Affecting over-engineering with elements and factors of frugal innovations

The cases of the mobile phone industry and medical industry for the Bottom of the Pyramid

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Preface

Dear reader,

This thesis "Affecting over-engineering with elements and factors of frugal innovations" that lies in front of you, presents research that was conducted regarding frugal innovations, of which the factors could affect over-engineering. These factors are affected by elements. This research has been done for the the mobile phone and medical industry. The thesis was written to complete the Management of Technology program's graduation requirements at Delft University of Technology (TUD). From February through September of 2022, I was studying and writing this thesis.

Unfortunately, during my studies in the Management of Technology program, I could not enjoy being a student at the TPM faculty much due to the current COVID-19 pandemic. However, I did enjoy the study and people I met. It gave me a feeling of still belonging somewhere, especially during the difficult time of COVID-19.

Without the help of many people, my thesis would not have been possible. First, I would like to thank my first supervisor **Prof.dr. C.P. (Cees) van Beers** for his guidance, feedback and time during this process. He pushed me into the right direction when I felt at loss. I would also like to thank my second supervisor **Prof.dr.ir. I.R. (Ibo) van de Poel** for sharing his insights and giving feedback during the kick-off, midterm and greenlight meeting. Giving feedback and criticism by both my supervisors on my work allowed me to develop it into what it is now.

Finally, I would like to thank my boyfriend **Dirk-Jan Rosenmuller** for the moral support, encouragement, love and the burden of being my go-to person when I felt stressed, sad or happy. Without him, I would not be able to go through the most difficult parts of my student life, including my thesis. I would like to thank my closest friends **Pranathi Srikrishna** and **Nikki Bouman** for keeping the student life fun and helping me through. I would also like to thank my parents for their moral support. My parents, **Sharda Akloe** and **Roberto Hanuman** always stood by my decisions, made it possible for me to study and enabled me to achieve what I aimed for in my life. Without them, graduating at a university and achieving most of my other accomplishments would not have been possible. I am forever grateful for their support, sacrifices, encouragement and love.

I hope you enjoy your reading.

Vanisha Jaggi
Rotterdam, September 23, 2022

Executive Summary

About half of the world's population lives at the Bottom of the Pyramid. They are the "base" of the income pyramid, which are the poorest people of the world and are underserved in the market. Many products and services are unavailable to the this group, because of over-engineering. Over-engineering is when a product or a solution to a problem is designed in an intricate or sophisticated manner when a simpler option can be proved to exist with the same efficiency and effectiveness as the original design and is more expensive in terms of price. This problem is often seen in the medical industry, of which medical care is a basic necessity of life, and the mobile phone industry, which on the other side of the spectrum is not a basic necessity of life. For the latter, the low-income consumers have devised techniques to save expenses while maintaining communication access, however, it affects them negatively. On the other hand, medical equipment must adhere to regulations such as safety, which is one reason the price and complexity of the equipment are increased. Those people in need may not be able to afford the over-engineered equipment or not be able to operate it, while it may be of medical importance for them. Therefore, it is crucial to find a solution to this issue. A potential solution for over-engineering in both industries could be frugal innovations. Frugal innovations are new innovations that are often associated with affordability in terms of price, low-cost production (and other operational/financial aspects) which could relate to the business model, low-cost materials and design that focuses on fundamental functioning and feature sets for the unserved end of the mass market, while meeting or even exceeding certain pre-defined quality standards.

However, adequate literature on the connection between over-engineering and frugal inventions had not been found. Therefore, the following primary research question has been asked in this study in order to further analyse this relationship: *How can frugal innovations have an impact on over-engineering in the mobile phone industry and in the medical industry?* This question is relevant, because little literature can be found regarding this topic, hence, this proposed research will have the scientific research relevance to how frugal innovations can affect over-engineering, with the focus on the mobile phone industry and medical industry and thereby contributing to closing the research gap. Furthermore, research regarding the effect of frugal innovations on over-engineering is highly societally relevant, since overly complex and expensive products are unavailable to the majority of the world's population, but can be made available to them. These products can vary from luxury products to products of medically importance.

To answer the research question, literature research has been done followed by two case studies: one for the medical industry and one for the mobile phone industry. With case studies, it can be explored what success factors and elements of frugal innovations are, substantiated with real-life examples, that could potentially influence over-engineering. It gives an in-depth understanding of the topic and insights in context. The case studies have been done using a case study protocol: overview of the case studies, data collection procedures, protocol questions and tentative outline for the case study report. As for the data collection for the medical industry, an interview has been conducted with one person in combination with literature research. For

the mobile phone industry, literature research has been done, because conducting an interview for this case study was not feasible. Furthermore, protocol questions have been made to gather useful and relevant data for the research.

Based on the literature research and case studies, the main research question could be answered. It showed that the frugal innovations and over-engineering share three factors that could influence them, which showed to be its price, design and business model. Hence, when changing one or more factors, it may have an affect on both frugal innovations and over-engineering. For example, changing the price of an innovation from expensive to affordable, the innovation will become less over-engineered and more frugal. Not only these factors are important, but the elements that influence these factors are important as well. The most important elements for both industries are modularity (design factor) and sort company (business model factor - a start up or multinational). In addition to medical industry, the element regulations (price and design factor) is also of importance. It is important to create a product that is modular. When a product is non-modular, it will be difficult to modify the over-engineered product to be more frugal. Modular products are investments, but are cheaper to produce and in price in the long run. Furthermore, a start up has a higher chance of success in selling frugal innovations than a multinational and has a cheaper infrastructure in order to keep the price of the product/service affordable. The usual target market and audience of multinationals differ majorly from the ones for the frugal innovations. Their decisions are also scrutinised and could lead to severe backlash and reputational damage, which happens less often and not as large to start ups. Furthermore, for the medical industry, regulations raises the ethical question on whether or not to provide low resource economies medical equipment that do not fully comply with the national and international regulations, while it could potentially save a large amount of lives. These regulations could be too strict for the environment they are meant to be used in.

Based on this research, I would give advice to the manager of a project on a frugal or non-frugal innovation in a multinational, who would like to have their product/service less complex, less expensive or less costly. First, I would advice to have researchers do further examination on this topic. To be more specific, gain more primary data for a higher reliability by means of multiple interviews and case studies. Preferably, the interviewees need to have an equivalent function within the company they work for, because then the results of the interviews can be compared. Additionally, one of the topics for future research that should be looked into, is diffusion of innovation. This is important in the success of the adoption of an innovation, therefore, it relates to the topic of this thesis. Furthermore, I would advice to manufacture the innovations to be modular, since this could make the production process and innovations cheaper in the long run. In addition, I would advice to collaborate with start ups. The multinational could manufacture the innovations, while a start up could sell it. Lastly, for the medical industry, when manufacturing innovations for low-income economies, I would advice to only adhere to regulations of the economies that the innovation is intended for. Advice should be given to the Ministry of Health in these economies to reanalyse their regulations in order to provide them with medical equipment. When following up these advises, the innovation would be less complex, less expensive or less costly and more frugal.

Contents

List of Abbreviations

BOP - Bottom of the Pyramid
CHARM - Children's Automated Respiration Monitor
CLC - Community Life Center
EMNC - Emerging multinational corporations
GDP - Gross domestic product
MNC - Multinational company
MOT - Management of Technology
NGO - Non-governmental organisation
PET - PowerFree Education Technology
R&D - Research and development
SME - Small and medium-sized enterprise

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1 Introduction

The smartphone is a technical advancement that has made an indelible effect on our lives and society in recent years. These helpful gadgets have disturbed past methods of doing things since they allow for not just basic phone capabilities (i.e. voice calls, texting, and e-mails), but also a slew of other features that make life more interesting and convenient. They are certainly beneficial to a person's life, enhancing problem-solving abilities. But, in terms of creating harm to social cohesion, may using mobile phones as intermediaries to connect with the world become a hazard for the person (Nguyen et al., 2016)?

Mobile phone penetration is highest in the globe, with developing nations accounting for 75% of all mobile subscribers. The growing relevance of mobile telephony for consumers at the Bottom of the Pyramid (BOP), the poorest, is mirrored in the high percentage of their income spent on it. The BOP refers to the world's biggest, and generally poorest, population, which is represented by an untapped market of more than 4 billion people living on less than $2 dollars a day in 1990s prices, which is equivalent to $4.47 in 2022 (Arshad, 2021; Khan, 2016). In low-income economies, low-income consumers have devised techniques to save expenses while maintaining communication access (Tabeck, Singh, & Banerjee, n.d.). Still, the phones are too expensive and complex, which could be made simpler with the same efficiency and effectiveness. This is an example of over-engineering. Over-engineering in the literature is being used in a different context than in this research, for example for software tools, data and programming[1]. Hence, in this research, over-engineering will be defined for the context of this research. Over-engineering is when a product or a solution to a problem is designed in an intricate or sophisticated manner when a simpler option can be proved to exist with the same efficiency and effectiveness as the original design. It is more expensive in terms of price, more complex in terms of design and has a high-cost production and/or other operational/financial aspects.

There are two types of over-engineering:

1. to over-engineer to serve the existing demanding consumers with ever-improving products.
2. to over-engineer to comply with rules and regulations.

The first type of over-engineering is happening, because incumbents often strive to give ever-improving products and services to their most profitable and demanding clients, while paying less attention to less-demanding consumers or non-consumers. The incumbents enable the feasibility of disruptive innovations by the fact that these innovations begin in two types of marketplaces that incumbents ignore: the less-demanding consumers and the non-consumers. In reality, incumbents' offers frequently outperform the latter's performance criteria (Christensen, Raynor, & McDonald, 2013). The less demanding customers will be provided with products that are good enough and non-consumers could be turned into consumers, which could disrupt the over-engineered product (Christensen et al., 2013). This type of over-engineering is visible

[1]Examples of papers are Hodkiewicz, Klüwer, Woods, Smoker, and Low (2021), Golomb, Gangadharan, Chen, Sokolsky, and Lee (2018) and Hoare (1996), respectively.

on the demand-side of the market, which often means that the products are not a necessity of life, such as oxygen, food and drinks, however, still, there is a high demand for these products. An important note about the demand-side is that while it often means that it is not a necessity of life, it depends on the context. Smartphones are an example of this type of over-engineering. It is therefore interesting to look at possibilities to affect the process of over-engineering in the industry of mobile phones.

On the other hand, medical devices are over-engineered on the supply-side and belong to the second type of over-engineering. The supply-side of the market does not focus on improving their products and services to their most profitable and demanding clients, while paying less attention to less-demanding consumers (David, Judd, & Zambuto, 2020). The products and services on the supply-side are not luxury goods, but are a necessity. Medical equipment, such as magnetic resonance imaging (MRI) devices, is an example of a product that is frequently unavailable to residents in BOP markets due to long lead times, customised needs, low volume and resulting prices. As a result of these circumstances, up to 80% of medical equipment in BOP countries comes from donations. Unfortunately, roughly 40% of donated equipment is non-functional, compared to only 1% in rich countries. While BOP markets appear to be appealing to medical equipment producers, new techniques are required to supply goods with the appropriate attributes for a given BOP location at a reasonable price (Ahrens, Dobrzykowski, & Sawaya, 2018). This industry needs to comply with regulations and policies. Measures and policies lead to over-engineering and increases the price. Healthcare encompasses everything from illness prevention to the maintenance of physical and mental health and its delivery is heavily reliant on technology, particularly medical technology. As a result, one of the key components of the healthcare system is medical technology management (David et al., 2020). The increase in price and complexity reduces the accessibility to medical equipment for the people in need. Those people in need may not be able to afford the equipment or not be able to operate it, while it may be of medical importance for them.

1.1 Problem

The topic of over-engineering itself is broad, since multiple industries/sectors are involved and differs per context. It would not be feasible to research into all of these industries and contexts. This is why the scope has been narrowed down to the mobile phone industry and the medical industry. In these industries, over-engineering can be looked at on the supply- and demand-side. As seen in the previous section, the reason for over-engineering differs for each side. With these different sides, it can be compared how over-engineering affects the BOP.

On the demand-side of the market, the mobile phone industry has been chosen because it can be seen that over-engineering happens often in that industry. It is unavailable to the poorest in the world, because of their complexity, price and infrastructure. While the poorest save money for mobile phones due to the social impact, individuals in the BOP often have relatively low purchasing power since they have low income levels and spend a big amount of their money on necessities such as food and housing. Spending money on mobile phones while saving up for the necessities, are making their lives more difficult. Though mobile phones

are not a necessity, the poor purchase these non-essential products to alleviate poverty-related guilt, portray a more positive self-image, display self-determination and feel content. In this sense, it is addressing the fundamental inequities in the social system.

On the supply-side of the market, the medical industry is interesting, especially medical equipment. While the mobile phones are getting more complex due to potential demanding customer, medical equipment need to comply with policies, such as safety. Since the measures and policies reduce the accessibility of medical equipment to people, it is important to solve this problem. Ethically, every person should have access to healthcare, if not, medical equipment, without having to fight for their lives when they cannot afford it or when they do not understand how to operate it.

Healthcare

Healthcare systems encompass a broad range of activities, including scientific, technical, social, political and economic aspects. The relationship between these elements is highly complicated, offering a significant challenge to healthcare system governance in order to accomplish public health goals. Controlling growing costs while enhancing medical services is a key challenge for healthcare systems across the world. Increasing healthcare expenditures is the result of a number of variables that interact and reinforce one another. Two of these are especially important to health innovation research. First, the world population is ageing; as life expectancy increases, healthcare systems are under pressure to provide more health services for a longer length of time (Bianchi, Bianco, Ardanche, & Schenck, 2017).

High costs that limit access to health services, particularly in the healthcare sector, are a major cause of disappointing developments. The term "access" refers to the degree to which healthcare systems may be tailored to the needs of its consumers. The idea of access has been widened to encompass the hurdles to successful utilisation as well as the availability of services. Technological complexity, budgetary constraints, and a lack of collaboration within the health system are all potential roadblocks. Demand-driven innovation incorporating user engagement might be a technique for decreasing medical technology access obstacles. When specific domain aspects are evaluated, frugal innovation will be offered as a separate innovation type that can fulfil both assessment criteria (Bianchi et al., 2017).

1.2 Potential Solution

A potential solution for over-engineering could be frugal innovations. An innovation called "frugal innovation" aims to reduce the cost of systems, services and products and are accessible to the BOP (Knorringa, Peša, Leliveld, & Van Beers, 2016). It is often associated with affordability in terms of price, low-cost production (and other operational/financial aspects) which could relate to the business model, low-cost materials and design that focuses on fundamental functioning and feature sets for the unserved end of the mass market while meeting or even exceeding certain pre-defined quality standards (Hossain, Simula, & Halme, 2016; Lim & Fujimoto, 2019; Tiwari & Herstatt, 2012).

The factors of frugal innovations could affect over-engineering. By using the factors of

frugal innovations to affect over-engineering, perhaps the mobile phones industry, for example functions on the mobile phones such as mobile banking, and medical equipment will be produced to be simpler, cheaper and altered to the needs of the BOP. The way frugal innovations will affect over-engineering can differ for the supply- and demand-side of the market, so for the medical industry and mobile phones industry, respectively. By researching into this, the gap in the literature can (partially) be filled.

1.3 Knowledge Gap

When combining the problem and possible solution, it can be seen that the knowledge gap in the literature is therefore the effect of frugal innovations on over-engineering. Adequate literature on the connection between over-engineering and frugal inventions had not been found

There are two types of over-engineering, one on the demand-side of the market and one on the supply-side of the market, for which the reasons for over-engineering differ per side. The problem is that over-engineered products are unavailable to for example the BOP. While this may not be a large problem for the demand-side of the market, it is a large problem on the supply-side.

On the demand-side of the market in the mobile phone industry, the BOP frequently has relatively limited purchasing power since they have low income levels and spend a large portion of their income on basics like food and housing. Their lives are made more challenging by their decision to purchase mobile devices while saving money for essentials. Even though they are not necessary, mobile phones are often bought by the impoverished to allay guilt associated with their poverty, present a more positive self-image, show self-determination, and feel pleased. It is tackling the underlying injustices in the social structure in this way.

However, on the supply-side in the case of the medical equipment, medical equipment are a necessity since they could save lives. Unfortunately, these equipment are hardly available to the BOP, due to it being over-engineered and thus being complex and unaffordable to them.

Both problems of over-engineering could potentially be solved by applying factors of frugal innovations so that over-engineering could be affected to serve the poor. The solutions could differ for both types of over-engineering, which then could be compared to each other. The knowledge gap therefore is that there is no adequate literature on what the effect is of frugal innovations on over-engineering and its potential to impact it.

1.4 Research Objectives

Due to the problem and the gap in literature, I am studying the effect of frugal innovations on over-engineering in the mobile phone industry and medical industry. I want to find out how frugal innovations can be used to influence over-engineering, in order to help my readers understand whether frugal innovations can be a remedy for over-engineering in the mobile phone industry and in the medical industry. The main research objective of this study is therefore

to investigate the factors of frugal innovations that can affect over-engineering in the mobile phone industry and in the medical industry.

If the factors of frugal innovation can affect over-engineering, this study needs to find out to what the factors are, how the factors can be influenced and how it can be used against over-engineering, thus be a remedy for over-engineering. The research objective needs to be reached in a scientific manner by conducting a scientific research. This will be done by doing literature research and conducting an interview.

1.5 Research Questions

To be able to reach the research objective, the main research question that should be answered is:

How can frugal innovations have an impact on over-engineering in the mobile phone industry and in the medical industry?

To answer this question, several sub-research questions have to be addressed:

1. What is over-engineering and its characteristics?
2. What are the causes of over-engineering
   (a) in the medical industry?
   (b) in the mobile phone industry?
3. What are the characteristics of frugal innovations?
4. What are the factors of frugal innovations to affect over-engineering
   (a) in the medical industry?
   (b) in the mobile phone industry?
5. What are the elements that influence the factors of frugal innovations?
6. How can the elements of the factors of frugal innovations be used to influence over-engineering?

1.6 Research Relevance

It has been found that there is a research gap on what effect frugal innovations has on over-engineering. As over-engineering could pose a risk for the Bottom of the Pyramid, such as no access to medical equipment, frugal innovations intuitively seem to be a solution to oppose this risk. Over-engineered products or services could potentially be influenced by frugal innovations. However, no adequate literature can be found on this topic, hence, this proposed research will have the scientific research relevance to how frugal innovations can affect over-engineering, with the focus on the mobile phone industry and medical industry and thereby contributing to the research gap in the literature and described in Research Objectives.

Research regarding the effect of frugal innovations on over-engineering for the Bottom of the Pyramid is highly societally relevant, since overly complex and expensive products are unavailable to the majority of the world's population, but can be made available to them. These products can vary from luxury products to products of medically importance. A new market can be reached. For the social impact, United Nations Foundations (n.d.) has created 17 Sustainable Development Goals[2] to alleviate severe poverty, decrease inequality, and safeguard the environment by 2030. This research contributes to four of their goals:

- Goal 3: Good health and well-being
- Goal 8: Decent work and economic growth
- Goal 9: Industry, innovation and infrastructure
- Goal 10: Reduce inequalities

This research will contribute to these goals by looking into the effect of frugal innovations on over-engineering in the mobile phone industry and medical equipment. The knowledge resulting from this research can be taken into account for future research into frugal innovations and over-engineering, with a possible outcome for frugal innovations to be a possible solution to over-engineered products. In the long run, this might help to reduce inequalities by increasing the number of people who have access to inexpensive and less complicated medical equipment and mobile phones, increases economic growth and fosters innovations.

1.7 Relevance MOT

This study was completed in partial fulfilment of the Master of Science (MSc) degree requirements in Management of Technology (MOT). This research focuses on the investigation and comprehending how businesses may utilise technology to design and produce products and services that improve customer satisfaction, in this case the Bottom of the Pyramid, while also looking at the company productivity, profitability and competitiveness[3]. This thesis study is therefore exceptional for the MSc MOT program for three reasons:

1. The first reason is that the research presents the findings of a scientific investigation conducted in a technological setting (i.e. technology and strategy, managing knowledge processes, research product development management, innovation processes).
2. The second reason is that the work demonstrates a grasp of technology (partially) as a business resource.
3. The last reason is that this research evaluates the issue of over-engineering and frugal innovations using scientific methods and procedures as outlined in the MOT curriculum.

[2]https://unfoundation.org/what-we-do/issues/sustainable-development-goals/?gclid=CjwKCAiAvaGRBhBlEiwAiY-yMH-EKWRpKkrMG6P1AS-moJJD2zDjxRcj1nhwuTPedFFaAFfU5oHVeBoCw9EQAvD$_{B}wE$

[3]The criteria for MOT review can be found here: https://www.tudelft.nl/studenten/faculteiten/tbm-studentenportal/onderwijs/master/graduation-portal/step-1-start-your-master-thesis-project

1.8 Overview

In section 2 - Literature Review, the literature research has been conducted on the Bottom of the Pyramid, over-engineering, disruptive innovations, frugal innovations and reverse innovation. After, section 3 - Research Method describes the research methods on how to collect data and analyse the obtained data, followed by section 4 - Case Study, which consists of two case studies, one for the medical industry and one for the mobile phone industry. In section 5 - Results, the data from the previous chapter will be analysed in the form of results. section 6 - Reflection shows the reflection of the research, including the limitations, which is followed by the conclusion in section 7 - Conclusion. Following the conclusion of the research, a discussion will follow in section 8 - Discussion, followed by recommendations in section 9 - Recommendations for further work.

2 Literature Review

This chapter covers the present state of knowledge on the Bottom of the Pyramid, over-engineering, disruptive innovation, frugal innovations and reverse innovations. This literature research addresses the first, second and third sub-research question, which are *What is over-engineering and its characteristics?*, *What are the causes of over-engineering (a) in the mobile phone industry and (b) for medical equipment in the medical industry?* and *What are the characteristics of frugal innovations?*, respectively.

2.1 Bottom of the Pyramid

The Bottom of the Pyramid (BOP) is the target market this research is focused on. Before the first three sub-research questions can be answered, it is important to know more about the BOP and the challenges regarding this group, since that information helps in defining characteristics of frugal innovations and can help in explaining the impact over-engineering has on the BOP.

The BOP represents the "base" of the income pyramid, which lies below the growing middle class and the rich (von Carlowitz, 2020), which Figure 1 shows. The BOP markets are characterised by institutional holes and are unclear and turbulent (Khan, 2016). The BOP marketplaces are varied and they must be appropriately discovered in terms of both functional and aspirational customer demands. Customers' wants should be well understood, since this will aid a company in developing constraints and subsequently designing innovative and clever solutions inside the limitations system (Arshad, 2021).

86% of people in India (which equals 1.21 billion people, based on a population of 1.41 billion people as per July 16 2022 (WorldOMeter, n.d.)) and 52% of people in China (which equals 0.75 billion, based on a population of 1.45 billion people as per July 16 2022 WorldOMeter (n.d.)) experience these conditions. The world population consists of 7.96 billion people as per July 16th 2022 (WorldOMeter, n.d.). The BOP population from these two countries only, China and India, already consists of 24.6% ((1.21 billion + 0.75 billion)/7.96 billion = 24.6%) of the world's population. Considering other countries and populations, the BOP population reaches 4 billion people, which is 50.3% of the world's population. Thus, more than half of the world's population live at the BOP.

