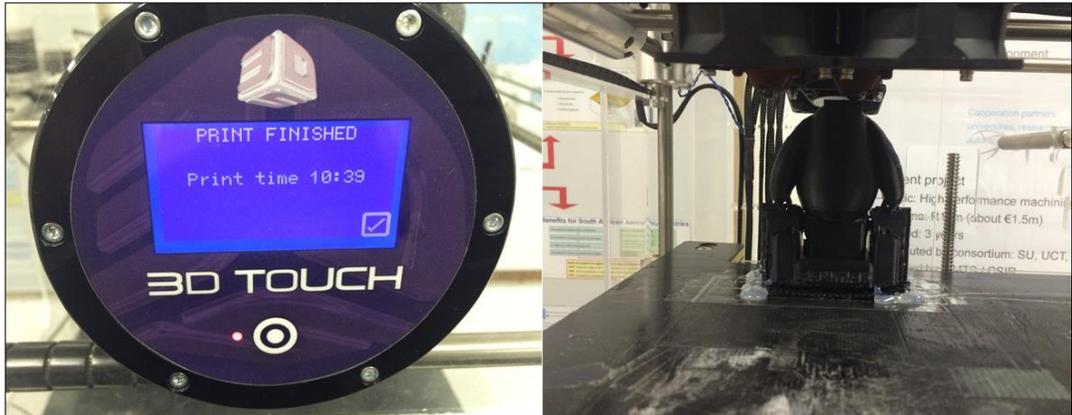


Figure 4-4: 3D printing of the improved design of the OWC product

- Friday: Package, Deliver Product and Social Media Crowd Feedback

The final day of the OWC is used for finishing and delivery. After the 3D printed product is done with finishing by adding the required paint finish, the product can now be delivered. The hype (on the Social Media platforms) peak was reached with a succession of posts about the manufacturing and delivery event to get the IC involved and excited for the revealing of the actual product. The final product is then revealed at the scheduled event of the Facebook group.

4.1.4 Data Collection for One Week Challenge

The method of data collection for the two iterations of this experiment will be discussed in this section. The Social Media platforms provide data summaries with regards to the online platform engagement with the users of the online community. This section will provide a summary of the categories of the data collected that will be focused on for this experiment. These categories are: Amount of Post Reach, People Engaged by Age and Gender, and People Engaged by Location. The results of the data can be found in section 5.1.

- Post Reach

Post Reach is defined as the number of unique people (unique Facebook users) who have seen the Facebook page posts. These posts count as reaching someone when it is shown in their news feed and include desktop and mobile devices [127]. Post reach is divided between two types of reach, namely 'Organic-Reach' and 'Paid-Reach' for the OWC Facebook page posts.

‘Organic-Reach’ is defined as the number of unique people (unique people meaning the reach total will not account for the same Facebook user more than once) who viewed posts from the OWC Facebook page through unpaid distribution and/or viewed post content through ‘friends’ commenting, liking or sharing the content from the OWC Facebook page [128].

‘Paid-Reach’ is defined as the number of unique people who viewed post content from OWC Facebook page through paid distribution in the form of advertising [128]. This is a useful tool to grow awareness around a product as the marketing is cost effective versus the amount of unique users viewing the advertised product. Therefore, this tool will be used to test the difference between ‘Organic- and Paid-Reach’.

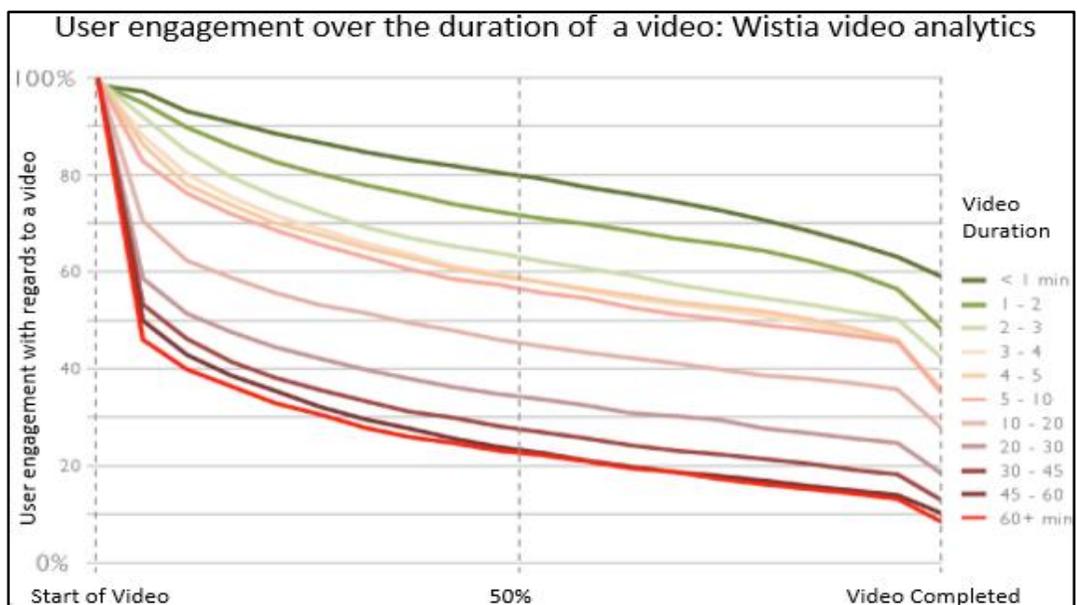


Figure 4-5: User engagement over the duration of a video: Wistia video analytics (Adapted from [129])

A Post Reach comparison between graphic (photo) and video posts will be conducted to give an indication of which format to use with regards to marketing on Social Media platforms. The expectation is that a graphic (photo) will have more reach than a video as most users lose interest at a significant rate [129]. This is shown with the data in Figure 4-5 and according to Kim [130]: ‘The average person gets distracted in eight seconds, though a mere 2.8 seconds is enough to distract some people (from a video).’

- People Engaged by Age and Gender

The data obtained for age and gender will be used to see if the community relates more to specific products that appeal to their age or gender group. This will be done by changing the product type and the product target market for the two iterations.

- People Engaged by Location

The online community is stretched across the world and therefore, the location of the community that contributes to the experiment, will indicate if a local supplier relates more to local people or if the location of the company does not have an effect.

4.2 Complexity Model of Open Design

Social manufacturing can be described as a complex system, as the interaction between the community through a platform can have so many different communication problems and to organise this can be difficult. This problem was identified in the OWC background case study and for social manufacturing to be run through a business model, the complex system must be redefined to ensure that information and communication are organised.

Using the theory on complexity in manufacturing systems from section 2.4.1 and the background case study of the OWC in section 4.1, a model was developed for the complexity of open design as shown in Figure 4-6.

The OWC and literature review highlighted problems that need to be taken into consideration and corrected by the model of complexity. These problems are listed below and a brief discussion on how the model of complexity for open design will solve these problems, will follow thereafter.

1. Co-creation amongst users was difficult to achieve.

The entire concept of social manufacturing is to enhance the idea of co-creation and therefore, the community must have minimal, if any, restrictions with regards to communications amongst themselves. The OWC was based on a random network (shown in Figure 2-26 b)) and had no structure to support the communication or co-creation on the platform.

Therefore, the model of complexity for open design must use a scale-free network as shown in Figure 2-26 a) and must force hubs to emerge where users can interact with each

other. This will mean users are divided into groups/ hubs/ sub-networks and work together to find one optimal solution.

These sub-networks can be any size, as the community can still give feedback whilst the design is still in process. These sub-networks can be groups of a class, classes from a school, schools from a country or even countries from the world. This is dependent on the size of the community or IC.

The group must still have an incentive to work together, however, this will be dependent on the specifics of the product or company that will influence the process of how these sub-networks will be formed. For this study, the discussion on how to achieve sub-networks for the IC of this project will continue in section 4.3 on the BBfA experiment and section 4.4 on the 99percentDesk validation experiment.

2. Quality and effort put into designs were not sufficient.

The reason for low quality in the designs can be that the platform used in the OWC (Facebook), does not force the community to use standardised software, formats, methods or layouts in the design phase. Current companies for example, Local Motors [104], Open Desk [94], Quirky [99] and Shapeways [100], use standardised platforms for CAD software in order to guide the community to post their designs in a standardised format to stream line the process.

Due to limited resources, this study is, however, not able to develop one of these platforms. Limitations will have to be set for the community with regards to producing and presenting designs on the Facebook platform. This will be adjusted in the process for the BBfA and 99percentDesk validation experiments which can be found in section 4.3 and section 4.4.

3. Users lack understanding of the OWC and social manufacturing concepts.

Establishing an understanding of social manufacturing and the OWC concepts within the community is important. From community feedback and interactions, it was clear that these concepts weren't produced by the platform in a manner which described the process in detail. Therefore, it is important to prepare a community with a model which will be similar to Figure 4-6 depending on the exact scenario, to ensure that the community understands the entire process. For the BBfA and 99percentDesk validation experiments,

this was taken into consideration whilst developing the processes for these experiments that is shown in Figure B-1, Figure B-2 and Figure D-1.

4. The time frame for the entire process for each run was too short.

The time frame for the design phase given to the community to contribute to the OWC, was too brief. In the OWC, the community had 24 hours to submit designs and 24 hours to choose from those designs. By using this model for complexity of open design, the design phase will be extended to create space for more designs to be submitted and more time for the community to contribute to the process.

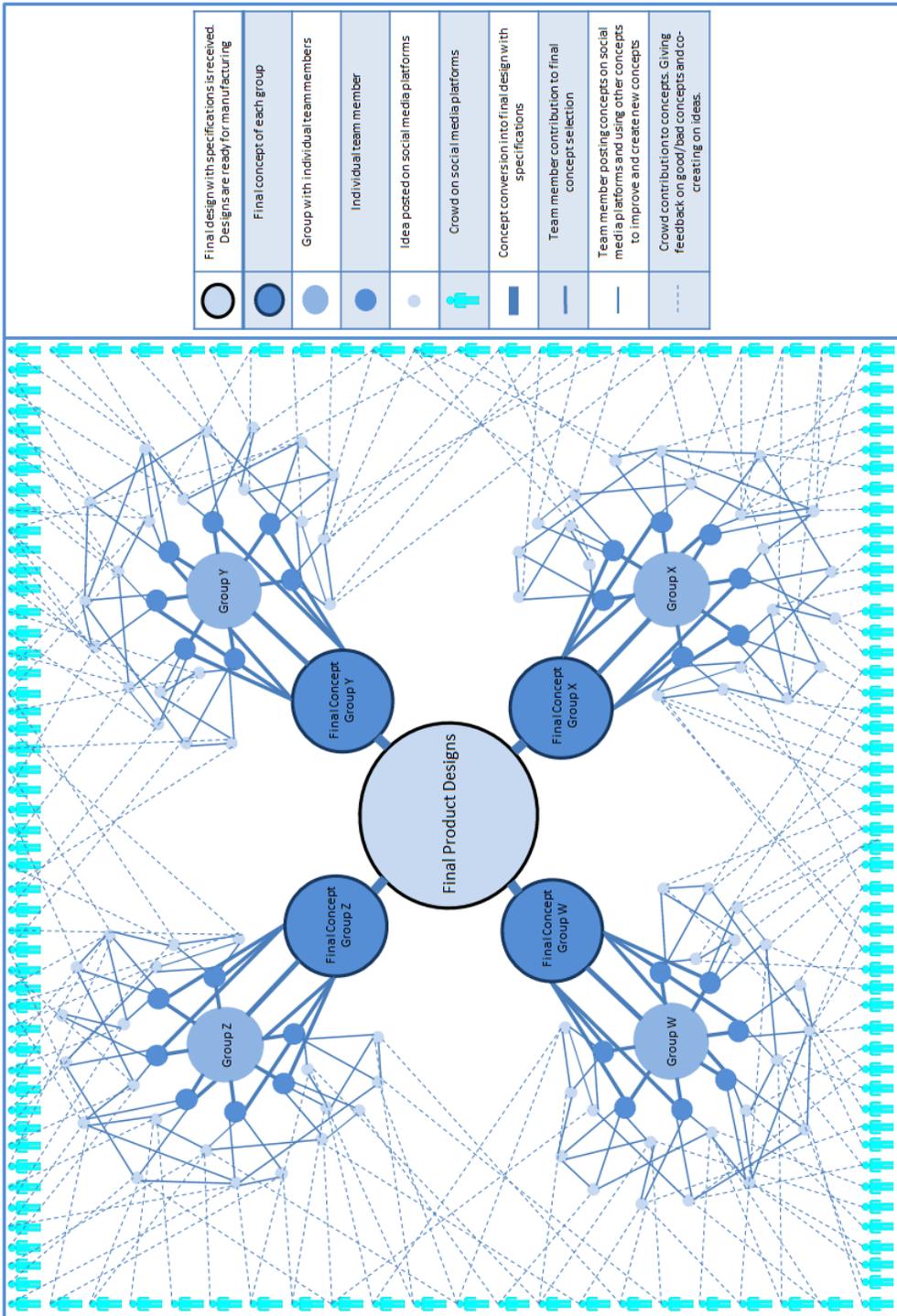


Figure 4-6: Model to illustrate the complexity of open design (Not to scale – for illustrative purposes only)

4.3 Bamboo Bikes for Africa Experiment

In order to develop tools for local suppliers to incorporate social manufacturing in their business model, an experiment is required. This experiment is called the BBfA experiment and will be used to develop a BMC and PDL for social manufacturing that is discussed in detail in section 5.4. This section will describe the experimental setup and design for the BBfA experiment.

4.3.1 Bamboo Bikes for Africa Experimental Setup and Process

The knowledge obtained from the Literature review, Background case study OWC, and the model of complexity for open design from section 4.2, will be used to formulate this experiment. Social Media will be used as the platform for the online community to simulate the social manufacturing experiment.

For this experiment, the IC will be the 4th year students from the Industrial Engineering Department of Stellenbosch University in the Advanced Manufacturing 414 course tutorial. The tutorial will be divided into two design phases and each phase will be conducted in a period of one week. The problems stated in section 4.2 will be addressed to ensure that these problems do not occur in the BBfA experiment.

Regarding the first problem, the IC must be divided into sub-networks to ensure co-creation within the community. To accomplish this, the students are divided into sub-networks of 10 members. These members will work together to produce ideas and/or designs for the BBfA experiment.

With regards to the second problem, in order to improve the quality of the designs, an incentive is required. In a typical business or manufacturing industry, the IC might have an incentive through a reward. This reward can be financial e.g. If the user's design is used in/as the final design of the manufactured product, the user receives a percentage of the profit made of that specific product. However, utilising the students from Stellenbosch University, the incentive will be the assessment of their designs and this will ensure that the students will contribute to social manufacturing for a reward.

Regarding the third problem, it is important to ensure that the IC understands the problem and the project layout of the BBfA experiment. Therefore, an introduction video and presentation is used to establish the concepts and the layout of social manufacturing in

general and specifically for the BBfA. This will ensure that the IC understands their role and how to get involved in the project.

With regards to the fourth problem, the design phase is extended to 2 weeks as the OWC experiment period was too short for quality co-creation from the community. These 2 weeks will only include the design phase and the manufacturing will start after the 2 weeks. Using sub-networks, an incentive scheme, presentation, increasing the design phase period and using the model of complexity for open design, from Figure 4-6, the process for the BBfA was developed and is shown in Figure B-1 and Figure B-2 from Appendix B: Bamboo Bikes for Africa Experiment

The two week process will be the design phase for the BBfA experiment. The first week is the plan and concept generation phase; the students must design free hand sketches of Bamboo Bicycles and upload these designs onto the different Social Media platforms of the BBfA experiment (Instagram, Twitter, Facebook and Dropbox for monitoring the student progress).

The BBfA experimental project is about building bicycles for the community in rural Africa. However, these Bamboo Bicycles must not just be a means of transport, it must improve the lives of the community and therefore, the designs must include Swiss-army-knife technology (attachable appliances or technology) that will improve the everyday life of a community living in rural Africa.

After the designs are posted on Social Media, they are then promoted on BBfA's Facebook-, Twitter- and Instagram platforms. The best design from each group is then identified as the one with the most 'Likes'. The marketing and validation of this design is then completed and will then be used in week 2 of the project. The process for week 1 is shown in Figure B-1 in the appendix.

The second week design phase is used to produce 3D CAD models from the selected 'best' design from week 1. This design will be completed within the group and will then be used as the groups' final design as illustrated in the middle of the model of complexity of open design, shown in Figure 4-6.

The CAD model will only include the frame of the bamboo bicycles as this is the more difficult part of the bicycle design. Focus is put on the joints in order to find new solutions

to combine the bamboo together. The attachments are not of importance for the 3D CAD model, therefore, the IC is instructed to not focus on the attachments (Swiss-army-knife technology).

The IC will then have to make a video around their specific design and show how this bicycle will benefit rural Africa. The 3D CAD model and video will then be posted onto Social Media to create awareness around the project. The reason for this is to ensure the community grows for future social manufacturing projects.

These 3D CAD models will be used to develop a bicycle frame that will be manufactured at Stellenbosch University and donated to the local community. For more information on the manufacturing process around the bamboo bicycle of the BBfA experimental project refer to [131-133]. The process for week 2 follows the process shown in Figure B-2. The social manufacturing BBfA IAMOT conference paper is shown in Appendix G: IAMOT Social Manufacturing Bamboo Bikes for Africa Paper.

4.3.2 Data Collection for Bamboo Bikes for Africa

The method of data collection for this experiment through the Social Media platforms will be discussed in this section. These platforms provide data summaries with regards to the online platform engagement with the users of the online community. This section will provide a summary of the categories of the data collected that will be used for this experiment. These categories are: Data Analysis, Manage Complexity and the Outputs of the BBfA experiment. The results of the data can be found in section 5.2.

- Data Analysis of the BBfA Experiment

The data analysis is divided into four categories: Social Media Platform ‘Likes’, Facebook page ‘Likes’, Facebook page reach and Facebook page activity. The students were requested to promote all the designs they produced on the different Social Media platforms of the BBfA experiment. Using these platforms Facebook, Instagram and Twitter, the students had to see on which platform they could get the most ‘Likes’. A comparison between the different Social Media platforms ‘Likes’ will be conducted to find the most effective platform.

The IC for the BBfA was requested to ‘Like’ the BBfA Facebook page where all the designs of the different groups will ultimately be posted. A analyse for the Facebook page ‘Likes’ will be conducted for the first week.

In order to find the amount of user views of the BBfA Facebook page and posts on the BBfA Facebook page, the total reach is important. The definition of reach is defined in section 5.1.1 or refer to [127]. An analysis for the Facebook page reach will be conducted for the first week.

In order to find the amount of user shares, comments and ‘Likes’ experienced only on the BBfA Facebook page, the amount of activity is important. An analysis for the Facebook page activity will be conducted for the first week. The discussion on the data analysis for BBfA can be found in section 5.2.1.

- Manage Complexity of the BBfA Experiment

The power law can prove that this experiment follows a natural phenomenon. If this is true, then the model of complexity of open design is applicable to any similar system of any size. Therefore, this model of complexity of open design can then be scaled to a larger complex system and should have the same results.

The power law was discussed in the literature review in section 2.4 and a similar result must be found in the data from the BBfA experiment. The data extracted from the Facebook page will be used to proof the power law. This data contains the amount of reach of the posts on the BBfA Facebook page and can be found in Table C-1 in Appendix C: Power Law Data Table.

Table C-1 is divided into five columns with the first being the post number. The second column summarises the reach (for definition of reach refer to [127]) of each individual post from unique users. This means that the reach will only increase if a user views the post for the first time and the reach will not increase if a user is reached by the same post more than once.

The third column summarises the reach of each individual post compared to the total amount of unique users reached by all the posts. Therefore, this value is a percentage of the specific post divided by the total posts reach as shown in Eq. (6) below.

$$\% \text{ of Total Population} = \frac{\text{Individual Post Reach (Unique Users)}}{\text{Total Posts Reach (Unique Users)}} \times 100\% \quad (6)$$

The fourth column summarises the total reach of each individual post from all users. This means that the reach will increase if a user views the post more than once. Therefore, this will indicate if the post is attractive to users as users view the post multiple times.

The fifth column summarises the disinterest factor per design. This factor summarises the interest towards a specific design and the higher the factors' magnitude, the lower the users' interest. Therefore, the disinterest factor per design is shown in Eq. (7) below.

$$\text{Disinterest factor per design} = \frac{\text{Total Posts Reach (Unique Users)}}{\text{Total individual post reach of specific design}} \quad (7)$$

This data will be displayed using a graph that compares the % of total population reach of each design (Eq. (6)) to the disinterest factor each design (Eq. (7)). The discussion on the manage complexity for BBfA can be found in section 5.2.2.

- Outputs of the BBfA Experiment

The BBfA has a number of outputs: The group CAD designs, the final CAD design and the manufactured first prototype bicycle. The discussion on the outputs for BBfA can be found in section 5.2.4.

4.4 99percentDesk Validation Experiment

This validation experiment will validate the BMC and PDL for social manufacturing that was developed in the BBfA experiment. This section will describe the experimental setup and design for the 99percentDesk validation experiment.

4.4.1 99percentDesk Experimental Setup and Process

The knowledge obtained from the Literature review, Background case study OWC, the model of complexity of open design from section 4.2 and the BBfA experiment, will be used to formulate the 99percentDesk validation experiment. For this experiment the same Social Media platform will be used as for the BBfA experiment.

For this experiment, the IC will be the 2nd year students from the Industrial Engineering Department of Stellenbosch University in the Manufacturing Processes 244 course tutorial. The tutorial will have one design phase conducted in a period of one week. The problems

stated in section 4.2 will be addressed through the same methods as for the BBfA experiment.

The IC must be divided into sub-networks to ensure co-creation within the community. To accomplish this, the students are divided into sub-networks of 10 members. These members will work together to produce the designs for the 99percentDesk experimental project.

In order to improve the quality of the designs, an incentive and guidance process is required. Similar to the BBfA experiment, using the students from Stellenbosch University, the incentive will be the assessment of their designs and this will ensure that the students will contribute to social manufacturing for a reward. To improve the quality of the designs, the 99percentDesk will use a template design sheet that must be used by the students in order to add design features onto the current design, as seen in Figure D-2.

Similar to the BBfA experiment, it is important to ensure that the IC understands the problem and the project layout of the 99percentDesk. Therefore, a presentation is used to establish the concepts and the layout of the 99percentDesk project. This will ensure that the IC understands their role and how to get involved in the project.

Using sub-networks, an incentive scheme, presentation, BBfA experiment and using the model of complexity of open design, from Figure 4-6, the process for the 99percentDesk experiment was developed and is shown in 99percentDesk in Figure D-1. This process will be used in a similar, but improved, manner to the BBfA to validate the results for the BMC and the PDL.

The idea of the 99percentDesk is for the IC to design a student desk that will be used by a university student. However, this desk must not just be a normal study desk, it must improve the study environment of the student, therefore, including Swiss-army-knife technology (attachable appliances or technology) that will improve the study experience of the student, by adding technology to establish a 'smart' study desk. The reason for the 99percentDesk name is this desk must be so helpful to students that they will be able to leave the 99% and become one of the 1% richest people in the world.