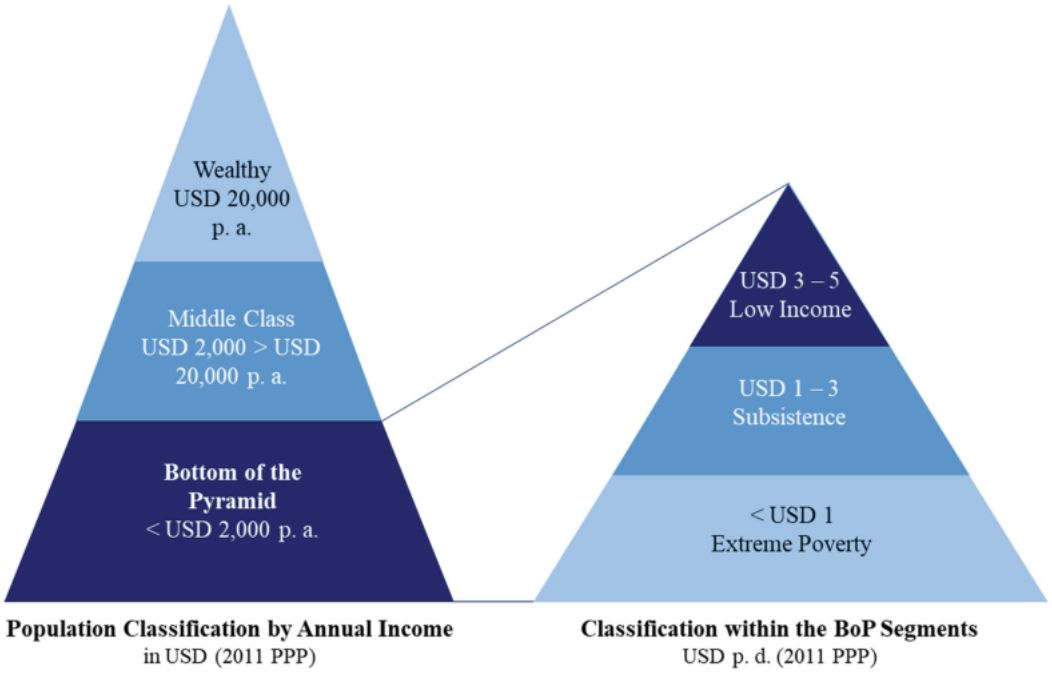

Figure 1: The world's income pyramid and the classifications of the BOP (von Carlowitz, 2020).

2.1.1 The non-existent market

As mentioned, the BOP is the largest segment of the population. Still, this market is underserved (Leliveld & Knorringa, 2018). BOP has the ability to produce value for both businesses and the poor. Multinational companies (MNCs) overlook the BOP market in favour of existing markets because they consider the BOP demographic to be unprofitable. By treating the destitute like respectable consumers, it is feasible to benefit from them. These four billion micro-consumers make up a sizeable market and are a source of innovation, energy and development (Khan, 2016).

Reason for non-existence

Despite the BOP making up a sizeable market, it is still non existent. The prevalent logic—the way managers are educated to think and the analytical tools they use—determines how market opportunity is seen. In most MNCs, the BOP, for example, would be immediately removed from consideration if looked at per capita earnings. The poor are again removed from active consideration if one begins the examination with the existing range of products and services tailored toward the developed world. As a result, transforming the poor into active customers necessitates MNC executives confronting their dominant logic, or the firm's basic set of ideas and behaviours. Managers must face and recognise their genetic code (Prahalad & Hart, 1999).

The business potential at the BOP has remained unseen due to the predominance of five key assumptions among MNCs (Prahalad & Hart, 1999):

1. MNCs do not target the poor because they can not compete in that market with their existing cost structures. The cost structures of multinational corporations are unavoidable.

2. The poor cannot afford and do not require the goods and services supplied in developed

markets. The focus is on the product, not on the functionality. MNCs are concerned with detergents rather than cleanliness.

3. New technology is only appreciated and paid for in mature markets. The impoverished have access to the most recent version of technology. MNCs concentrate on product and process improvements rather than business innovations. The highest tier (Wealthy) is where innovation happens.

4. The BOP is unimportant to the company's long-term success. The Wealthy and Middle class tiers may be their priority, while the lowest tier can be left to governments and non-profits. The BOP does not appear to be compelling MNCs to innovate in the area of sustainable development.

5. In developed markets, intellectual excitement is high. Managers who desire to spend time building a commercial infrastructure at the BOP would be difficult to find, train, and inspire. Managers are uninterested in business difficulties that have a humanitarian component.

2.1.2 Paradoxes

MNC executives are held back by the above prevailing logic and key assumptions, yet individuals at the BOP have their own point of view. They live in a world full with paradoxes (Prahalad & Hart, 1999):

1. Closed societies are opening up and seeking to gain from market economy dynamics, yet the majority of the globe is unable to engage in the market economy, because they are too poor, due to the pattern of global wealth distribution. The widening divide between wealthy and poor throughout the world may strengthen the belief that the poor, even if, for example, they make up 80% of the population, are unable to participate in the global market economy.

2. MNCs today arose in a period when natural resources were plentiful and waste sinks were not a concern. As a result, it is no surprise that MNCs have a proclivity for producing resource- and pollution-intensive goods and services. As a result, rich consumers increasingly use an excessive amount of world resources. MNCs will have to impose drastic limitations on resource usage and pollution in order to create a global free market. The BOP, with its large population and quick expansion, has the potential to serve as a test-bed for future technologies and products—those that enable more sustainable ways of life. Few attempts to innovate around these limits are now being seen by the poor.

3. The wealthy cannot afford to overlook the needy. The BOP may easily undermine the rich's lifestyle and safety due of their large numbers. Providing opportunities for the world's poor to better their quality of life through commercial growth may be the key to the affluent and multinational corporations' continuing prosperity. While worldwide economic equality may be an intellectual pipe dream, maintaining the market economy

requires lifting the bottom. MNCs' long-term success will be more contingent on improving the lives of individuals at the bottom of the economic pyramid.

2.1.3 Challenges

In addition to the key assumptions and paradoxes that prevent the BOP market to be served, several other aspects of the BOP market provide hurdles for businesses. Market, distribution and organisational challenges prevent businesses from serving the underserved.

Market challenges
The market challenges that form a hurdle for businesses are informal economies, low purchasing power an institutional voids (Ramdorai, Herstatt, et al., 2015):

- The informal economy dominates BOP marketplaces. Informal markets are unregistered and operate without institutional regulation, but they are not illegal. Local vendors and suppliers of items at the BOP may operate in shadow economies and transact exclusively in cash, making this environment tough for companies who are used to dealing with formal paper work. Companies that conduct business with competitors that operate fully in the shadow economy, with no laws or quality requirements, suffer greater transaction costs (Ramdorai et al., 2015).

- The comparatively low purchasing power and poor demand in BOP markets is another market barrier that enterprises encounter. Individuals in the BOP often have relatively low purchasing power since they have low-income levels and spend a big amount of their money on necessities such as food and housing. This problem is exacerbated by erratic income. The lack of demand for items and services that are regarded "essential" from a Western perspective is a contributing cause. This makes it difficult for businesses to predict demand, which has led to a number of blunders in the past (Ramdorai et al., 2015).

- Institutional gaps define BOP marketplaces. This means that important institutions and infrastructure, which are required for market development and operation, are frequently absent or ineffective. Companies involved in the BOP are frequently required to overcome these gaps in order to create a functional ecosystem (Ramdorai et al., 2015).

Large corporations in developing nations typically replicate or replace institutions to fill institutional holes, according to research into institutional voids. Cross-sector collaborations with non-governmental organisations (NGOs) and other intermediaries have been emphasised as one strategy to mitigate the detrimental consequences of institutional vacuum for MNCs in the BOP setting. Firms can benefit from cross-sector collaborations to adapt to market conditions, and companies can benefit from partnerships with governmental bodies to deal with institutional difficulties (Ramdorai et al., 2015).

Distribution challenges

In some nations, the BOP population is predominantly rural. In India, for example, rural regions account for 78% of the BOP population. Physical delivery of commodities to the BOP sector is difficult due to this, as well as the fact that infrastructure to access these places is generally inadequate. Using India as an example, bad infrastructure affects not just long lead times for the logistics business, but also higher prices. In purchasing power parity measures, coastal and rail logistics in India cost up to 70% more than in the United States. This is mostly due to significant capacity limits in Indian rail and ocean freight transportation, as well as hidden expenses associated with poor handling, extended transit times, and damage (Ramdorai et al., 2015).

While rural India has a high rate of mobile phone penetration, internet penetration is still fairly low, at around 4% in 2012. This complicates not just infrastructural issues, but also information access. Informational inequalities are a typical issue for BOP producers, such as farmers in rural areas, as well as consumers. This is why distribution is said to be "essential for the development of the BOP market" and "distribution innovations are as important as product and process innovations" (Ramdorai et al., 2015).

Organisational challenges

Organisations confront internal constraints while advocating BOP projects, in addition to the external market obstacles mentioned above. BOP projects frequently need patient investments and the belief that the firm will deliver strong returns over time. Furthermore, BOP initiatives need innovation that is typically outside of a company's core competencies. These are some of the reasons why BOP initiatives frequently run into internal organisational issues. At a Danish multinational, internal organisational hurdles to BOP activities have been discovered. The attitude as well as organisational practices, such as project assessment criteria and managers' incentive structure, were the fundamental causes of these hurdles (Ramdorai et al., 2015).

2.1.4 The start of making the market existent

Developing cost-effective technologies for the BOP market needs creativity and foresight. Any type of entrepreneurial activity at BOP, whether through a MNC or a social enterprise, an NGO, or a small and medium-sized enterprise (SME), can help eradicate poverty in an economically viable manner if the conditions are favourable for achieving specific success criterion. It necessitates a setting that begins with (a) recognising the basic requirements of the BOP population; (b) establishing an entrepreneurial eco-system that includes collaborations with other businesses and the public sector; and (c) cultivating a "innovation sandbox" that stimulates new ideas. As a result, the strategies and procedures supplied to this market must address resource restrictions while also maintaining or improving societal, ecological, and economic sustainability (Khan, 2016).

Serving BOP markets successfully necessitates a unique set of products and services. Products and services should be much less expensive, preserve (technical) functionality, be affordable to low-income clients, and work in resource-constrained settings. Frugal innovation was initially

portrayed as a financial opportunity for corporations to produce goods, services, or systems that would allow them to tap into underserved markets (Leliveld & Knorringa, 2018).

Firms can succeed in BOP marketplaces by viewing the poor as creators, co-producers of invention, entrepreneurs, or inventors, rather than as simply recipients. These enterprises and their sustainable innovations may easily access the BOP markets by employing techniques such as creating local capability and co-inventing unique solutions with non-traditional partners. Furthermore, the lessons these established firms acquire in BOP markets will help them become internationally competitive and pave the road for global economic growth. Affordability and sustainability are replacing plenty and premium pricing as drivers of innovation (Khan, 2016).

2.2 Over-engineering

As specified in the introduction, over-engineering is when a product or a solution to a problem is designed in an intricate or sophisticated manner when a simpler option can be proved to exist with the same efficiency and effectiveness as the original design. Over-engineering dramatically increases the costs of design, installation and operation. It also could affect the long-term viability, raising maintenance and replacement costs as well as total CO2 emissions. The cumulative effect of margins (error, safety, etc.) added to the specification by numerous stakeholders to hedge against their own individual risks is one cause of over-engineering (Eckert, 2019).

In all business, a disruptive innovation lurks under the surface. While the major players are focused on improving their products or services to the point where the average consumer has no idea what they are using (e.g. over-engineered computers), they overlook simpler, more convenient and less expensive offerings that were originally designed to appeal to the lower end of the market (Christensen, Bohmer, Kenagy, et al., 2000).

2.2.1 Reasons for companies to over-engineer

Due to over-engineering, the largest population of the world cannot be reached and disruption lurks under the service, but still, a majority of the companies do not make a frugal version of the over-engineered product available to the BOP. Over-engineering has several reasons, of which they differ for the mobile phone sector and medical sector. Here, the list provided is not extensive. There could be more reasons for medical devices and products in the mobile phone industry to be over-engineered, however, this section highlights the major reasons.

Mobile phone sector

As mentioned before in this research, companies often strive to give ever-improving products and services to their most profitable and demanding clients, while paying less attention to less-demanding consumers (Christensen et al., 2013). This is especially true in the mobile phone sector:

- Performance: The desire for phones and its functions is impacted heavily by characteristics of the phone's brand name as well as social influence from peers and family. Performance

(battery, speed, etc.) here, is a critical element. It has a social influence and impact on an individual (Suki, 2013). Thus, performance is improved for the demanding customers.

- Competitiveness/profit: In a highly competitive economy, businesses are attempting to earn a profit and even survive (Hasan, Yeasmin, & Dey, 2013).

- Demand: Colour screens, mobile Internet and voice dialling are just a few of the features that may have a big influence on customer pleasure. Users are more satisfied with phones that have a colour screen and mobile Internet than with phones that do not. Mobile phone cameras should create higher-resolution photographs so that consumers may access graphic information with more accuracy and clarity. There is a greater desire for mobile phone functions to be improved. Thus, there is a demand for phones with such features and the demanding customers are willing to pay for the price (Ling, Hwang, & Salvendy, 2006).

Medical sector

While the mobile phone sector mainly focuses on the demanding customers rather than it being essential, the medical sector has other causes for their products to be over-engineered:

- Safety: Over-engineering devices to attain desired safety performance comes at a cost, and there are multiple trade-offs between cost and complexity. The achievement of cost, quality and time balance is an ongoing issue. By focusing heavily on design quality in an attempt to account for all unanticipated circumstances, project costs and timelines are likely to be greatly inflated. Furthermore, equipment that are overly engineered for safety may have slower or limited operation. Certain medical gadgets contain safety features that allow them to continue working even if they have failed (Block III & Kuo, 2018).

- Performance: Regulatory agencies frequently need specialised performance testing for the equipment. Equipment must be created to treat the condition or illness while also being durable enough to last the patient's whole life without sacrificing other parts of their quality of life (Block III & Kuo, 2018).

- R&D: Due to the way medical devices interact with people, they have a variety of R&D processes and ethical issues that are specific to them. Companies choose R&D projects based on a number of factors, including the need to meet an unmet clinical need, alignment of technological challenges with internal capabilities and available expertise, infrastructure to effectively distribute and support the product, anticipated time to market, financial risks and rewards, and the likelihood of market acceptance. The consequences for research and development are significant. These considerations could drive up the price and make the device overly complex (Citron, 2012).

- Testing: Medical device design necessitates significant planning and testing with known and unknown variables that might affect device function, such as interoperability concerns (Block III & Kuo, 2018). Substantial trials, extensive human and non-human studies must be done in order for the device to be approved by a regulatory body. This drive up the

price of the device (Bergsland, Elle, & Fosse, 2014). If the tests do not pass, the product could be over-engineered to pass.

- Other regulations: Due to regulations, which can differ per country, sometimes cheap and efficient equipment cannot be made available to emerging nations (Long, Martin, Troxell, & Kim, 2018). Regulations could lead to a product being over-engineered. Safety, for example, belongs under the regulations. However, there are a lot more regulations that affect the equipment's complexity and price.

2.2.2 Impact

A potential risk regarding over-engineering is that products or services could be unavailable to certain populations, such as the BOP, due to (Matzler, Mooradian, Füller, & Anschober, 2014):

- Skills and abilities: For many people, for example the BOP, who lack the essential expertise, products are too difficult to utilise.
- Price: High-tech solutions are costly and clients who do not want all of the bells and whistles are unwilling or unable to pay for them.
- Access: Using or consuming a product frequently necessitates the installation of specific infrastructure or other prerequisites. Customers without access to this infrastructure are unable to use the items.
- Time: The usage of a product, or learning how to utilise one, can take a long time.

Mobile phone sector

Phones and its functions are frequently utilised by the poor across the world as an antidote to poverty-related shame and isolation among all the gadgets and systems that make up digital technology (Reza, Amir, & Kazmi, 2021). Social influence plays a crucial part in the adoption; individuals who have a higher percentage of their closest friends who already have a phone are more likely to adopt, implying that people tend to interact in groups (Tabeck et al., n.d.). It was first used by the top tier of society, but it rapidly spread to a much broader populace. Because of their position as information carriers and conduits, mobile phones should reduce information asymmetry in markets, making rural and underdeveloped markets more efficient, for example the BOP (Tabeck et al., n.d.).

Mobile phone penetration is highest in the globe, with developing nations accounting for 75% of all mobile subscribers. For the most part, voice communication has been attained through fierce competition, with rates driven to near-unsustainable lows. New services and apps offered service providers with new revenue streams. More importantly, from a development standpoint, they provide a mechanism for customers at the BOP to obtain information and services at lower transaction costs. The growing relevance of mobile telephony for consumers at the BOP is mirrored in the high percentage of their income spent on it. Evidence from low-income communities in the developing world, where low-income consumers have devised techniques to save expenses while maintaining communication access (Tabeck et al., n.d.). They buy these

non-essential items to avoid poverty-related guilt, project a better self-image, demonstrate self-determination, and feel happy. It is tackling the social structure's underlying disparities in this way. Observation reveals that, despite the BOP's restricted financial resources, they are making non-essential expenditures (Reza et al., 2021).

Medical sector

Supply chains must accommodate requirements for local BOP market customisation, responsiveness, and early/late build cycle design commitment to address the often rapidly changing BOP conditions, all while achieving volume production advantages, in order to serve a BOP market while generating acceptable profits. However, markets in the BOP are frequently fragmented and logistically disconnected from others. This eliminates the possibility of a "global platform" offering. Over-engineered medical equipment therefore cannot be easily offered to the BOP. Another impact of tiny, isolated markets is that demand and design needs might be variable, necessitating the responsiveness of a supply chain (Ahrens et al., 2018).

The expectation of a short delivery lead-time for a wide range of items is referred to as responsiveness. The decoupling point, or the time in the construction cycle when the supplier must commit to a design feature, is dealt with by early/late design commitment (Ahrens et al., 2018).

Furthermore, medical equipment that are manufactured for the BOP need to comply to regulations (Long et al., 2018). With this, safety of people's lives and the instrument reliability are preserved, however, at the expense of over-engineering, thus making the products more expensive, complicated and lack to make them available to the BOP, for example due to their infrastructure.

2.3 Disruptive Innovations

As mentioned in the previous section, disruptive innovations are lurking in businesses that are over-engineering. Disruptive Innovation, popularised by Christensen (1997), is one sort of innovation that is emerging as strategically essential in practice. Christensen (1997) mentioned that "Occasionally, however, disruptive technologies emerge: innovations that result in worse product performance, at least in the near-term. Ironically, in each of the instances studied in his book, it was disruptive technology that precipitated the leading firms' failure. Disruptive technologies bring to a market a very different value proposition than had been available previously" (Christensen, 1997, p.11). The idea was well-received by practitioners in a variety of industries, and it influenced thinking and research in areas such as innovation management, strategy, and organisation. Disruptive innovations, according to researchers, are "a potent technique for generating and enlarging new markets" (Ramdorai et al., 2015). Christensen (1997)'s definition formed the basis of the disruptive innovation theory.

2.3.1 Disruptive Innovation Theory

Christensen (1997) divides innovations into two types: those that are sustainable and those that are disruptive. Companies use sustained innovations to increase product/service characteristics

that their mainstream customers desire in order to achieve growth. Disruptive innovations, on the other hand, may look inferior to mainstream customers at first, but they appeal to developing customers in the low-end or new niche sectors because they perform better on a different dimension. As these inventions mature, their performance is adequate to please the market's more mainstream clients (Ramdorai et al., 2015).

According to the disruptive innovation theory, mainstream consumers should not be over-served in search of new growth prospects; instead, new chances should be considered through linking the BOP markets because of their high growth potential and social responsibility (Arshad, 2021).

Critique of Disruptive Innovation Theory

Disruptive innovation theory has received widespread appreciation and traction in the practitioner world, but it has also received criticism. The first line of attack is directed at the notion of disruptive innovation and its inability to forecast outcomes. While disruptive innovations are described as those that outperform incumbent products/services at first, it is still unclear how to tell them apart from other failing technology. As a result, opponents say that the inability of disruptive innovation theory to anticipate ex-ante makes it less useful to managers. While it is still unknown if a particular disruptive innovation will succeed, great progress have been made in this area. Frameworks have been developed that can better forecast organisations that are more likely to disrupt and markets that are more likely to be disrupted (Ramdorai et al., 2015).

The sampling for empirical validation of disruptive innovation theory is the subject of the second attack against the theory. Critics say that Christensen qualified his thesis by using only a few successful situations. Christensen explains this by stating that the case studies he chose were chosen to highlight anomalies in current theory rather than to validate his hypothesis (Ramdorai et al., 2015).

The disruptive innovation theory development is still an "ongoing process". While the theory has been continually developed and applied to a variety of sectors, academics may still look for anomalies and enhance the theory through theoretical and empirical research (Ramdorai et al., 2015).

2.3.2 Relation to frugal innovations

Frugal innovations based on new product designs are frequently disruptive; for example, a frugal innovation may reach an entirely new customer group by making a stationary product portable (Zeschky, Winterhalter, & Gassmann, 2014). While a product could be inexpensive, it could necessitates a significant investment in R&D as well as technological skills, meaning that not all disruptive innovations are frugal innovations.

2.4 Frugal Innovations

Frugal innovation is described as an effort to maximise the value-to-resource ratio. Customers, shareholders or society at large might all benefit from value. Energy, capital or time are all

examples of resources. As a result, frugal innovation is defined as the being able to serve more people with less resources, i.e. to produce considerably more value while using fewer resources. The cost-cutting approach to innovation is a game-changer. It necessitates firms focusing on maximising value while decreasing resource consumption at the same time (Prabhu, 2017).

The importance placed on reduced pricing in frugal innovation prevents the designer from utilising more resources than are required. The frugal design process is expedited by further optimisation of other elements such as quality, resulting in a product with the bare minimum of components that performs as well as or better than traditional current products in some cases. Furthermore, prioritising cost reduction allows frugal innovation to have a jump start on developing a product that is both functional and lean, whereas old standard goods may never grow into a leaner version (Ashfaq, Ilyas, & Shahid, 2018).

Performance

To affect over-engineering, the performance level in frugal innovation is not necessarily lower; in certain circumstances, the demand might be higher. The performance level must be tailored to the intended purpose and specific requirements of the context in which the frugal innovation will be employed, particularly for emerging and developing markets, which have unique requirements, but also for developed markets. The second reason is that the specified level must be adhered to to the letter. Costs are too expensive if the performance level is too high. As previously said, one of the most important aspects of frugal innovation is cost reduction. Specific needs are not satisfied if the performance level is too low, and frugal innovation's aim to produce high value, keep quality and maximise value to the customer is not realised. As a result, achieving peak performance is critical (Weyrauch & Herstatt, 2017).

2.4.1 Identifying frugal innovations

Current frameworks and terminology aid in our understanding of frugal innovation and its potential. Three requirements for frugal innovation have been defined by (Weyrauch & Herstatt, 2017): significant cost reduction, concentrate on essential functionality and optimised performance level. It is proposed that innovations be classified as frugal if they fulfil all three requirements at the same time.

First, an innovation may only be called frugal if all three conditions are satisfied. As a result, these factors may be used to determine whether or not a certain innovation is frugal.

Second, the requirements serve to explain why frugal innovations are unique and why their creation might be difficult: all three criteria must be satisfied at the same time. This has practical implications: all three criteria should be addressed when developing frugal innovations in order to find the exact traits that make a new product or service inexpensive (Weyrauch & Herstatt, 2017).

Substantial cost reduction

Significant cost reduction is the first criterion for frugal innovation. When compared to traditional products and services, frugal innovation has a substantially lower price or significantly

lower expenses. From the customer's standpoint, the requirement of significant cost reduction must always be satisfied. This already includes the manufacturer's or service provider's point of view (Weyrauch & Herstatt, 2017). It is difficult to quantify how much money can be saved through frugal innovation. Because there are no representative samples, determining a definite threshold value for this criterion is difficult. As long as no sample publications are accessible, it is recommended that the considerable cost savings from frugal innovation must be at least a third lower than comparable items, albeit this is highly dependent on the user context. In terms of this criterion, frugal innovations have a significantly lower purchase price or total cost of ownership from the customer's perspective; one third or more, when prices and costs are compared to current market solutions or, if no solution exists yet, with the assumed costs of bringing them to market, such as by importing current solutions (Weyrauch & Herstatt, 2017).

Concentration on core functionalities

Concentration on key functionality is the second criterion for frugal innovation. Core benefits, fundamental functions and decreased complexity are frequently connected with frugal innovation. As a result, frugal innovation involves a focus on the key features that provide the greatest consumer advantages, as well as a direct focus on user requirements. Concentrating on key functionality is not only a cost-cutting strategy. Concentrating on essential features can also be done to make a product or service easier to use, reduce environmental effect, or cater to a certain lifestyle or consumer behaviour. As a result, the criteria emphasis on key functionalities is a distinct criterion that covers all of the aforementioned characterisations. In summary, as compared to current market solutions, frugal innovations must focus on fundamental functionality (Weyrauch & Herstatt, 2017).

Optimised performance level

It is insufficient to concentrate just on basic functions. A thorough analysis of whatever levels of performance and quality are actually necessary is also essential. The term "performance" is used here to refer to all functionality and engineering features, including speed, power, durability and precision. The necessary technical criteria that must be identified to define the performance level vary depending on the circumstance. However, not all forms of innovation fit the requirement for optimal performance, particularly product innovations from developed markets, which are frequently over-engineered. The question of which performance level should be pursued is frequently overlooked. Frugal innovation should achieve the performance and quality standards that are actually necessary while keeping expenses to a minimum (Weyrauch & Herstatt, 2017).

This criteria is called optimised performance level for two reasons. First, in some circumstances, traditional performance levels are insufficient for frugal innovation. The performance level must be tailored to the intended purpose and specific requirements of the context in which the frugal innovation will be employed, particularly for emerging and developing markets, which have unique requirements, but also for developed markets (Weyrauch & Herstatt, 2017).

The second reason is that the specified level must be adhered to to the letter. Costs are too

expensive if the performance level is too high. Specific needs are not satisfied if the performance level is too low, and frugal innovation's aim to produce "high value," "keep quality," and "maximise value to the client" is not realised. As a result, achieving optimised performance is critical (Weyrauch & Herstatt, 2017).

In summary, as compared to current market solutions, frugal innovations must satisfy the performance level required for their de facto purpose and local conditions (Weyrauch & Herstatt, 2017).

Managerial implications

Two managerial implications result from these criteria. In order to create frugal innovations, businesses must first determine what a particular frugal innovation should look like. Qualities of frugal innovations can differ tremendously. The precise characteristics of frugal innovations are heavily influenced by the setting, including the environment, the demands of the market and the market structure. Therefore, businesses should utilise the three criteria as a framework to determine the particular qualities needed to suit consumers' particular wants in a particular situation and for an intended purpose rather than attempting to identify the fundamental characteristics of frugal innovation, to which there is no single correct answer (Weyrauch & Herstatt, 2017).

Second, in order to generate frugal innovations, businesses should think about all three criteria to find all of the unique qualities and characteristics that make a new product or service frugal. Each factor must be examined since developing frugal inventions necessitates achieving all three requirements at the same time (Weyrauch & Herstatt, 2017).

2.4.2 Value proposition

Frugal innovations are defined by a greater requirement to provide a compelling value proposition in order to gain traction. Firms selling low-cost goods and services are frequently competing not just against traditional competitors, but also against "non-consumption", because the potential customer may lack the financial means to purchase the product or service on offer, as well as (access to) the necessary infrastructure to use it. The following are some ways to achieve this value proposition (Tiwari, Kalogerakis, & Herstatt, 2014):

- Reduced overall costs: A significant success element for frugal innovations is not simply the price point at the moment of purchase. Rather, the low expenses of consumption, maintenance, and repair from purchase through disposal result in a much lower total cost of ownership.

- Robustness: Customers in emerging nations' rural and semi-urban areas are frequently targeted for frugal technologies. The items must be able to deal with a variety of infrastructure issues, including voltage fluctuations, power outages, dust, and severe temperatures. Planned obsolescence practices, which aim to purposefully shorten a product's lifespan while lowering the related expenses for the consumer, are incompatible with frugal innovation.

- User friendliness: Many (possible) frugal goods purchasers have no prior hands-on experience with such products. Companies cannot assume that their customers have a high level of knowledge with their products. As a result, frugal items must be simple to use and fault resistant.
- Economics of scale: The necessity for considerable cost reductions, as well as the tight profit margins nearly always associated with low-priced products, need access to a large volume of business to lower research and manufacturing unit costs.

2.4.3 The unserved

People who have never purchased a product in a specific category or class are referred to as "the unserved" (Lim & Fujimoto, 2019). Resource scarcity drives frugal innovation, which is putting limited resources to work to suit the demands of low-income customers. It is founded on the idea of converting financial, material or institutional resource restrictions into benefits (Hossain et al., 2016). Commercial artefacts having many functional needs, structural features, and causal relationships between them, or those with more complicated designs, are considered relatively complex goods. While frugal innovations are frequently considered in terms of further simplifying an existing relatively basic product by decreasing its functions, components, processes, and interconnections, today's consumers must deal with complicated items like vehicles and smartphones (Lim & Fujimoto, 2019).

By incorporating the private sector, frugal innovations solve challenges in a variety of areas, including healthcare, water, energy, transportation, and communication. Few basic features, minimal cost, an emphasis on local usage, local and discarded materials, simple usability, and the use of the fewest resources are all hallmarks of frugal innovations. Frugality has also been identified as a trait of long-term behaviour or lifestyle (Levänen et al., 2016).

2.4.4 Developing and Emerging Markets

The collection of knowledge on modern innovation management is mostly concerned with new products and services aimed at markets in developed economies where consumers can afford expensive high-end products. Developing economies are experiencing tremendous population expansion at the same time and as people there are naturally looking for new ways to improve their lives, these economies have started to attract new customers. However, the majority of people in developing economies with modest incomes cannot purchase the items created by western companies for wealthier consumers. As a result, the solution is to innovate and approach problems in new ways.

Emerging markets with low incomes are also increasingly providing new sources of innovation. This trend will provide new opportunity for inventive and open-minded businesses to find new business. In reality, this means that the innovation loci and focuses are shifting, necessitating the updating of innovation management theories, models, and frameworks. By addressing previously underserved client segments, frugal and reverse innovations are establishing new markets in both emerging and established nations. Both of these ideas are based on

the idea of reaching out to a new consumer base. Despite the fact that the target clients for frugal products and reverse innovation are distinct, they have many characteristics. Low-income clients in emerging nations are the first to benefit from frugal innovations. We can talk about reverse innovations when some of those innovations transfer to industrialised countries. The capacity of a company to capitalise on the possibilities of reverse innovation boosts its chances of succeeding in the global innovation environment and capturing value (Simula, Hossain, & Halme, 2015).

Frugal innovation depicts a new entrepreneurial environment in which low-income nations' unserved customers are addressed by tiny businesses with little resources. Financial institutions also help to build new markets and contribute to long-term sustainability. Firms are under growing pressure to offer sustainable goods, therefore they must establish innovative strategies that take into account economic, social, and environmental considerations in order to obtain a competitive advantage. Many small businesses are producing items for emerging market low-income clients, contributing to long-term viability. Emerging markets are seen as fertile ground for low-cost innovation, and they are increasingly keen for solutions to local problems. As a result, businesses face a significant problem in supplying relevant products and services to low-income consumers in emerging regions (Hossain, 2020).

Developed market

There has been an increase in academic interest in how western firms are using frugal innovation as a potential product category, or how they are organising frugal innovation activities and adapting to frugal innovation principles in order to effectively grow into untapped emerging markets. The notion of frugal innovation, which was originally designed to fulfil the demands of low-income markets, has grown to be recognised as essential in developed markets as well. The application of frugal innovation to advanced economies has been researched throughout established markets, and its cheap prices and no-frills structure have gained favour since poor customers in developed markets want service as well (Khan & Melkas, 2020). In this research, however, the focus lies on the developing market.

Growth

Frugal innovation is likely to be a major driver of industrial growth, possibly inclusive growth, and may open up a previously unserved domain of innovation in both emerging and developed countries (Lim & Fujimoto, 2019).

2.4.5 Western multinationals corporations

Individual, social and society levels are all affected by frugal innovations. A considerable number of frugal innovation instances, as well as their sources and features, have been reported in several research. Frugal innovations have been embraced by certain western MNCs to cater to low-income clients (Hossain, 2018). MNCs generate successful technologies in their subsidiaries in developing nations and then export these ideas to western countries, giving them new competitive advantages. Reverse diffusion is a strategy used by MNCs to improve their

competitiveness. Typically, modified and degraded versions of inventions designed for developed markets disseminate to emerging markets or poor nations when purchasers cannot afford to acquire the most up-to-date high-end versions (Hossain et al., 2016).

MNCs are more likely to be associated in high-tech frugal innovations, which service both low- and high-income clients, even in wealthy economies. MNCs have vast financial, human, marketing, operational, and technological resources at their disposal, which they may combine with their experience to develop solutions for low-income nations. Until recently, multinational corporations devoted little attention to designing products for low-income clients since they were generally unappealing to them. The extremely fragmented character of low-income markets, as well as their low present value, is a significant hurdle to overcome (Hossain, 2018).

Competition

Low-cost producers, many of whom are from developing countries, are entering a new era of competition, as businesses from emerging economies have begun to export domestic products geared to fulfil local demands to established markets. Western corporations, on the other hand, should see frugal innovation as an opportunity rather than a threat. Despite the fact that frugal innovations may compete with existing items in emerging and developed markets, the potential for significant low-end profits may likely offset losses in higher-end product lines. As a result, western businesses should consider adjusting their current innovation methods to the emergence of frugal innovation (Zeschky, Widenmayer, & Gassmann, 2011).

The beginning of successful frugal innovation is in the head. Before western MNCs can effectively participate in frugal innovation, they must first comprehend the distinct qualities of frugal products: strong customer benefits at low costs. The route to effective frugal innovation also necessitates encouraging a frugal attitude within R&D teams and putting in place the required structures through empowering R&D subsidiaries in emerging markets (Zeschky et al., 2011).

The way western businesses approach frugal innovation has ramifications for worldwide R&D and business in general. Power and duties will progressively be pushed to the peripheral in the future, where distinctive frugal-innovation capabilities will be developed. Central R&D offices are expected to take on the role of network coordinators, bringing together unique talents across the network to launch new development operations anywhere on the planet. In this perspective, the capacity to produce frugal innovation is a distinct and important skill. Nonetheless, the western MNC will play an essential role as a parent business; subsidiaries producing frugal innovation will benefit from the firm's global brand and global sales channels, potentially giving them a competitive advantage over new low-cost competitors (Zeschky et al., 2011).

Obstacles

For western firms, the burgeoning demand for frugal innovation poses two major obstacles. To begin, western firms must reconsider their old business strategies in order to achieve long-term success in frugal innovation. Typically, western corporations operating in emerging nations have centred their business strategies on the rich few at the top of the demographic pyramid

who have the purchasing power to acquire western items, rather than the resource-constrained customer. However, for two reasons, this technique of obtaining large margins from a small group of wealthy customers is becoming increasingly unpopular:

- On the one hand, cost-effective innovations will attract affluent consumers who will choose less costly items that yet suit their demands over time. The burgeoning middle class, on the other hand, is becoming a more appealing market with significant business possibilities. Western corporations risk losing market share to increased competition, both in emerging economies and in their home markets, if they continue to disregard the growing middle class in developing countries. These shifts will compel western businesses to adapt, radically changing how goods and markets are defined and linked (Zeschky et al., 2011).
- Second, western organisations that wish to engage in frugal innovation must have organisational structures and competencies that will allow them to design inexpensive goods. Existing R&D processes and structures, like the economic models that define them, are frequently optimised for the development of sophisticated products and technologies aimed at high-end consumers. Local R&D units' current duty is frequently still to adapt centrally generated goods to local demands, so using existing expertise and reducing the expense of new product development. The resultant goods generally include design and functionality modifications, but they are still often based on complex western product architecture that only a few wealthy individuals can purchase. Previous research implies, on the other hand, that successful frugal innovation necessitates a thorough grasp of the context in which such goods are generated. To build a really successful frugal innovation process, a stronger local presence and a fundamental new-product development effort may be required (Zeschky et al., 2011).

Emerging multinational corporations
Emerging multinational corporations (EMNCs) have a higher chance of succeeding with frugal innovation. To create frugal innovations, they have vast resources and local expertise. The developing world is the primary target market for many EMNCs. As a result, EMNCs have a greater potential for frugal innovations than MNCs (Hossain, 2018).

2.4.6 Drivers in developed/emerging markets

Frugal innovations are underpinned by certain basic characteristics. These aspects are both macro and micro in nature.

Macro-level drivers in developed markets
The economic slump has hit many western economies, and recovery has been slower than expected. Many nations' export businesses have suffered, resulting in substantial unemployment. These occurrences correspond with a growing shortage of natural resources, which results in higher raw material prices, putting pressure on retailers to raise product pricing. Many nations are experiencing insecurity and a welfare system crises as a result of political volatility and an ageing population. As a result of these and other causes, there is a need for new goods

and services that provide greater value with fewer resources and lower costs (Simula et al., 2015).

Micro-level drivers in developed markets
In both emerging and developed economies, many customers want to save money. As the unemployment rate in many low-income emerging countries rises, cost awareness is becoming more prevalent. Furthermore, many goods have been affected by the so-called over-engineering syndrome, which has resulted in feature fatigue among customers, who are hesitant to pay for too many features that they believe do not bring value. A similar phenomenon is innovation overload, which is defined as "a consumer's response to the constantly rising speed of change in information, knowledge, and inventions." Furthermore, individuals are becoming more concerned about problems like as sustainability and well-being (Simula et al., 2015).

Macro-level drivers in low-income emerging markets
Emerging economies have experienced tremendous population increase. Furthermore, economic development in low-income developing countries has been significantly faster than in developed nations in the West. Urbanisation has risen, and certain cities are rapidly expanding, such as in China, Latin America, and numerous African nations, posing significant infrastructural issues. Many developing nations are promoting innovation as a means of achieving social development and poverty reduction. India's government, for example, has legislation and financial provisions in place to help low-income individuals (Simula et al., 2015).

In low-income developing countries, resource scarcity is still a major macro trend. In any case, although western markets are contracting, a growing number of individuals in low-income developing economies are rising from the ranks of the working class to the ranks of the middle class, which naturally attracts many multinational firms looking for new business prospects (Simula et al., 2015).

Micro-level drivers in low-income emerging markets
In low-income emerging markets, cities and residential areas are transforming at an unprecedented rate. A number of technical breakthroughs, particularly in the ICT industry, have altered how people live, work, and spend their leisure time. People's likes and preferences are influenced by global community networks. People are still cost conscious, and they like the concept that things do not need to be cutting-edge, but only enough to fulfil fundamental necessities. To put it another way, there is a rising desire for good-enough solutions that are cost-effective (Simula et al., 2015).

2.4.7 Supply & Demand Drivers of Frugal Innovations

Companies are constantly under pressure to increase the value they provide to their consumers in order to stay competitive. This competitive pressure also motivates them to increase the efficiency with which they produce and distribute their products to customers. Growing resource scarcity and volatility have increased the demand on businesses to pursue frugal innovation in recent years. Several firms have put environmental sustainability at the centre of their business

strategies, or are in the process of doing so (Prabhu, 2017). These factors are mainly about the developed countries instead of the emerging ones, however, these factors are still important, as it could impact companies and have overlap with factors for emerging countries.

Supply

Companies have had to apply the frugal innovation approach to a variety of activities, including (i) how they source raw materials and manage their factories and supply chains, (ii) how they design and package their products and (iii) how they engage with consumers to encourage them to be more environmentally conscious in their consumption habits (Prabhu, 2017). For the last point, in a market economy, the power balance between corporations and consumers may be perplexing. While consumers are strong as a group, they are impotent to effect systemic change on their own. Corporations, particularly large ones, have significant market power, yet even the most powerful firms cannot force customers to modify their behaviour much. Firms, on the other hand, have a variety of methods at their disposal to persuade customers to change. The product that businesses sell to customers is one such tool (Prabhu, 2017).

Demand

On the demand side, three factors have to be looked at: (i) prosumers and the frugal economy, (ii), the sharing economy and (iii) the maker movement (Prabhu, 2017):

(i) The growth of so-called prosumers, customers who are no longer passive users of products and services from corporations but are actively participating in the economic process, is a significant demand-side development, particularly in western nations. These prosumers are fuelling at least two important movements towards a new, more frugal economy: the maker movement and the sharing economy (Prabhu, 2017).

(ii) Consumers are increasingly empowered to trade, share, or exchange spare assets with one another, frequently using internet and smartphone platforms designed to make these transactions as smooth, simple, and efficient as possible. These "collaborative consumption" services are asset light, scale quickly, and make greater use of available resources (rather than requiring the use of new resources). As a result, they are intrinsically frugal and pose a significant threat to many existing industries and business methods. The movement toward collaborative consumption and sharing reflects a broader trend in consumption: a shift away from owning and consuming physical goods and toward consuming intangible experiences. This demand for experiences, particularly among younger customers, reflects the growing importance of the service sector over manufacturing, particularly in developed nations. This so-called 'servitisation' of industry heralds the arrival of a more resource-light economy in the future, one in which value is produced more via the development of non-physical, psychological, or social experiences than through the utilisation of physical resources (Prabhu, 2017).

(iii) Consumers all throughout the world, but particularly in the West, are becoming increasingly empowered to get more done with less. Small groups of prosumers may now create in ways that only huge firms or the government could in the twentieth century, thanks to more widespread technologies and networks of like-minded individuals. These tools and places,

in combination with crowd-funding sites and social media, are fueling a ground-up, start-up revolution in software and hardware, in which 'prosumers' develop and subsequently market do-it-yourself (DIY), inexpensive solutions to local problems that may swiftly find worldwide applicability (Prabhu, 2017).

2.4.8 Frugal innovations in healthcare

The principle of frugal innovation has benefited emerging nations' healthcare sectors. Despite its significant contribution to the global community, the terrain of frugal innovation and its applicability has yet to be fully explored. Frugal innovation helps to improve people's quality of life by giving inexpensive items to the economically disadvantaged. Furthermore, frugal innovation allows the underprivileged to make a livelihood. Despite the fact that various inexpensive innovations have evolved in healthcare in recent decades, proper knowledge of the features of frugal innovation remains critical for researchers and practitioners to enjoy its full advantages (Arshad, 2021).

Only a few studies have looked at the potential of frugal innovation to enhance global health, and most of them have focused on single frugal breakthroughs. It is a human right to have access to healthcare and happiness. Despite the progress made in recent years throughout the world to increase healthcare access and well-being, healthcare inequities still remain (Arshad, Radić, & Radić, 2018).

Medical devices

Medical device usage is concentrated in high-income nations, with only 13% of the worldwide population accounting for 76% of global medical device use. When medical device makers did address the requirements of low and middle-income nations in the past, they tended to "glocalize," or eliminate features from high-tech goods that were built for more developed countries in order to market them in poorer countries. The industry is increasingly recognising that removing the bells and whistles is rarely enough to adapt medical devices for health workers who may lack training and technical skills and who work in environments that are not always equipped to handle the technology (Arasaratnam & Humphreys, 2013).

Power-hungry technologies, for example, designed for use in high-income nations with electrical power networks, might leave hospitals and clinics in low-income countries scrambling for generators or batteries. Furthermore, gadgets that are not built to withstand heat, humidity, or dust, or that are used often, are unlikely to live long. These types of concerns have contributed to a scenario where a considerable majority of medical equipment in underdeveloped nations may be partially or completely useless. According to WHO's Guidelines for Health Care Equipment Donations, up to 70% of medical equipment in Sub-Saharan Africa is unused. Companies' approaches are likely to evolve as they understand the business potential in low- and middle-income nations. The rising demand for effective and resilient low-cost medical equipment from emerging countries, particularly China and India is one of the major drivers of change (Arasaratnam & Humphreys, 2013).

Accessibility

Making medical equipment accessible in low-income settings is about more than just lowering the initial unit cost. The cost of ownership over time matters. Furthermore, the focus on locally contextualised research and design, clinical efficacy, and robustness that appears to define low-cost medical device endeavours suggests that such devices may, on the whole, prove to be more dependable than their more costly counterparts. They may also be more accessible, in addition to being more trustworthy. Low-cost medical devices offer immense potential to bridge the gap between the developed and developing countries, as well as to reach the "last mile" of people in the most creative ways possible (Arasaratnam & Humphreys, 2013).

Competitive advantage MNCs

MNCs benefit from frugal innovation since it gives them a competitive advantage. Affordability and availability are important issues for developing and emerging countries. MNCs should handle these issues as effectively as feasible by collaborating with local partners in the affected region. MNCs must first evaluate the needs of their consumers, and then endeavour to meet those demands by cultivating local links and creating a conducive environment for research and development. Partnerships between the public and private sectors, as well as reciprocal collaboration, have an influence on the implementation of frugal innovation. By including the low-income section of society, frugal healthcare innovation produces homogeneity in healthcare facilities. This will improve long-term sustainability (Arshad, 2021).

Examples of frugal innovation in healthcare demonstrate the concept of re-purposing existing technology in a more suitable and efficient manner, lowering the total cost of ownership. These examples serve as guidance for businesses to think more frugal in order to succeed in today's environment. Researchers are examining sustainability by focusing solely on the role of frugal innovation in achieving it. For continued growth, a viable business model for frugal innovation must be developed, so that MNCs may use it to adopt frugality in their organisations. Following the construction of the business model, a comparison between developed and developing nations, as well as MNCs and SME, should be made (Arshad, 2021).

Though the value of frugal innovation for competitive advantage has been discussed, it is still necessary to determine whether a company need two separate streams for the same project, one for frugal products and the other for products produced for highly competitive economies. The difficulty now is how to manage frugal innovation in the portfolio of a firm. In order to build a good solution, it is necessary to investigate how a company should manage this additional stream inside their existing business context. If a company wants to pursue frugal innovation, another point that has to be addressed is how to do so successfully (Arshad, 2021).

Distribution

Another point that has to be addressed is what factors should be checked before the frugal product is distributed globally. Despite the importance of frugal innovations for global health, there is little study on the subject. India is the market where the majority of healthcare innovations are first introduced, followed by the United States, where the majority of research

innovations are initially introduced. Overall, it was found that advanced economies account for over 85% of MNC and research-based innovations. As a result, they play an important role in accomplishing global health and welfare goals. Product innovations account for three-quarters of all innovations. The majority of the advances are preventive in nature. Another third of the cost-effective advances are medical in nature (Arshad, 2021).

2.4.9 Related terms

Frugal innovation resembles comparable business concepts such as shared value in terms of socially responsible innovation. Frugal innovation, like shared value, is concerned with performing better not only for the corporation but also for the various stakeholders with whom the organisation interacts (e.g. communities). Frugal innovation, on the other hand, is a broader idea than shared value. First and foremost, frugal innovation is about creating more value for anyone the company chooses to create value for: consumers, shareholders, or society as a whole. Second, frugal innovation is very concerned with the methods used to create more value, particularly the resources used to create value. This aspect of the equation is often overlooked when discussing shared value. Frugal innovation, in particular, considers how more value may be generated while lowering the resources required to do so, whether those resources are financial, natural, or time (Prabhu, 2017).