The designs are posted on Social Media and promoted on 99percentDesk's Facebook social platform. The marketing and validation of the designs are completed on the platform

by the community indicating what designs appeal to them. These designs will then be combined in the final design of the project. The process is shown in Figure D-1 in the appendix.

This validation experiment will use crowd funding to fund the project, therefore, the Jumpstarter website will be used to see if the community will fund a project like this in order to validate the crowd funding mechanism. The final design 3D CAD model will be used to develop a desk that will be manufactured at Stellenbosch University and donated to a local student in the community.

4.4.2 Data Collection for 99percentDesk

The method of data collection for this experiment through the Social Media platforms will be discussed in this section. These platforms provide data summaries with regards to the online platform engagement with the users of the online community. Most of the data will be analysed similar to the BBfA experiment. This section will provide a summary of the categories of the data collected that will be used for this experiment. These categories are: Data Analysis, Manage Complexity, Questionnaire and the Outputs of the 99percentDesk experiment. Find the results of the 99percentDesk in section 5.3.

- Data Analysis of the 99percentDesk Validation Experiment

This analysis is conducted in the same method as for the BBfA experiment, therefore, refer to section 4.3.2. The discussion on the data analysis for 99percentDesk can be found in section 5.3.1.

- Manage Complexity of the 99percentDesk Validation Experiment

This analysis is conducted in the same method as for the BBfA experiment, therefore, refer to section 4.3.2. The discussion on the manage complexity for 99percentDesk can be found in section 5.3.2.

- Outputs of the 99percentDesk Validation Experiment

The BBfA has a number of outputs: The final CAD design and the manufactured first 99percentDesk. The discussion on the outputs for 99percentDesk can be found in section 5.3.3.

- Questionnaire of the 99percentDesk Validation Experiment

The questionnaire will be conducted to establish the community's knowledge and perspective on social manufacturing concepts. The questionnaire gives insight on the capabilities of the online community's ability to contribute towards social manufacturing.

The class of students (104 students in total is used as the IC of the project) are given a brief description at the beginning of the project of what the project entails and receives a questionnaire to test the knowledge of the IC before the start to use and understand the concepts behind social manufacturing. Therefore, listed below are the 9 questions of the questionnaire:

99percentDesk social manufacturing questions (1-9):

1. Do you have a 'Facebook' account at the moment?
2. How active are you on a daily bases on Social Media rated from 0 to 5?(0 being never and 5 being you go onto Social Media at least 5 times a day)
3. Do you know anything about 'co-creation' and/or 'Open Source Software'?
4. What would you say is your knowledge of 'Social Manufacturing' rated from 0 to 5? (0 being nothing and 5 being very high)
5. Do you think a company can use an online community to design products and will you get involved in something like that?
6. If you would get involved in designing a product online, what would the reason be?
7. Have you ever used the internet to find practical solutions? (e.g. a quick solution to a problem or a product that you can easily build to help you around the house)
8. Thinking of a situation, if any, where you had to use the internet for a practical solution, rated from 0 to 5 (0 being not at all and 5 being very effective), how effect would you say was the solution?

The discussion on the questionnaire results for 99percentDesk can be found in section 5.3.4.

5. RESULTS AND DISCUSSION

This chapter will be used to describe the results obtained from the three experimental projects of this study. The three experimental projects are the One Week Challenge, Bamboo Bikes for Africa and the 99percentDesk. All three experiments were used to develop and validate the BMC (business model canvas) and the PDL (product development lifecycle) for social manufacturing that is discussed at the end of this chapter.

5.1 Background Study: One Week Challenge Results

The OWC was run for two iterations, with the same steps as mentioned in section 4.1. The final product of the first week, a 'Baymax' paperweight designed as a replica from Disney's movie, 'Big Hero 6' [134], as shown in Figure 5-1 a), was delivered to the Industrial Department's secretary. This product had the most votes on the Facebook page (Facebook page of the OWC is shown in Figure E-1) and was co-created, crowd funded and co-manufactured.



Figure 5-1: a) The community selected Baymax final product from week 1 [124] and b) The community selected I AM GROOT final product from week 2

For the second week of the OWC, the OWC administrators left the concept generation, design, manufacturing and delivery to the online community as the Facebook page was established and it was necessary to see if the community could drive itself. This was successful as the community co-created and delivered the product within a week. The final product of the second week, an 'I AM GROOT' designed as a replica from Marvel Comics movie, Guardians of the Galaxy' [135], as shown in Figure 5-1 b), was delivered to the Industrial Department's secretary.

The results of the OWC Facebook page will be discussed and analysed in the following categories: Amount of Post Reach, People Engaged by Age and Gender, and People Engaged by Location as described in section 4.1.4. The figures and graphs for these results can be found in Appendix A: Background case study - One Week Challenge.

5.1.1 Post Reach

Figure A-1 represents the amount of post reach divided between the two types of reach, namely 'Organic-Rreach' and 'Paid-Rreach' for the OWC Facebook page posts. Over the course of week 1, two (one video post and one picture) of the OWC Facebook page posts were promoted (Paid reach) to compare the reach and test the visual effectiveness of graphic- and video posts.

The 'Organic-Rreach' per post is directly related to the amount of people that are subscribed to the OWC Facebook page. Although the 'Organic-Rreach' does not have a substantial amount of reach compared to the 'Paid-Rreach', it serves as a better indication of the participation from the IC with the OWC project.

The 'Paid-Rreach' has two points of interest. The first day of the OWC (Monday), an investment of seventy rand (R70) was made into marketing a graphic (photo) that explains the OWC and this marketing campaign will run for one day. This marketing campaign reached just over two thousand people that made contact with this post. The second day, (Tuesday), a video of the OWC was marketed for the same amount and duration as the graphic (photo) from the first day.

Figure A-1, more users were reached using a video (total reach of 2959 users compared to the graphic total reach of 2017 users). The reason can be the fact that the OWC is a

difficult concept to explain and users needed a video to explain the concept in more detail compared to a graphic (photo).

For week 2 of the OWC, the results of the total reach are shown in Figure A-2. Here two posts were promoted, namely the scheduled event for the presentation of the final product (marketing on the Tuesday) and a poster of the final product (marketing on the Friday). As shown in Figure A-2, the photo of the final product reached almost 3 times more users than the event of the presentation.

5.1.2 People Engaged by Gender and Age

Figure A-3 a) summarises the post engagement by gender for week 1 and indicates that more female subscribers engaged with the posts made on the OWC Facebook page than men. The aim of week 1 was to manufacture a product for a female (Industrial Departments Secretary) and this might be the reason why more subscribers were females as the product and project relates more to women than to men.

Figure A-3 b) summarises the post engagement by gender for week 2 and indicates that the same amount of subscribers were men and women that engaged with the posts. This can be due to the product not being manufactured for a specific person or gender and therefore, obtained equal engagement from both genders.

Figure A-4 summarises the age distribution of people that engaged on the OWC Facebook page for week 1. Figure A-4 indicates that the OWC achieved majority engagement in the age group between 18 and 24 by a combined total of just over 40 percent. If the age bracket between 18 and 34 is added, then the combined engagement is two thirds of the total engagement. This indicates that the OWC reached the desired IC of young adults between the age of 18 and 34.

Figure A-5 summarises the age distribution of people that engaged on the OWC Facebook page for week 2. Week 2 has the same majority engaged age group as week 1. Figure A-5 indicates that two thirds of the people engaged with the OWC Facebook page are in the age bracket of 18 to 34 which is the desired IC for the OWC.

5.1.3 People Engaged by Location

The focus area and target market, IC, consisted of Industrial Engineering students of the University of Stellenbosch. By examining the pie chart in Figure A-6, it is clear Stellenbosch had the most people that engaged with the OWC Facebook page.

Furthermore, the combined OWC Facebook page engagement of Cape Town, Paarl and Stellenbosch (Paarl and Cape Town are two towns in close proximity of Stellenbosch) consists of more than three quarters of the total engagement. Both these above-mentioned facts prove that the OWC reached the desired IC.

In total, 58 people subscribed to the OWC Facebook page by the end of week 1 and by the end of week 2, 104 people subscribed to the OWC Facebook page. This means 104 people engaged in the OWC where, compared to a traditional project, only a few people would engage on customer data and specifications and it would take longer to achieve the same output.

5.1.4 One Week Challenge Lessons Learned

The OWC background experiment is used to formulate a model of complexity for open design for the other experiments to ensure that the process is structured with regards to social manufacturing. This model of complexity for open design is discussed in section 4.2 and shown in Figure 4-6.

The OWC background experiment used numerous platforms to interact with the online community and was used over two weeks. The process was rerun to ensure that the results obtained from the process remains the same for at least two iterations. The OWC showed that using an online community in the design phase was more complex than initially thought.

The main reason for the complexity was due to the fact that the online community struggled to relate and understand the problem at first, as the concepts and background of the OWC and social manufacturing was not clear. The second problem was that the online community struggled to work together as they did not have incentive to work with other individuals and therefore, had no direct access to other individuals of the community.

It is also important to note that the online community had no reason to contribute, as the OWC did not have any rewards or purpose to try and receive quality feedback. These

problems are taken into consideration in section 4.2 of the model of complexity of open design and in section 4.3 for the development of the process of the BBfA experiment.

Analysing the data obtained from the Social Media platforms for the experiment indicated the following business model elements that would incorporate open design:

- Using online marketing through Social Media and running a project on the same platform (e.g. a social manufacturing project) can reach more customers/users than only paying for the online marketing. Therefore, co-creation can have a positive effect on online marketing.
- While running an online project, the explanation of the concept is more effective using a video rather than long descriptive text or graphics.
- Users relate more to the product if it relates to their location, age and gender group. Therefore, to incorporate co-creation, the type of product must be selected to reach the biggest group possible

5.2 Bamboo Bikes for Africa Experiment Results

This section will discuss the results and trends identified in the Bamboo Bikes for Africa experiment and will be used to develop the BMC and the PDL. The figures and graphs for these results can be found in Appendix B: Bamboo Bikes for Africa Experiment.

5.2.1 Data analysis of Bamboo Bikes for Africa Experiment

The page layout of the BBfA Facebook page can be found in Figure E-2 in Appendix E: Social Media Platforms for the Experimental Projects. As discussed in section 4.3, using these platforms - Facebook, Instagram and Twitter- the students had to see on which platform the most 'Likes' can be obtained.

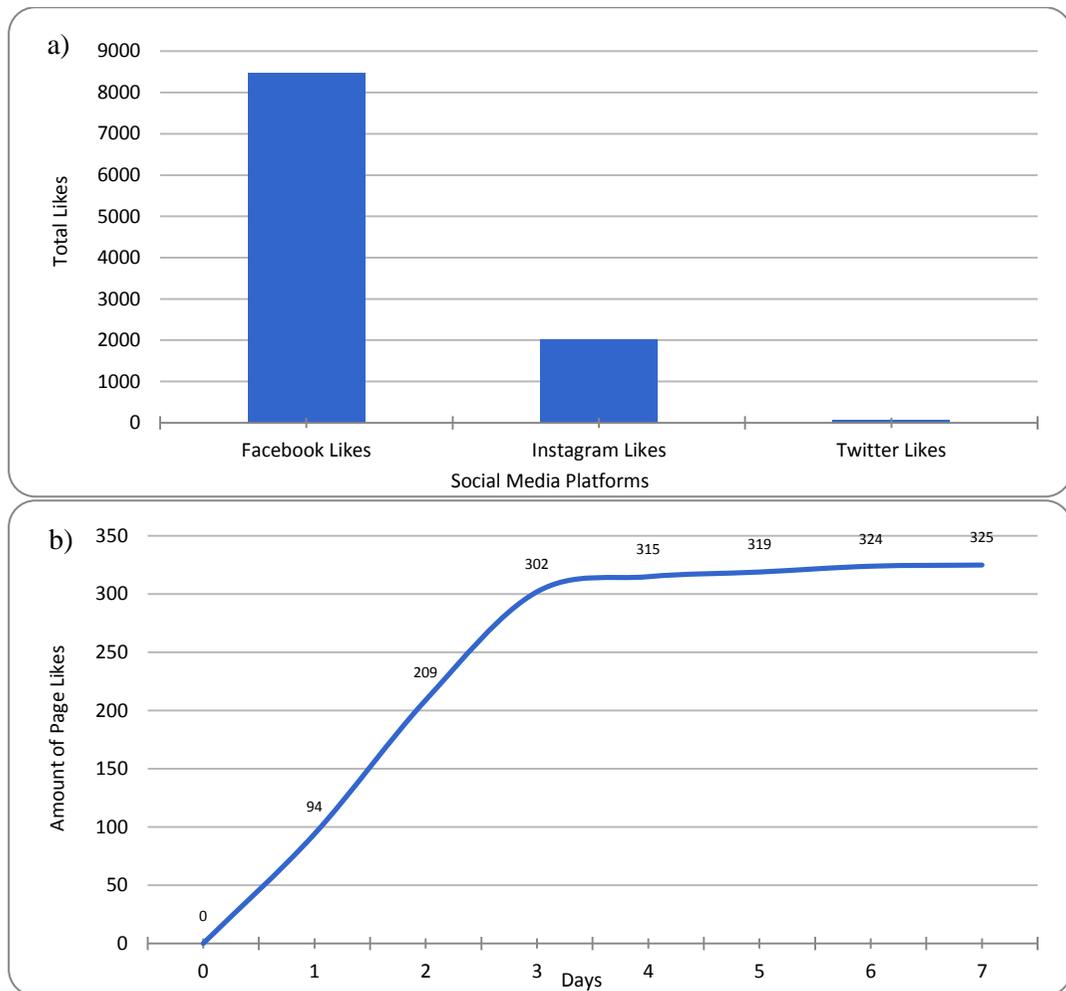


Figure 5-2: a) Different Social Media platforms total 'Likes' and b) Total BBfA Facebook page 'Likes' [14]

Figure 5-2 a) provides a summary of the total 'Likes' from the entire IC for each platform. Facebook reached a total of 8472 'Likes', Instagram a total of 2013 'Likes' and Twitter a mere 68 'Likes'. From these results it is evident that Facebook and Instagram are more effective than Twitter. Facebook generated 4 times the amount of 'Likes' compared to Instagram.

The IC (class of students) consisted of 89 students and as summarised in Figure 5-2 b), in the 7 days of Week 1, the BBfA Facebook page 'Likes' increased from 0 to 325. This indicates that the amount of 'Likes' is more than 3 times the amount of the IC, therefore, each user from the IC, on average, attracted at least 3 extra followers to the BBfA Facebook page.

The total reach for the BBfA Facebook page is illustrated in Figure 5-3 a), in 7 days the BBfA posts reached 10552 people. The IC started at 89 users which transformed into a total reach of 10000+. The total post reach proves that using Social Media is relatively easy to connect to a large online community in a short period of time.

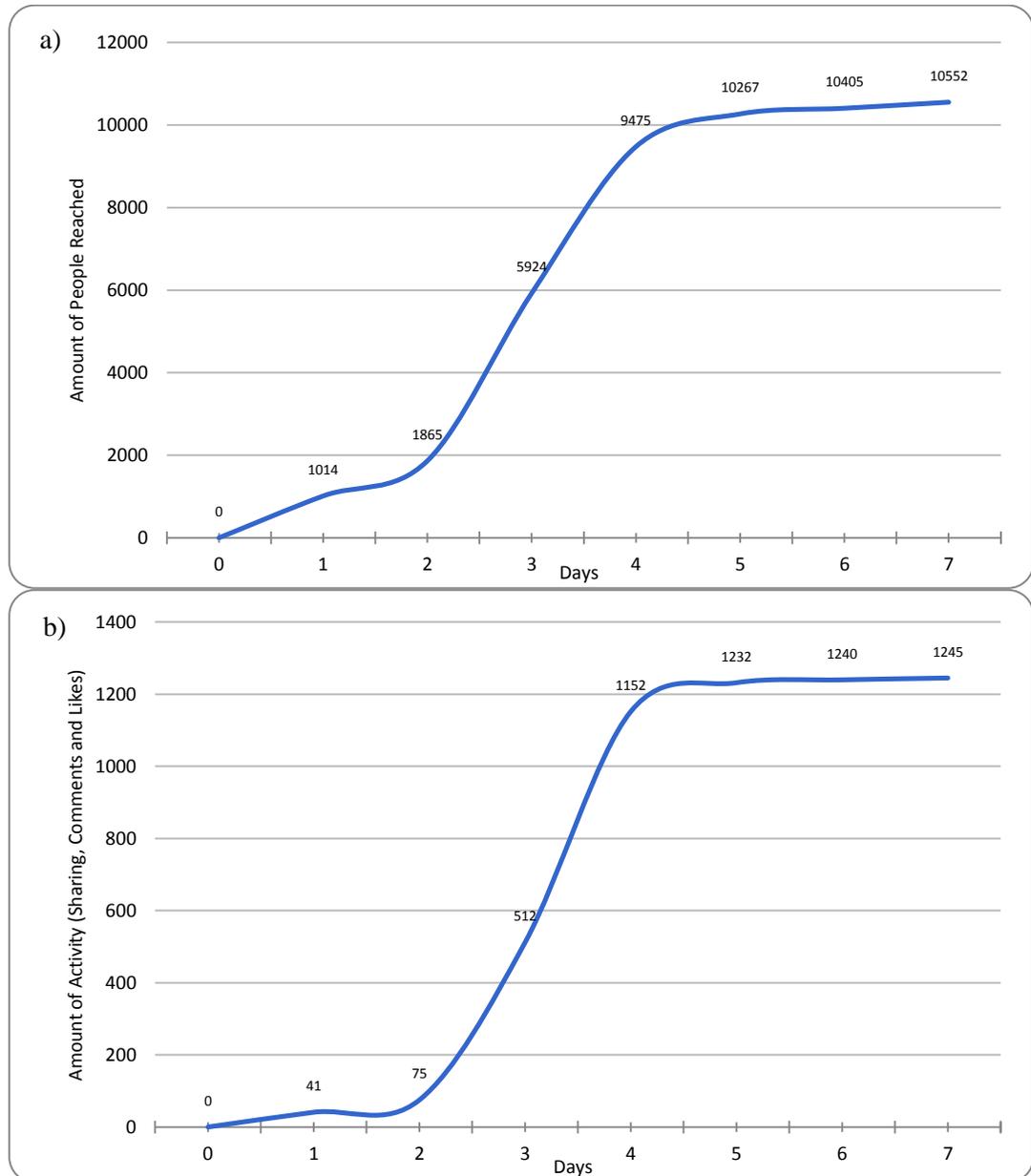


Figure 5-3: a) Total BBfA Facebook page reach and b) BBfA Facebook page activity [14]

The BBfA Facebook page activity is illustrated in Figure 5-3 b). In 7 days, the BBfA page had 1245 page activities. These results indicate that with the page only having 325 ‘Likes’, each user, on average, contributed at least 4 times in the 7 days to the BBfA Facebook page.

It is important to notice from Figure 5-2 and Figure 5-3, the significant increase in activity from day 1 to 4. The reason for the decline from day 5 to 7 was that the cut-off date for submissions on the BBfA Facebook page was on the fourth day. Therefore, no submissions on the page occurred after this date. If the submissions could have continued, the activity experienced on the BBfA Facebook page might have kept on increasing at the same slope as from day 1 to 4.

5.2.2 Manage Complexity for Bamboo Bikes for Africa Experiment

The power law graph for the BBfA experiment is shown in Figure 5-4. This graph is from the method discussed in section 4.3.2 and compares the % of total population reach of each design (Eq. (6)) to the disinterest factor each design (Eq. (7)). These comparisons show that there are a low number of designs that have high interest and there are a high number of designs that have low interest.

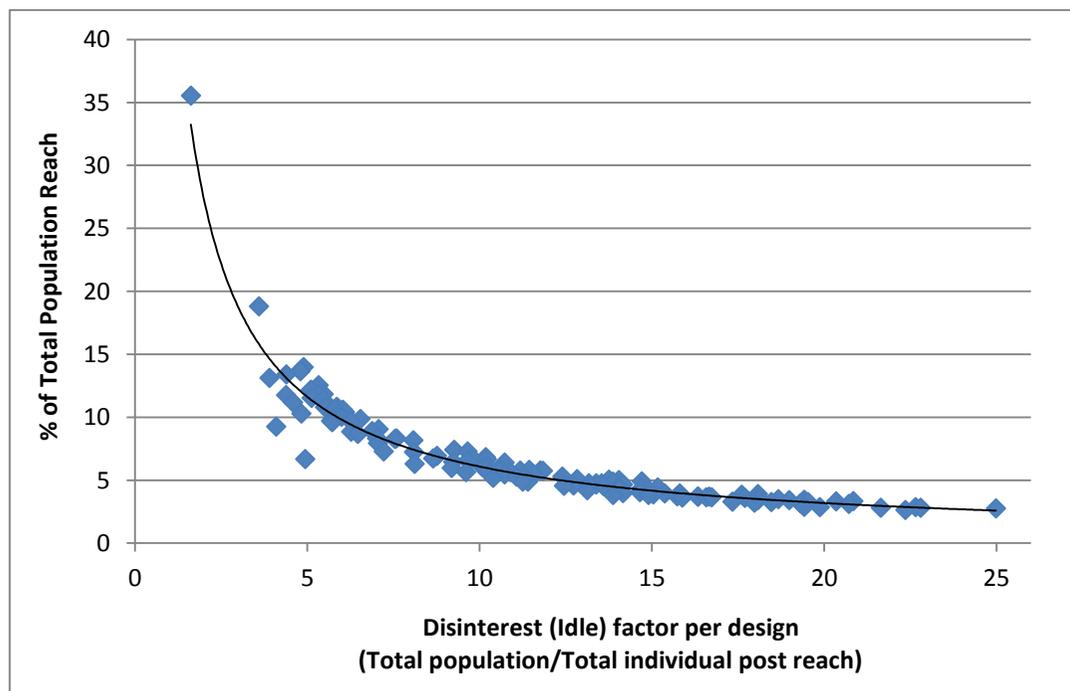


Figure 5-4: Power Law of the BBfA experiment

Figure 5-5 is the Log-Log graph of the power law from the graph in Figure 5-4. Comparing the graphs in Figure 5-4 and Figure 5-5 to the graphs in Figure 2-25 of the power law literature review, it is clear that the graphs follow the same pattern. This indicates that the BBfA experiment and the model of complexity for open design, follow the power law. This experiment follows a natural phenomenon and future work should scale the experiment to larger complex systems.