Jugaad, Grassroots, BOP and inclusive innovations

Frugal innovations have also numerous traits with other related words such as "Jugaad," "Grassroots Innovations," "Bottom of the Pyramid" and "Inclusive Innovations", albeit not all. Their context can be seen in Figure 2 However, it is safe to claim that the phrase frugal innovation can serve as a unifying tool to bring these disparate ideas together. The fact that frugal innovations are not always focused at the absolute bottom of the economic pyramid distinguishes them from basically cost-driven (BOP centred) methods. Rather, they aim to appeal to customers who, by need or choice, prefer items with a lower overall cost of ownership than conventional (entry level) products. Such clients' needs have frequently gone unmet in the past (Tiwari & Herstatt, 2012).

An explanation of the Bottom of the Pyramid can be found in subsection 2.1 - Bottom of the Pyramid. A short explanation of what Jugaad, Grassroots innovations and Inclusive innovations follows:

- Jugaad: Jugaad is a Hindi term that approximately translates to an ingenious remedy; an improvised solution born of creativity and cunning. It is a distinct style of thinking and behaving in response to obstacles; it is the brave art of seeing chances in the most inhospitable situations and resourcefully devising solutions with modest means. Jugaad is the art of getting more done with less (Radjou, Prabhu, & Ahuja, 2012).

- Grassroots innovations: Individuals as agents of change are the focus of grassroots innovation. Grassroots innovations are new products or processes developed at the bottom of the pyramid, frequently in response to a need, adversity, or a challenge. Individual inno-

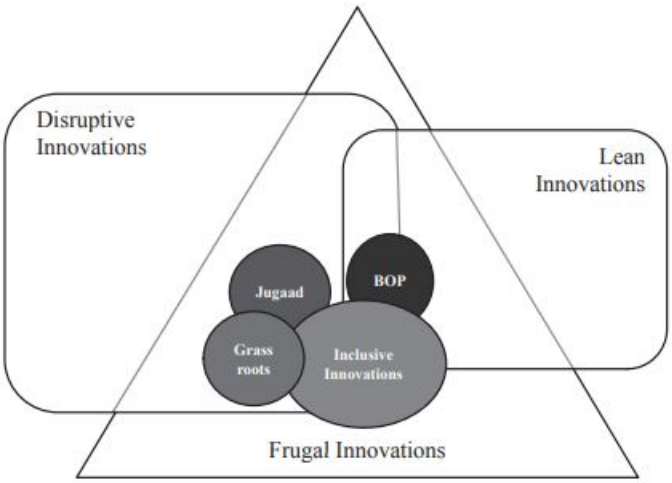

Figure 2: Context of frugal innovations with disruptive innovations and its related terms (Tiwari & Herstatt, 2012).

vators who act beyond the sphere of formal organisations such as corporate enterprises and typically make inventive attempts to tackle localised problems (Hilmi, 2012).

- Inclusive innovations: Inclusive innovation is the process of developing new goods and services for and/or by those who have been left out of the development mainstream, notably the billions of people living on the lowest wages (Heeks, Amalia, Kintu, & Shah, 2013).

2.5 Reverse Innovations

Emerging markets were the primary source of frugal innovations. The key goal was to provide products and services that met the specific demands and expectations of these markets while remaining affordable to non-affluent customers. Meanwhile, frugal innovations have made their way into developed markets, which is referred to as reverse innovation (Weyrauch & Herstatt, 2017).

Erroneously, the word "reverse innovation" is frequently used interchangeably with "frugal innovation". Despite the fact that they both refer to the same term and are interconnected, there is a distinction between them (Khan, 2016). Reverse innovation is the process by which products created as low-cost models to address the requirements of developing countries, such battery-operated medical tools in economies with poor infrastructure, and are then repackaged as low-cost new products for developed economies (Basu, 2017). Reverse innovations are usually built on the foundation of low-cost, good-enough, or frugal innovations. They are "clean-slate" inventions, which implies they must be created from the ground up and need a shift in how businesses approach innovation. The difference between frugal and reverse innovation is that frugal innovation includes developing solutions exclusively for low-income market groups, whereas reverse innovation involves developing new items in emerging economies and then modifying them for sale in established markets (Khan, 2016). It occurs when a product is produced in an emerging market to meet the demands of customers, then exported to an

established market. It focuses on the creation of new markets and business models, and it may be implemented in the market by shifting the center of gravity to the local market and gaining skills and knowledge in emerging economies. The established and developing economies are distinguished by performance, sustainability, infrastructural, regulatory and preference gaps (Arshad, 2021).

A major success factor in the development of reverse innovation is the development of capabilities regarding frugal product innovations. A company's capacity to capitalise on the possibilities of reverse innovation increases its chances of global innovation success (Khan, 2016). Reverse innovations therefore innovate in the other direction. While the notion appears to be possible, just a few companies have succeeded in reverse innovation, which potentially necessitates a new organisational structure, re-orienting product development and innovation methodologies, and offering new surroundings for salespeople (Hossain et al., 2016). Nevertheless, reverse innovation casts doubt on the widely held idea that wealthy economies are the centres and sources of inventions, which then spread to underdeveloped countries in stripped-down form. As a result, developing economies are no longer exclusive beneficiaries of developed-country advances. To grasp the extent of reverse innovation, consider the following definition: Reverse innovation is described as a resource-constrained approach, such as a product, service, process or business model, that has been effectively moved (with some adjustments) from emerging markets or poor nations to industrialised countries (Hossain et al., 2016).

They are low-cost innovations that are initially embraced in developing countries and then 'trickle up' to wealthier economies. Rather of focusing on a product, their ideas center around the market. Successful inventions are first developed in developing nations by Western MNCs with innovative techniques of gaining a competitive advantage and then exported to Western countries. Western MNCs employ reverse innovation as a tactic to improve their competitiveness (Ashfaq et al., 2018).

The notion of reverse innovation is conceivable, but it necessitates corporations discarding their prior structure, reorienting their manufacturing processes, and adopting new inventive procedures with a fresh sales force setting, resulting in just a few firms succeeding in the endeavour. The issue for businesses is not only to get adept at inventing in developing markets; it is also to figure out how to bring these ideas back to their main markets. Some companies, such as General Electronics (GE), take this method and first target low-income consumers in emerging economies for frugal ideas, before bringing them back to wealthy nations as reverse innovations (Ashfaq et al., 2018).

2.6 Conclusion sub-research questions 1, 2 and 3

Based on the literature review, sub-research questions 1, 2 and 3 can be answered.

2.6.1 Sub-research question 1: What is over-engineering and its characteristics?

Over-engineering is when a product or a solution to a problem is designed in an intricate or sophisticated manner when a simpler option can be proved to exist with the same efficiency

and effectiveness as the original design. Over-engineering dramatically increases the costs of design, installation and operation.

There are two types of over-engineering:

1. to over-engineer to serve the existing demanding consumers with ever-improving products.
2. to over-engineer to comply with rules and regulations

The first type of over-engineering is happening, because incumbents often strive to give ever-improving products and services to their most profitable and demanding clients, while paying less attention to less-demanding consumers or non-consumers. The incumbents enable the feasibility of disruptive innovations by the fact that these innovations begin in two types of marketplaces that incumbents ignore: the less-demanding consumers and the non-consumers. In reality, incumbents' offers frequently outperform the latter's performance criteria. The less demanding customers will be provided with products that are good enough and non-consumers could be turned into consumers, which could disrupt the over-engineered product. This type of over-engineering is visible on the demand-side of the market, which means that the products are mostly not a necessity, depending on their context, however, there is a high demand for these products.

On the other hand, the second type of over-engineering belongs to the supply-side of the market and does not focus on improving their products and services to their most profitable and demanding clients, while paying less attention to less-demanding consumers. The products and services on the supply-side are not luxury goods, but are a necessity.

2.6.2 Sub-research question 2a: What are the causes of over-engineering for medical equipment in the medical industry?

The causes and reasons for over-engineering in the medical industry is due to:

- Safety: There are several trade-offs between complexity and expense when designing devices to achieve desired safety performance. Cost, quality and time balance are never easy to achieve. Project costs and schedules are likely to be considerably exaggerated by placing a strong emphasis on design quality in an effort to account for all unforeseen eventualities. Additionally, machinery that has been unduly built for safety may operate slowly or with a limited range of motion. Some medical devices have safety mechanisms that enable them to function even in the event of failure.
- Performance: Regulatory bodies typically need specialised equipment performance testing. To cure the sickness or illness, equipment must be made that is also long-lasting enough to last the patient their entire life without compromising other aspects of their quality of life.
- R&D: Medical devices include a range of RD procedures and ethical challenges that are unique to them because of how they interact with people. The need to address unmet clinical needs, the alignment of technological challenges with internal capabilities and

available expertise, the infrastructure required to effectively distribute and support the product, the anticipated time to market, financial risks and rewards and the likelihood of market acceptance are just a few of the considerations that companies make when choosing RD projects. The effects on development and research are substantial. These factors could increase the cost and complicate the product excessively.

- Testing: Medical device design requires careful planning and testing with known and unknowable variables that might effect device operation, such interoperability issues. For the gadget to be approved by a regulatory agency, thorough human and non-human investigations as well as significant trials must be conducted. As a result, the device's cost increases. If the tests are unsuccessful, the product could have been over-engineered to succeed.

- Other regulations: Sometimes low-income economies are unable to get affordable, effective equipment due to regulations, which might vary by country. Regulations could force manufacturers to over-engineer a product. For instance, safety comes under the regulations category. However, there are many additional rules that have an impact on the complexity and cost of the equipment.

2.6.3 Sub-research question 2b: What are the causes of over-engineering in the mobile phone industry?

The causes and reasons for over-engineering in the mobile phone industry is due to:

- Performance: Characteristics of the phone's brand name as well as social influence from peers and family have a significant impact on consumers' demand for phones and its features. Performance (battery, speed, etc.) is a key factor in this situation. It affects a person personally and socially. Performance is enhanced as a result for the demanding consumers.

- Competitiveness/profit: Businesses are striving to make a profit and even survive in a very competitive environment. When there is hardly any competition, businesses can increase the price to generate profit. In case of a competitive environment, the prices will be kept low enough such that the demanding customers will not go to the competition, but high enough to generate profit or to survive.

- Demand: Voice dialling, colour displays and mobile Internet are just a few of the features that might significantly affect how happy customers are. Phones with mobile Internet are more popular with users than those without. Higher-resolution images should be produced by mobile phone cameras so that users may access visual information with more precision and clarity. The demand to enhance mobile phone features is growing. As a result, there is a demand for phones with these functions and the price is one that the demanding customers are willing to pay.

2.6.4 Sub-research question 3: What are the characteristics of frugal innovations?

An innovation manifestation called "frugal innovation" aims to reduce the cost of systems, services and products and are accessible to the Bottom of the Pyramid. It is often associated with affordability, low-cost production, low-cost materials and design that focuses on fundamental functioning and feature sets for the unserved end of the mass market while meeting or even exceeding certain pre-defined quality standards.

There are three requirements for frugal innovations:

- Substantial cost reduction: When compared to traditional products and services, frugal innovation has a substantially lower price or significantly lower expenses. Defining a threshold for 'substantial' is difficult. Therefore, a recommendation has been made, which is that the considerable cost savings from frugal innovation must be at least a third lower than comparable items.
- Concentrate on core functionalities: Core benefits, fundamental functions and decreased complexity are frequently connected with frugal innovation. As a result, frugal innovation involves a focus on the key features that provide the greatest consumer advantages, as well as a direct focus on user requirements
- Optimised performance level: Frugal innovation should achieve the performance and quality standards that are actually necessary while keeping expenses to a minimum.

2.7 Theoretical knowledge sub-research questions 4 and 5

Based on the literature research, sub-research questions 4 and 5 cannot be answered yet. However, prior knowledge can be found in this section that will help in researching into these questions and helping to answer them.

Frugal innovations
Important information regarding frugal innovations from the literature research in helping to do more research and answering these two sub-research questions are the three criteria to identify frugal innovations, how to achieve the value proposition of companies with regards to frugal innovations and the characteristics of frugal innovations. For frugal innovations, the price needs to be affordable for the BOP, its design needs to focus on the fundamental functioning and features to serve the BOP and it needs to have a low-cost production (and other operational/financial aspects), which relate to the business model. This information is needed, because for this research, frugal products, services and systems will be looked into and it is useful to know what characteristics the products, services and systems have that can relate to over-engineering, how it can be achieved to produce frugal innovations and what makes frugal innovations frugal.

The first item that is needed for the sub-research questions is the three criteria to identify frugal innovations. These criteria are, substantial cost reduction, concentration on core functionalities and optimised performance level. The frugal innovations this research is going to

explore therefore must meet these three criteria points.

The second item that is needed for the sub-research questions is how to achieve the value proposition of companies with regards to frugal innovations. Companies that offer inexpensive products and services are also competing against "non-consumption" instead of focusing on traditional competition. This value proposition can be achieved by reduced overall costs, user friendliness and economics of scale.

The third and last item is the characteristics of frugal innovations. The most common characteristics of frugal innovations are that it is affordable (for the BOP), producing more value with fewer resources and easy to use (for the BOP), while the performance is still optimal.

Over-engineering

Furthermore, important information regarding over-engineering from the literature research in helping to do more research and answering these two sub-research questions are the reasons over-engineering occurs and the impact it has on the BOP. Over-engineered products/services/systems, are expensive in terms of price, more complex in terms of design and have a high-cost production and/or other operational/financial aspects. This information is needed, because for this research, it needs to be researched upon what the link between over-engineering and frugal innovations is. Due to this information, it can possibly be researched on how the factors of frugal innovations can limit the impact of over-engineering and the source of over-engineering.

The reason over-engineering occurs in the medical industry is due to safety of the product/service, its performance, R&D, testing of the product/service and other regulations. In the mobile phone industry, the reason to over-engineer is due to the performance of the product/service, competitiveness/profit and due to demand of customers.

Furthermore, the impact that over-engineering has on the BOP is that the products or services could be unavailable to them, due to their skills and abilities (e.g. product/service is too complex), its price, its access (e.g. not compatible with the infrastructure such as electricity) and time (e.g. required time to learn how to utilise the product/service).

3 Research Method

In addition to the Literature Review, which answers the first, second and third sub-research questions, another method of doing research needs to be done to answer the remaining research questions.

3.1 Strategies

In order to see what influence frugal innovations can have on over-engineering, the reasons to over-engineer and the elements of frugal innovations need to be known. Since this research is an exploratory research[4], the best research approaches are doing (1) case studies, (2) survey research, (3) experiments or (4) pseudo-experiments. Doing (pseudo-)experiments (approaches 3 and 4) is not feasible within the time-frame of this thesis, nor is it what I aim to do, since this thesis does not test for causality using variables that can be manipulated. The research needs to be done on products or services to explore the existing practical issues regarding frugal innovations in the related fields. For this, a survey (approach 2) has high external validity and is statistical generalisable, however, no follow up questions can be asked, nor can interesting and relevant additions be explained. Therefore, a case study, the first approach, seems to fit this research, since it gives an in-depth understanding of the topic and insights in context. Case studies can shed light onto the phenomena of frugal innovations for the BOP in the mobile phone industry and medical industry. With case studies, it can be explored what success factors of frugal innovations are, substantiated with real-life examples, that could potentially influence over-engineering. Furthermore, by doing case studies and linking the cases with the definitions of frugal innovations and over-engineering, it indirectly can find causality. By doing literature research on frugal innovations and over-engineering and linking them to the case studies and analysing the results, causality will follow. Therefore, with the case studies, the research objective - *to investigate the factors of frugal innovations that can affect over-engineering in the mobile phone industry and in the medical industry* - can be achieved.

3.2 Case study

The case study approach is defined as a thorough study of a single unit or a small group of units (the cases) with the goal of understanding a wider class of related units (a population of cases). Case studies lend themselves to idiographic analysis, whereas quantitative work lends itself to nomothetic analysis (Gerring, 2006). In this thesis, the case studies will be used as a framework in relation to the literature review. To conduct the case studies, a case study protocol has been made.

3.2.1 Protocol

There are four essential sections for the protocol: overview of the case studies, data collection procedures, protocol questions and tentative outline for the case study report (Yin, 2018).

[4]Information gathered from the course MOT2312 Research Methods (2020/2021 Q2)

These sections will be discussed per industry, the mobile phone industry and medical industry.

3.2.1.1 Medical industry - A. Overview of the case study

The case for the medical industry is about three products/services of the Philips Africa Innovation Hub.

Background
About half of the world's population lacks access to healthcare. To be more precise, 56% of people living in rural areas around the world lack access to healthcare, with 83% in Africa. In Sub-Saharan Africa, four out of ten individuals lack access to healthcare facilities or personnel and those who do have poor quality services. Investing in long-term, accessible and high-quality primary care is critical to solving Africa's most serious health care concerns and improving the lives of Africans. The difficulties surrounding primary care in Africa are complex and numerous and jointly tackling these concerns is required to achieve long-term change. Lack of skilled healthcare staff, non-operational medical equipment, a lack of electricity, water and basic healthcare technologies, as well as a lack of sustainability and trustworthy data, are all challenges (Philips, 2017).

To tackle this problem, the MNC Philips started the Africa Innovation Hub that developed healthcare services and products for its Community Life Centers (CLCs). The CLCs are platforms that combine new technologies with primary healthcare services. It is a primary healthcare center that provides the fundamental healthcare services and goods required to prevent sickness, improve health, and manage disease, with an emphasis on maternity and child health in Africa, mainly for the BOP. In semi-urban, rural and remote locations, it modernises and turns primary healthcare institutions into economic and social hub, placing community involvement at the center of product creation and facility management. The healthcare services and good were developed by the Africa Innovation Hub (Onsongo, 2021). In order to develop ideas in Africa, for Africa, Philips created the Africa Innovation Hub in Kenya in 2014 as a hub for developing innovations in order to provide locally relevant technologies that address these concerns. It is based in its headquarters in Nairobi, where African and researchers and researchers from other countries work together in this "open innovation" environment in close coordination with the larger R&D ecosystems in Kenya and Africa. The hub focuses on generating low-resource medical solutions as well as sustainable commercial structures for growing these discoveries. The technology it employs take into account the difficult local conditions and problems that African health workers face on a daily basis (Philips, 2017). Three innovations of the Africa Innovation Hub will be discussed, the Wind Up Fetal Doppler, the Children Automated Respiration Monitor and INUKA.

Rationale selection case and selection criteria
The Philips Africa Innovation Hub has been selected based on the following criteria:

- The project/company has/had frugal innovation(s) for the BOP that have been successful.

- The project/company has/had frugal innovation(s) for the BOP that have been unsuccessful.
- An employee of the company or competent and knowledgeable person with regards to this topic that has helped in producing or selling the products mentioned in the previous points must be willing to participate in an interview.
- The information gained in the interview regarding the successful and unsuccessful frugal innovations must not be private corporate information and should be allowed to be shared or be publicly available.
- The product/service must be about medical equipment.

With this case study, real-life problems that need to be solved can be seen. The Philips Africa Innovation Hub created frugal innovations that have been used to tackle the problems. Three of these products will be discussed. With these three products/services, it is evident what features or circumstances lead to the success or failure of such an innovation and how it helped to tackle the problems. These features and circumstances potentially could be expanded to other frugal innovations. With the three frugal innovations in this case study, the successful and less successful factors and elements of frugal innovations will be shown that could potentially influence over-engineering.

Goal of case study
With this case study, consisting of conducting an interview and literature research, I aim to gain knowledge on

- the factors that make the frugal products affordable.
- the factors that make the frugal products successful.
- the factors that make the frugal products unsuccessful.
- the reasons to engage in frugal innovations.
- the limitations that the environment of developing economies bring to producing or selling frugal products.
- the effect of factors of frugal innovations on over-engineering.

Broader theoretical or societal relevance
With this case study, the knowledge gap, as discussed in the introduction, can be partially closed. The successful and unsuccessful factors of frugal medical innovation can be seen, which could impact over-engineering. The relation of the impact of over-engineering of frugal innovations can hardly be found in the literature for the medical industry.

Case study selection design
The case study is an embedded, single case study design (Yin et al., 2003). There is one

context, which is the Africa Innovation Hub, that has more than one units of analysis; the three innovations of the Africa Innovation Hub that are going to be discussed, the Wind Up Fetal Doppler, the CHARM and INUKA. The multiple units of analysis are studied to understand the differences and the similarities between these innovations in context of the Africa Innovation Hub. Using an embedded, single case study design, the differences and similarities can be easier analysed, as there are not as many diverging variables that influence the innovations. Hence, an embedded, single case study design has been chosen.

3.2.1.2 Medical industry - B. Data collection procedures

There are several ways of collecting data conducting a case study[5]. I aim to conduct an interview in the medical industry in combination with literature research. This allows for gaining information regarding sub-research questions 4a and 5.

For the interview for the case study, one person has been interviewed. With the information of the interview, relevant literature sources have been found as reference. The reason for the extra literature research and references to this literature, is because of potential risks to the interviewee due to Personally Identifiable Information and/or Personally Identifiable Research Data. A full list of risks and mitigation can be found in Appendix A - Human Research Ethics.

Advantages interview
Conducting interviews have several advantages, such as having a high response rate during the interview. If there is need for special visual aids or scoring devices, it can be provided. Furthermore, if there are uncertainties or doubts, it can be clarified on the spot. Moreover, non-verbal clues can be witnessed, such as body language.

Disadvantages interview
Conducting interviews do not only have advantages, it can have geographical limits. Moreover, it could be expensive and can cost a lot of time. Furthermore, confidentiality is difficult and there could be a bias in response. Lastly, there is a need for trained interviewers.

Motivation interview
Doing interviews can help me in navigating the questions and rephrasing them in order to get an answer to my questions and a high response rate during the interview. If something is unclear, I can clarify it. If the interviewee tells something interesting, I can easily follow up on it. If there are special cases or outliers regarding certain topics, it is easier to gather that knowledge conducting interviews. It can also give me an insight in their products. On hands experience with their products can be gained. Furthermore, by researching into what is the best way to create conduct an interview, the last disadvantage can be decreased.

Semi-structured interview
The interview that has been conducted was semi-structured. First, a general interview scheme

[5]Information gathered from the course MOT2312 Research Methods (2020/2021 Q2)

with questions has been used. All the questions can be found in Appendix B - Interview Questions. With these questions, when something interesting comes up during the interview, the interviewee has the opportunity to tell more about the matter and the interviewer can ask follow-up/clarification questions. Here, the interviewee gets the freedom to express more than is required and is the main person that will do the talking. With this, a conversation or discussion can be started.

Criteria interviewees
The selection of the interviewee has been done based on the following criteria:

- The interviewee must have worked on the frugal innovation, must have had projects based on these frugal innovations or must at east be knowledgeable about the innovation.
- The interviewee must have knowledge on the frugal innovation and is willing to share them.

Process contacting companies
Based on the criteria in the sections above, the companies that have been contacted are GE Healthcare, Phillips Healthcare, Siemens Healthineers, Medtronics plc., Abbott Laboratories and Canon Medical Systems. Unfortunately, the several companies that have been contacted, have either not responded or could not help me with the research, with an exception of someone who is knowledgeable about frugal innovations of Philips, who was willing to participate in the interview.

Informed consent
Before data gathering can happen by means of interviews, it is important to identify risks for the interviewee and interviewer, minimise those risks and creating communicating these risks and measures to the interviewee. These can be found in Appendix A - Human Research Ethics.

3.2.1.3 Medical industry - C. Protocol questions

The protocol questions are for the researcher to ask themselves for the inquiry of data (Yin, 2018). Therefore, for the data collection, together with the interview questions, protocol questions have been asked in order to gather data in a structural manner. Furthermore, it will help in answering sub-research questions 4a and 5. The questions are as followed:

- What are Philip's objectives? Does is relate to the reason they have set up the Africa Innovation Hub?
- Wind Up Fetal Doppler
  - What is the Wind Up Fetal Doppler?
  - What problem does the Wind Up Fetal Doppler solve?
  - What is the relationship between the Wind Up Fetal Doppler and frugal innovations?

  - What are the successful and unsuccessful factors of the Wind Up Fetal Doppler?
- CHARM
  - What is the CHARM?
  - What problem does the CHARM solve?
  - What is the relationship between the CHARM and frugal innovations?
  - What are the successful and unsuccessful factors of the CHARM?
- INUKA
  - What is INUKA and what problem does it solve?
  - What is the relationship between INUKA and frugal innovations?
  - What are the successful and unsuccessful factors of INUKA?
- How did regulations influence the products for the Africa Innovation Hub?
- Why does reverse innovation occur with the products?
- What are the differences between a start up/spin-out and a multinational with regards to producing and selling the products of the Africa Innovation Hub?
- What is the relationship between the three discussed innovations and frugal innovations?
- What are factors of frugal innovations of the three discussed products in the Africa Innovation Hub?
- What elements have an influence on factors of frugal innovations?
- What is the relation of the frugal three products with over-engineering? Are the three discussed innovations of the Africa Innovation Hub generalisable with regards to frugal innovations in the medical industry?

3.2.1.4 Medical industry - D. Tentative outline for the case study report

Before the data analysis will be conducted, a tentative outline for the case study report will be made, because it will force the researcher to think about it beforehand. The case study will not contain data analysis, since this will be outlined in the report. The outline of the case study will consist of the protocol questions as headers, so that the report will be structured. The length of the case study will be between 10 and 15 pages.

3.2.1.5 Mobile phone industry - A. Overview of the case study

The case for the mobile phone industry is M-Pesa.

Background
Approximately 20% of Kenyans had a formal bank account in 2006. The lack of branches

and ATMs in rural areas contributed to this in part. Only four branches were present in the country's whole north-eastern area at the time, and nearly half of all branches were in Nairobi, the nation's capital. Formal banking was impossible due to the distance from banks. Due to this, most transactions were conducted in cash, and people had to travel up to several hundred kilometers to make withdrawals or pay bills. Long trips with big sums of money were not only time-consuming but also dangerous in a nation with a high crime rate. Families who were reliant on relatives who worked in business hubs faced an existential threat as a result. Such migrant workers had little options for providing the badly needed financial support to their family in rural locations, and the majority of the solutions available were very expensive. Small business owners had less opportunity to succeed due to the weak banking infrastructure. These business owners had to either plan complicated payment logistics or were limited to using only local suppliers (Martin, 2018).

This changed with the introduction of M-Pesa. M-Pesa is a virtual banking system that uses a SIM card to deliver transaction services. It was introduced in Kenya as a different manner for the country's citizens to access financial services. M-Pesa was launched in 2007 by Safaricom, Kenya's leading mobile phone operator. The service combines two entities: M stands for mobile, and Pesa stands for money or payment in Swahili (Kagan, 2020). It uses "e-float", Safaricom's electronic money - until users are ready to utilise it for transfers, airtime purchases or bill payments (Eijkman, Kendall, & Mas, 2010). Users can swap cash for e-float on their phones, transmit e-float to other cellular phone users and exchange e-float back into cash via M-Pesa. The tale of mobile phone adoption in Africa is one of a seismic and unanticipated shift in communications technology. From being practically unconnected in the 1990s, over 60% of Africans now have access to mobile phones and there are now over ten times as many mobile phones as landline phones (Edwards, Johnson, & Weil, 2016).

Even with the growth of mobile phones as a backdrop, M-Pesa's growth has been astounding. Over 1.1 million Kenyans had registered to use M-Pesa within eight months of its launch in March 2007 and over US$87 million had been transferred through the system. Over 8.5 million Kenyans had registered to use the service by September 2009 and US$3.7 billion (equal to 10% of Kenya's GDP) had been exchanged over the system since its introduction. This rapid expansion was paralleled in the number of M-Pesa agents (or service locations), which had risen to over 18000 by April 2010 from a low of around 450 in mid-2007 (Edwards et al., 2016).

Rationale selection case and selection criteria

M-Pesa has been selected based on the following criteria:

- The project/company has/had frugal innovation(s) for the BOP that have been successful.
- The product/service/system must relate to the mobile phone industry.
- Information regarding the product/service/system must not be private and can be openly shared.

With this case study, a real-life example of a problem that needs to be solved can be seen. M-Pesa is a frugal innovation and while it is not a mobile phone, it can shed light onto the phe-

nomena of frugal innovations and over-engineering with regards to mobile phones. When mobile phones are made frugal, complementary products/services/systems, such as M-Pesa, also can be made frugal, and vice versa. M-Pesa serves as support for the mobile phone industry to shed light onto the phenomenon. Therefore, M-Pesa is an innovation with relation to the mobile phone industry that tackled the existing problem as described before. Furthermore, M-Pesa as a case study can be used evidently to show what the successful factors have been for the innovation. This can be used to show what the impact is of the frugal factors on over-engineering.

Goal of case study
With this case study, consisting of literature research, I aim to gain knowledge on

- the factors that make the frugal products affordable.
- the factors that make the frugal products successful.
- the reasons to engage in frugal innovations.
- the limitations that the environment of developing economies bring to producing or selling frugal products.
- the effect of factors of frugal innovations on over-engineering.

Broader theoretical or societal relevance
With this case study, the knowledge gap, as discussed in the introduction, can be partially closed. The successful and unsuccessful factors of frugal innovation in the mobile phone industry can be seen, which could impact over-engineering. The relation of the impact of over-engineering of frugal innovations is yet unknown in the mobile phone industry.

Case study selection design
The case study is a holistic, single case study design. Only one unit of analysis is being investigated and researched upon. M-Pesa is the unit of analysis. M-Pesa can shed light on the phenomena of frugal innovations in the mobile phone industry. It serves as aid in this research for the mobile phone industry. When mobile phones are made frugal, complementary innovations, such as M-Pesa, also can be made frugal. Since M-Pesa serves as an aid to the mobile phone industry, to not drift away from the original research idea and the mobile phone industry, M-Pesa is the only case that will be investigated. Other cases could deviate too much from the original idea of the research as well as M-Pesa. Hence, this case study is a holistic, single case study.

3.2.1.6 Mobile phone industry - B. Data collection procedures

There are several ways of collecting data conducting a case study[6]. I aim to conduct an extensive literature research. This allows for gaining information regarding sub-research questions 4b

[6]Information gathered from the course MOT2312 Research Methods (2020/2021 Q2)

and 5. Literature research has been done in an online research form through my laptop. The literature research started in June 2022 and ended in August 2022.

Conducting an interview for this case study was not feasible, because no contact could be established with someone that worked on M-Pesa. Fortunately, the required information needed for this research can be found in literature. The protocol questions could be answered by doing literature research. Based on literature research and data analysis, the research questions can be answered in a satisfactory manner.

3.2.1.7 Mobile phone industry - C. Protocol questions

For the data collection, protocol questions have been asked in order to gather and analyse data in a structural manner. Furthermore, it will help in answering sub-research questions 4b and 5. The questions are as followed:

- How does M-Pesa work?
- What problem does M-Pesa solve?
- Who were the early adopters of M-Pesa and what did this do for M-Pesa?
- What were the previous methods of money transfer in Kenya and why is M-Pesa a better method?
- What is the effect of M-Pesa on the Bottom of the Pyramid in Kenya?
- How did M-Pesa become a disruptive innovation?
- Why did M-Pesa become a success in Kenya?
- Why did M-Pesa receive criticism in Kenya?
- Why did reverse innovation occur?
- What is the relationship between M-Pesa and frugal innovations?
- What are the successful factors of frugal innovations for M-Pesa?
- What elements have an influence on factors of frugal innovations?
- What is the relation of M-Pesa with over-engineering?
- Os M-Pesa generalisable with regards to frugal innovations that are linked to the mobile phone industry?

3.2.1.8 Mobile phone industry - D. Tentative outline for the case study report

Before the data analysis will be conducted, a tentative outline for the case study report will be made, because it will force the researcher to think about it beforehand. The case study will not contain data analysis, since this will be outlined in the report. The outline of the case study will consist of the protocol questions as headers, so that the report will be structured. The length of the case study will be between 10 and 15 pages.

3.2.2 Generalisability

The factors of frugal innovations to impact over-engineering will not follow from the case studies, but rather based from the definition. Therefore the factors of frugal innovations will be generalisable. Furthermore, the case studies for both industries will single case study designs. Due to this, the study's further findings should not be generalised, since only one interview has been conducted and literature research has been done regarding one situation/context per industry (M-Pesa and Philips Africa Innovation Hub). Due to this small sample size, there is a lack of generalisability in this study. It was difficult to find people willing to be interviewed regarding this topic. While potential interviewees have been found spread over multiple companies, thus having a larger sample size and multiple case studies, they were not willing to participate.

Nevertheless, in this study, only one interview has been conducted and literature research has been done regarding one context per industry, hence the findings should be interpreted with caution.

3.3 Data Analysis

After the data has been collected, data analysis needs to be conducted. The data was collection based on one interview (medical industry) and literature research (medical and mobile phone industry). To analyse this data, questions have been written down based on the sub-research questions in order to help guide in finding useful information and structure the data needed for this research. Based on these guiding questions, sub-research questions 4 and 5 can be answered after the data analysis.

These guiding questions for analysing data have been divided per case study. The questions differ per case study, thus per industry, because as mentioned in the Data Collection section, they are two different single case studies that do not describe the same phenomena and that do not need to be compared with each other. Only the answers to the research questions can be compared to each other, not the contexts themselves. Furthermore, the questions have overlap with the protocol questions in the previous section.

3.3.1 Guiding questions - Medical industry

- What are the factors of frugal innovations for the three products of the Africa Innovation Hub?
- What do the factors mean for other medical equipment in the medical industry?
- How can the factors and characteristics of frugal innovations for the three equipment of the Africa Innovation Hub be linked to over-engineering in the medical industry?
- What are the elements that influence the factors of frugal innovations for the three products of the Africa Innovation Hub?
- What are the factors of frugal innovations to affect over-engineering for medical equipment in the medical industry?

- What are the elements that influence the factors of frugal innovations in the medical industry?
- How can the elements of the factors of frugal innovations be used to influence over-engineering in the medical industry?

3.3.2 Guiding questions - Mobile phone industry

- What are the factors of frugal innovations for M-Pesa?
- What do the factors mean for other products/services/systems in the mobile phone industry?
- How can the factors of frugal innovations for M-Pesa be linked to over-engineering in the mobile phone industry?
- What are the elements that influence the factors of frugal innovations for M-Pesa?
- What are the factors of frugal innovations to affect over-engineering in the mobile phone industry?
- What are the elements that influence the factors of frugal innovations in the mobile phone industry?
- How can the elements of the factors of frugal innovations be used to influence over-engineering in the mobile phone industry?

4 Case Study

In this section, two different single case studies will be explored. These case studies will help in gaining insight on the successful and unsuccessful factors of frugal innovations, what elements can influence these factors and how it can impact over-engineering. With these case studies, sub-research questions 4, 5 and 6 can be answered after analysing the the cases in section 5, the Results section. Furthermore, this section uses the protocol questions for gaining information for the case studies. Some questions are in subsections (e.g. 4.1.1 What is ...), which highlights the importance of those questions, since these are needed to answer the sub-questions in the results.

4.1 Medical - Philips Africa Innovation Hub

For the case study in the medical sector, research has been done on three innovations of the Philips Africa Innovation Hub.

What are Philip's objectives? Does is relate to the reason they have set up the Africa Innovation Hub?

To help improve the health and well-being of individuals, Philips' mission is to make life better by 2030 for 2.5 billion people annually, including 400 million individuals who are underserved (Philips, n.d.). The Community Life Center Program, which was created due to the Africa Innovation Hub, was created as a method of expanding into to the African market (Onsongo, 2021). Philips is open to collaborating with key stakeholders, such as governments and non-governmental organisations, to develop innovative solutions that benefit people and address society's most pressing issues (Philips, 2014).

Philips' mission relates to the Africa Innovation Hub by aiming to reduce the current health-care problem. Their reason for engaging in frugal innovations therefore aligns with this research; to improve the lives of the BOP and underserved by providing them with products that they actually can use.

Products

Three products of the Africa Innovation Hub will be discussed. The first is the Wind Up Fetal Doppler, which has been least successful. This will be followed by the Children's Automated Respiration Monitor (CHARM), used to detect pneumonia for children. The last innovation that will be discussed is INUKA. INUKA is not a product, but a service and has proved to be the most successful innovation of the three.

Wind Up Fetal Doppler

What is the Wind Up Fetal Doppler?

One of the products from the innovation hub is the Wind Up Fetal Doppler, as seen in Figure 3a. The Wind-up Fetal Doppler is a gadget that can be used to count the fetal heart rate quickly and precisely while a mother is in labour. When the fetal heart rate slows near the conclusion of a uterine contraction, it is a sign that the fetus is not getting enough oxygen and is at risk of brain damage or death. The appropriate actions can be taken by a midwife or delivery nurse to protect the child is this is identified early enough (Philips, 2014).

What problem does the Wind Up Fetal Doppler solve?

Preventable complications during childbirth kill many women and newborns in Africa's semi-urban and rural settings. As a result of the baby receiving little oxygen when the mother is giving birth, many babies, especially in low-resource environments, die during labour or suffer brain harm. Many of these deaths and cases of brain impairment may be avoided if midwives and delivering nurses used a Doppler ultrasonography device to assess the baby's well-being throughout labour (Philips, 2014).

Philips announced a collaboration with PowerFree Education Technology (PET), a non-profit organisation based in South Africa, to continue to create, evaluate and market a Wind-up Doppler ultrasound fetal heart rate monitor (further mentioned in this document as Wind-up Fetal Doppler). For several years, PET worked on developing the hand-cranked, Wind-up Fetal Doppler, and they proved the device's great outcomes in Uganda, where 60% more cases of irregular fetal heart rate were identified in labour than with a typical Pinard-stethoscope. With a Pinard-stethoscope, it is difficult to get an exact measurement because you need to be able to hear the fetal heart clearly and count the rate correctly. It is frequently distressing for the mother as well. A Doppler ultrasonography fetal heart rate monitor is a good solution, however the current devices on the market are not robust enough and require mains or battery power (Philips, 2014).

The Wind-up Fetal Doppler was created with the express purpose of enabling midwives and delivering nurses to provide better care. Current fetal heart rate monitoring devices are either too costly, too imprecise, or depend on replaceable batteries or other energy sources to operate (Philips, 2014). The Wind-Up Fetal Doppler contains internal batteries that may last up to 10 hours and when a mains supply is not available, operating the device for up to 10 minutes only requires one minute of turning the wind-up handle on the back of the device (Figure 3b). By turning the wind-up handle, the product generates electricity to power the device (Philips, 2016). It served the need of the people in the area of the Africa Innovation Hub. However, if the medical staff is not taught how to utilise the technology effectively, supplying it is useless. According to data from the World Health Organization (WHO), almost half of the medical equipment in Africa is not used because there is not enough people trained in its usage. In order to meet this requirement, Philips makes sure that the CLC's medical staff receives ongoing training and mentoring. As a result, the community will genuinely profit from the Wind Up Fetal Doppler (Philips, 2016).

(a) Appearance of wind up Doppler.

(b) The lever of the Doppler on the back.

Figure 3: The Wind up Fetal Doppler (Philips, 2014).

What is the relationship between the Wind Up Fetal Doppler and frugal innovations?

The Wind Up Fetal Doppler is seen as a frugal innovation. It fulfils the three criteria for frugal innovations:

- Substantial cost reduction: the Wind Up Fetal Doppler has a significantly lower price and lower expense for customers than other similar products, however, the price rose due to collaborations with partners and regulations (Onsongo, 2021).
- Concentration on core functionalities: the Wind Up Fetal Doppler decreased the complexity with regards to other fetal Dopplers. Non-doctors are able to use it. Complexity has been decreased, while still maintaining the key functionality of measuring the fetal heart rate. Moreover, the performance has not been affected negatively. It has been catered to the BOP's lifestyle in Africa's semi-urban and rural settings. However, training is still needed to operate the device.
- Optimised performance level: the Wind Up Fetal Doppler's performance has not been affected negatively. Its accuracy is higher than the current practice of determining the fetal heart rate and a Pinard-stethoscope. 60% more cases of irregular fetal heart rate were recognised in labour than with a Pinard-stethoscope.

It fulfils the three criteria, hence is a frugal innovation. Furthermore, the Wind Up Fetal Doppler is competing against non-consumption. To reach this value proposition, the following is being done to achieve this:

- Reduced overall costs: the Wind Up Fetal Doppler has lower expenses of usage and maintenance in comparison to other Dopplers. The price rose due to collaborations and regulations. Still, it has a much lower total cost of ownership.
- Robustness: the Wind Up Fetal Doppler is able to deal with the local infrastructure in Africa's semi-urban and rural areas, such as lack of electricity. The product is able to generate its own electricity by spinning the lever/handle on the product.

- User friendliness: the Wind Up Fetal Doppler is user-friendly when one has had training and mentoring for utilising the product. Users need hands-on experience or a higher level of knowledge of the product to use it.
- Economics of scale: the Wind Up Fetal Doppler is in need of cost reduction, due to its price.

While the the costs are substantially reduced, the Wind Up Fetal Doppler's price is still higher than it should be, thus potentially unaffordable to the BOP. Therefore, the characteristic of frugal innovations of being affordable is not applicable on this product. The characteristics of frugal innovations that the Wind Up Fetal Doppler partially has, is that it produces more value with fewer resources and due to its design, while the performance is still optimal. However, training is needed to operate the device.

Furthermore, the price, design and business model factor can be found in the definition of frugal innovations. In the definition of frugal innovations, the price needs to be affordable for the BOP, its design needs to focus on the fundamental functioning and features to serve the BOP and it needs to have a low-cost production (and other operational/financial aspects) which relate to the business model.

What are the successful and unsuccessful factors of the Wind Up Fetal Doppler?

The unsuccessful factors of the Wind Up Fetal Doppler were its price and the business model. The price of the Wind Up Fetal Doppler rose due to collaborations between Philips and partners. The price also rose due to Philips being an MNC. Their organisational structures and business models are generally built for the creation of advances products/services for the wealthy few at the top of the pyramid (Zeschky et al., 2011). Therefore, its business model for its own, standard products differs majorly than the business model needed for the Wind Up Fetal Doppler as well as the target audience and market. Thus, as stated in the Literature Review, it must reconsider its old business strategy in order to achieve long-term success for the Wind Up Fetal Doppler.

A partial (un)successful factor of the Wind Up Fetal Doppler was its design. The product served the need of the people in the area of the Africa Innovation Hub due to its design of the lever that can generate its own electricity. However, training and mentoring is needed in order to utilise the device, which costs time and a higher level of knowledge.

CHARM

What is the CHARM?

Another product of the Africa Innovation Hub is the CHARM. Using specifically designed algorithms, the CHARM translates chest motions recorded by accelerometers into an accurate breathing count of children. The monitor gives the healthcare clinician both quantitative and qualitative input based on the World Health Organisation's IMCI 5 (Integrated Management of Childhood Illness) standards for recognising fast breathing rates, which is one of the major

vital signs for diagnosing pneumonia (Philips, 2015). To secure the tool to the child, it features a belt (Helldén et al., 2020). The product can be seen in Figure 4.

Collaboration between the Philips Africa Innovation Hub in Nairobi, Kenya, the Philips Research team in Eindhoven, the Netherlands and the Philips Innovation Campus in Bangalore, India resulted in the invention of the Philips Children's Automated Respiration Monitor. The CHARM was field tested in East Africa and India, with feedback from local community health workers and clinical officers in these low-resource settings used to improve the design and technology (Philips, 2015).

Figure 4: The Philips Children's Automated Respiration Monitor (Philips, 2015).

What problem does the CHARM solve?

Pneumonia kills more children each year than AIDS, malaria, and tuberculosis combined and it is the largest infectious cause of death among children under the age of five, killing approximately 25003 children per day, with the majority of victims being under the age of two. A child dies of pneumonia every 35 seconds, with 99% of deaths occurring in low-resource settings in developing nations, which are often rural with few healthcare facilities and where treatment is unavailable for many children (Philips, 2015).

Monitoring a child's respiratory rate is a vital part of detecting pneumonia. In many emerging countries, community health professionals manually count how many breaths a child takes in one minute by visual inspection. However, because short breaths are difficult to detect, children frequently move about, there is subjectivity and there may be distractions and other tests to do, getting an exact count can be challenging (Philips, 2015). Accurate breathing count diagnosis would aid health workers in delivering antibiotics to children with pneumonia, potentially reducing the number of deaths caused by pneumonia each year. Furthermore, proper diagnosis may aid in the rationalisation of antibiotic usage by reducing wasteful costs and antibiotic overuse rates, both of which contribute to the emergence of drug-resistant illnesses (Philips, 2015). Moreover, for measuring breath count of children, the CHARM has proven to be at least as good as a trained physician and its user interface is pictogram-based, simple to use and ideal for service providers with little literacy. (Save the Children, 2017).

What is the relationship between the CHARM and frugal innovations?

The CHARM is seen as a frugal innovation. It fulfils the three criteria for frugal innovations:

- Substantial cost reduction: the CHARM has a significantly lower price and lower expense for customers than other similar products, however, the price rose due to collaborations in producing the product and regulations (Onsongo, 2021).
- Concentration on core functionalities: the CHARM decreased the complexity with regards to other devices. Non-trained people are able to use it and interpret the results. Complexity has been decreased, while still maintaining the key functionality of measuring the breath count. Moreover, the performance has not been affected negatively. It has been catered to the BOP's lifestyle in Africa's semi-urban and rural settings.
- Optimised performance level: the CHARM's performance has not been affected negatively. Its accuracy is better than current practices of determining the breath count of a child manually and it is as good as a trained physician (Save the Children, 2017).

The CHARM fulfils the three criteria, hence is a frugal innovation. Furthermore, it is competing against non-consumption in the African semi-urban and rural areas. To reach this value proposition, the following is being done to achieve this:

- Reduced overall costs: the CHARM has lower expenses of usage and maintenance in comparison to other similar devices. However, the price rose due to collaboration and regulations. Still, it has a much lower total cost of ownership.
- Robustness: the CHARM is able to deal with the local infrastructure, such as lack of health professionals or subjectivity. The product is able to be used by non-trained people and the results can be interpreted by a non-doctor as well.
- User friendliness: the CHARM is made user-friendly. It is not complex and users do not have to have a high level of knowledge of the device to use it. Non-trained people are able to use it and interpret the results.
- Economics of scale: the CHARM is in need of cost reduction, due to its price.

While the the costs are substantially reduced, the CHARM's price is still higher than it should be, thus potentially unaffordable to the BOP. Therefore, the characteristic of frugal innovations of being affordable is not applicable on this product. The characteristics of frugal innovations that the CHARM does have, is that it produces more value with fewer resources and due to its design, it is easy to use for the BOP while the performance is still optimal.

Furthermore, the price, design and business model factor can be found in the definition of frugal innovations. In the definition of frugal innovations, the price needs to be affordable for the BOP, its design needs to focus on the fundamental functioning and features to serve the BOP and it needs to have a low-cost production (and other operational/financial aspects) which relate to the business model.

What are the successful and unsuccessful factors of the CHARM?

The unsuccessful factors of the CHARM were the business model and price. The price of the CHARM was unaffordable, mainly due to collaborations and regulations. The CHARM was subjected to lengthy regulatory approval procedures for which capacity was lacking. This made the production slow and expensive (Onsongo, 2021).

The price also rose due to Philips being an MNC. Their organisational structures and business models are generally built for the creation of advances products/services for the wealthy few at the top of the pyramid (Zeschky et al., 2011). Therefore, its business model for its own, standard products differs majorly than the business model needed for the CHARM as well as the target audience and market. Thus, as stated in the Literature Review, it must reconsider its old business strategy in order to achieve long-term success for the CHARM.

The successful factor of the CHARM was its design. The product served the need of the people in the area of the Africa Innovation Hub and was easy to use by local, non-trained people.