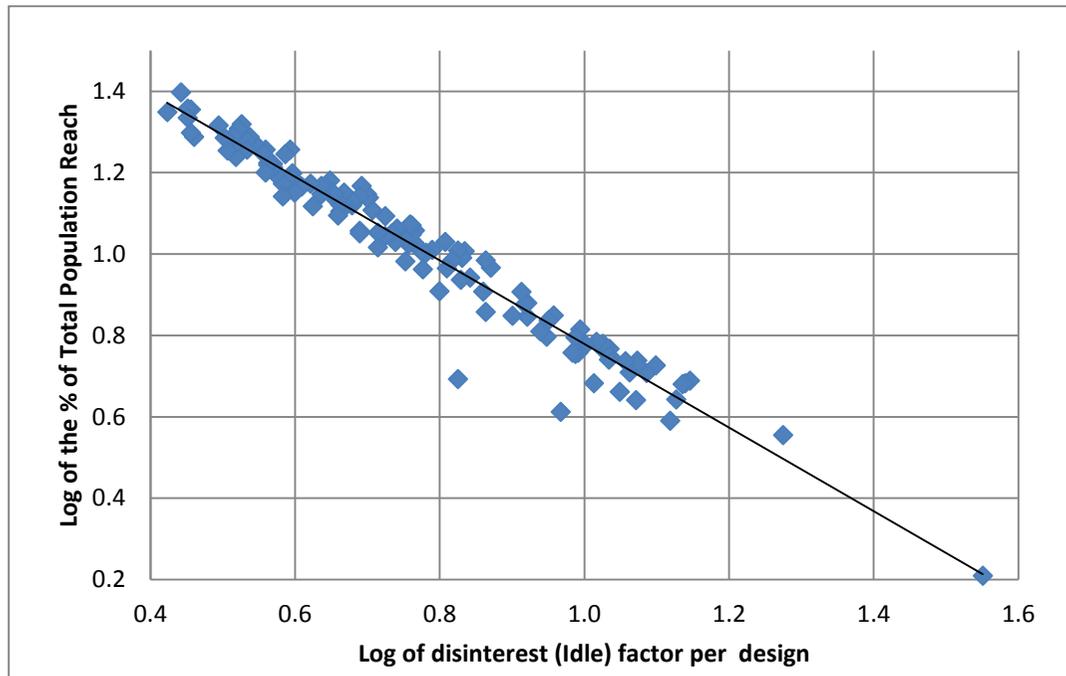


Figure 5-5: Power Law Log-Log of the BBfA experiment

5.2.3 Identified Trend in Bamboo Bikes for Africa Experiment

The BBfA experiment identified a new trend with regards to the quality of the designs that the IC submitted onto Social Media. From the 10 groups of the IC for the BBfA experiment, 151 bamboo bicycle designs were submitted in the first week. This means that each group on average produced 15 bamboo bicycles designs.

Some of the designs are shown in Table B-1 in Appendix B: Bamboo Bikes for Africa Experiment. In Table B-1 are some of the initial and later stage conceptual sketches. The designs are not specifically ranked in quality according to a matrix; the designs are simply divided into the initial and later stage designs and give a clear indication to the reader of the quality of the designs over time.

After analysing the growth rate in quality of these designs, it was clear that the quality of the designs increased over time. The design process followed the trend line as illustrated in Figure 5-6 by the solid black line. It is important to notice that the design process was started by the BBfA administrators that posted a few examples of possible designs.

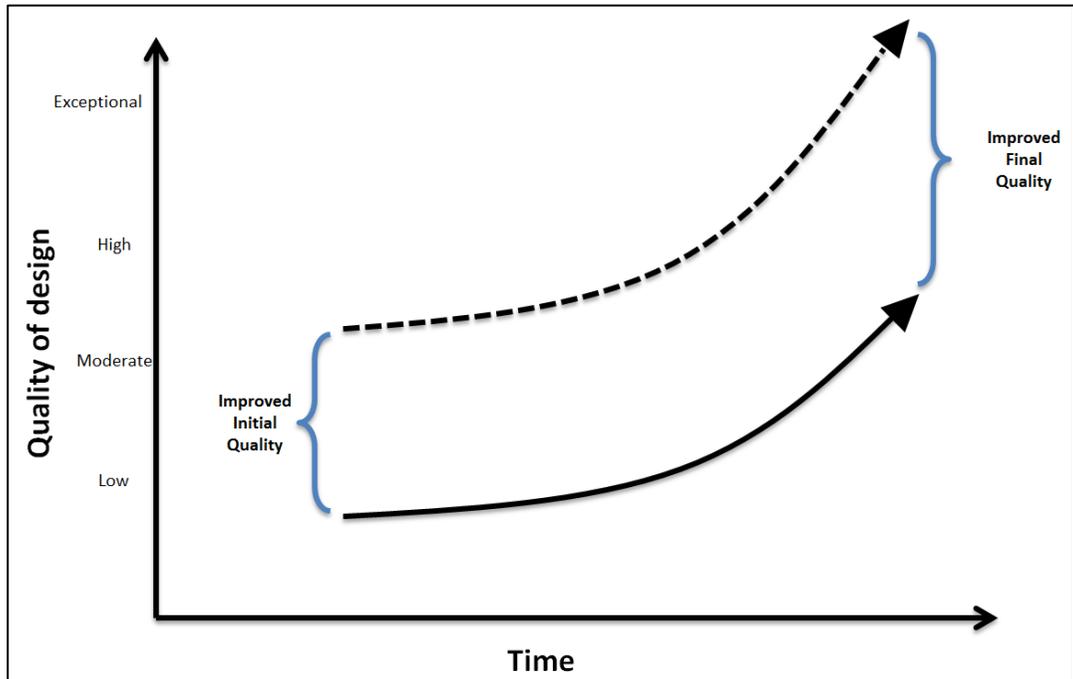


Figure 5-6: Design quality of the BBfA experiment improvement over time (Not to scale - only for illustrative purposes)

If the example designs of the required product are of higher quality, the IC or online community will react to this and try to equal or improve on the example designs. This will improve the quality of the final design and the new design trend, will follow the dotted black line in Figure 5-6 (which will ultimately deliver a higher quality design).

5.2.4 Outputs of Bamboo Bikes for Africa Experiment

The second week of the BBfA experiment develops the 3D CAD models and detailed 2D sketches, on Autodesk Inventor, from each group of the IC, with the most ‘Likes’ from week 1. This phase is described in the model of complexity of open design as the ‘final concept of the group’ to ‘final detailed product design’, as shown in Figure 4-6.

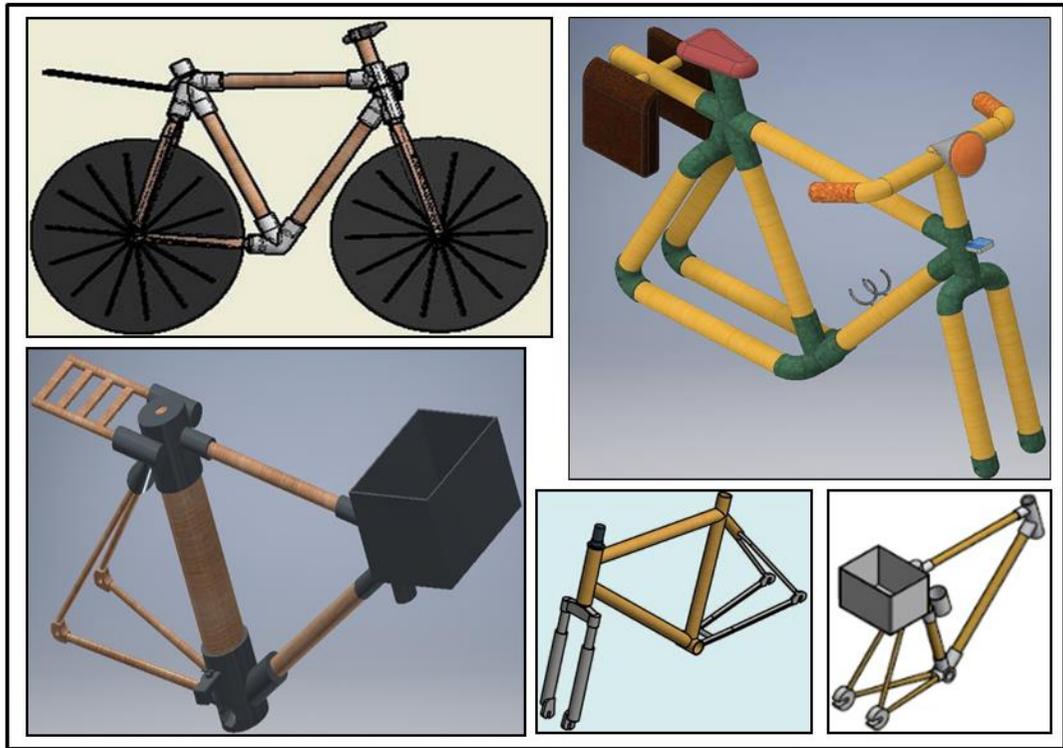


Figure 5-7: Final 3D CAD designs of the BBfA experiment [14]

Shown in Figure 5-7, are a number of the CAD final group designs from the BBfA experiment. The 2D sketches and 3D CAD models of the groups can be found attached in Table B-1 in Appendix B: Bamboo Bikes for Africa at the back of this document. Using all the 3D CAD designs that the BBfA experiment generated, a final prototype was developed. This final prototype was then manufactured. The CAD model for the final prototype is shown in Figure 5-8.

The bicycle frame is manufactured from bamboo and the joints are made of steel and fibreglass. The final product has the exact dimensions as shown in Figure 5-8 and all the detailed drawings of the bicycle frame joints can be found in Figure B-3 - Figure B-6 in Bamboo Bikes for Africa. The final manufactured bicycle can be seen in Figure 5-9.

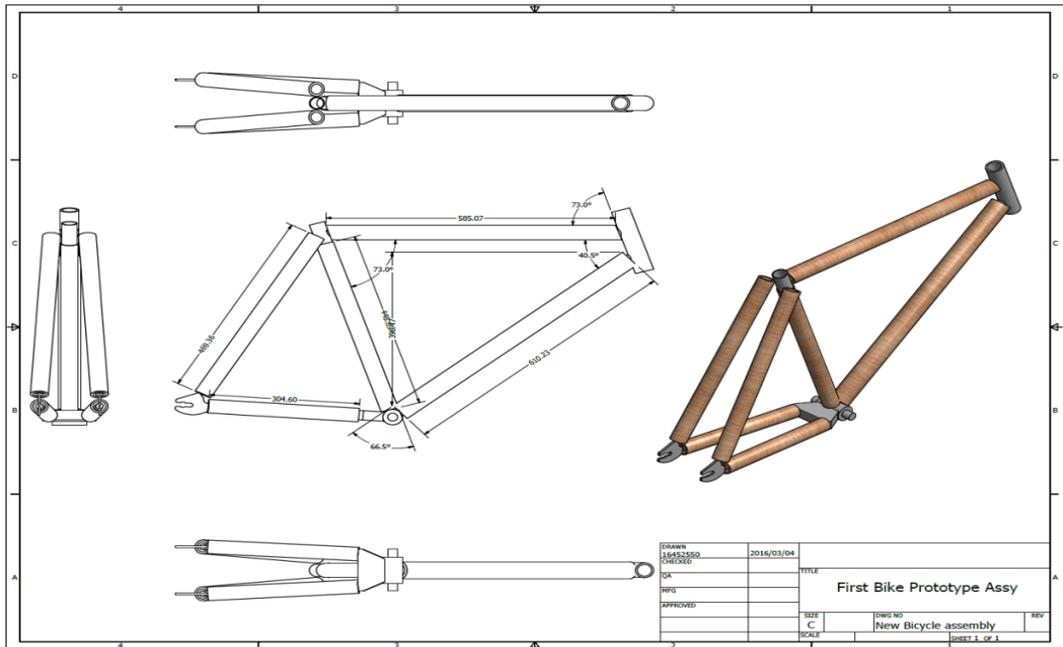


Figure 5-8: Final prototype CAD design for the BBfA experiment



Figure 5-9: Final Bamboo Bicycle manufactured from social manufacturing [14]

5.2.5 Bamboo Bikes for Africa Lessons Learned

Analysing the data obtained from the various Social Media platforms for the experiment indicated the following business model elements for local suppliers that would incorporate open design:

- Complexity theory forms the foundation of the open design process.
- Co-creation introduced a significant amount of ideas that would be difficult to generate with traditional methods.
- The plan, concept, design and validation phases (Figure 5-19) are successfully executed in this experiment using open design.
- Using open design and co-creation can generate a sustainable product because the community (society) designs exactly what is required by the market.
- Social Media provides significant exposure to be used as a marketing tool.
- Social manufacturing can be managed by the online community and can therefore be described as a socially driven process.
- The social manufacturing experiment was proven to be a natural phenomenon through the power law. Therefore, if this experiment follows a natural phenomenon, future work should scale the experiment to larger complex systems.

5.3 99percentDesk Experiment Results

This section will discuss the results of the 99percentDesk experiment and will be used to validate the BMC and the PDL that was developed using the BBfA experiment.

5.3.1 Data analysis of 99percentDesk Validation Experiment

In the section the data obtained from the 99percentDesk Facebook page will be analysed. The page layout of the 99percentDesk Facebook page can be found in Figure E-3 in Appendix E: Social Media Platforms for the Experimental Projects. As discussed in section 4.4, using Facebook the students had to see how many ‘Likes’ can be obtained for their designs.

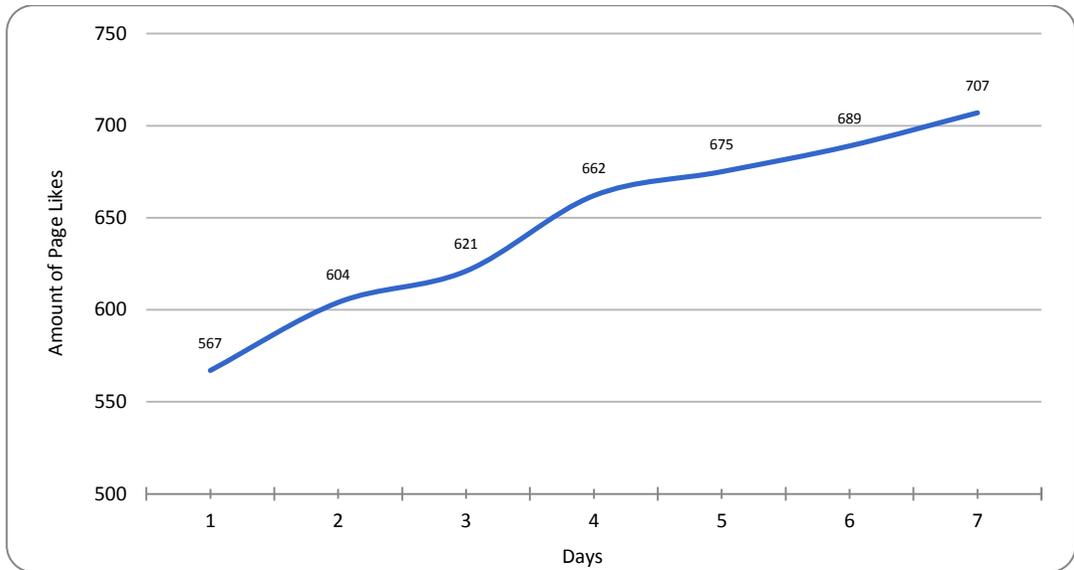


Figure 5-10: Total 99percentDesk Facebook page ‘Likes’

The IC (class of students) for the 99percentDesk was not forced to 'Like' the 99percentDesk Facebook page where all the designs of the different groups will ultimately be posted. The IC consisted of 104 students and as summarised in Figure 5-10, in the 7 days the 99percentDesk Facebook page 'Likes' increased from 567 to 707. This indicates that without forcing the IC to 'Like' the page (as was done in the BBfA experiment), organically the page will grow due to the amount of activity on the page.

The total reach for the 99percentDesk Facebook page posts are illustrated in Figure 5-11 a), in 7 days the 99percentDesk page reached 8261 people. The IC consists of 104 users which transformed into a total reach of 8000+. The total post reach proves that using Social Media is relatively easy to connect to a large online community in a short period of time.

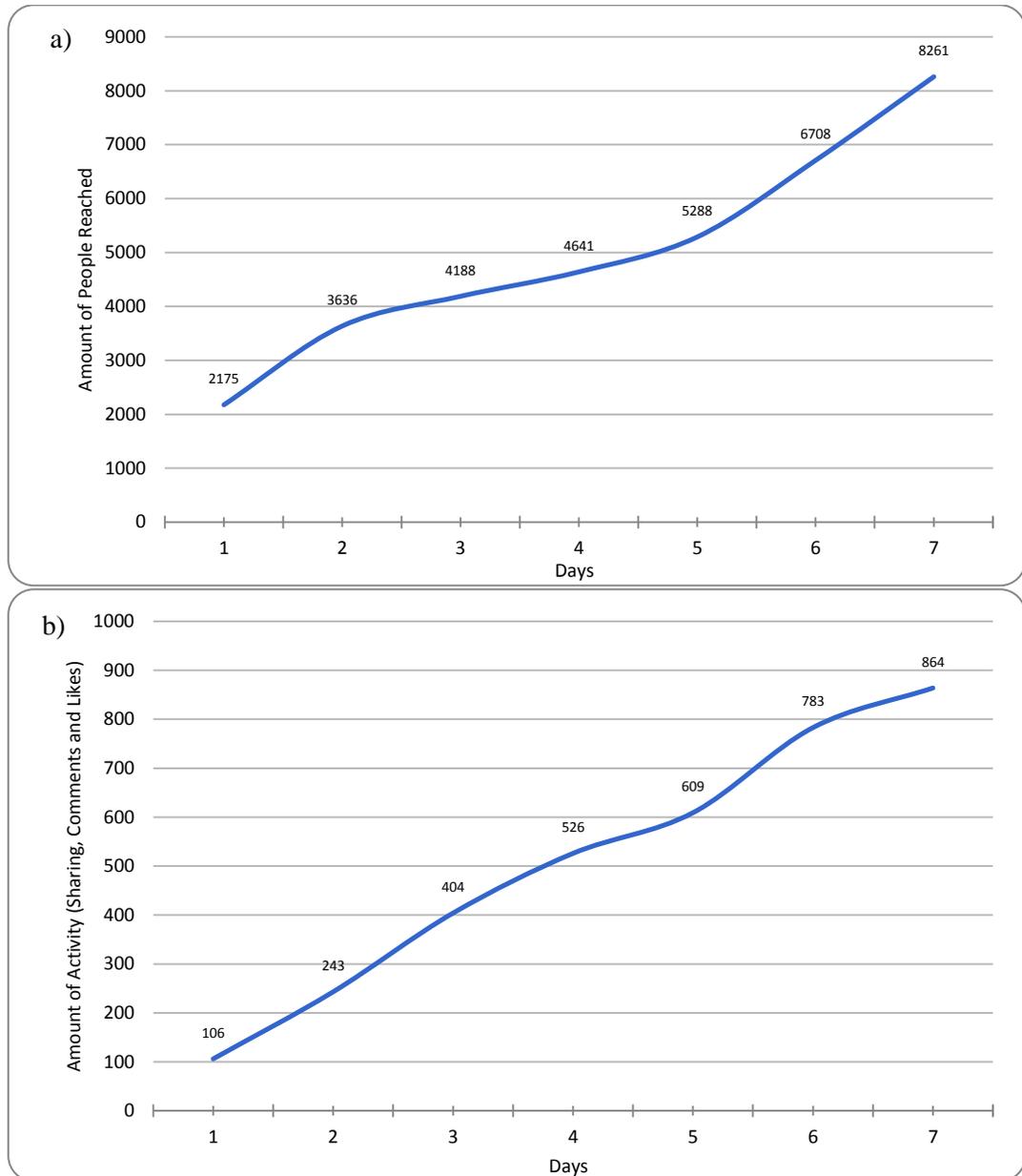


Figure 5-11 a) Total 99percentDesk Facebook page reach and b) 99percentDesk Facebook page activity

The 99percentDesk Facebook page activity is illustrated in Figure 5-11 b). In 7 days the 99percentDesk page had 864 page activities. These results indicate that with the page only having 707 'Likes', each user, on average, contributed at least once in the 7 days to the 99percentDesk Facebook page.

It is important to notice from Figure 5-2 and Figure 5-3 (BBfA) compared to Figure 5-10 and Figure 5-11 (99percentDesk), the significant increase in activity for the BBfA

experiment from day 1 to 4 did not show again. The reason for this is no cut-off date for submissions was set on the 99percentDesk. Therefore, the submissions and activity could continue increasing at the same slope as from the day 1.

5.3.2 Manage Complexity for 99percentDesk Validation Experiment

The power law was discussed in the literature review in section 2.4 and in section 5.2.2 that was used in the BBfA experiment. Similar results must be found in the data from the 99percentDesk validation experiment compared to the BBfA results as discussed in section 5.2.2. The data extracted from the Facebook page will be used to prove the power law. This data contains the amount of reach of the posts on the 99percentDesk Facebook page and can be found in Table C-2 in Appendix C: Power Law Data Table.

The power law graph for the 99percentDesk validation experiment is shown in Figure 5-12. This graph is from the method discussed in section 4.3.2 and compares the % of total population reach of each design (Eq. (6)) to the disinterest factor each design (Eq. (7)). These comparisons shows that there are a low number of designs that have high interest and there are a high number of designs that have low interest.

It is important to note that Figure 5-12 and Figure 5-13 have a low amount of posts compared to the BBfA experiment. The reason for this is that with the BBfA experiment each design was posted as a individual post. With the 99percentDesk experiment each group's designs were grouped together and posted as one post (an album of designs). Therefore, each of these posts has 20 designs in the album and can thus be seen as 20 individual posts.

Figure 5-13 is the Log-Log graph of the power law. Comparing the graphs in Figure 5-12 and Figure 5-13 to the graphs in Figure 2-25 of the power law literature review, it is clear that the graphs follow the same pattern. This indicates that the 99percentDesk validation experiment and the model of complexity of open design follow the power law. This experiment follows a natural phenomenon and future work should scale the experiment to larger complex systems.