INUKA

What is INUKA and what problem does it solve?

The most successful project of the Africa Innovation Hub is INUKA. INUKA is Swahili for 'arise'. INUKA is not a medical product, but a medical service for mental health. In most parts of Africa, there is a stigma against mental health issues. There, there are hardly any psychologists/psychiatrists. In Zimbabwe, there are 13 psychiatrists. This presents a number of issues in a country with a population of 16 million people, the majority of whom lack basic well-being support. To solve this problem, community members – particularly grandmothers – were taught problem-solving techniques so that they might help others who were struggling with their health (Twan, n.d.). After this success, Philips and the University of Zimbabwe worked together between 2015 and 2016 to create a functional prototype of a digital platform, an app, of which Philips was the owner (Doukani et al., 2021).

The INUKA coaching in Kenya was provided during four chat sessions using an android smartphone at the health center's chat-based service. Prior to their session, a research assistant contacted the participants to remind them of their appointment. Sessions at the health center were held once a week or twice a month and were scheduled to run up to 60 minutes each (Doukani et al., 2021). Participants received KSh 300 as payment for their travel expenses to the health center. Through a text-based conversation on a mobile app at the healthcare center, customers received structured sessions as part of the INUKA coaching program. Three factors led participants to finish their sessions at the health center. First, the participants' access to a mobile device or the internet was unknown. Therefore, it was predicted that providing the intervention at the health center would lower obstacles to enrolment in the research. Second, conducting the event at the health center provided participants with access to technical support for using the mobile app. Given that the INUKA coaching app was still in the beta stage, having access to assistance was very crucial. Third, there were not enough resources to provide each participant who signed up for the research with an Android phone and a data plan (Doukani

et al., 2021).

The intervention has been modified recently to be administered by non-specialist workers for the treatment of common mental disorders across a variety of communities across the African and Asian continents. It has the same structure as a low-intensity face-to-face problem-solving therapy session. Due to its straightforward, step-by-step methodology, the problem-solving therapy session was shown to be an effective method for delivering via non-traditional mediums, such as the telephone (Doukani et al., 2021).

What is the relationship between INUKA and frugal innovations?

INUKA is seen as a frugal innovation. It fulfils the three criteria for frugal innovations:

- Substantial cost reduction: INUKA is free for the BOP due to a foundation being set up by wealthier economies (inuka, n.d.). Therefore, it has a significantly lower price and lower expense for customers in the BOP than other similar services.
- Concentration on core functionalities: INUKA's complexity is not high. It works based on a chat-function. If needed, help can always be provided by heath center employees.
- Optimised performance level: INUKA's performance has not been affected negatively. It has been proven to be well, even though no trained psychologists are needed.

INUKA fulfils the three criteria, hence is a frugal innovation. Furthermore, it is competing against non-consumption in the African semi-urban and rural areas. To reach this value proposition, the following is being done to achieve this:

- Reduced overall costs: INUKA has lower expenses of usage and maintenance in comparison to other methods. Customers need to travel to health centers, however, this is compensated by giving the participants KSh 300 as payment. Therefore, INUKA has a much lower total cost of ownership.
- Robustness: INUKA is able to deal with the local infrastructure, such as lack of physicians/psychologists. Non-trained psychologists can help the customers with their well-beings. Furthermore, due to lack of knowledge about mobile phones distribution amongst customers of INUKA, the mobile phones are provided at health centers where customers can go to to have their INUKA coaching.
- User friendliness: INUKA is made user-friendly. It is not complex and users do not have to have a high level of knowledge of the system to use it. If needed, help can be provided at the health centers.
- Economics of scale: INUKA does not result in (a lot of) profit.

INUKA is affordable to the BOP, it produces more value with fewer resources and due to its design, it is easy to use for the BOP while the performance is still optimal. INUKA therefore has all characteristics of frugal innovations.

Furthermore, the price, design and business model factor can be found in the definition of frugal innovations. In the definition of frugal innovations, the price needs to be affordable for the BOP, its design needs to focus on the fundamental functioning and features to serve the BOP and it needs to have a low-cost production (and other operational/financial aspects) which relate to the business model.

What are the successful and unsuccessful factors of INUKA?

The price of INUKA is affordable. The mobile phones that need to be used to participate in the INUKA coaching are in health centers. Travelling to these places generates additional costs, however, the participants, at least in Kenya, get compensated for their travels. Furthermore, currently, the INUKA platform is a social enterprise start-up that is independent of Philips. They created an INUKA Foundation with the goal of providing free access to INUKA to the BOP (inuka, n.d.).

The design of INUKA is simple and easy to understand by locals of the BOP where INUKA was needed. The most difficult part of the design is the main functionality, the chat-function, but since the coaching takes place in a health center, technical support can be provided.

Philips' organisational structures and business models are generally built for the creation of advances products/services for the wealthy few at the top of the pyramid (Zeschky et al., 2011). As Philips is an MNC, the business model needed for the frugal innovation did not fit within Philips. Its business model for its own, standard products/services differs majorly than the business model needed for INUKA as well as the target audience and market. Therefore, as stated in the Literature Review, it must reconsider its old business strategy in order to achieve long-term success for INUKA. It has not been as successful as it is now. INUKA has become a large company that is active in multiple countries, for example in Kenya, but also in wealthier economies such as the Netherlands (inuka, n.d.). INUKA currently is successful, however, after it became independent of Philips through a start up.

How did regulations influence the products/services for the Africa Innovation Hub?

For all the medical products/services in the Africa Innovation Hub, there are regulations that need to be complied with. These regulation can differ per country. Due to regulations, sometimes cheap and efficient equipment cannot be made available to low-income economies (Long et al., 2018). Substantial trials, extensive human and non-human studies must be done in order for the device to be approved by a regulatory body, for example as with the CHARM. This drive up the price of the device (Bergsland et al., 2014).

The main influence regulation had on the products/services for the Africa Innovation Hub was on the price and design factor. The price increased and the design has been changed accordingly to the results of the tests being done.

Why does reverse innovation occur with the products?

In Africa, there is hardly any healthcare system. The healthcare system yet needs to be build. In low income economies, there is a lack of doctors, while they have potentially the most people

that are sick. Unfortunately, this will not change quickly, because doctors cannot be trained as quickly to a level that is needed. A potential solution is to use non-doctors. For example, when a woman goes into labour, volunteers can take the CHARM device and use it to detect pneumonia. This is an innovative manner of setting up healthcare. What a doctor needs to detect, can be detected by a non-doctor. While these are helpful in low resource economies, these innovations can also potentially influence healthcare in wealthier economies, where there are many costs involved and where there is the 'Law of the handicap of a head start'[7]. One example of a solution that came from the low income economies and made its way into the wealthier economies is INUKA.

This is important to mention, because all three products/services were not successful under Philips, while INUKA became successful under a different (smaller) company. As can be seen, INUKA became successful after it continued in a start up. This also relates to the business model that is different. The business model changed from one that an MNC uses to the one a start up can use and can easier modify in comparison to an MNC. This business model is one of the factors of frugal innovations, which can have an influence on over-engineering.

What are the differences between a start-up and a multinational with regards to producing and selling the products of the Africa Innovation Hub?

The Africa Innovation Hub was founded within Philips. This induced several limitations, since Philips is a multinational. For frugal projects for low income economies and vulnerable people, there are advantages and disadvantages regarding Philips to be producing and selling such products.

The disadvantage of Philips relating the sales of a frugal product, Philips does not have a lot of freedom. When a product is not doing well, for example with the strategy or sales, the production likely will stop. For them, a lot of costs are involved in continuing the production and they will be looking for other opportunities. Philips' resources are not as limited as with a start up.

The type of products also matters in terms of success for Philips. Frugal innovations for the low income economies do not fit within Philips' structure as much as it would fit within a start up. The prices of the frugal products fall within a different range than Philips offers, have a different business model and a different target market than than the normal structure of Philips.

When looking back at Africa Innovation Hub, Philips was good in designing the frugal products. Selling the products is what was their big challenge. Due to their internal MNC infrastructure, such as systems, processes, organisational structures and business models, reaching the target audience remains difficult. With a start up, these challenges are tremendously lower. One example of such an innovation is INUKA.

[7] https://en.wikipedia.org/wiki/Law_of_the_handicap_of_a_head_start

4.1.1 What is the relationship between the three discussed innovations and frugal innovations?

As can be seen in the respective sections of the three products/services, the Wind Up Fetal Doppler, the CHARM and INUKA, all three innovations fulfil the requirements of substantial cost reduction, concentration on core functionalities and optimised performance level of frugal innovations. The three innovations also compete against non-consumption by having reduced overall cost, robustness, user friendliness and economics of scale. All three innovations therefore are considered frugal innovations.

Based on characteristics of frugal innovations, only INUKA was affordable to the BOP. The CHARM and Wind Up Fetal Doppler were too expensive for the BOP, partially due to Philips' (internal) infrastructure. Philips also needed to use a new business model for these products, one that was not focused on their usual target audience and advanced products/services. For INUKA, only after it continued in a start up, the service became successful. Furthermore, INUKA and the CHARM have an easy to use design. The BOP should be able to use the products/services without prior knowledge nor on-hands experience. To use the Wind Up Fetal Doppler, training and mentoring is needed.

4.1.2 What are factors of frugal innovations of the three discussed products in the Africa Innovation Hub?

The factors of frugal innovations can be found in its definition and shows to be the price, design and business model. The price of the innovation needs to be affordable for the BOP, the design needs to focus on the fundamental functioning and features to serve the BOP and it needs to have a low-cost production (and other operational/financial aspects) which relate to the business model. These factors can also be found when analysing the three products. Therefore, the most important factors of frugal innovations for the previously discussed products/services are the business model, price and design of the product.

It is important to know the audience of the product/service. It is not only technical, but what also needs to be taken into consideration is that the product will change how people will do tasks. For example, with the CHARM, volunteers take over tasks the doctor should do and the routine will change. The volunteers have not been trained to become doctors, yet, they still will take over this task. Another example is the INUKA. Instead of psychologists, grandmas have been trained to do coaching. Furthermore, there is a challenge for multinationals, because they will need to serve a new target group with a new business model. Deep insights need to be gained in what the product does, what is needs to do and how it will be used. This has been tested with the CHARM and feedback was sent back to improve the product based on the target audience's needs. However, to scale the product is remains a big challenge for a multinational, because of the internal structure. Internal structures are built on relative expensive products.

4.1.3 What elements have an influence on the factors of the frugal innovations?

Price

The factor *price* of frugal innovation can be influenced by the regulations that come when producing or selling the product. These regulations can differ per country. Regulations can lead to an increase in price due to extra testing or changes in design. Products could be made more complex or have extra components added to them in order to comply with regulations, which could lead to an increase in price. Due to their manufacture, certain product components, such a belt or lever as seen for Wind Up Fetal Doppler and CHARM, could have a higher cost. The design therefore is also an element that influences the price of the product. The more advanced a product is being made, the more expensive the product can be. Some elements of a product, for example a lever or belt, could increase the price due to their production process. Lastly, the price could increase due to the company's collaboration and infrastructure, such as the business model, organisational structures, systems and processes that provide a base for a company's operations. For Philips, this could be expensive, which is calculated into the consumer price, while for start ups, this is tremendously lower.

Design

The factor *design* of frugal innovation can be influenced by the need of target audience. Based on what the need is of the target audience, the product or service need to be designed in a manner that it serves as a solution to them for a problem they encounter. The limitations of their environment needs to be taken into account for this. The idea of a product or service can serve the needs of the people, however, it should be usable in the environment of these people. An example is lack of electricity; the innovation should therefore not need a lot of electricity, as seen with the Wind Up Fetal Doppler. The product/service needs to be designed to bypass these limitations. Another element that could influence the design of a product is regulations, as also seen in the price factor. Due to regulations, for example for safety, a product may be produced to have a complex design, so that it makes the product comply with the regulations and therefore for example safer.

Furthermore, when a product is made modular, it can potentially become less complex and cheaper. Modularisation of products is an investment. In the long term, it will be beneficial in terms of costs. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management (Pakkanen, Juuti, Lehtonen, & Mämmelä, 2022). Modularity has the capacity to lower life-cycle costs by minimising the number of procedures and eliminating repeated ones (Gershenson, Prasad, & Allamneni, 1999). These ideas need to be kept in mind when manufacturing a product. When a product is not modular, it will be difficult to modify a product to make it more frugal once the product has been manufactured. Removing extra

features will be difficult for example due to the construction of the design. Then, when making decisions for the design, it needs to be kept into mind that the product must be frugal from the start.

Lastly, since Philips is an MNC, its business model for its own, standard products differs majorly than the business model needed for the Wind Up Fetal Doppler as well as the target audience and market. It must reconsider its old business strategy in order to achieve long-term success for the product.

Business model
The factor *business model* of frugal innovation can be influenced by the type of company (e.g. being a start-up or MNC) that is producing or selling the frugal innovation, the target audience, the target market and the goal of the company. The type of company influences the success of the business model, since for example Philips needs to reconsider its old business strategy in order to achieve long-term success, while start ups mostly do not encounter this issue as much, since they have more flexibility and freedom. Philips encounters more intense scrutiny and attention to their decisions than start ups. Furthermore, the target audience and market take part in the business model, since this needs to be adapted to the market and audience the product or service is meant for. This also majorly differs for Philips with regards to their standard customers and market. Lastly, the goal of the company with regards to selling the product or service has an influence on the business model. If Philips wants to make large profits, the business model will be different than when the company wants to provide the audience with a solution to their problems without large returns. INUKA for example, is free for the BOP due to a foundation that has been created and filled by wealthier economies.

4.1.4 What is the relation of the frugal three products with over-engineering?

Important factors of the three products, the Wind Up Fetal Doppler, the CHARM and INUKA, are its price, its design and the business model. These factors can also be found in the definition of over-engineering; Over-engineered products or services, are expensive in terms of price, more complex in terms of design and have a high-cost production and/or other operational/financial aspects. These factors therefore are the link between the frugal innovations in this case study and over-engineering. Based on these three factors, an innovation can for example be frugal or over-engineered. When changing one of these factors the over-engineered product or frugal product will be affected to be either more or less frugal/over-engineered. One example is that when the price or design of INUKA becomes more expensive or complex, INUKA would be less frugal and would be a little more over-engineered than it is. It shifted from being frugal to being less frugal and a little more over-engineered. This does not mean that the service is in fact over-engineered. It only shifted further away from being frugal, more towards being over-engineered.

4.1.5 Are the three discussed innovations of the Africa Innovation Hub generalisable with regards to frugal innovations in the medical industry?

This case study is a embedded single case study, which is difficult to generalise. It consists of one context, the Africa Innovation Hub, and three products/services, the Wind Up Fetal Doppler, the CHARM and INUKA. The three innovations could be compared and a conclusion followed. As said, however, they have been researched in one context.

However, despite the small sample size, a few generalisations can be made due to the Africa Innovation Hub, because first a link has been established between frugal innovations and over-engineering, and the innovations have been linked to the definition of these. The definitions and link between frugal innovations and over-engineering remain the same in all contexts. The difference that is non-generalisable, could be the elements that influence the factors of over-engineering and frugal innovations. Therefore, the results can be generalised a little, however, the findings should be interpreted with caution.

4.2 Mobile phones - M-Pesa

For the case study regarding the mobile phone industry, literature research has been done on M-Pesa.

How does M-Pesa work?

People with access to a mobile phone may send and receive money, pay bills and top up airtime due to the product's basic features. Safaricom trained the network of cellular dealers that already existed to work as qualified M-Pesa agents. After inserting the SIM card into the mobile device's card slot, customers can send SMS messages to vendors and family members to make payments and transfer money. The numerous M-Pesa outlets dispersed around the nation may be used by those without bank accounts. The user gives the kiosk attendant the cash to be saved and the cash is then digitally transferred to the user's M-Pesa account. Cash collected through M-Pesa is deposited in Safaricom's bank accounts. The Deposit Protection Fund insures the bank accounts up to a maximum of 100000 shillings (or $1000) like standard checking accounts. M-Pesa issues receipts as proof of purchase. Both sides must exchange phone numbers in order for a transaction to take place, as phone numbers serve as account numbers. Both parties receive an SMS notice with the counterparty's full name and the amount of monies deposited or taken from the user's account after settlement. The smartphone receipt, which is received in seconds, contributes to transaction transparency for all parties involved. M-Pesa enables small business owners in distant and rural locations to make secure and convenient financial transactions using their mobile phones. Users are charged a nominal fee for utilising the service to send and withdraw money (Kagan, 2020).

Thus, there are only three easy steps needed to transfer money. A customer initially visits an authorised M-Pesa agent to top off their mobile phone with cash. After the top-up procedure is complete, the customer can send money via text messages to other M-Pesa members. Similar to a credit card, this process requires a security pin and the customer must confirm the transaction before funds are transferred. The recipient of the text message can then take the transferred funds to the closest M-Pesa agent to withdraw them. No action necessitates a formal bank account (Martin, 2018).

For example, a farmer without a bank account who wishes to deposit his 1000 shillings in commodity sale revenue visits an M-Pesa location and deposits the money with the kiosk agent. In turn, the agent uses his/her phone to log into the customer's account using the customer's registered phone number and deposits $1,000 into the account. Within seconds of the deposit, the farmer receives an SMS notification on his cellphone, confirming the amount transferred and his current account balance. Using a unique PIN and the M-Pesa agent's number issued at the outlet, the farmer can effortlessly withdraw cash from his account (Kagan, 2020). An example of transferring money can be seen in Figure 5.

Figure 5: Transfer of money using M-Pesa on a Nokia phone (Oluwole, 2022).

What problem does M-Pesa solve?

Approximately 20% of Kenyans had a formal bank account in 2006. The lack of branches and ATMs in rural areas contributed to this in part. Only four branches were present in the country's whole north-eastern area at the time, and nearly half of all branches were in Nairobi, the nation's capital. Formal banking was impossible due to the distance from banks. Due to this, most transactions were conducted in cash, and people had to travel up to several hundred kilometers to make withdrawals or pay bills. Long trips with big sums of money were not only time-consuming but also dangerous in a nation with a high crime rate. Families who were reliant on relatives who worked in business hubs faced an existential threat as a result. Such migrant workers had little options for providing the badly needed financial support to their family in rural locations, and the majority of the solutions available were very expensive. Small business owners had less opportunity to succeed due to the weak banking infrastructure. These business owners had to either plan complicated payment logistics or were limited to using only local suppliers (Martin, 2018).

One of the driving forces behind Fintech developments like M-Pesa is Financial inclusion, which is primarily oriented toward an underbanked or unbanked segment of people. In the digital banking era, financial inclusion is a program that aims to include residents who do not have access to banks or who cannot afford the requisite minimum deposits. In order for this endeavour to be successful, diverse sectors must work together to share data and create a useful digital platform. M-Pesa's cross-communication strategy is fast gaining traction in Sub-Saharan Africa, where the telecommunications and banking sectors are collaborating to provide mobile banking services for people who do not have access to traditional banking (Kagan, 2020).

Therefore, the problem that M-Pesa solves is that the majority of Kenya's citizens were unable to participate in banking; they did not have a bank account. M-Pesa reached the underbanked and provided them with something they did not have.

Who were the early adopters of M-Pesa and what did this do for M-Pesa?

Some members of many Kenyan rural households live and work in Nairobi or other cities and towns, while the remainder stay in the village. M-early Pesa's adopters were well-educated, high-income earners who lived in urban areas, primarily Nairobi, Kenya's capital. They sent

money home to their parents and relatives in rural areas using M-Pesa. The majority of such recipients lacked bank accounts, and for those who had, the banks were in towns that took an hour or more to get by public transportation. Similarly, if the money were sent physically, it would take hours to go to rural locations, a scenario made worse by bad road conditions. As a result, the introduction of M-Pesa was seen as a cure to all of these problems (Adhikari & Roy, 2017).

Safaricom gained a first mover advantage in mobile banking by targeting the majority, the poor, who had previously been unable to afford bank accounts. This also facilitated a customer lock-in effect. Safaricom was an early adopter of mobile banking in Kenya, partnering with other businesses to expand their agent network before competitors entered the market. Safaricom also struck deals with utility firms to distribute or collect payments on their behalf, allowing it to capture a larger share of the local market than its competitors (Adhikari & Roy, 2017).

What were the previous methods of money transfer in Kenya and why is M-Pesa a better method?

Finding a simple and reliable method of transmitting money to rural/remote individuals was the unmet requirement of the working and business people. This demand could not be satisfied by existing money-transfer mechanisms, which had a number of flaws, resulting in M-Pesa's early success. By 2007, right before the launch of M-Pesa, there were five common means of transmitting money to friends, relatives or enterprises (Ngugi, Pelowski, & Ogembo, 2010).

Sending money via family/friends to the same location where one wanted to donate money was the most common (58%). The difficulty with this strategy was that it was random and unexpected, and the chances of someone else heading in the same direction as you were was slim to none, especially in emergency situations. Furthermore, such friends and family were not always trustworthy, and the money was frequently lost.

The use of public bus companies for passengers or goods was the second most popular technique (27%). As a side business, these organisations delivered mail, goods and money. However, theft from bus staff, passengers or roadside thieves was a typical occurrence, making this system unstable.

Sending money via postal services via money order and telegram was the third most popular way (24%). However, the commission fees were high and they were accompanied by bad service.

Putting money straight into relatives' or friends' bank accounts was the fifth most preferred way (11%). This presumption was that the other individual possessed a bank account, which was not always the case.

Using formal money transfer firms like Western Union was the sixth most common technique (9%). Existing money transfer firms, on the other hand, paid hefty commissions and were not always available in most localities, especially in rural areas.

M-Pesa eliminated the challenges associated with other preexisting methods of sending money by lowering the cost of sending money, eliminating middlemen and employing technology to make sending money faster, convenient, dependable and secure (Ngugi et al., 2010).

What is the effect of M-Pesa on the Bottom of the Pyramid in Kenya?

Kenya's standard of living has substantially increased thanks to mobile payment services such as M-Pesa. Market dealers, debt collectors, farmers and cab drivers do not need to carry big amounts of cash with them. This means that theft, robbery and fraud are less likely to occur. Individuals and businesses do not have to stand in huge queues for hours to pay their electricity or water bills, because M-Pesa allows them to do so. Safaricom SIM card customers who wish to sign up for M-Pesa must do so using a legitimate government ID, such as a Kenyan national identification card or a passport, in order to combat fraud. This way, the person who makes a transfer, payment, deposit or withdrawal from an account is identified with each transaction (Kagan, 2020).

Mobile money is becoming more popular in underdeveloped countries, where a large portion of the population lacks access to traditional banking. Paga, MTN Mobile Money, Airtel Money and Orange Money are upsetting traditional payment systems used by inhabitants of emerging countries, transforming the economy from a cash to a digital one (Kagan, 2020).

Furthermore, Tavneet Suri of Massachusetts Institute of Technology and William Jack of Georgetown University have developed a series of articles praising the benefits of M-Pesa with the help of Financial Sector Deepening Kenya and the Bill Melinda Gates Foundation. Their 2016 publication in "Science" was particularly important in the international development sector. Access to M-PESA increased per capita consumption levels and moved 194000 people, or 2% of Kenyan households, out of poverty, according to the paper's most often quoted finding (Suri & Jack, 2016). However, these findings on M-Pesa's role in poverty reduction have been challenged by Bateman, Duvendack, and Loubere (2019), which claims that Suri and Jack's work contains so many serious errors, omissions, logical inconsistencies, and flawed methodologies that it is more accurate to say that they have helped to catalyse the creation of a largely false narrative surrounding the fin-tech industry's power to advance the cause of poverty reduction and sustainable development in Africa (and elsewhere).

How did M-Pesa become a disruptive innovation?

M-Pesa is seen as a game-changing invention. It is a type of innovation that establishes a new market and value network, then disrupts the existing system by displacing market leaders and alliances as can be seen in the previous question. The development of products that do not strive to copy, replicate or outperform existing products, but rather focus on developing new markets with items that perform less well but are more affordable, simpler and convenient, is what dominates particular sectors. These items appeal to new types of consumers at the lower end of the market, disrupting industry leaders' longer-term trajectory and dominance (Adhikari & Roy, 2017).

M-Pesa, for example, has brought banking and money transfer services to the BOP, a group that has previously been unable to access such services, thus bridging the gap between the connected and the disconnected. The service's simplicity appeals to even illiterate and semi-literate persons who would otherwise be unable to use a bank. Unlike online banking, which requires internet access, M-Pesa transfers and payments do not require this. This provides

greater ease, adds value where none previously existed, and taps into consumers' hidden desires, all of which are features of disruptive innovation. Consumers had to go to banks to make money transactions prior to the debut of M-Pesa. In Kenya, online money transfers are still in their infancy, owing to a lack of internet access and security concerns. M-Pesa, on the other hand, shifted the user's perspective and behaviour. Users may use the app with trust, and because it is mobile, it gives convenience (Adhikari & Roy, 2017).

M-Pesa is a disruptive innovation that, as it grew and spread, posed a challenge to incumbent businesses while also spurring the emergence of new businesses and entrepreneurship. Mobile money, which was pioneered by M-Pesa, is a rare situation in which an impoverished African country, Kenya, is the global market leader and an innovator. After surpassing the rate of adoption of mobile phones, M-Pesa achieved the highest rate of adoption in the history of the developing world. M-Pesa transactions in Kenya outnumbered Western Union transactions every day in 2012. M-Pesa, like smartphones in Western countries, generated an entirely new banking environment (Adhikari & Roy, 2017).

Why did M-Pesa become a success in Kenya?

Even though M-Pesa has received criticisms, it is still a success with that many users. The success of M-Pesa was influenced by numerous variables. Without impediments or restrictions, Safaricom was able to provide its service because to an open regulatory environment. Since mobile technology was accessible over a sizeable portion of the nation, the connection between mobile networks and money transfers was essential to the success. Other financial services were only available in some locations, and the financial sector as a whole was frequently viewed with suspicion. On the other side, M-Pesa offered a quick and dependable replacement utilising a mobile phone. People in rural areas complimented and trusted their cell phones, in contrast to the negative perception of banks. As M-Pesa used cellular technology and was run by Safaricom, the business that also provided customers with important airtime, it benefited from this confidence. People were eager to use the service because of the favourable impression of mobile phones and the dearth of effective alternatives, and a variety of use cases developed (Martin, 2018).

So, one of M-Pesa's success point in Kenya with points to the existing financial institutions' failure to address the demands of the underbanked. By the time M-Pesa was launched in 2007, only 19% of Kenyans had access to financial services. It can be added that additional impediments to the preceding discussion that have stopped this segment of the population from even having the fundamental capacity to open a bank account. These considerations become the causes for this vast population's long existence on the other side of the technology divide, as well as the reason for the chasm's closure thanks to M-Pesa's unique solutions (Ngugi et al., 2010).

The first consideration was illiteracy. Since most underbanked people were illiterate, they could not fill out the paperwork required to obtain a typical bank account. This was combined with the requirement for creating a typical bank account of documentation and bureaucratic procedures enforced by individual banks or central bank rules under the notion of "Know Your

Customer." These requirements included the requirement for introduction letters from individuals with current accounts with the bank of interest, identification documents, passport photographs, and high minimum deposit amounts to start and maintain an account. These bureaucratic procedures became obsolete with the launch of M-PESA, while Safaricom continues to use the "Know Your Customer" concept but simply requires national identity cards and phone numbers. This is made possible by mobile money's micro-transaction and pay-as-you-go structure (Ngugi et al., 2010).

Another consideration is that existing financial institutions demanded that a specific minimum quantity of money must be kept in the account at all times, as well as charging expensive monthly fees if the minimum amount was not met. Account closure due to non-performance was also a typical occurrence among Kenyan banks. For most people, these obstacles simply made the concept of running and keeping a bank account unappealing and costly. Just prior to the launch of M-Pesa, the average cost of opening a current bank account was US$ 105, while the average cost of operating one was US$ 19 per month, implying that by the end of the year, if one kept only the minimum required amount, they would owe the bank at least US$123 in fee charges alone. M-Pesa accounts, on the other hand, do not require any cash to open or operate, and there are no costs for deposits or withdrawals, nor are there any monthly ledger fees. Only when sending money does one have to pay fees. Even yet, the fees paid each transaction are significantly lower than those charged by traditional banks (Ngugi et al., 2010).

A last consideration was the actual spread of financial services. The majority of banking services were located in large town centers or economically viable places. However, the rural areas of Kenya are home to about 70% of Kenya's population. As a result, the majority of people were either denied access to these services or had to travel significant distances to the nearest town centers to do so; travel, in and of itself, was costly and time consuming, further increasing the cost of banking services. Due to the aforementioned constraints, the underbanked poor of society have a gaping need for financial services. They required a solution as well as a change agent to introduce them to it. Safaricom provided the solution, having previously deployed vast network coverage with its mobile phone technology and agents selling airtime all over the country and turning the above necessities into a business opportunity. This allowed the company to quickly deploy M-Pesa services across the country. The change agent took the form of working and business people who became early adopters in order to meet their own unmet needs (Ngugi et al., 2010).

Why did M-Pesa receive criticism in Kenya?

Kenya lacks a data protection regulation, allowing Safaricom to freely use sensitive data from its subscribers. Safaricom was sued in court in 2019 for allegedly breaching the data privacy of an estimated 11.5 million users who had used their Safaricom numbers for sports betting. The information was purportedly sold on the illicit market (Itimu, 2019).

Another criticism is that M-Pesa's providers have been chastised for the hefty costs the program imposes on its frequently impoverished consumers. In 2013, the Bill and Melinda Gates Foundation cautioned that a lack of competition could push up rates for mobile money

clients, citing M-Pesa in Kenya as an example. According to the Foundation, a $1.50 transfer cost $0.30 at the time, whereas the same service charged only a tenth of that in Tanzania, where it was more competitive (Lamb, 2013).

Why did reverse innovation occur?

Solutions in the future could potentially come from Africa, since it is easier to implement it there first. They do not have the 'Law of the handicap of a head start'[8] and there are no internal structures blocking the path. New digital phenomenons that cannot go to wealthier economies, can easier be implemented in Africa. The M-Pesa payment system in Kenya, is a good example. In wealthier economies, the payment systems through phones started years later. While M-Pesa had reached developing economies, but had not yet reached developed markets, Barclays in the UK has imitated the wildly popular idea by launching Pingit in 2012. However, M-Pesa had established its global presence: M-Pesa targets both EU member states like Romania and other African nations like the adjacent Tansania. Academically speaking, the reverse innovation was successful (Martin, 2018).

Furthermore, the idea of mobile phone banking itself started in Kenya and made its way into wealthier economies. For example, the Apple Pay currently is a popular method and was initially released in 2014 (Jeffries, 2014). In Kenya, paying with SMS was possible with a simple Nokia phone in 2007. People who did not have a bank, suddenly had a bank account. It was possible to transfer money from one side of the country to the other side. The idea started in Kenya and made its way to wealthier economies.

4.2.1 What is the relationship between M-Pesa and frugal innovations?

M-Pesa is seen as a frugal innovation. It fulfils the three criteria for frugal innovations:

- Substantial cost reduction: M-Pesa has a significantly lower price and lower expense for customers than traditional banking systems.
- Concentration on core functionalities: M-Pesa decreased the complexity with regards to traditional banking. Illiterate and semi-literate people are able to use it. Complexity has been decreased, while still maintaining the key functionality of banking. Moreover, the performance has not been affected negatively. It has been catered to the BOP's lifestyle in Kenya.
- Optimised performance level: M-Pesa's performance has not been affected negatively. Its speed is fast, as one SMS message is needed to transfer money, which leads to the duration of the process not being long. The process of banking using M-Pesa this does not take a long time and is precise. The amount of money to transfer that has been written in the SMS is being transferred, no less and no more.

[8] https://en.wikipedia.org/wiki/Law_of_the_handicap_of_a_head_start

M-Pesa fulfils the three criteria, hence is a frugal innovation. Furthermore, M-Pesa is not only competing against traditional competitors, but also against non-comsumption. To reach this value proposition, M-Pesa uses the following to achieve this:

- Reduced overall costs: M-Pesa has lower expenses of usage and maintenance in comparison to traditional banking. It has a much lower total cost of ownership.
- Robustness: M-Pesa is able to deal with the local (in this case, Kenya) infrastructure, such as lack of transportation to the large cities for banking, illiteracy which lead to inability to use traditional banking due to a lot of paperwork and the little money the poor citizens can spend.
- User friendliness: M-Pesa is made user-friendly. It is not complex and users do not have to have prior hands-on experience or a high level of knowledge of the system to use it.
- Economics of scale: M-Pesa does not make a lot of profit in absolute terms, however, in terms of percentages when comparing Kenya to Tanzania, the price has increased with 1000% (10 times) for Kenya, from $0.03 to $0.30 for a transfer of $1.50.

M-Pesa is trying to reach the value proposition by reduced overall costs, robustness and user-friendliness. Furthermore, M-Pesa's price is affordable to the BOP, at least in Kenya, it produces more value with fewer resources and due to its design, it is easy to use for the BOP while the performance is still optimal. M-Pesa therefore has all characteristics of frugal innovations.

M-Pesa can be made frugal, because it does not require formal paperwork and a long process to open a bank. M-Pesa only requires a form of identification, which will be linked to each transaction done by that person. The cashless banking and personally linked transactions reduce the criminality rate in banking. M-Pesa bypasses the formal, complicated process, having made it simpler, thus making it a frugal innovation as well.

Furthermore, the price, design and business model factor can be found in the definition of frugal innovations. In the definition of frugal innovations, the price needs to be affordable for the BOP, its design needs to focus on the fundamental functioning and features to serve the BOP and it needs to have a low-cost production (and other operational/financial aspects) which relate to the business model.

4.2.2 What are the successful factors of frugal innovations for M-Pesa?

There are three successful factors of M-Pesa, which are the price, design and business model.

The price/costs of using M-Pesa is lower than the costs of opening and maintaining a bank account in Kenya. M-Pesa does, in contrary to a traditional bank account, not charge an opening fee of US$105 and operating fee of US$19 per month. The only fee M-Pesa charges is when money needs to be sent, but these charges per transaction are significantly lower than the fees with traditional banking.

The design is has been serving the need to the BOP by taking into consideration the environmental limitations, such as lack of internet access. Furthermore, the service has been made simple to understand for the BOP as even illiterate and semi-literate people who could not use

a bank, can make use of M-Pesa. A large untapped market has been captured by the design of M-Pesa.

The business model of M-Pesa has been successful. It caused disruption by serving the underserved and local needs. M-Pesa has been produced by a local company, which partly resulted in its success in contrary to a multinational producing such a system for this target audience, due to the operational, organisational en financial aspects of a business model that will be much lower for a local company.

4.2.3 What elements have an influence on factors of frugal innovations?

Price

The factor *price* of frugal innovation can be influenced by the design of the system. The more advanced a product is being made, the more expensive the product can be. Furthermore, depending on the competition and desired profit the company wants to have, the price could rise. M-Pesa did not have competition in Kenya, where it was being charged 10 times higher than in Tanzania, where it was more competitive. Lastly, the price could increase due to the company's collaboration and infrastructure, such as the business model, organisational structures, systems and processes that provide a base for a company's operations. For MNCs, this could be expensive, which is calculated into the consumer price, while for start ups or in this case, a local company, this is tremendously lower.

Design

The factor *design* of frugal innovation can be influenced by the demand of target audience. Based on what the demand is of the target audience, the product or service need to be designed in a manner that it serves as a solution to them for a 'problem' they encounter. The limitations of the infrastructure needs to be taken into account for this. The idea of a product or service can serve the demands of the people, however, it should be usable in the environment of these people. An example is lack of transportation and a large amount of paperwork by the illiterate; the innovation should therefore not a lot of transportation and should not require lots of paperwork that need to be filled in as seen for M-Pesa. The product needs to be designed to bypass these limitations. Furthermore, the company's decisions also take part in the design of the product or service. There is not only one way to design a product or service, therefore, the company producing the product or service can choose how it wants to make the design of the product. Since M-Pesa is a local company, its business model differs majorly from a business model that would have been created by an MNC. Therefore, the business model is also an element that has an influence on the factor.

Furthermore, M-Pesa is a system, not a product or service. It aids in researching the mobile phone industry, while M-Pesa itself if not part of this industry. While modularity may not apply to M-Pesa and while it is not evident from the case study, by having done research into modularity, modularity seems to be applicable into this industry as well. When a product is made modular, it can potentially become less complex and cheaper. Modularisation of products

is an investment. In the long term, it will be beneficial in terms of costs. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management (Pakkanen et al., 2022). Modularity has the capacity to lower life-cycle costs by minimising the number of procedures and eliminating repeated ones (Gershenson et al., 1999). These ideas need to be kept in mind when manufacturing a product. When a product is not modular, it will be difficult to modify a product to make it more frugal once the product has been manufactured. Removing extra features will be difficult for example due to the construction of the design. Then, when making decisions for the design, it needs to be kept into mind that the product must be frugal from the start.

Lastly, since M-Pesa is created and offered by a company in a low resource economy, its business model for its own, standard products fit within the market they are in. They are familiar with the limitations of the environment, their infrastructure is not expensive and they are familiar with the market and audience. For an MNC, it would be difficult, since their products would differ from this market and they must reconsider its old business strategy in order to achieve long-term success for a product/service.

Business model

The factor *business model* of frugal innovation can be influenced by the type of company that is producing or selling the frugal innovation, the target audience, the target market and the goal of the company that is producing or selling the product/service. The type of company influences the business model, since for example multinationals need to adapt and modify their existing business models to one they are less familiar with, while M-Pesa did not encounter this issue. M-Pesa is familiar with the environment of the target audience, the target audience and the target market. Furthermore, the target audience and market take part in the business model, since this needs to be adapted to the market and audience the product or service is meant for. M-Pesa related more to demand of the target audience than to a necessity to survive. Lastly, the goal of the company with regards to selling the product or service has an influence on the business model. If the company wants to make a large profit, the business model will be different than when the company wants to provide the audience with a solution to their problems without returns or with a small profit.

4.2.4 What is the relation of M-Pesa with over-engineering?

Important factors of M-Pesa are its price, its design and the business model. These factors can also be found in the definition of over-engineering; Over-engineered products or services or in this case systems, are expensive in terms of price, more complex in terms of design and have a high-cost production and/or other operational/financial aspects. These factors' values are the

opposite of that of M-Pesa. Based on these three factors, an innovation can for example be frugal or over-engineered. When changing one of these factors the over-engineered product or frugal product will be affected to be either more or less frugal/over-engineered. One example is that when the design of M-Pesa becomes more complex, M-Pesa would be less frugal and would be a little more over-engineered than it is. It shifted from being frugal to being less frugal and a little more over-engineered. This does not mean that the product is in fact over-engineered. It only shifted further away from being frugal, more towards being over-engineered.

4.2.5 Is M-Pesa generalisable with regards to frugal innovations that are linked to the mobile phone industry?

This case study is a holistic single case study, which is difficult to generalise. It consists of one context and product, M-Pesa. Furthermore, this case is not within the mobile phone industry, however, M-Pesa has been used as a way to shed light onto the phenomenon in the mobile phone industry, due to the need of a mobile phone to use the system. When phones are made simper, complementary systems, services or products can be made simpler as well or vice versa.

However, despite the small sample size, a few generalisations can be made due to M-Pesa, because first a link has been established between frugal innovations and over-engineering, and the innovations have been linked to the definition of these. The definitions and link between frugal innovations and over-engineering remain the same in all contexts. The difference that is non-generalisable, could be the elements that influence the factors of over-engineering and frugal innovations. Therefore, the results can be generalised a little, however, the findings should be interpreted with caution.

5 Results

This section shows the results following from the Case Study in combination with the Literature Review. These results have been divided in the medical industry and mobile phone industry.

5.1 Medical industry

5.1.1 What are the factors of frugal innovations for the three products of the Africa Innovation Hub?

As can be seen in the case study for the medical industry, the factors of frugal innovations of the three products of the Africa Innovation Hub are the price, the design and business model. These factors have been concluded from the definition of frugal innovations. It is often associated with affordability in terms of *price*, low-cost production (and other operational/financial aspects) which could relate to the *business model*, low-cost materials and *design* that focuses on fundamental functioning and feature sets for the unserved end of the mass market while meeting or even exceeding certain pre-defined quality standards.

5.1.2 What do the factors mean for other medical equipment in the medical industry?

The factors are generalisable, because they have been established using the definition of frugal innovations and over-engineering. The elements that influence these factors, however, could differ per context, thus are not generalisable. These have been product/service specific, which makes it non-generalisable. The elements about target audience and target market for example, will remain the same for all situations, since the aim is not to change it since that would be the goal of the company, else the product/service would not have been made, while the element the design element could differ per product/service.

5.1.3 How can the factors and characteristics of frugal innovations for the three equipment of the Africa Innovation Hub be linked to over-engineering in the medical industry?

The three factors of frugal innovations of the three products are the price, the design and business model. These factors can also be found in the definition of over-engineering, but then with opposite values, such as the price being expensive instead of affordable.

Furthermore, with the case study, it can be seen that INUKA was more successful than the CHARM and Wind Up Fetal Doppler. The latter two were not over-engineered, but not as frugal as they should have been, mainly due to the price. The main reason for INUKA's success in comparison to the other two innovations was due to INUKA being continued in a start up. This eliminated the expenditures due to the business', in this case, Philips, (expensive) infrastructure. The business model was different, mainly in terms of operational, organisational and financial aspect. Therefore, it can be seen that the business model has a great impact on the price of an innovation and partially its success. Furthermore, while the designs of two products were the complete opposite a potential over-engineered counterpart, the price

remained a problem. For example, the CHARM has an increase in price potentially due to a design choice, which could be the belt to keep the product in place. By removing this and holding the product by hand, it could potentially lead to lower prices. However, a trade-off needs to be made between keeping the product affordable by for example removing the belt, or making the product more handy to use by keeping the belt. With the increase in price, the innovations become one step closer to the characteristics, as can be found in its definition, of over-engineering. Therefore, by modifying the values of these factors of frugal innovations, an innovation could, in theory, be frugal or over-engineered. In the case of frugal, the price needs to be affordable to the BOP, the design needs to be easy to understand by the BOP and the business model needs to contain low-cost production and other operational/financial aspects. The case for over-engineering is the complete opposite; the price is expensive, the design is complex and the business model does not focus on low-cost production and other operational/financial aspects. Therefore, the factors of frugal innovations are also factors of over-engineering.

Lastly, by changing the factors of frugal innovations and over-engineering (price, design and business model) to values that (partially) fit frugal innovations, the impact of over-engineering (skills and abilities, price, access and time) could be limited. By modifying the price factor to it being inexpensive and affordable, more people are able to afford the product/service. By modifying the design factor to it being easy to use and not complex, the product/service can be used by many more people and saves time, since people do not need essential expertise to utilise it and they do not have to learn it. Moreover, the design influences its access to certain populations. Their infrastructure needs to be taken into account when designing a product/service. By modifying the business model factor to it containing low-cost production and other financial/operational aspects, the price will be kept low.

5.1.4 What are the elements that influence the factors of frugal innovations for the three products of the Africa Innovation Hub?

Regulations that apply to the manufacture or sale of the innovations have an impact on the price and design factor of the Wind Up Fetal Doppler, CHARM and INUKA. These rules may vary from country to country. Regulations may result in higher costs from further testing or altered design. Therefore, the product's design has a role in determining pricing. A product's price might increase with its increase in complexity. Due to their manufacture, certain product components, such a belt or lever as seen in the medical case study of the Wind Up Fetal Doppler and CHARM, could have a higher cost. Furthermore, complexity could increase due to the regulations. A product for example should be produced to be safer, potentially leading to a more complex product.

The *infrastructure* of the company, such as the methods and procedures that serve as the foundation for a company's operations, has an impact on the price factor as seen in the case study for the Wind Up Fetal Doppler and the CHARM.

The *design* of a product or service has an impact on the price factor. While design is also a factor, it has an influence on its price. The more advanced a product is being made, the more

expensive the product can be. Some elements of a product, for example a lever or belt for the Wind Up Fetal Doppler and CHARM, could increase the price due to the production of these elements.

The *target audience's needs* and their *environment* have an impact on the design factor. The product or service must be developed in such a way that it meets the needs of the target market and offers them a solution to a problem they may be experiencing. For this, the environment's restrictions must be taken into consideration. The concept of a product/service might meet people's requirements, but it must also be practical in their environment. A shortage of electricity is one example; the invention should then not require a lot of electricity, as seen in the case study for the Wind Up Fetal Doppler.

The *modularity* of a product has an influence on the design factor. The product's need to be frugal must be considered while making design selections. Once a product is manufactured, it will be challenging to change it to be more cost-effective. For instance, because of how the design is built, removing more features will be challenging, such as a belt or lever for the Wind Up Fetal Doppler and the CHARM in the case study. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management. Therefore, it is essential to bear in mind that the design must be frugal from the beginning of the process. Only when a product has been produced to be modular, it could potentially become easier to modify features. Since they need fewer parts and make the product easier to alter, modular products are in the long term more affordable.

The *business model* of a company for the product or service has an impact on the design factor. While the business model is also a factor, it has an influence on the design. For an MNC, the frugal products and services will differ majorly with the MNC's standard products. The business model therefore will also differ. They must reconsider their old business strategy in order to achieve long-term success for the product, as seen in the case study.

The *sort organisation* manufacturing or selling the frugal innovation (i.e. start up or MNC), *target audience* and *target market* and *goal* of the company have an influence on the business model factor. For instance, an MNC's business model for its own, standard products differs majorly than the business model needed for a frugal innovation as well as the target audience and market. It must reconsider its old business strategy in order to achieve long-term success for the product. Start ups often do not face this problem as frequently. The target audience and market take part in the business model, since this needs to be adapted to the market and audience the product or service is meant for. This also differs for the MNCs in comparison to start ups with regards to their standard customers and market. Furthermore, if the goal of the company is to make a large profit, its business model would be different than when the company does not focus on large profits.

A list of the elements per factor can be seen in Figure 6.

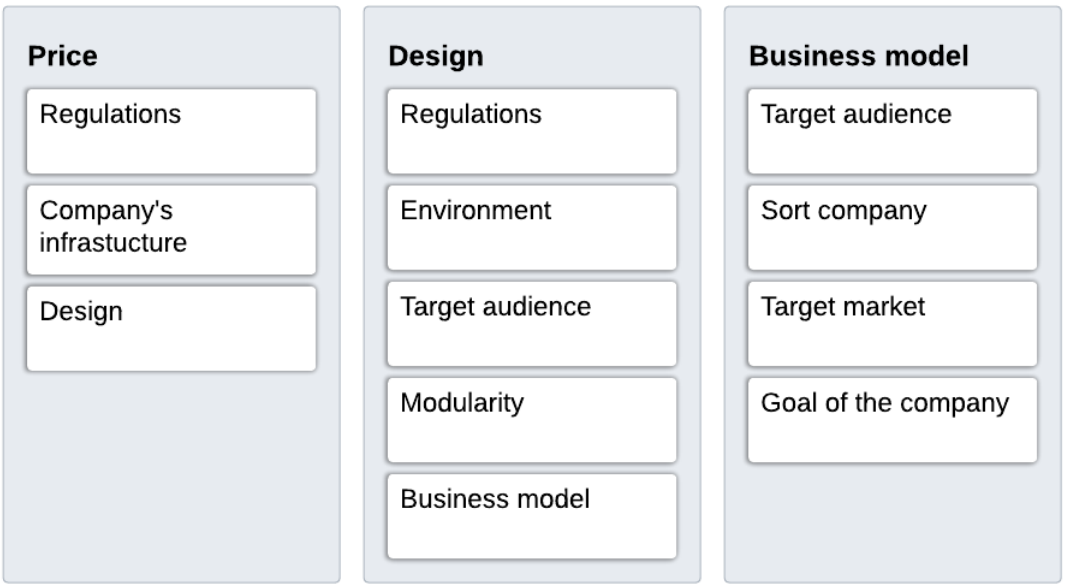

Figure 6: Elements that influence the factors of frugal innovations for the medical industry.