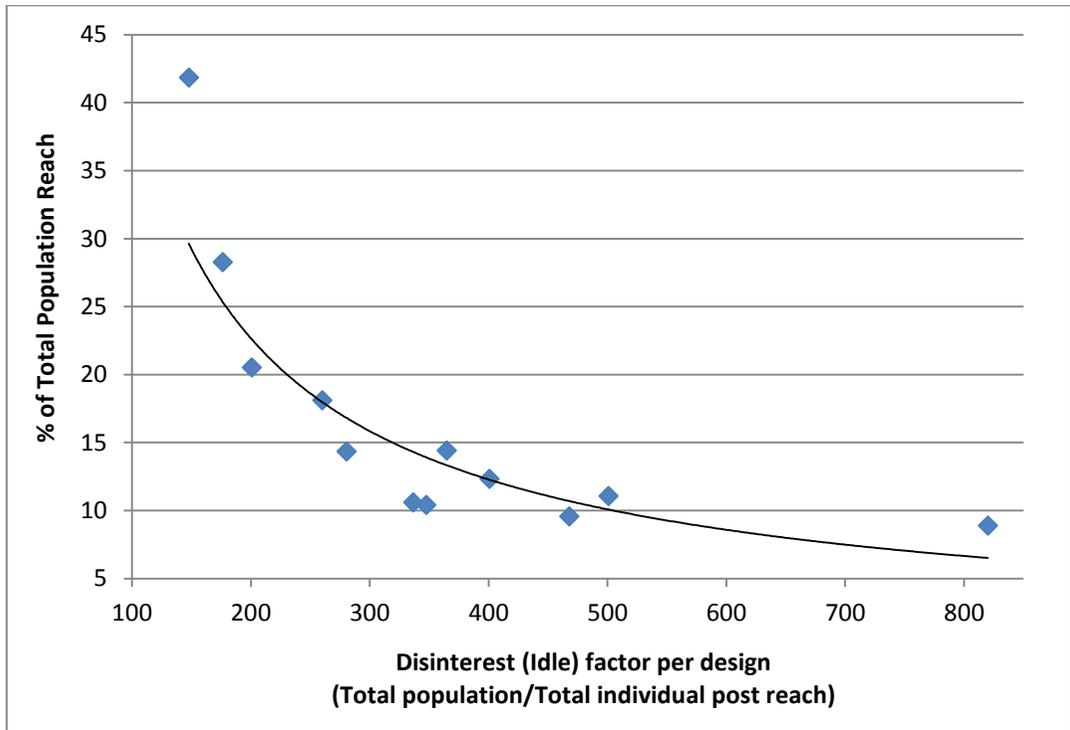


Figure 5-12: Power Law of the 99percentDesk validation experiment

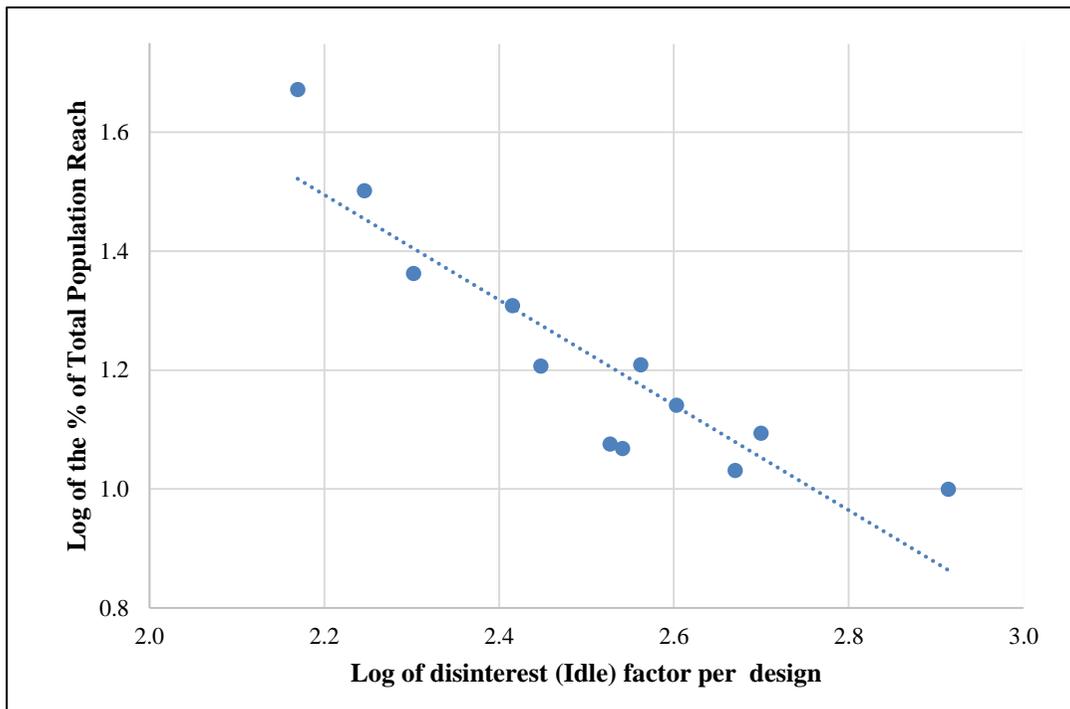


Figure 5-13: Power Law Log-Log of the 99percentDesk validation experiment

5.3.3 Outputs of 99percentDesk Validation Experiment

Using the ideas and designs of the different groups a 3D CAD model and detailed 2D Sketch was developed to be manufactured. This phase is described as the ‘final concept of the group’ to ‘final detailed product design’, as shown in Figure 4-6 of the model of complexity of open design.

However, for this experiment a template design was provided to the IC as shown in Figure D-2 in Appendix D: 99percentDesk Validation Experiment. This enables the IC not to have to do the detailed designs, but rather add on to a detailed design template that the social manufacturing platform provides. This ensures less effort and higher quality designs from the IC because they do not have to design each design from the base and can then focus on only designing the ‘Swiss-army-knife’ like technology.



Figure 5-14: First prototype scale 4:1 model without Swiss-army-knife technology

Shown in Figure 5-14 is a prototype scale 4:1 model that was built to show the online community what the basic desk will look like. This model does not have the ‘Swiss-army-knife’ technology, however, the final desk will have the ‘Swiss-army-knife’ technology.



Figure 5-15: Final 3D CAD design of the 99percentDesk validation experiment

Shown in Figure 5-15 is the final CAD design from the 99percentDesk experiment with the chosen ‘Swiss-army-knife’ technology; more detail of the 3D CAD model is shown in Figure D-5 in Appendix D: 99percentDesk Validation Experiment.

The 99percentDesk was used to simulate the crowd funding mechanisms through using an online funding website. The crowd funding website for South Africa is called Jumpstarter [35]. The website requires the user to set a total amount of money that needs to be raised in a set amount of time. The 99percentDesk required R5000 and this goal was met. Therefore, the crowd funding mechanism was proven to be successful with a total of R5000 raised to use for the manufacturing of the product. The layout of 99percentDesk crowd funding page is shown in Figure E-4 in Appendix E: Social Media Platforms for the Experimental Projects.

5.3.4 Questionnaire for 99percentDesk Validation Experiment

This questionnaire was given to the IC of the 99percentDesk and the results of the questionnaire can be found in Appendix F: Questionnaire of the 99percentDesk Results. This section will focus on the questionnaire results from the listed 9 questions of the questionnaire in section 4.4.2.

- Question 1

The project used Social Media platforms, similar to the OWC and BBfA, to post designs and therefore, this question checks whether the IC used Facebook before the 99percentDesk project. Figure F-1 shows that 86.75% have Facebook which means 86.75% of the IC will be accessible from the Social Media platform.

- Question 2

This question checked the frequency of daily Social Media visits for the IC before the 99percentDesk project. This is important as users need to be on Social Media frequently in order to be able to contribute to social manufacturing and co-creation platforms. Illustrated in Figure F-2 is the daily activity on Social Media platforms from the IC prior to the 99percentDesk project.

If a rating of 3 (3 daily visits to Social Media) is significant, as this means each user can contribute on average 3 times a day to a social manufacturing company, then it is important to sum the percentages of the ratings that are 3 and higher. Therefore, using Figure F-2, the total for the daily visits of a rating 3 or higher is 62.96% prior to the 99percentDesk project. This means that more than 60% of the IC might contribute to a social manufacturing company through Social Media 3 times or more on a daily basis.

- Question 3

Co-creation and OSS are relatively new concepts and it is important for everyday online users to understand these concepts for social manufacturing to be sustainable. Therefore, this question was used to check the IC knowledge on whether the concepts are familiar to them. Figure F-3 shows that prior to the 99percentDesk 64.20% of the IC did know something about co-creation and OSS. However, after the 99percentDesk project, the knowledge on these concepts can improve.

- Question 4

The 99percentDesk project not only simulates a social manufacturing company, it is used to see whether the crowd community (or IC) will be able to use and understand social manufacturing. Thus, this question is used to check the knowledge on social manufacturing of the IC, prior to the project. The results of the question are shown in Figure F-4.

If a rating of 2 is considered to be average, then comparing the percentage of the total population that have an average knowledge in their opinion is required. As seen in Figure F-4, prior to the project, 59.04% of the total population had knowledge of social manufacturing of rating 2 or higher.

- Question 5

This question is used to see what the IC opinion is with regards to getting involved with a social manufacturing company and if this company can be successful. The results of the question are shown in Figure F-5. The IC indicated that 75.9% of the population will get involved and that the concept will work, however, it is important to understand why these people will get involved.

- Question 6

This question asked the reason, if any, why people will get involved in a social manufacturing company and the results are illustrated in Figure F-6. The results show that only 28.05% of the IC wants a financial reward. However, over 70% of the IC will contribute towards social manufacturing for no financial reward and 37.80% will contribute to help others. These results indicate that the cost of human resources with regards to co-creation and crowd sourcing will be minor, if any, compared to traditional manufacturing processes.

- Question 7

This question is used to see whether the IC currently uses the internet to find practical solutions. This will indicate if currently the internet is used to harvest ideas and solutions. As indicated by Figure F-7, more than 65% of the IC uses the internet to find practical solutions on a regular basis. This shows that the social manufacturing concepts are already starting to surface on the internet as people work together to find solutions.

- Question 8

This question checked the effectiveness of the practical solutions that is found online. The results for this question are shown in Figure F-8. If a rating of 3 is considered to be above average, then from Figure F-8, then 93.08% of the practical solutions that the IC has found online are considered to be above average in effectiveness. This is a very high percentage and indicates that the IC has a good experience using the online community for practical solutions.

5.3.5 99percentDesk Lessons Learned

The data obtained from the Social Media platforms and the questionnaire indicated the following business model elements for local suppliers to incorporate open design:

- The 99percentDesk experiment did achieve similar results to the BBfA results described in section 5.2.5.
- Using a template design along with the model of complexity of open design improves the management and quality assurance of the conceptual design phase.
- The questionnaire showed that for an Industrial 2nd year class of students (IC), between the ages of 18 and 23 years, the concepts of a social manufacturing company is something that can be considered. The IC indicated that most of the students currently use online communities to find practical solutions and will get involved with co-creation or social manufacturing for no financial reward.
- The crowd funding mechanism was proven to be successful with a total of R5000 raised to use for the manufacturing of the 99percentDesk product.

5.4 Business Model and Lifecycle Development

The results used to validate the research objectives from Table 3-1 will be discussed in this section. These results include the social- and traditional manufacturing comparison, the development of the BMC and the PDL that was obtained through the Bamboo Bikes for Africa experiment and validated by the 99percentDesk experiment.

5.4.1 Social Manufacturing compared to Traditional Manufacturing

The social manufacturing and traditional manufacturing comparison will be used to validate the first research objective. The comparison will be similar to the comparison from Figure 2-27 from the literature study and the result is shown in Figure 5-16. The data that will be used for this comparison is shown in Table 5-1. Table 5-1 is divided into the normal data (Row 1, 2 and 3) and is then converted into a percentage of the higher number (Row 4, 5 and 6) between social- and traditional manufacturing.

Traditional manufacturing is defined in this study as the current manufacturing process, where the manufacturer and the consumer are separated and is called mass customisation and personalisation. The four elements that will be discussed are the design cycle rate, prototype cost, human resources-designers and human resources-input activity. In order to have a relative comparison between the two types of manufacturing systems, it will be assumed that 5 engineers will be used for the traditional manufacturing system.

- Design Cycle Rate

The BBfA and 99percentdesk validation experiments used 89 and 104 students respectively as the IC. The students produced 151 designs for BBfA and 200 designs for 99percentdesk in a week. Therefore, if the 200 designs, 104 students and the 5 engineers are used in Eq. (8) then traditional manufacturing produces 9.62 designs. The 200, 151 and 9.62 designs are converted into percentages using Eq. (9). These percentages are documented in Table 5-1 and shown in Figure 5-16. It is clear that the design cycle rate is faster for social manufacturing compared to traditional manufacturing.

$$\text{Designs of Traditional Manufacturing} = \frac{\text{Maximum Experiment Design Output}}{\text{Total Student Designers}} \times \text{Engineers} \quad (8)$$

$$\% \text{ of variable} = \frac{\text{Variable}}{\text{Biggest number of type}} \times 100\% \quad (9)$$

- Prototype Cost

If it is assumed that design engineers work at a rate of \$25.24 per hour [136], which converts more or less to R400 per hour, the total amount of hours spent on developing the design by 5 engineers was 8 hours, then the total prototyping cost is R16 000 for traditional manufacturing. However, using the BBfA and 99percentDesk validation experiments, an incentive can be given to the best design or the design that is chosen as the final product.

This incentive can be a financial reward that is equivalent to one engineer at an hourly rate of R400 for 8 hours. This will mean that 89/104 people can design on a prototype at a cost of R3 200. The R16 000 and R3 200 are converted into percentages using Eq. (9). These percentages are documented in Table 5-1 and shown in Figure 5-16. It is clear that the prototyping cost is significantly less for social manufacturing compared to traditional manufacturing.

- Human Resources - Designers

For traditional manufacturing, the total number of engineers required to complete this task, is assumed to be 5. For the BBfA and 99percentDesk validation experiments, the total human resources with regards to designers equal 89/104, as this is the IC that was divided into the different groups. The 5, 89 and 104 people are converted into percentages using Eq. (9). These percentages are documented in Table 5-1 and shown in Figure 5-16. It is clear that the amount of human resources, with regards to designers, is higher for social manufacturing compared to traditional manufacturing.

- Human Resources - Input Activity

The amount of human resources used as input to the entire design process for traditional manufacturing remains 5, as only the engineers will work on the project. However, for the BBfA and 99percentDesk validation experiments, a total of 1245/864 people contributed to the designs by commenting, posting, liking and giving feedback.

The 5, 1245 and 864 people are converted into percentages using Eq. (9). These percentages are documented in Table 5-1 and shown in Figure 5-16. It is clear that the amount of human resources, with regards to input, is higher for social manufacturing compared to traditional manufacturing. Therefore, from Figure 5-16, it is clear that social

manufacturing has a faster design cycle rate, the prototyping cost is less, uses more human resources with regards to designers and input activity than traditional manufacturing.

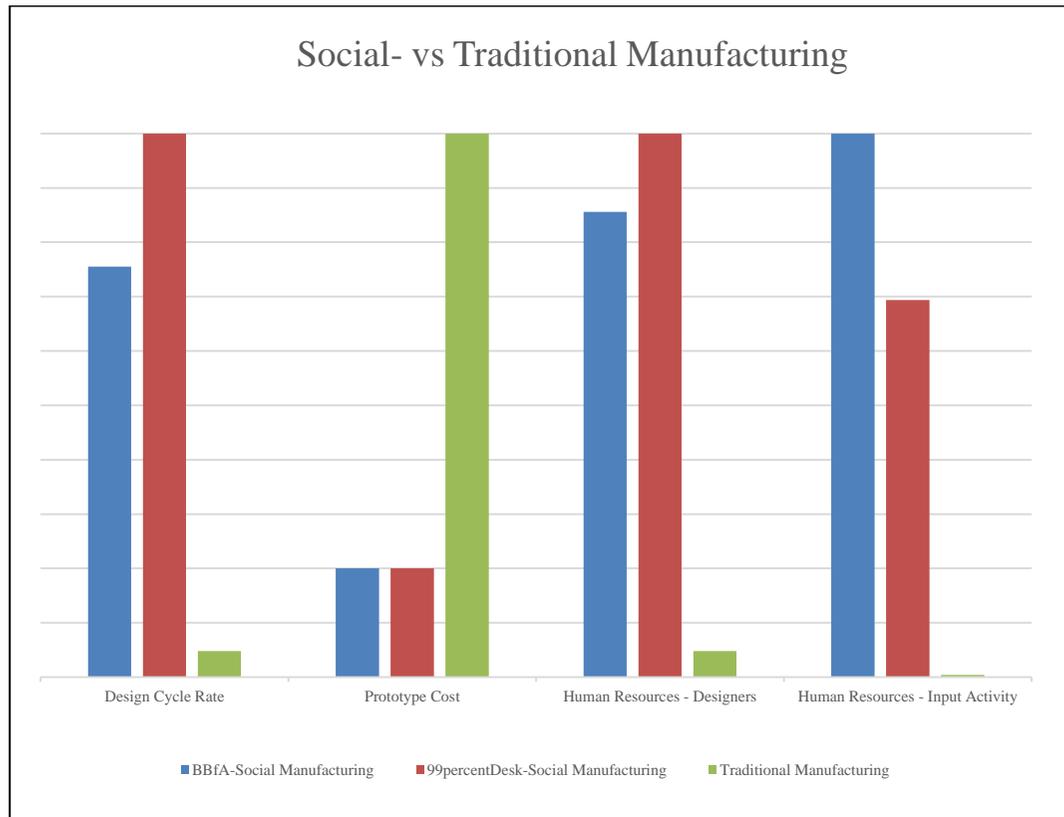


Figure 5-16: Comparing social manufacturing to traditional manufacturing

Table 5-1: Comparing social manufacturing to traditional manufacturing

	Design Cycle Rate	Prototype Cost	Human Resources - Designers	Human Resources - Input
BBFA (Social)	151 designs	R3200	89 people	1245 people
99percentDesk (Social)	200 designs	R3200	104 people	864 people
Traditional	9.62 designs	R16000	5 people	5 people
% BBFA (Social)	76%	20%	85.57%	100%
% 99percentDesk (Social)	100%	20%	100%	69.39%
% Traditional	4.81%	100%	4.8%	0.4%

5.4.2 Key elements for Social Manufacturing

In order to populate the business model canvas and the product development lifecycle, the elements that summarise the different aspects of social manufacturing, need to be taken into consideration to incorporate social manufacturing within a business. Therefore, using the experimental results and the background case study, six key elements for social manufacturing are identified and illustrated in Figure 5-17.

These key elements links with the social manufacturing companies from Figure 2-5 that indicates the emerging synthesis as described in section 2.5. Apart from the key elements, there are numerous other sub-factors that local suppliers need to take into consideration. A brief discussion on the six key elements will follow.

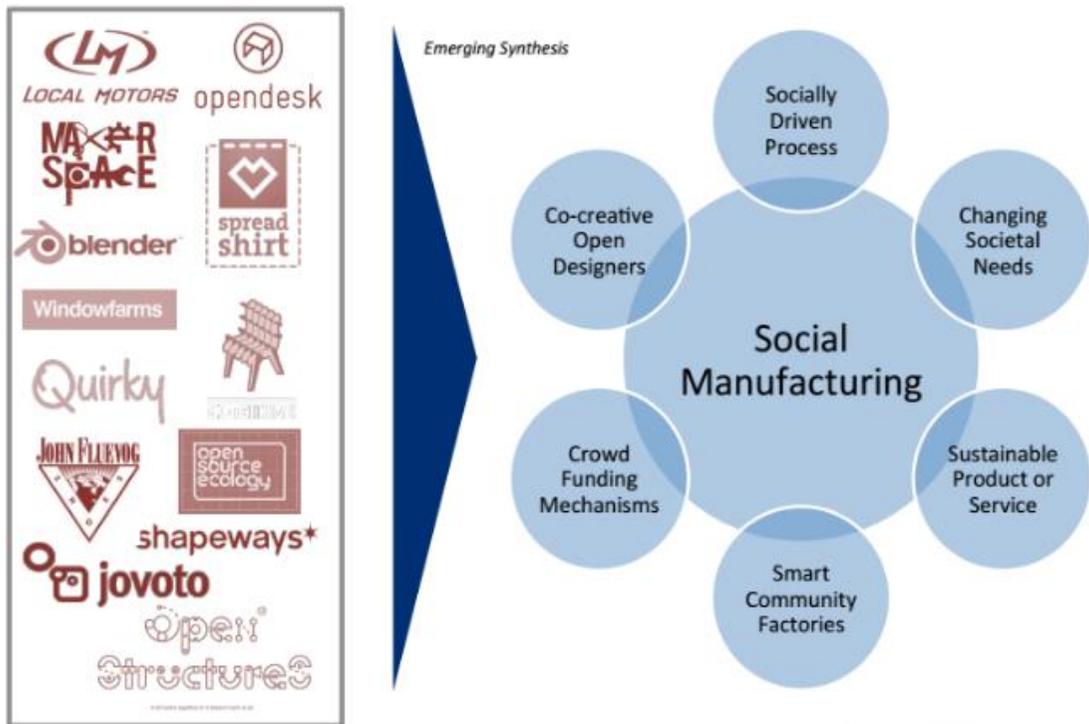


Figure 5-17: Key elements of social manufacturing business model

- Socially Driven Management

The management process is driven by establishing an online community. This online community will run through an online platform for co-creation and communication purposes. Management of the online community will mostly be run by the platform, however, it is essential that quality assurance is done through design filtering to validate

the product. Local suppliers will need to setup and manage an online social platform. This was done using the IC in the different experiment iterations using Facebook as the online community.

- Changing Societal Needs

Through analysing the different manufacturing paradigms and as illustrated in Figure 1-1, social manufacturing has a complete different need from the society. These needs must incorporate a higher degree of the economics of scope and remain at a high degree of economics of scale. In other words, products must have a high variety accompanied by the ability to adapt to market demand fluctuations. This is enabled by the latest technology and knowledge processing which is described in Table 2-5 . Local Suppliers will have to use online platforms to reduce design time to meet market demand fluctuations.

- Co-creative Open Designers

The product concepts and design generation phases will follow the model of complexity of open design that is described in Figure 4-6. This model is validated through the BBfA experiment and the 99percentDesk validation experiment. Using co-creation will enable local suppliers to have a higher design cycle rate and use more human resources with lower cost than traditional manufacturing processes, as shown in Figure 5-16.

Therefore, using Co-creative Open Designers is effective as the customer changes to a prosumer and ensures that the product meets the market demands. Co-creative designers ensure that the design phase is shorten to ensure that local suppliers can respond to market demand fluctuations as shown in Figure 4-2.

- Crowd Funding Mechanisms

This tool enables local suppliers to be established within the market through enquiring venture capital. Once the process of producing products have run through a number of iterations, the products will start to fund themselves, however, for start-up funding, crowd funding mechanisms are essential. For example Jumpstarter [35] is a crowd funding mechanism that was used in the 99percent Desk validation experiment and generated the required R5000 venture capital from crowd donations to build the first product.

- Community Factory

The community factory is used through the online community getting involved in the manufacturing process of the local supplier. Therefore, users from the online community can bid to be outsourced on certain tasks of the manufacturing process. This is possible through the available technology (3D- printing, CNC-machining or any other required machines) and can ensure that the technical and practical skills of the online community can be used by the company. This enables local suppliers to offer products that they might not have been able to in the past due to a lack of permanently employed trained professionals. However, these skills will be less expensive than hiring a trained professional on a permanent basis. This was done in the BBfA experiment through building the bamboo bicycle in Figure 5-9.

- Sustainable Product or Service

The product or service that is generated, on the platform, by the online community, will be analysed throughout the design phase. This co-creation process will determine the market demand by itself and this product or service will therefore be sustainable as the product will meet customer demand. These products or services that surface will then be validated by the online community to ensure that the customer receives the demanded product. Co-creation will then guarantee a sustainable product or service for local suppliers to sell.

5.4.3 Industry Case Study

The industries described in section 2.2 and Figure 2-5 includes transportation, work and living space, personal and professional services, financial services and goods. Each of these industries along with social manufacturing is summarised in Figure 5-18 in a honeycomb structure.

As seen in Figure 5-18, each industry is divided into individual honeycombs and each honeycomb has sub-industries. The sub-industries have examples of current operating companies that use some of the six key elements of social manufacturing within their business model. Therefore, the middle honeycomb of Figure 5-18, is a summary of which of the six key elements of social manufacturing is relevant to that honeycomb (industry).

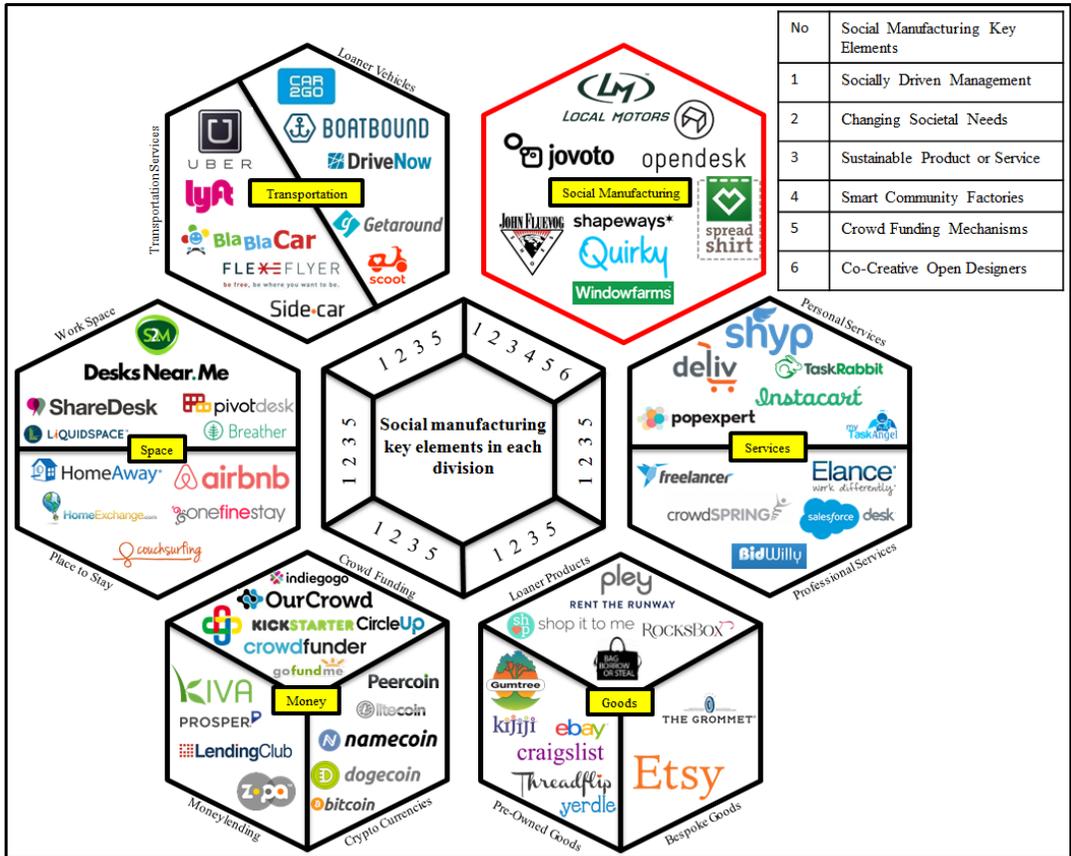


Figure 5-18: Companies currently using social manufacturing elements compared to the six key elements adapted from Figure 2-5

The five industries other than social manufacturing include the following four key elements from social manufacturing: Socially driven management, changing societal needs, sustainable product or service and crowd funding mechanisms. Companies currently using social manufacturing include: Local Motors [104], Shapeways [100], Quirky [99], Opendesk [94], Windowfarms [102], etc. (more examples can be found in Figure 5-18).

These companies include all six of the key elements of social manufacturing. All the above mentioned examples incorporate co-creation platforms for their design process similar to the BBfA and 99percentDesk experiment. Therefore, local suppliers will have to consider all six key elements in the manufacturing industry. The companies in Figure 5-18 will be used in the development of the PDL and the BMC for social manufacturing.

5.4.4 Product Development Lifecycle

The PDL for social manufacturing can be found in Figure 5-20 and will be discussed in this section. The PDL incorporates the key elements of social manufacturing from Figure 5-17, companies from industry with social manufacturing elements from Figure 5-18 and the development phases of a product's lifecycle.

The PDL has six phases to complete the lifecycle of a product, namely Plan, Concept, Design, Validate, Production and Support as shown in Figure 5-19. For this study, the first four phases have been validated with the three experiments, however, the production phase was implemented in the BBfA experiment but is not discussed in detail. For more information on the process of the production phase for BBfA, refer to [131-133]. The support phase is not validated as this is not within the scope of the project. However, for the PDL development, all six phases have been taken into account and have been incorporated with the key elements of social manufacturing from Figure 5-17.

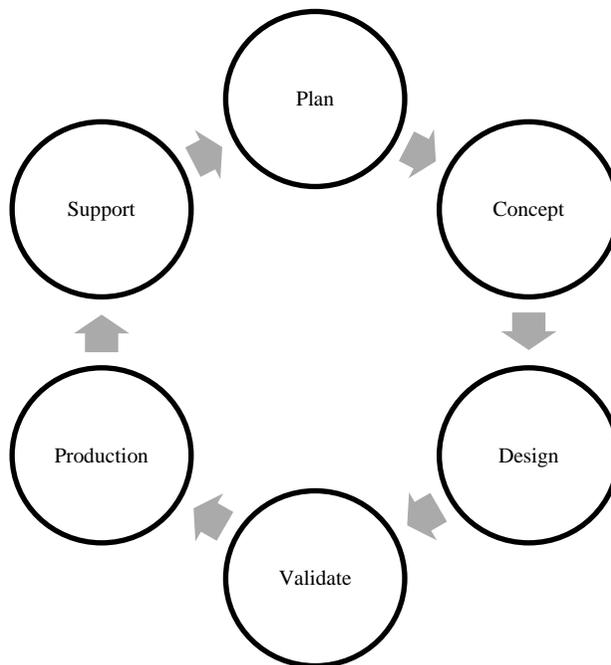


Figure 5-19: The six phases of the product development lifecycle

The key elements in the PDL, shown in Figure 5-20, are divided into the smaller elements of that specific element. The smaller elements are divided along the six phases of the product lifecycle. This indicates at what stage of the lifecycle the different elements should

be taken into consideration. Corresponding to the key elements are online platforms/companies, from Figure 5-18, that can be useful in that specific element. This PDL can be used to incorporate social manufacturing on selected or all of the phases in the development of a product or service of a new or current local supplier. The PDL serves as a tool to highlight the requirements for social manufacturing in the different phases of the product development.

5.4.5 Generic Social Manufacturing Business Model Canvas

The BMC for social manufacturing, will be developed in this section, taking into consideration the experiments and data from this study. However, it is important to use a basis from which to develop the BMC. Therefore, the study done by Kiel *et al* [137] is used as a basis for the nine building blocks as described by Figure 2-13 and section 2.3.

The BMC from Kiel *et al* [137] is for the IIoT (Industrial Internet of Things) which is a similar concept to social manufacturing, therefore, only the relevant information within the BMC of Kiel *et al* [137] with regards to social manufacturing, will be used. The elements of the BMC that was identified in this study will be added to the nine building blocks that will be discussed individually below.

- Key Partners

In social manufacturing, customers are key partners and co-designers. The customers turn into prosumers, as described in section 5.4.2, and they are integrated via open innovation and open source processes. External sources and customers can participate in the product development processes as described in Figure 5-20.

These processes are enabled by the implementation of cloud technologies that changes supply relationships. Smart community factories are used to produce the designed products using the crowd funding mechanisms. Production and/or services of any kind along the PDL can be outsourced to other online platforms to harness their online community and capability.

Two reasons for local suppliers to form an alliance (Partners) are present in social manufacturing as described in section 2.3.1. The first reason is to acquire other online platforms resources and their community. The second reason is for the economics of scale and optimisation of the online community. Integration of other social/online platforms is a key partnership as customers have more tools at their disposal on the platforms.

- Key Activities

Customer integration is important when it comes to the BMC of social manufacturing. Customers become prosumers contributing in the entire PDL to design products in compliance to their needs. This is possible by changing key resources that will be described later in this section.

Key activities are managed with a socially driven process to use online communities to distribute social problems. These online communities will use co-creative open designers in order to find solutions in the form of sustainable products or services. Products and services can then be sold through an online platform. Therefore, it is important to have the necessary quality software or online platforms to enable the online community to drive itself to ensure that activities are sufficiently managed.

Value network, value shop and value chain are three configurations described in section 2.3.2 and Figure 2-16. All three configuration types are relevant to social manufacturing. The network infrastructure operation for social manufacturing is a value network attribute. The value shop has five attributes, namely Problem-finding and Acquisition, Problem Solving, Choice, Execution, Control and Evaluation. These attributes will be used and solved by the PDL shown in Figure 5-20.

The value chain for social manufacturing will use marketing and sales through the online platform, as was done with the experiments in this study. The trend of distributed manufacturing through social manufacturing and sourcing designs from an online community, establishes the basis for shortened delivery times, customised products and production on demand (From Figure 4-2, Figure 2-27 and Figure 5-16).

- Key Resources

The important resources of the social manufacturing are IoT, self-organising system and CPS, as described in 2.5. These resources enable an automatised, standardised and intelligent connectivity of design- and production systems, manufacturers, and customers via online platforms. These resources are IT systems that are dependable through adding value whilst remaining cost effective.

High levels of software integration into traditional manufacturing systems and processes result in productivity increases. The integration of cloud technologies into manufacturing environments, e.g. cloud manufacturing, offers decentralised on-demand services that are adapted to production processes. Online platforms can be used for data collections from social networks; consumers can be observed and communication with customers can be improved.

Co-creative open designers will be used as the human resources of the local suppliers. This will contribute to the revenue stream as the human resources cost is minimum compared to the current full-time employees cost as shown in Figure 5-16. Therefore, the key tangible and intangible resources of social manufacturing, as described in section 2.3.3, will be online software platforms (CPS, self-organising systems, IoT and online platforms) and human resources will be the online community.

- Value Proposition

The value proposition of social manufacturing is innovation, as discussed in section 2.3.4 and is shown in Figure 2-19. This type of innovation produces a product or service that is disruptive technology and is therefore brand new and changes the current industry. Social manufacturing offers products and services to customers that require unique custom products that can be accelerated to the market.

These products show an increase in quality over time, flexibility and innovativeness as shown in Figure 5-6, Figure 5-7, Figure 5-8 and Figure 5-9. The value proposition is that the design cycle rate is faster, the prototype cost is reduced and the human resources used are higher compared to traditional manufacturing, as shown in Figure 5-16. Therefore, the products are of a greater variety, meet customer demand and delivers higher value to the customer.

- Customer Relationship

Customers or consumers change into prosumers and will participate in the entire design process of the product. The customer will not only be used as the customer but also as a designer and marketing analyst. The customer relationship is strengthened through open source, online platforms, online communities, Social Media and open innovation. The data from these platforms can be used to add value to the value chain of the company.

Customers and key partners must have access to transparent information and be integrated into the local supplier's business structure by using the model of complexity of open design shown in Figure 4-6. The concept of prosumers and co-designers will develop all three types of customer relationships, as described in section 2.3.5, namely acquisition, retention and add-on selling. The reason for this is that customers will be able to find or design a product for their exact need and will therefore be retained.

- Channels

All channels will go through the online community and Social Media. Customer, factories, designers and distribution will all be connected using the online platform. The online platform will enable the CBC, in Figure 2-22 and in section 2.3.6, to become shorter, as the online community will evaluate, create awareness, produce and provide after sales assistance faster than traditional methods. The model of complexity of open design will be used to link the customer as a prosumer to the structure of the local supplier.

- Customer Segments

Customer segments will change to any individual requiring a specific product for their specific need. As stated in section 2.3.7, customer segments are important to identify as it can shape the way the product/service is designed, manufactured and presented as it needs to appeal towards the customer segments the local supplier has selected. However, social manufacturing is flexible in this regard, as the latest manufacturing technology enables the production possibilities to be broad compared to the traditional methods. The online platforms will be scalable as the experiments proved that the model of complexity for open design is a natural phenomenon and can work for larger customer segments.

- Cost Structure

Crowd funding mechanisms can help to establish the smart community factories for local suppliers as this will be the biggest cost to the company. From the 99percentDesk validation experiment, it is clear that crowd funding can be used to fund projects for local suppliers. If current free crowd companies does not offer the functionality required by the local supplier then the software development platform cost is important as the online community needs a platform to be driven from. The online platform development and smart community factory are the most expensive factors. If these factors are in place, the company will be able to run it self. Social manufacturing saves significant costs in labour, capital costs, inventory, complexity, quality assurance, maintenance, and logistics with the use of crowd companies and the online community as human resources.

- Revenue Streams

Crowd funding mechanisms can be used to secure initial funding to start local suppliers as proven in the 99percentDesk validation experiment. Crowd funding will remain a support

revenue stream, however, the product or service will be co-created and therefore will be exactly what the customer requires. This ensures that the customer will be willing to pay more than for the normal standard products that traditional manufacturing industries provide. Payment will be electronic and no money will be physically exchanged. Customers prefer this due to the convenience and safety. As discussed in section 2.3.9, the pricing method used in social manufacturing will be differential pricing as this depends on the volume of products and customer preference. The other two revenue streams will be online shopping and online marketing (advertising) through Social Media platforms.

Below is a summary of the BMC for social manufacturing. Please note: Only the important information is summarised in this model due to limited space.

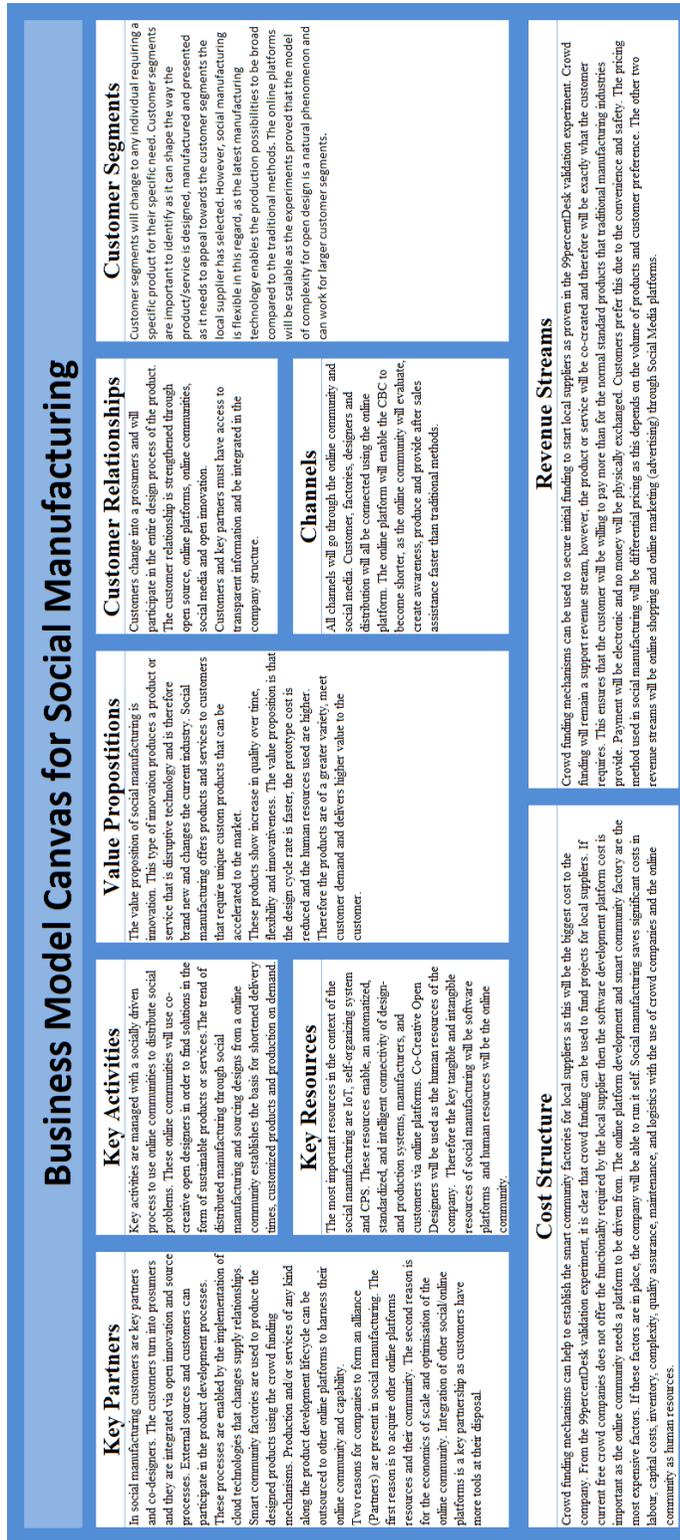


Figure 5-21: Business model canvas for social manufacturing

5.4.6 Validation of Research Objectives Results Summary

The results obtained from this section indicated the following with regards to the research objectives as described in Table 5-1:

- The first research objective was achieved using the comparison between social- and traditional manufacturing as shown in Figure 5-16.
- The second research was achieved through the BBfA experiment to develop the PDL and BMC for social manufacturing as shown in Figure 5-20 and Figure 5-21 respectively.
- The third research objective was achieved through the 99percentDesk validation experiment to validate and improve the PDL and BMC for social manufacturing as shown in Figure 5-20 and Figure 5-21 respectively.

6. CONCLUSION AND RECOMMENDATIONS

This chapter is divided into recommendations for future work in this field and the conclusion of this study.

6.1 Conclusion

The aim of this study was to investigate social manufacturing business elements that would lead to the development of a business model tool that local suppliers can use to incorporate social manufacturing in their business. In order to understand social manufacturing, the other manufacturing paradigms were investigated. This investigation was used to understand the different aspects of the revolutions the manufacturing industry has gone through the past two centuries. Crowd Companies was investigated to see how online communities currently affected manufacturing and other industries. The business model canvas (BMC) was identified as a suitable basis for the generic business model to be developed in this study. Social manufacturing is a complex system and the complexity in manufacturing was investigated to understand the concepts behind complex networks.

The research methodology was divided into three experiments, namely the One Week Challenge (background case study), Bamboo Bikes for Africa experiment and the 99percentDesk validation experiment. The OWC was used to understand the basic concepts of social manufacturing and resulted in the development of the model of complexity of open design. This model was then used to structure the complexity behind managing the online community through Social Media platforms. The BBfA experiment was then used to develop the product development lifecycle (PDL) and the BMC for social manufacturing. The PDL and the BMC was then validated and improved with the 99percentDesk validation experiment.

The study was divided into three research objectives that needed to be achieved. The first research objective was achieved using a comparison of the business model elements of social manufacturing compared to traditional manufacturing methods. The second research objective was achieved developing a generic business model to support local suppliers with the BBfA experiment. The third research objective was achieved validating the generic business model with the 99percentDesk validation experiment.

Therefore, this study achieved all three the research objectives and showed that utilising the online community can have significant results for local suppliers in the manufacturing industry. Social manufacturing is predicted to start by the year 2020 and using the tools developed in this study can support local suppliers to use social manufacturing to construct a business edge on their international competitors. This study indicated the business benefit of crowd sourcing and using an online community in the design phase of a manufacturing company.

6.2 Recommendations

- This study developed a generic business model for any type of local supplier to incorporate social manufacturing in their business, however, for future research this generic business model can be tested and refined to be improved to a more specific product or service.
- This business model is based on free online platforms that are crowd based. Future research can develop an online platform that incorporates the model of complexity of open design.
- Further research and validation can be done for the production and support phase of the PDL. The production phase will include the smart- and community factories. The support phase will include a validation of after sale support of the product through an online community as the source of the support tool.
- Research can be done to investigate the most effective method to force community co-creation by changing the incentives or rewards of the project.

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APPENDIX A: BACKGROUND CASE STUDY - ONE WEEK CHALLENGE

The results and data documented for the One Week Challenge background case study is shown in this appendix. The results are discussed in section 5.1.

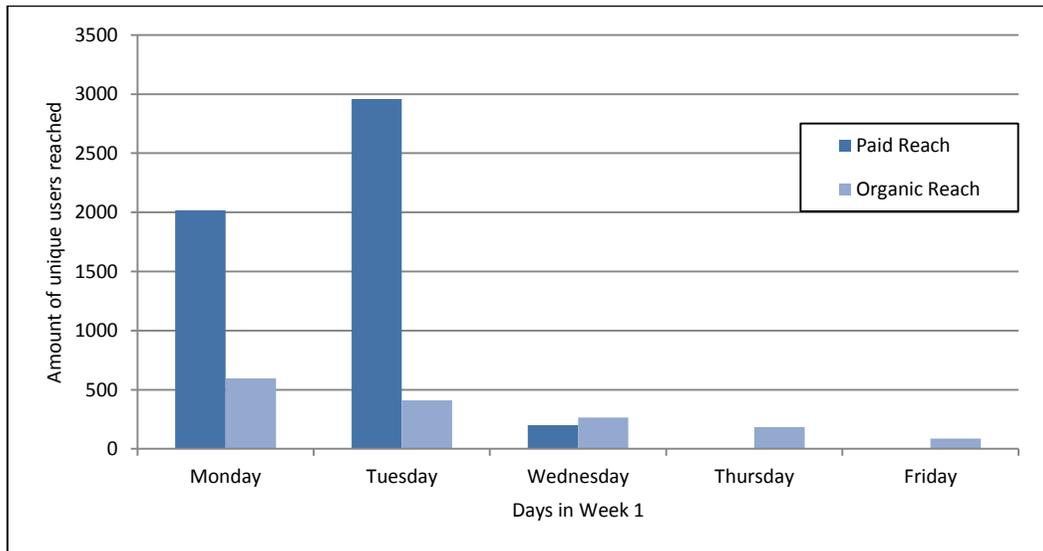


Figure A-1: Amount of unique users reached (Organic-R Reach and Paid-R Reach) for OWC Facebook page for week 1

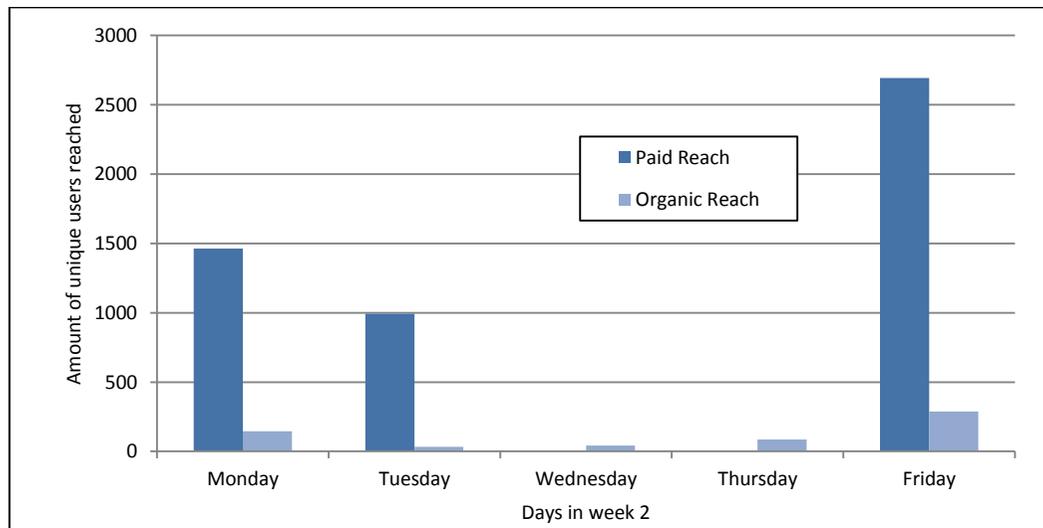


Figure A-2: Amount of unique users reached (Organic-R Reach and Paid-R Reach) for OWC Facebook page for week 2

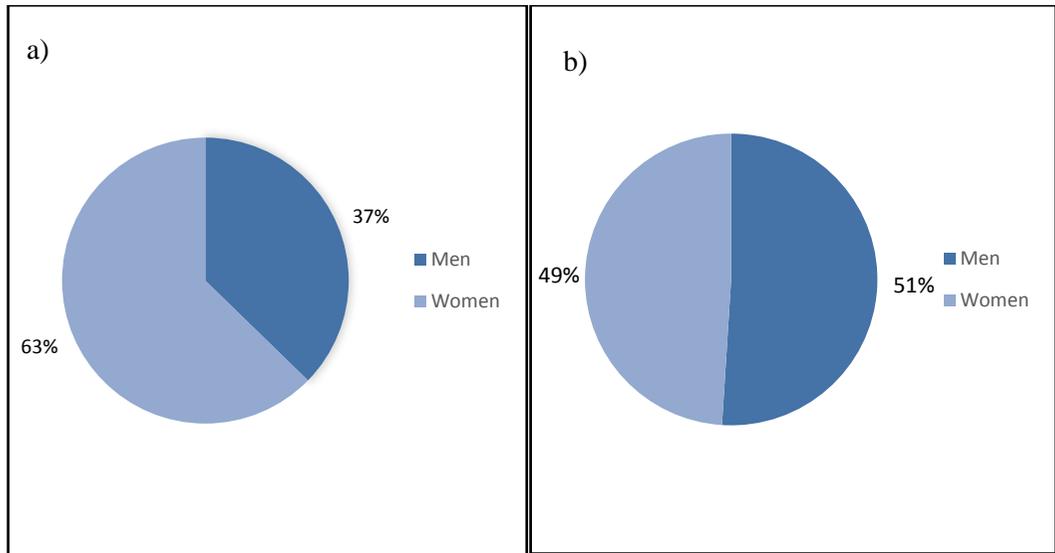


Figure A-3: a) Post engaged by gender for week 1 of the OWC and b) Post engaged by gender for week 2 of the OWC

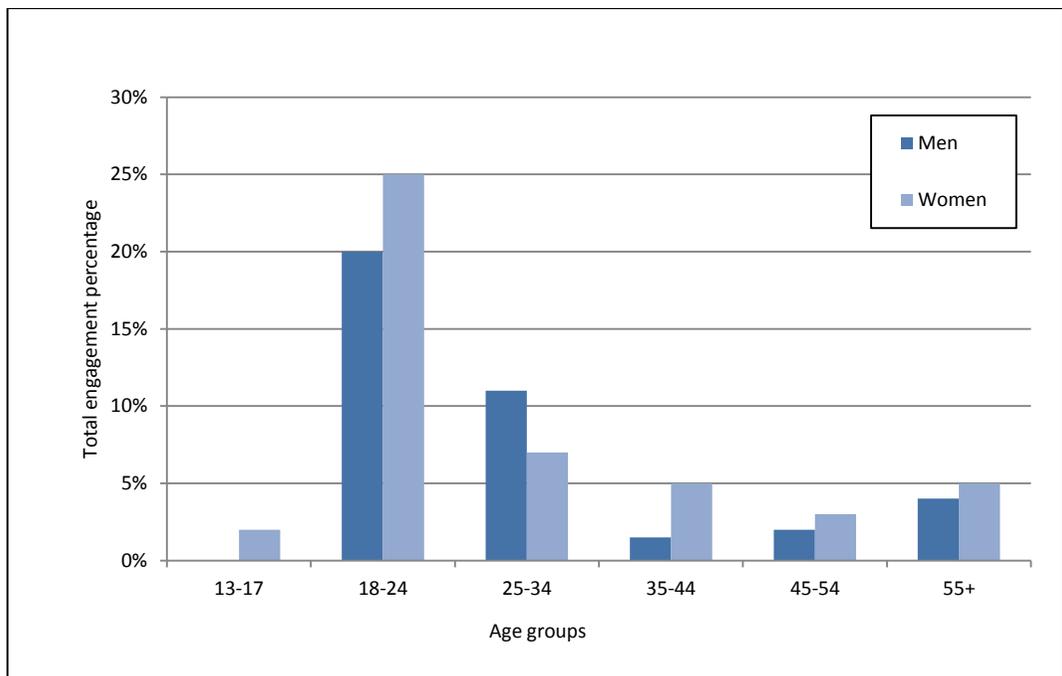


Figure A-4: People engaged by age on the Facebook page during the OWC for week 1

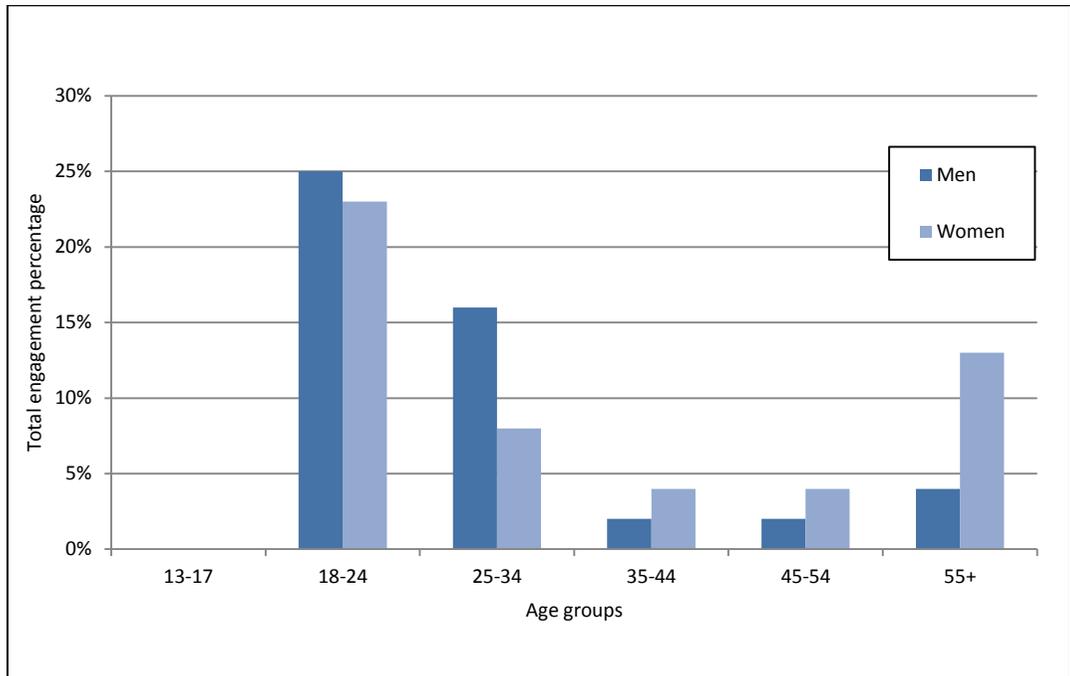


Figure A-5: People engaged by age on the Facebook page during the OWC for week 2

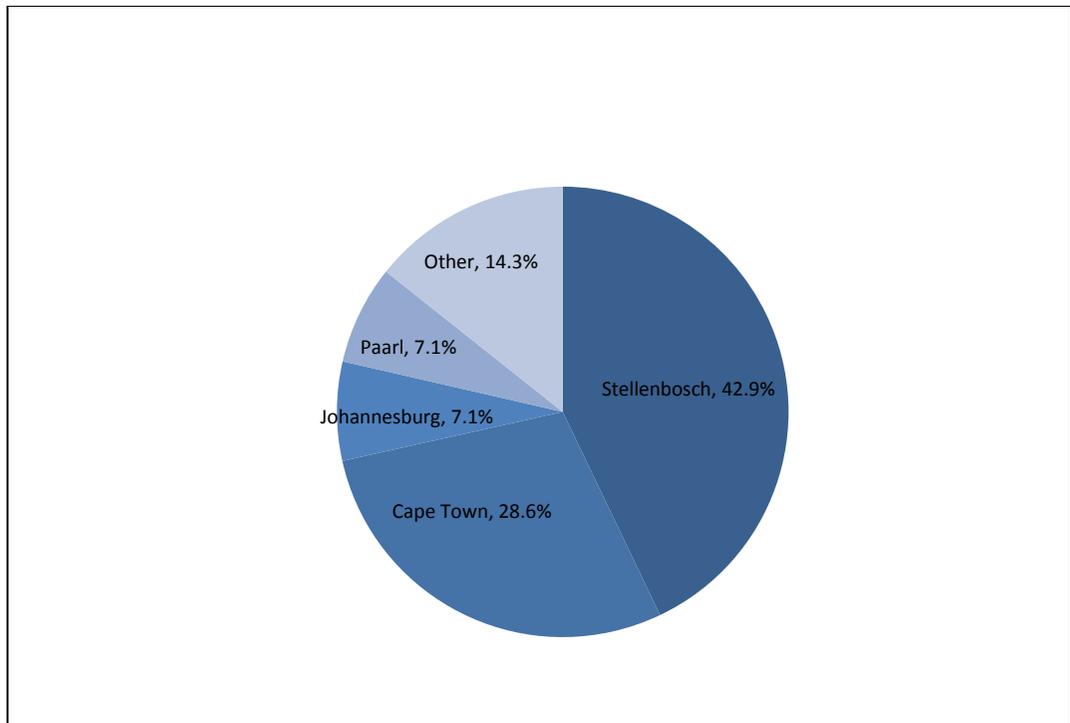
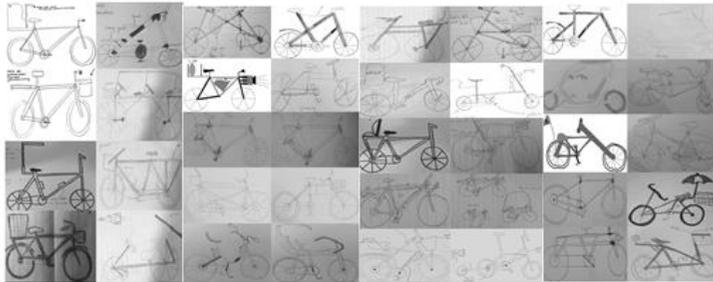
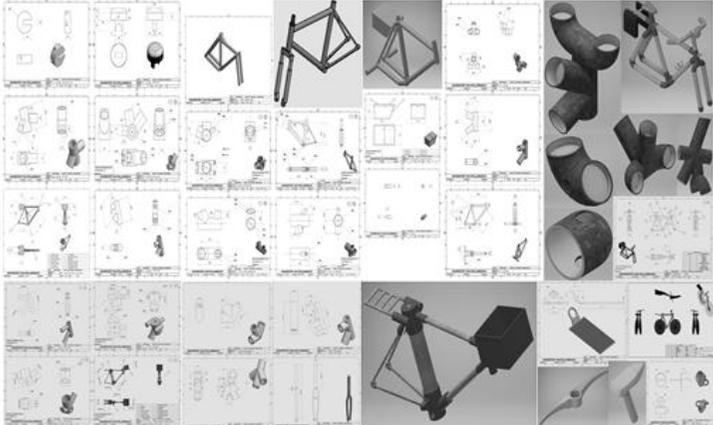


Figure A-6: People engaged by location on the Facebook page during the OWC for week 1 and week 2 (Adapted from [124])

APPENDIX B: BAMBOO BIKES FOR AFRICA EXPERIMENT

The process, results and data documented for the Bamboo Bikes for Africa experiment is shown in this appendix. The results are discussed in section 5.2.

Table B-1: Designs from the BBfA experiment.

Description of the designs	Example of the designs from the BBfA
<p>Examples of the initial conceptual free-hand sketches from week 1 of the BBfA experiment. The designs are not specifically ranked in quality according to a matrix, however, it is clear that the designs are of lower quality compared to the later stage conceptual sketches.</p>	
<p>Examples of the later stage conceptual free-hand sketches from week 1 of the BBfA experiment. The designs are not specifically ranked in quality according to a matrix, however, it is clear that the designs are of higher quality compared to the later stage conceptual sketches.</p>	
<p>Examples of the final CAD sketches from week 2 of the BBfA experiment.</p>	

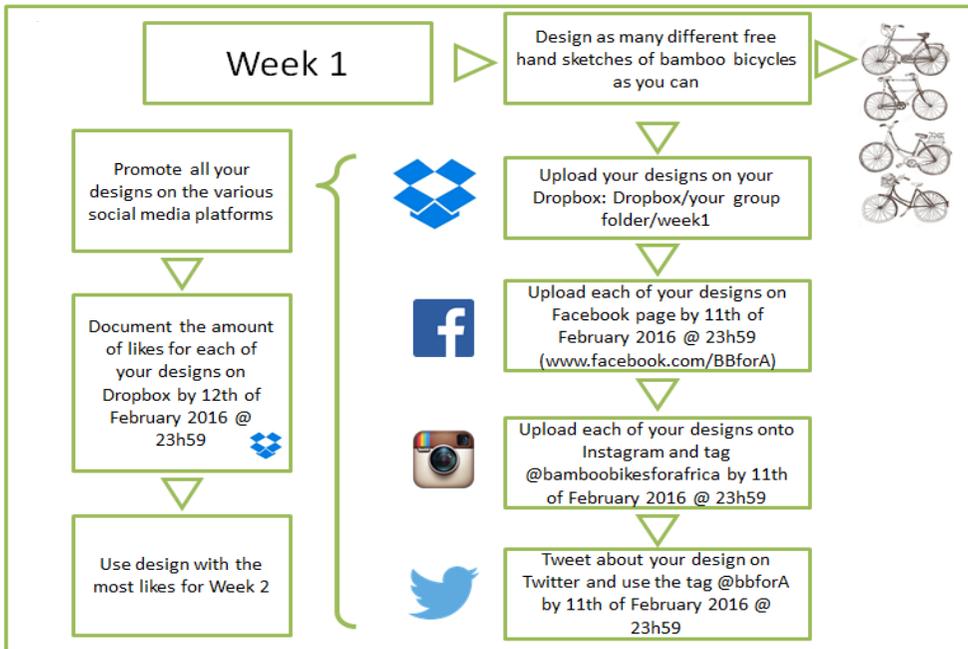


Figure B-1: Week 1 process illustrating the co-creation and open design steps for the BBfA experiment [14]

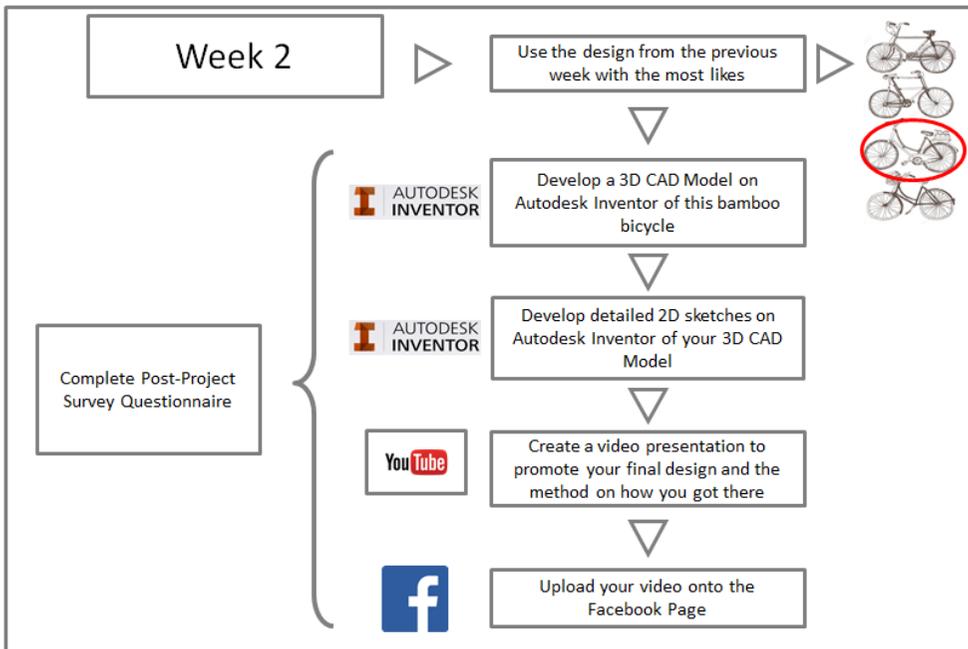


Figure B-2: Week 2 process illustrating the co-creation and open design steps for the BBfA experiment [14]

First prototype Bamboo Bicycle Joints CAD drawings

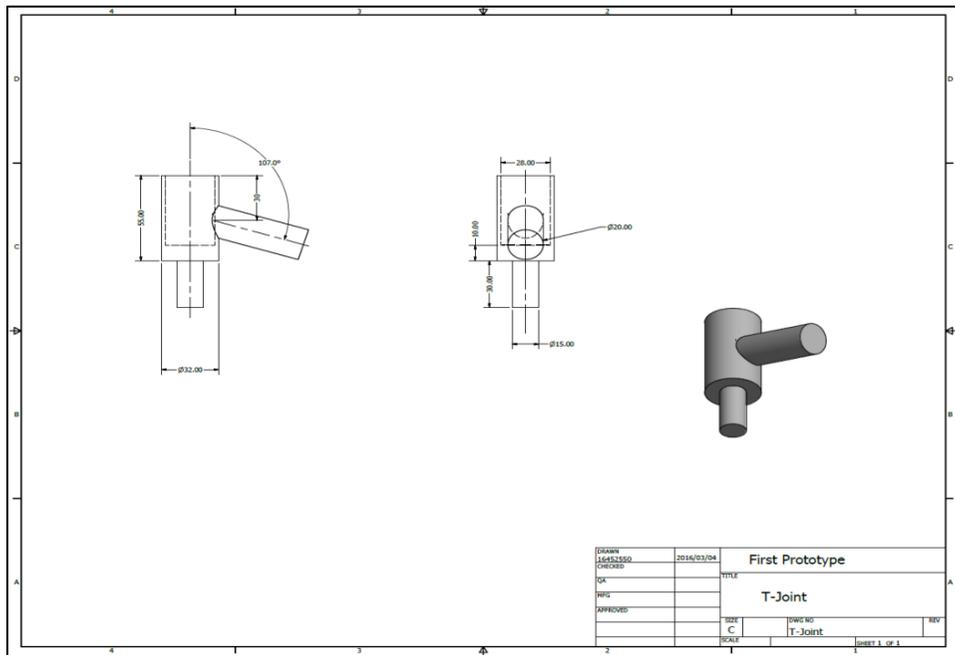


Figure B-3: Final prototype Bamboo Bicycle T-joint CAD detailed design

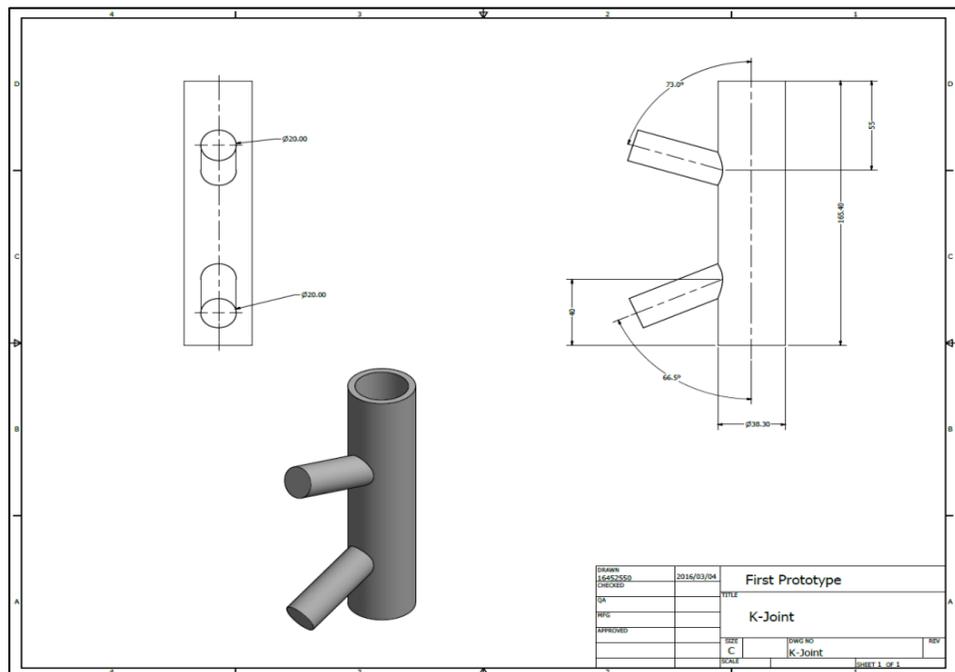


Figure B-4: Final prototype Bamboo Bicycle K-joint CAD detailed design

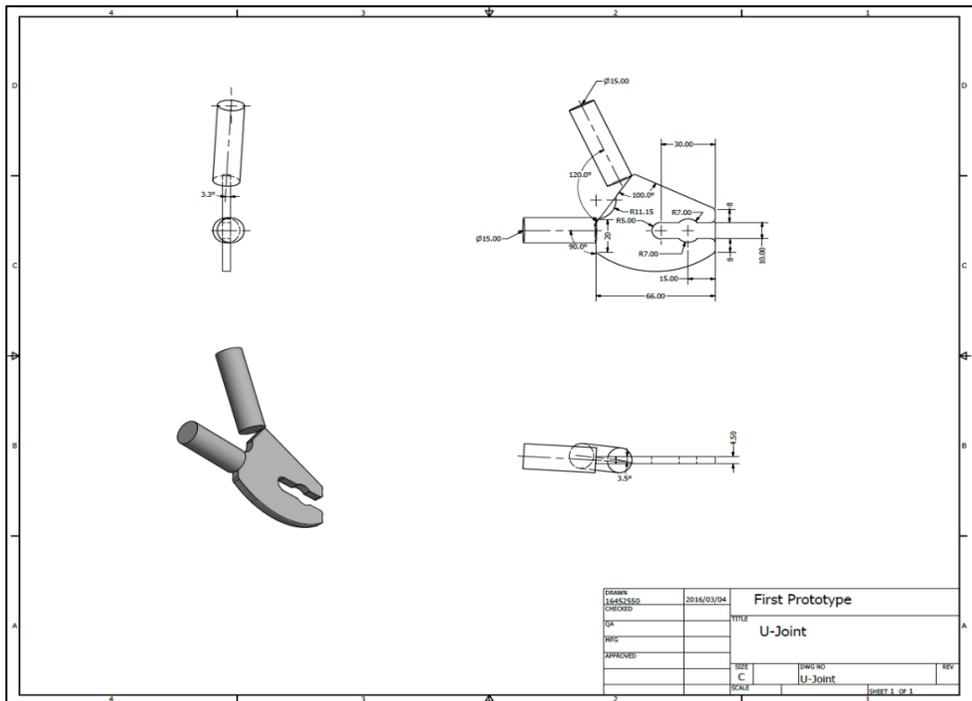


Figure B-5: Final prototype Bamboo Bicycle U-joint CAD detailed design

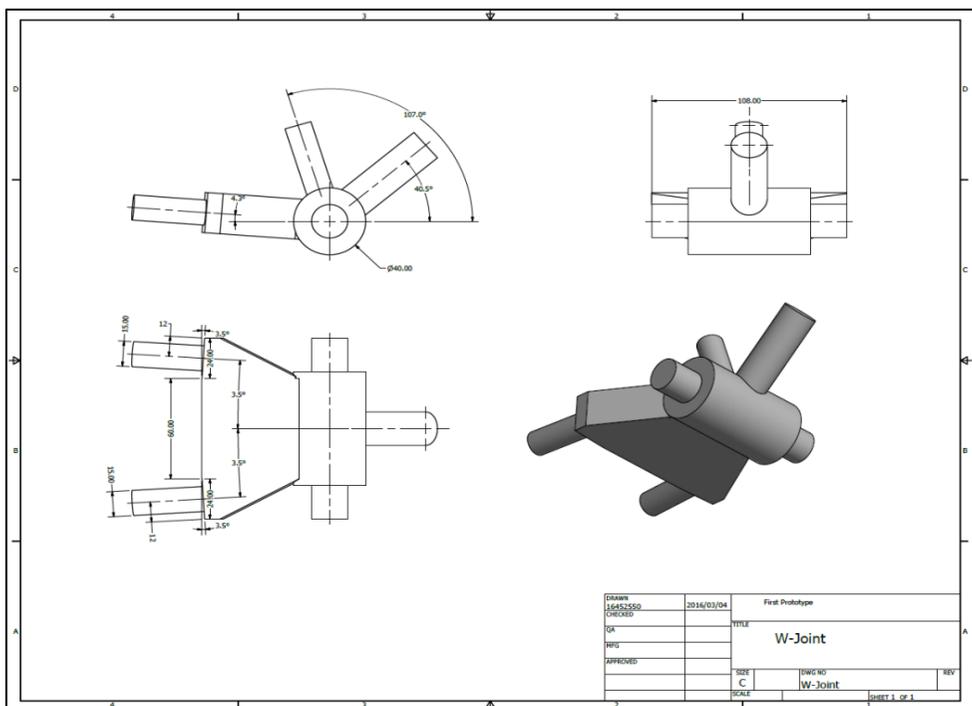


Figure B-6: Final prototype Bamboo Bicycle W-joint CAD detailed design

APPENDIX C: POWER LAW DATA TABLE

The data for the Power Law for the Bamboo Bikes for Africa and 99percentDesk experiments are shown in this appendix. The results are discussed in sections 5.2.2 and 5.3.2.

Table C-1: BBFA experiment Power Law table

Post nr	Lifetime Post organic reach (Percentage of Connections)	% of Total Reach	Total individual post reach	Total population/ Total individual post reach
1	1207	35.531	2098	1.619
2	639	18.811	947	3.587
3	475	13.983	695	4.888
4	468	13.777	706	4.812
5	464	13.659	709	4.791
6	455	13.394	774	4.389
7	446	13.129	872	3.896
8	426	12.540	638	5.324
9	414	12.187	666	5.101
10	402	11.834	621	5.470
11	402	11.834	638	5.324
12	400	11.775	776	4.378
13	392	11.540	664	5.116
14	387	11.392	623	5.453
15	380	11.186	741	4.584
16	369	10.863	608	5.587
17	368	10.833	581	5.847
18	367	10.804	617	5.506
19	363	10.686	575	5.908
20	362	10.656	587	5.787
21	360	10.598	564	6.023
22	353	10.392	558	6.088
23	350	10.303	705	4.818
24	341	10.038	567	5.991
25	335	9.862	520	6.533
26	333	9.803	594	5.719
27	330	9.714	544	6.244
28	330	9.714	598	5.681
29	327	9.626	594	5.719
30	315	9.273	830	4.093
31	308	9.067	481	7.062
32	303	8.920	494	6.877
33	301	8.861	542	6.268
34	295	8.684	526	6.458
35	283	8.331	448	7.583
36	283	8.331	484	7.019
37	281	8.272	451	7.532
38	278	8.184	421	8.069
39	270	7.948	482	7.048
40	252	7.418	367	9.256
41	248	7.301	352	9.651
42	248	7.301	471	7.212
43	246	7.242	420	8.088
44	236	6.947	388	8.755
45	232	6.830	334	10.171
46	230	6.771	347	9.790
47	229	6.741	393	8.644
48	227	6.682	333	10.201

49	227	6.682	689	4.930
50	223	6.565	352	9.651
51	219	6.447	368	9.231
52	218	6.417	317	10.716
53	214	6.300	419	8.107
54	209	6.152	332	10.232
55	205	6.035	337	10.080
56	203	5.976	370	9.181
57	202	5.946	334	10.171
58	198	5.829	297	11.438
59	198	5.829	320	10.616
60	196	5.770	304	11.174
61	196	5.770	289	11.754
62	195	5.740	287	11.836
63	194	5.711	321	10.583
64	192	5.652	354	9.596
65	192	5.652	312	10.888
66	187	5.505	294	11.554
67	186	5.475	317	10.716
68	184	5.417	302	11.248
69	180	5.299	274	12.398
70	180	5.299	307	11.065
71	176	5.181	301	11.286
72	176	5.181	327	10.388
73	173	5.093	265	12.819
74	171	5.034	247	13.753
75	170	5.004	242	14.037
76	170	5.004	247	13.753
77	167	4.916	231	14.706
78	166	4.887	245	13.865
79	166	4.887	298	11.399
80	166	4.887	302	11.248
81	162	4.769	254	13.374
82	162	4.769	258	13.167
83	162	4.769	251	13.534
84	158	4.651	254	13.374
85	158	4.651	240	14.154
86	156	4.592	267	12.723
87	156	4.592	257	13.218
88	155	4.563	273	12.443
89	154	4.533	250	13.588
90	153	4.504	242	14.037
91	151	4.445	224	15.165
92	149	4.386	231	14.706
93	147	4.327	242	14.037
94	147	4.327	231	14.706
95	143	4.210	259	13.116
96	142	4.180	228	14.899
97	138	4.062	232	14.642
98	135	3.974	240	14.154
99	134	3.945	215	15.800
100	134	3.945	221	15.371
101	133	3.915	188	18.069
102	132	3.886	226	15.031
103	131	3.856	193	17.601
104	130	3.827	228	14.899
105	130	3.827	245	13.865
106	127	3.739	216	15.727
107	126	3.709	204	16.652
108	126	3.709	208	16.332
109	126	3.709	208	16.332
110	124	3.650	205	16.571
111	124	3.650	203	16.734

112	123	3.621	188	18.069
113	123	3.621	214	15.874
114	122	3.591	192	17.693
115	119	3.503	182	18.665
116	117	3.444	175	19.411
117	116	3.415	179	18.978
118	116	3.415	188	18.069
119	114	3.356	163	20.840
120	113	3.326	167	20.341
121	112	3.297	196	17.332
122	111	3.268	184	18.462
123	111	3.268	174	19.523
124	109	3.209	189	17.974
125	108	3.179	176	19.301
126	106	3.120	164	20.713
127	98	2.885	175	19.411
128	97	2.855	150	22.647
129	97	2.855	171	19.865
130	96	2.826	149	22.799
131	96	2.826	157	21.637
132	94	2.767	136	24.978
133	90	2.649	152	22.349

Table C-2: 99percentDesk validation experiment Power Law table

Post nr	Lifetime Post organic reach (Percentage of Connections)	% of Total Reach	Total individual post reach	Total population/ Total individual post reach
1	1184	42	1915	148
2	800	28	1606	176
3	581	21	1411	200
4	513	18	1088	260
5	408	14	776	365
6	406	14	1009	280
7	349	12	706	401
8	313	11	565	501
9	300	11	841	336
10	295	10	814	348
11	271	10	605	468
12	252	9	345	820

APPENDIX D: 99PERCENTDESK VALIDATION EXPERIMENT

The process, results and data documented for the Bamboo Bikes for Africa experiment is shown in this appendix. The results are discussed in section 5.3.

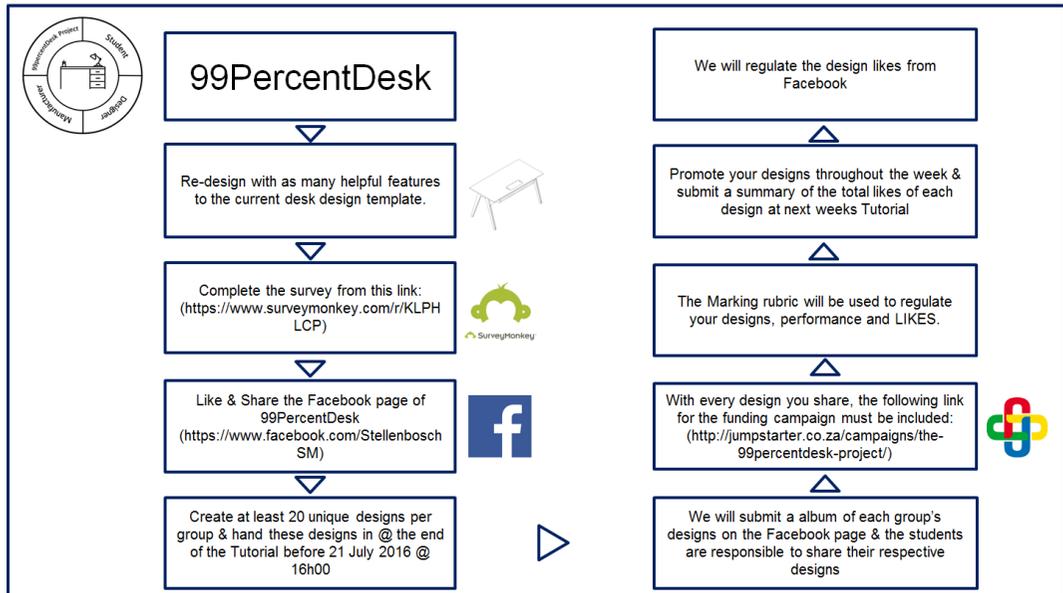


Figure D-1: The process illustrating the co-creation and open design steps for the 99percentDesk validation experiment

99percentDesk Sketches

Shown in this section are the free-hand sketches for the 99percentDesk validation experiment. The designs are divided into the different groups. Each group submitted 20 different desk designs using the template design from Figure D-2. The designs from group 1 are shown in Figure D-3 and all the remaining designs are shown in Figure D-4.

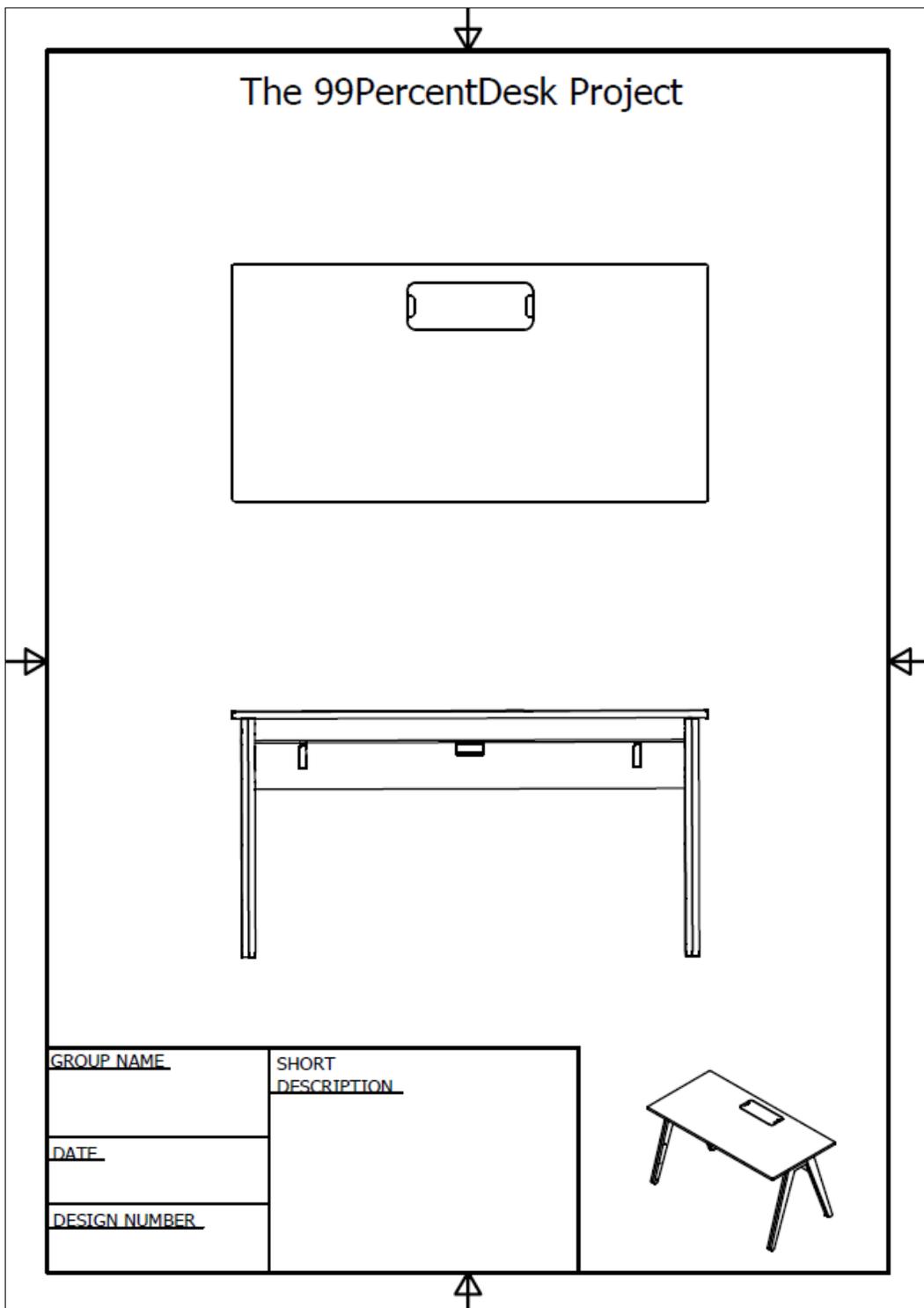


Figure D-2: 99percentDesk template design

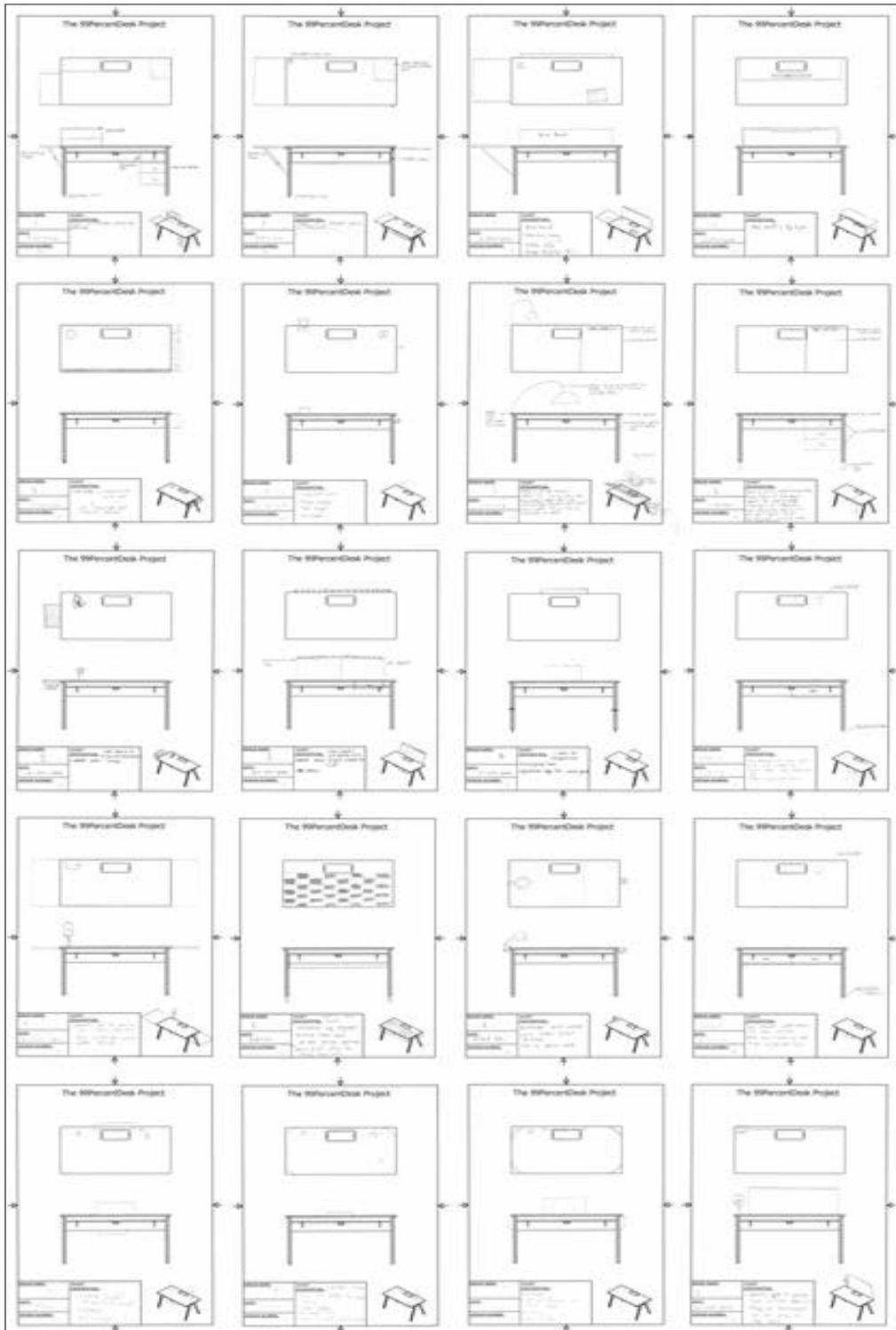


Figure D-3: Group 1 designs from the 99percentDesk validation experiment



Figure D-4: Group 2-10 designs from the 99percentDesk validation experiment

Final CAD Design for the 99percentDesk

All the features from the IC designs have been taken into consideration in the final CAD design. Below is the final CAD design from different angles.



Figure D-5: Final CAD design for 99percentDesk

APPENDIX E: SOCIAL MEDIA PLATFORMS FOR THE EXPERIMENTAL PROJECTS

The Social Media platforms (Facebook page and crowd funding page) used in the experimental projects are shown in this appendix.

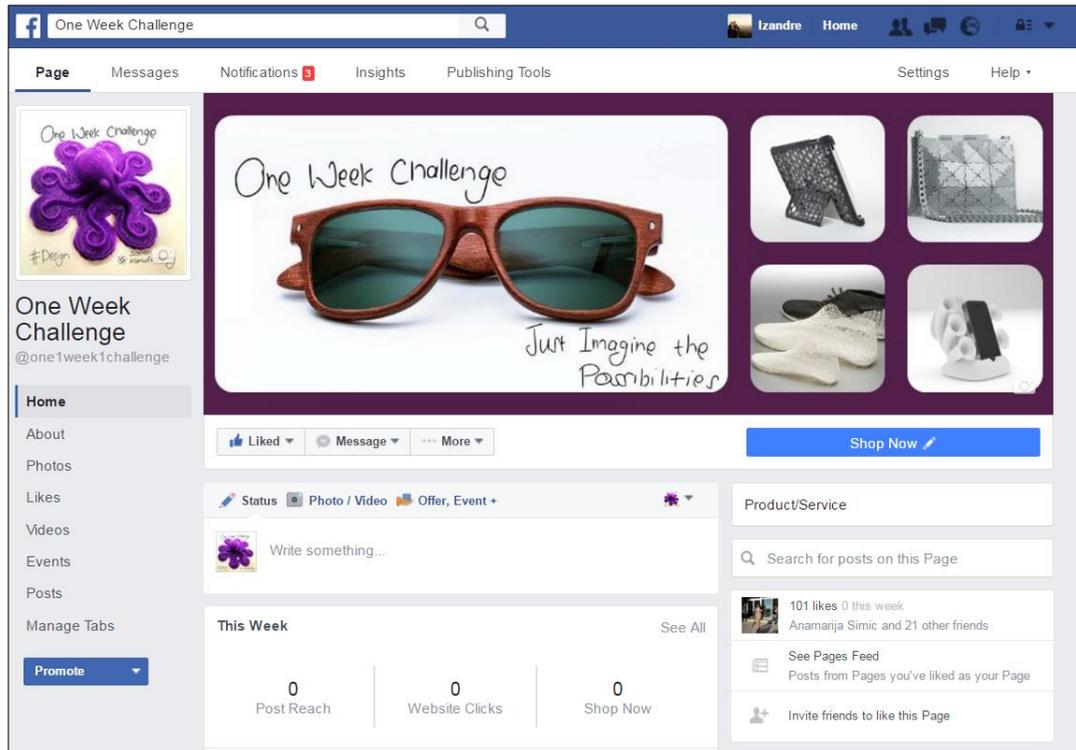


Figure E-1: One Week Challenge Facebook page

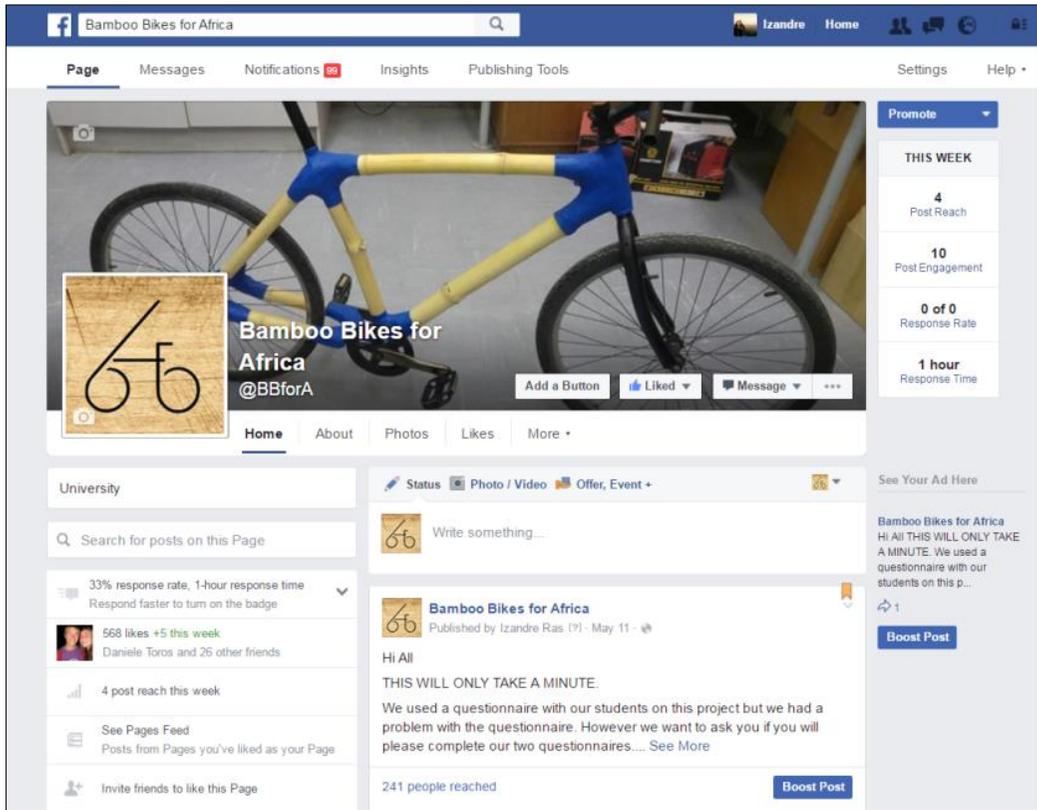


Figure E-2: Bamboo Bikes for Africa Facebook page

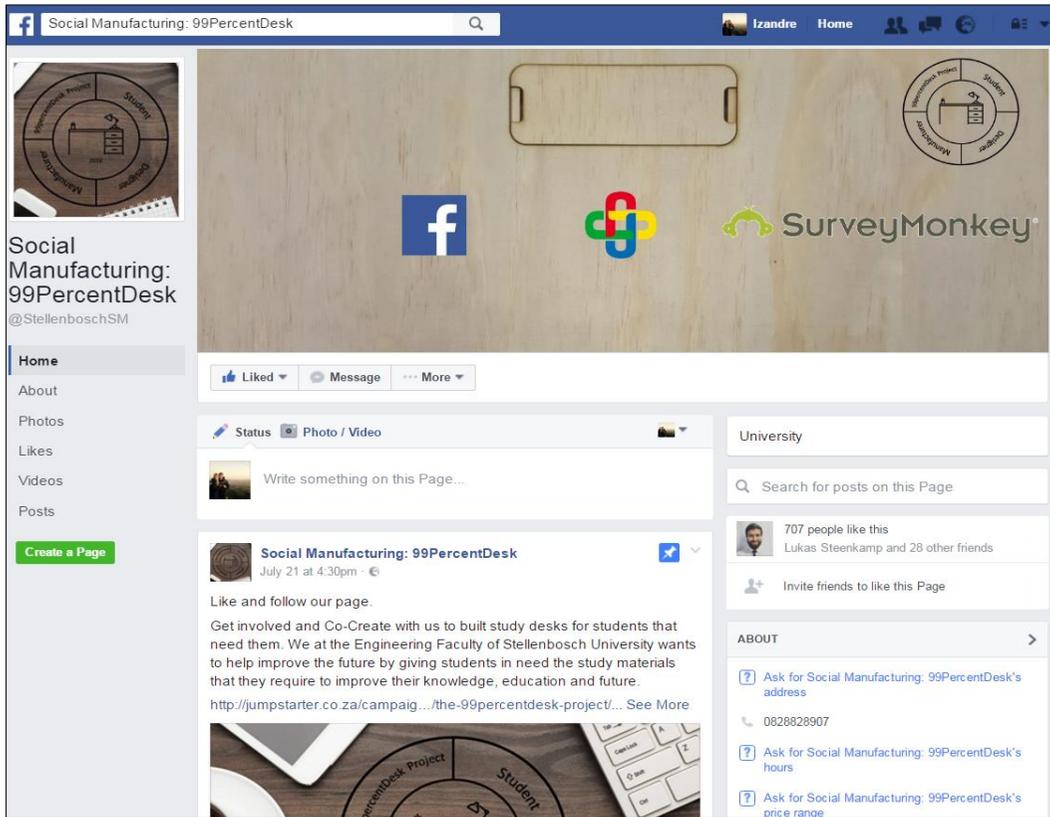


Figure E-3: 99percentDesk Facebook page

The screenshot shows the Jumpstarter crowdfunding website for the 99percentDesk project. The header includes the Jumpstarter logo and navigation links for START, BLOG, FAQ, CONTACT, and ACCOUNT. The main heading is "THE 99PERCENTDESK PROJECT BY STELLENBOSCH UNIVERSITY". Below this, there are buttons for COMMENTS and BACKERS, and a search bar. The central image features a desk setup with a circular diagram divided into four quadrants: "99percentDesk Project", "Student", "Manufacturer", and "Designer". The diagram also includes a desk icon, a lamp, and the year "2016". To the right of the image, a green progress bar indicates a goal of ZAR 5,000.00, with 7 backers and 1 day to go. A prominent green "CONTRIBUTE NOW" button is visible. At the bottom, a footer contains project details: "Launched: June 17, 2016", "Funding Ends: August 16, 2016", and "Stellenbosch, South Africa". An "ABOUT THE AUTHOR" section is partially visible at the bottom right.

Figure E-4: Jumpstarter (Crowd funder) website for the 99percentDesk

APPENDIX F: QUESTIONNAIRE OF THE 99PERCENTDESK RESULTS

The questionnaire results and data documented for the 99percentDesk experiment is shown in this appendix. The results are discussed in section 5.3.4.

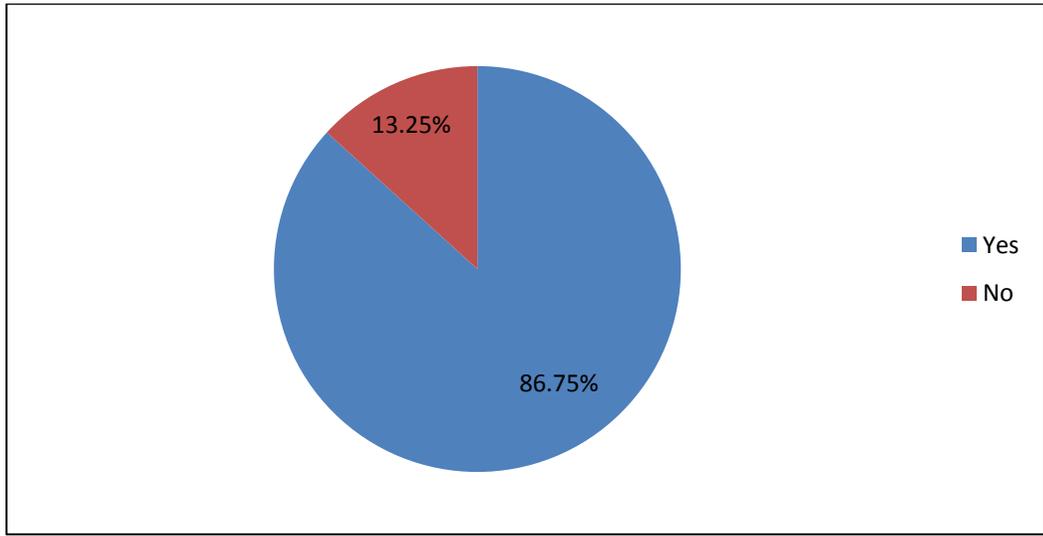


Figure F-1: Results of question 1 - Do you have a 'Facebook' account at the moment?

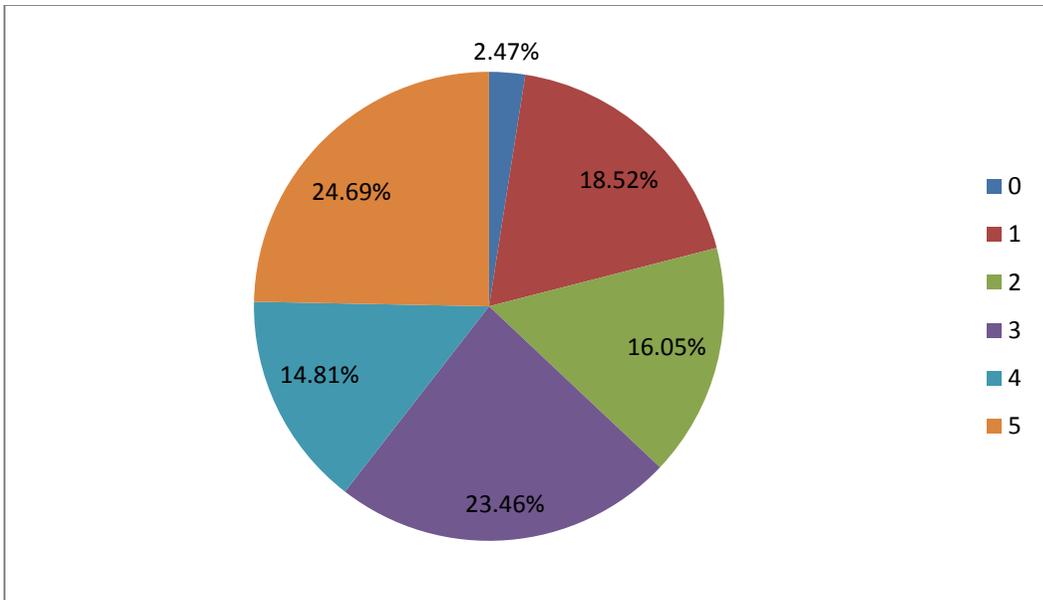


Figure F-2: Results of question 2 - How active are you on a daily bases on Social Media rated from 0 to 5?(0 being never and 5 being you go onto Social Media at least 5 times a day)

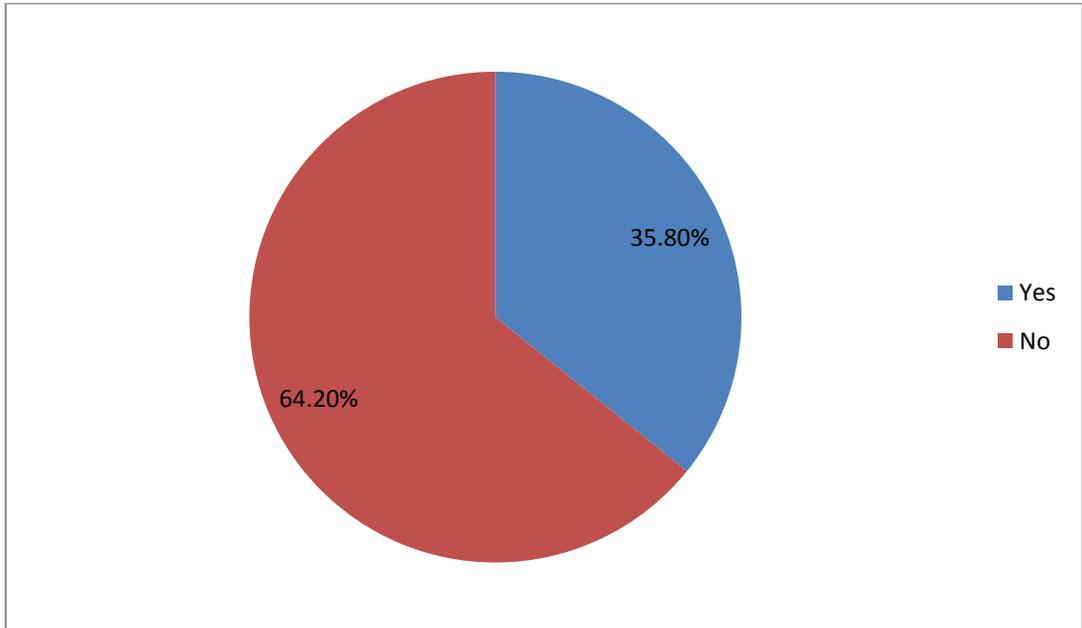


Figure F-3: Results of question 3 - Do you know anything about 'Co-creation' and/or 'Open Source Software'?

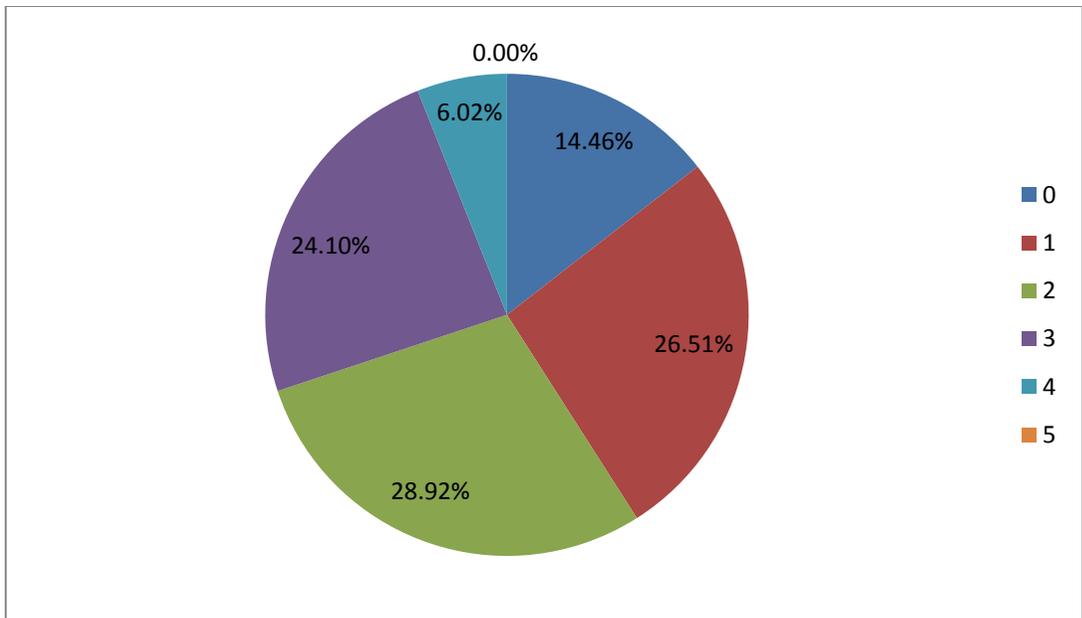


Figure F-4: Results of question 4 - What would you say is your knowledge of 'Social Manufacturing' rated from 0 to 5? (0 being nothing and 5 being very high)

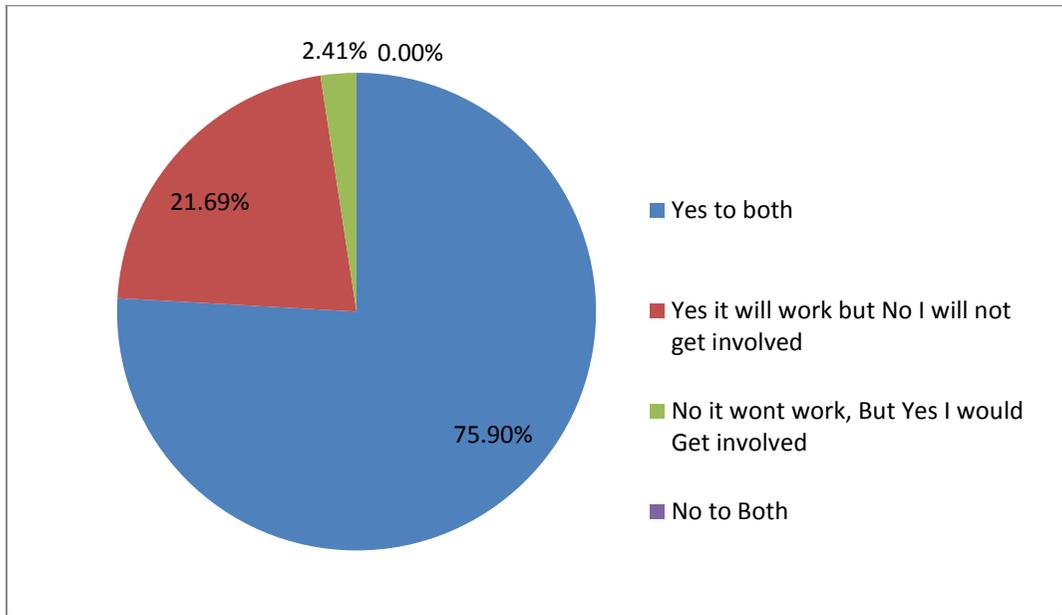


Figure F-5: Results of question 5 - Do you think a company can use an online community to design products and will you get involved in something like that?

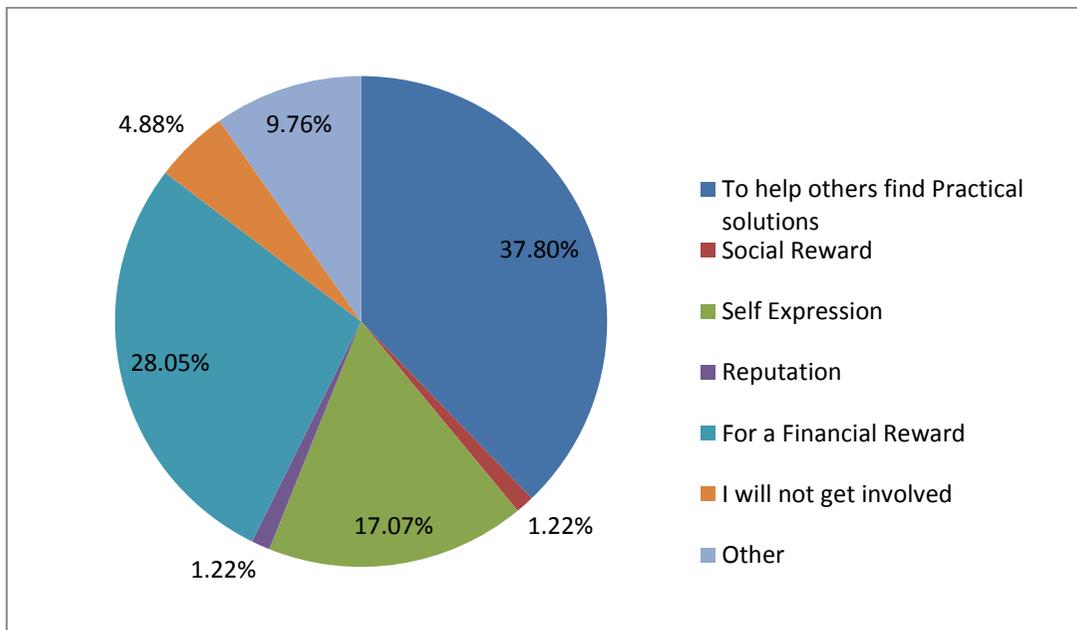


Figure F-6: Results of question 6 - If you would get involved in designing a product online, what would the reason be?

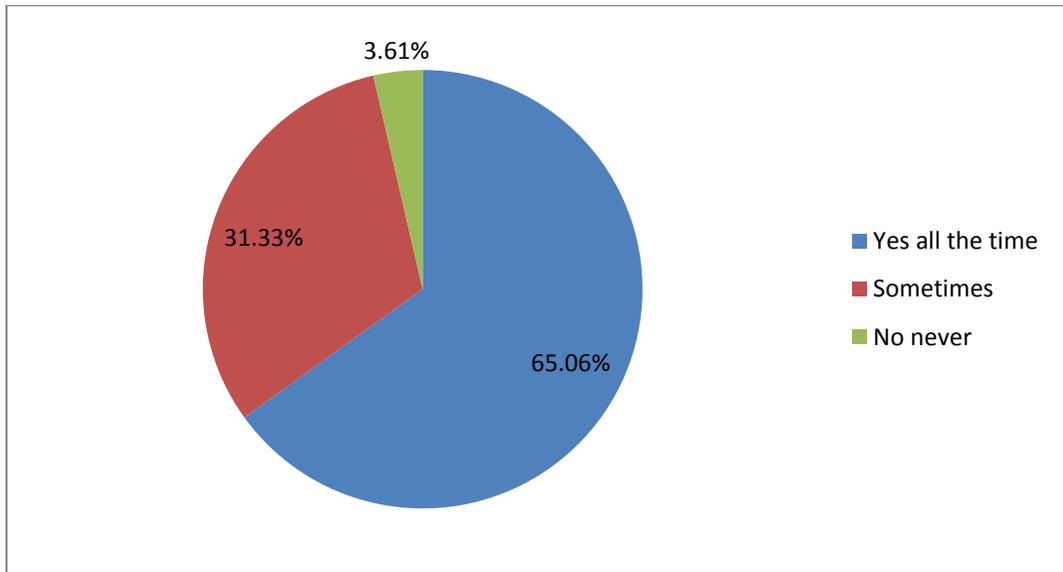


Figure F-7: Results of question 7 - Have you ever used the internet to find practical solutions (e.g. A quick solution to a problem or a product that you can easily build to help you around the house)?

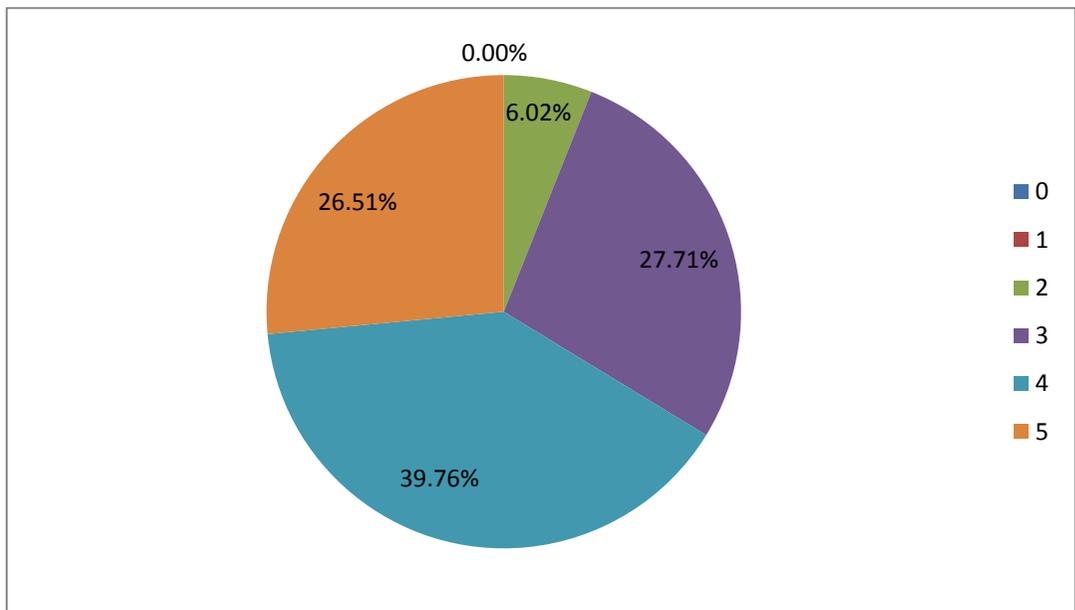


Figure F-8: Results of question 8 - Thinking of a situation, if any, where you had to use the internet for a practical solution, rated from 0 to 5(0 being not at all and 5 being very effective), how effect would you say was the solution?

APPENDIX G: IAMOT SOCIAL MANUFACTURING BAMBOO BIKES FOR AFRICA PAPER

The paper on the Bamboo Bikes for Africa experiment, that was submitted and accepted to the IAMOT conference in USA, is shown in this appendix.