5.2 Mobile phone industry

5.2.1 What are the factors of frugal innovations for M-Pesa?

As can be seen in the case study for the mobile phone industry, the factors of innovations of M-Pesa are its price, its design and the business model. These factors have been concluded from the definition of frugal innovations. It is often associated with affordability in terms of price, low-cost production (and other operational/financial aspects) which could relate to the business model, low-cost materials and design that focuses on fundamental functioning and feature sets for the unserved end of the mass market while meeting or even exceeding certain pre-defined quality standards.

5.2.2 What do the factors mean for other products/services/systems in the mobile phone industry?

The factors are generalisable, because they mainly have been established using the definition of frugal innovations and over-engineering. Most elements, however, could differ per context, thus are not generalisable. These have been product/service specific, which makes it non-generalisable. The elements about target audience and target market for example, will remain the same for all situations, since the aim is not to change it since that would be the goal of the company, else the product/service would not have been produced, while the element the design element could differ per product/service.

Furthermore, M-Pesa is part of the mobile phone industry, but is used as an aid to shed light onto the phenomenon in the mobile phone industry. When a mobile phone has been made

simpler, complimentary products/services can be made simpler too and vice versa. Therefore, since it serves as an aid, the factors are generalisable, but the results need to be interpreted with caution.

5.2.3 How can the factors of frugal innovations for M-Pesa be linked to over-engineering in the mobile phone industry?

The three factors of frugal innovations of M-Pesa are the price, the design and business model. These factors can also be found in the definition of over-engineering, but then with opposite values, such as the price being expensive instead of affordable.

Furthermore, with the case study about M-Pesa, it can be seen that M-Pesa has been successful. Its price was affordable by the BOP, its design was not complex and the business model did not contain high production/financial/organisational costs. These values of the factors are the compete opposite of an over-engineered prospective counterpart. The innovation gets one step closer to a prospective over-engineered counterpart as one of its factors, as included in its definition, will be modified. An example is to increase the price to be expensive instead of being affordable to the BOP. The factor price now fits within the definition of over-engineering. Therefore, an innovation might theoretically be over-engineered or frugal by changing the values of these elements of frugal innovations. In the case of frugal, the price needs to be affordable to the BOP, the design needs to be easy to understand by the BOP and the business model needs to contain low-cost production and other operational/financial aspects. The case for over-engineering is the complete opposite; the price is expensive, the design is complex and the business model does not focus on low-cost production and other operational/financial aspects. Therefore, the factors of frugal innovations are also factors of over-engineering.

Lastly, by changing the factors of frugal innovations and over-engineering (price, design and business model) to values that (partially) fit frugal innovations, the impact of over-engineering (skills and abilities, price, access and time) could be limited. By modifying the price factor to it being inexpensive and affordable, more people are able to afford the product/service/system. By modifying the design factor to it being easy to use and not complex, the product/service can be used by many more people and saves time, since people do not need essential expertise to utilise it and they do not have to learn it. Moreover, the design influences its access to certain populations. Their infrastructure needs to be taken into account when designing a product/service. By modifying the business model factor to it containing low-cost production and other financial/operational aspects, the price will be kept low.

5.2.4 What are the elements that influence the factors of frugal innovations for M-Pesa?

The *competition* and *profit* the company strives to achieve has an influence on the price factor. As seen in the case study, M-Pesa was uncontested in Kenya, where prices were 10 times higher than in Tanzania, where competition was greater.

The *infrastructure* of the company, such as the methods and procedures that serve as the foundation for a company's operations, has an impact on the price factor as seen in the case

study. M-Pesa's operations were not expensive, nor a long process, hence the price of usage of M-Pesa could be kept low.

The *design* of a product or service has an impact on the price factor. While design is also a factor, it has an influence on its price. The more advanced a product is being made, the more expensive the product can be and vice versa. As seen in the case study, M-Pesa's system is not advanced nor complex and not expensive for the locals.

The *target audience's demand* and their environment have an impact on the design factor. The product or service must be developed in such a way that it meets the demands of the target market and offers them a solution to the audience's demand. For this, the environment's restrictions must be taken into consideration. The concept of a product/service might meet people's requirements, but it must also be practical in their environment. For example, as seen in the case study, in the case of lack of mobility and illiteracy, the innovation should not demand a lot of transportation or a lot of paperwork that has to be filled out. The innovation has to be built to get around these limitations.

The *modularity* of a product has an influence on the design factor. The product's need to be frugal must be considered while making design selections. Once a product is manufactured, it will be challenging to change it to be more cost-effective. For instance, because of how the design is built, removing more features will be challenging. Therefore, it is essential to bear in mind that the design must be frugal from the beginning of the process. Only when a product has been produced to be modular, it could potentially become easier to modify features. Since they need fewer parts and make the component easier to alter, modular components are in the long term frequently more affordable to assemble. While this has not been a large issue in the case study, it still applies to the mobile phone industry. M-Pesa is not a product, nor part of the mobile phone industry, but helps in analysing it as such.

The *business model* of a company for the product or service has an impact on the design factor. While the business model is also a factor, it has an influence on the design. For an MNC, the frugal products and services will differ majorly with the MNC's standard products. The business model therefore will also differ. They must reconsider their old business strategy in order to achieve long-term success for the product. M-Pesa is a local company that did not have such problem as seen in the case study.

The *sort organisation* manufacturing or selling the frugal innovation (i.e. start up or MNC), *target audience*, *target market* and *goal* of the company have an influence on the business model factor. For instance, an MNC's business model for its own, standard products differs majorly than the business model needed for a frugal innovation as well as the target audience and market. It must reconsider its old business strategy in order to achieve long-term success for the product. Start ups often do not face this problem as frequently. The target audience and market take part in the business model, since this needs to be adapted to the market and audience the product or service is meant for. This also differs for the MNCs in comparison to start ups, or as seen in the case study, local companies, with regards to their standard customers and market. Furthermore, if the goal of the company is to make a lot of profit, its business model would be different than when the company does not focus on profit

A list of the elements per factor can be seen in Figure 7.

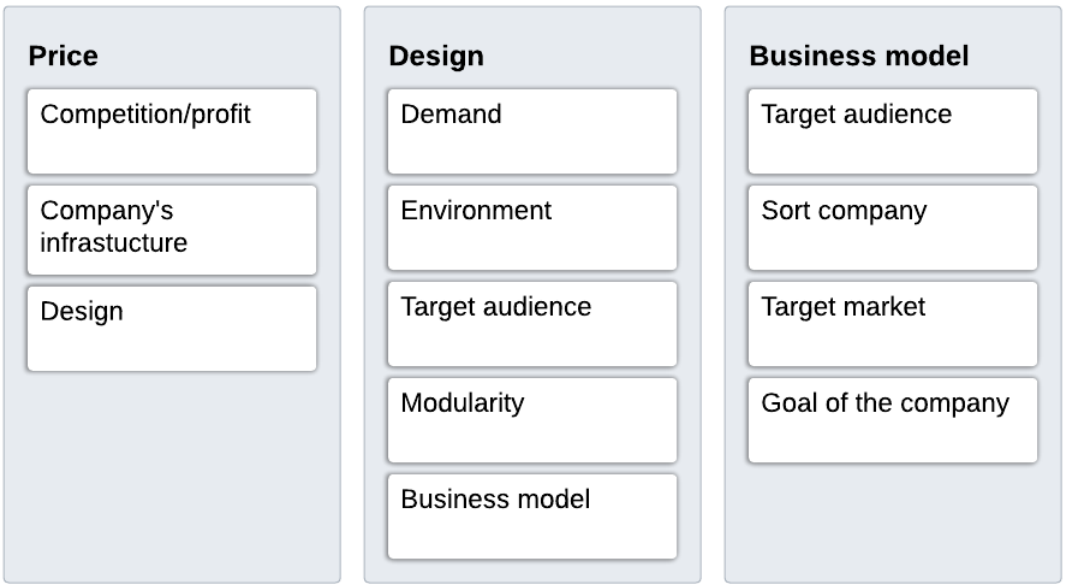

Figure 7: Elements that influence the factors of frugal innovations for the mobile phone industry.

5.3 Sub-questions 4, 5 and 6

Based on the case study and the previous questions of this chapter, sub-research questions 4, 5 and 6 can be answered.

5.3.1 Sub-research question 4a: What are the factors of frugal innovations to affect over-engineering for medical equipment in the medical industry?

The factors of frugal innovations and over-engineering are the same. Hence, when changing one factor, it may have an affect on both frugal innovations and over-engineering (e.g. changing the price from expensive to affordable). When a factor of over-engineering will be affected by the same factor of frugal innovations, the product or service then will shift from being over-engineered to being less over-engineered and more frugal. One example is that when a product is complex in design (factor of over-engineering) and will be made less complex in design (factor of frugal innovation), the product will be less over-engineered and more shifted towards being frugal. Therefore, the most important factors of frugal innovations to affect over-engineering are the business model, price and design of the product/service. Not only these factors are important, but the elements that influence these factors are important as well.

5.3.2 Sub-research question 4b: What are the factors of frugal innovations to affect over-engineering in the mobile phone industry?

As with the medical industry, the factors of frugal innovations and over-engineering are the same. Hence, when changing one factor, it may have an affect on both frugal innovations and

over-engineering (e.g. changing the price from expensive to affordable). When a factor of over-engineering will be affected by the same factor of frugal innovations, the product or service then will shift from being over-engineered to being less over-engineered and more frugal. One example is that when a product is complex in design (factor of over-engineering) and will be made less complex in design (factor of frugal innovation), the product will be less over-engineered and more shifted towards being frugal. Therefore, the most important factors of frugal innovations to affect over-engineering are the business model, price and design of the product/service. Not only these factors are important, but the elements that influence these factors are important as well.

5.3.3 Sub-research question 5: What are the elements that influence the factors of frugal innovations?

The majority of elements that influence the factors of frugal innovations are the same. The list of elements can be seen in Figure 6 and Figure 7 for the medical industry and mobile phone industry, respectively. Figure 8 shows the relations between the elements and factors of frugal innovations.

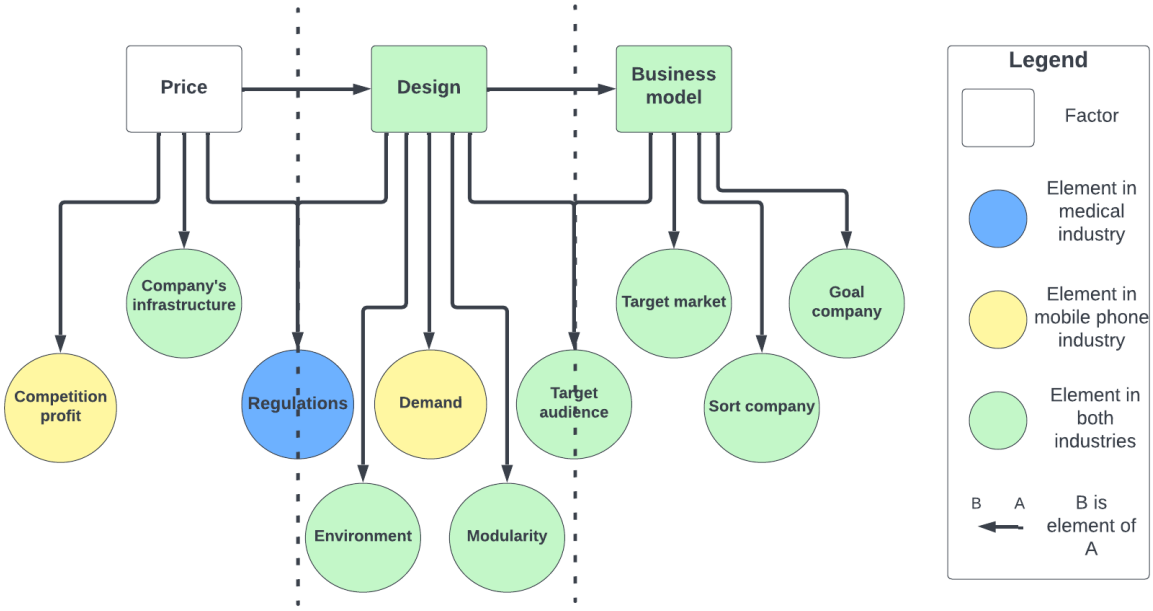

Figure 8: Relations between the factors of frugal innovations and the elements that influence them.

Medical and mobile phone industry

For both industries for the price factor, as seen for the Africa Innovation Hub and M-Pesa, the company's infrastructure is one of the elements. This element likely will not change. However, while the company's infrastructure likely will not change, What can be changed, is the company that will be selling the innovation, which bypasses the the inability to modify this element. A start up has a higher success of selling a frugal innovation than an MNC, as seen with INUKA. A start-up will be able to sell the innovation for a lower price than a multinational, due to the

company's infrastructure, which mostly is expensive for MNCs, as seen mainly in the medical case study. Also, a start-up has more freedom in the sales of a product/service, because there are less costs involved in comparison to an MNC, while multinational will likely stop their production and will look for other opportunities. Furthermore, the structure of an MNC does not lend itself to frugal innovations for low-income economies as well as a start up would. The frugal innovations' pricing are beyond the range that MNCs would sell and they have a different target market. However, the production can potentially be done by an MNC. As seen in the case study of the medical industry, a collaboration between an MNC and a start up is possible and could lead to success, as seen with INUKA. Furthermore, the design of a product or service is an element of the price factor. The more advanced a product is being made, the more expensive the product can be and vice versa.

For the design factor, the environment of the target audience cannot be modified. The product or service needs to be altered to make it work with the infrastructure. The same holds for the target audience and their demand or need; this cannot be influenced as well. The products or service is meant to solve the demand/need problem, hence it cannot be influenced before the production of the product/service. Furthermore, modularity is important when manufacturing a product as seen in the case studies. Once a product has been manufactured, it is difficult to remove features or components without affecting other features/components and it will be challenging to modify it to be more cost-effective, which can be seen for the CHARM and the Wind Up Fetal Doppler. In case of an innovation being modular, its design can be modified and should not contain irrelevant components and features. Moreover, when the product or service can be used in an alternative manner that leads to less features or components, then this should be followed up with, since it will potentially lead to an decrease in product/service price. In case of a non-modular innovations, modifying its design to make it more frugal will remain difficult, as seen in the medical case study. While manufacturing products to be modular is an investment, in the long term, it is beneficial in costs. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management. Furthermore, the business model of a company for the product or service has an impact on the design factor. While the business model is also a factor, it has an influence on the design. For an MNC, the frugal products and services will differ majorly with the MNC's standard products. The business model therefore will also differ, as seen mainly at INUKA. They must reconsider their old business strategy in order to achieve long-term success for the product. M-Pesa is a local company that did not have such problem as seen in the case study.

For the business model factor, the target market and target audience will not change, since this is the market and audience that the company wants to engage in/with. Furthermore, the goal of the company can be influenced, however, a company likely will not modify it. These

elements therefore cannot be influenced. The business model will change depending on whether the organisation intends to generate a large profit or a small profit/ give the audience a free product/service to their concerns. To prevent the innovation from going towards over-engineering, the profit should be low or potentially non-existent, at least in the beginning. However, this could be unrealistic and therefore this element cannot be influenced. Lastly, the sort of company that is producing or selling the frugal products/services matters. As seen mainly in the medical case study, a start up would be a better fit for selling the innovations. As seen in the medical case study, the sales of a frugal product is a disadvantage of an MNC, because they do not have a lot of freedom in this, their decisions are being scrutinised. When making wrong decisions, this could lead in large international backlash and has a high impact on their reputation. Furthermore, MNCs are not familiar with the target audience in low resource economies when comparing them to their usual target audience. Start ups do not encounter these issues as severe and as often. They have more freedom in selling products and in making decisions. They do not have that scrutiny and severe backlash and reputational damage. However, start ups could fail when making wrong decisions and possibly do not have a backup. Therefore, as seen in the medical case study, a product or service could be produced by an MNC, but sold by a start up. There is a possibly for collaborations, which has been successful for INUKA.

Addition mobile phone industry
In addition to the mobile phone industry, the competition and profit the company wants to generate influence the price. When there is hardly any competition, businesses can increase the price to generate profit, as seen with M-Pesa. In case of a competitive environment, the prices will be kept low enough such that the demanding customers will not go to the competition, but high enough to generate profit or to survive, which would lead to non-consumers. The influence over-engineered products to become less over-engineered, or to prevent an innovation from going towards over-engineering, the profit should be low or potentially non-existent in the beginning of the process. However, this could be unrealistic and therefore this element cannot be altered. Furthermore, the demand of the target audience can also not be altered.

Addition medical industry
In addition to the medical industry for the price and design factor, regulations also influence these factors, as seen in the case study. In theory, these regulations cannot be modified by the company manufacturing a frugal product/service. However, it is possibly to bypass regulations. This raised ethical questions. On the one hand, regulations have been created for a reason, such as safety. On the other hand, these regulations may be too strict and could deprive people from having medical care. As per the case study of the medical industry, regulations increase the price of the product or a product being rejected, which can lead to inaccessibility of these products for certain people, while the product potentially could safe lives. Furthermore, these regulations differ per country. A products needs to meet the requirements of the regulations of the country it is being produced as well as the country the product is being sold to.

5.3.4 Sub-research question 6: How can the elements of the factors of frugal innovations be used to influence over-engineering?

Not all elements that influence the factors frugal innovations and over-engineering can be modified. The elements that can be altered to influence factors of frugal innovations and over-engineering are the modularity (design factor), regulations for the medical industry (price and design factor) and sort company (business model factor).

Modularity
Once a product has been manufactured, it will be challenging to change it to be more cost-effective. For instance, because of how the design is built, removing more features will be challenging, such as a belt or lever for the Wind Up Fetal Doppler and the CHARM in the medical case study. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management. Therefore, it is essential to bear in mind that the design must be frugal from the beginning of the process. Only when a product has been produced to be modular, it could potentially become easier to modify features. Since they need fewer parts and make the product easier to alter, modular products are in the long term more affordable.

Sort company
As seen mainly in the medical case study, a start up would be a better fit for selling a frugal innovations. The sales of a frugal product is a disadvantage of an MNC, because they do not have a lot of freedom in this, since their decisions are being scrutinised. When making wrong decisions, this could lead in large international backlash and has a high impact on their reputation. Furthermore, MNCs are not familiar with the target audience in low resource economies when comparing them to their usual target audience. Start ups do not encounter these issues as severe and as often. They have more freedom in selling products and in making decisions. They do not have that scrutiny and severe backlash and reputational damage. However, start ups could fail when making wrong decisions and possibly do not have a backup. Therefore, as seen in the medical case study, a product or service could be produced by an MNC, but sold by a start up. There is a possibly for collaborations, which has been successful for INUKA.

Regulations (Medical industry)
When medical equipment are manufactured, they need to comply with national and international regulations. Regulations raise ethical questions, since regulations have been made for a reason, such as safety reasons, however, if it is at the expense of the people who are deprived of medical devices, should the regulations still be upheld? Sometimes, it would be better to have access to medical equipment to save a life rather than adhere to regulations, which can

be too strict. As per the case study of the medical industry, regulations increase the price of the product or a product being rejected, which can lead to inaccessibility of these products for certain people, while the product potentially could safe lives. As seen in the medical case study, regulations differ per country. A products needs to meet the requirements of the regulations of the country it is being produced as well as the country the product is being sold to. For high resource economies, these regulations are more strict as the healthcare in these economies is more developed and advanced than in low resource economies. Therefore, it would not make sense for low resource economies to also adhere to the regulations of the high resource economies. Hence, when producing medical equipment in high resource economies, the company producing the product should only focus on regulations of the low resource economy since the product only will be used there. Selling the product for an MNC such as Philips, will be difficult to do, since their decisions are scrutinised and will lead to large international backlash when selling products that bypass regulations. A start up has more freedom to do so, due to less scrutiny and less attention to their decisions.

In case the regulations in the low resource economies are too strict too, trade-offs need to be made in order to provide people with the best care they could get. The safety of the product and the people should still have a high priority, while in other areas, trade-offs could be made. What the regulations are and what areas can be bypassed are unclear, since these differ per country and need to be research upon extensively before reaching conclusions. Therefore, an advice I would like to give to the Ministry of Health in low resource economies is that the regulations regarding medical devices need to be reanalysed to see how the citizens can have access to medical devices while still adhering to most regulations. This could mean that some regulations need to be more flexible, while still putting safety as the main priority. More people could be saved by bypassing some regulations and providing them with care, rather than not giving them the care at all.

6 Reflection

This section provides reflections on the research results and the research method. subsection 6.1 - Reflection on used research method reflects on the research method that has been used to obtain the data used for the case study. subsection 6.2 - Reflection on research results reflects on the research results from section 5 - Results resulting from the two case studies in section 4 - Case Study. Lastly, subsection 6.3 - Reflection on data analysis reflects on the data analysis used in this research.

6.1 Reflection on used research method

The literature research provides a basis for this study. With this, part of the research objective has been fulfilled. As for the research results on elements that influence the factors of frugal innovations, they followed from two case studies. Two case studies are two occurrences that relate to the literature research. The research method that has been used consists of one case study for the medical industry and one for the mobile phone industry. Getting the appropriate data was one of the research's biggest obstacles. The initial idea of the research method for data collection consisted of conducting 8 interviews. 4 companies were going to be interviewed for the medical industry and 4 companies for the mobile phone industry. However, due to lack of responses, the research method for data collection needed to be changed. Waiting for the responses took more than six weeks of this research's time. While this time has been used to improve the interview questions and improve parts of this research report, the six weeks could have been spent on doing more research, since creating questions for the companies that did not participate has been lost time. Relying on large corporations for the research has been a pitfall. For the medical industry, one interview has been conducted in combination with literature research. For the mobile phone industry, literature research has been done. The interview has been helpful in gaining practical knowledge on frugal products and services that have been failing or succeeding and the reason behind their success/failure. To hold the interview in a semi-structured manner helped in gaining more information than I had anticipated in the pre-defined question list. With the semi-structured form, it was easier to follow up on answers, which is how the INUKA success story came into this research. However, more interviews would have increased the reliability, since the current sample size was too small. Unfortunately, due to the lack of responses from potential interviewees, no more interviews could have been held, therefore, more literature research has been done for the case study based on the interview. The lack of responses has an effect on the generalisability of the research. This has the implication on this research that one case study per industry is insufficient. However, on the other side, since the case studies have been used in combination with the literature review and definitions of frugal innovations and over-engineering, it still provides useful knowledge regarding the factors of frugal innovations and their effect.

6.2 Reflection on research results

The conclusion of the results with regards to the factors of frugal innovations and over-engineering have been taken based on their definitions. Therefore, the result will not change, unless the definition and characteristics of both terms will change. This information is not be new information in research.

Since these case studies provide knowledge on real-life frugal products and services that have been failing or succeeding, they give good insights on the frugal innovations and their success or failure, but not on the elements that influence their factors. It only provides this knowledge for the specific products/services. No conclusion can be made from these product/service specific elements. There could be overlap between different products/services, as can be seen with the three innovations of the Africa Innovation Hub, however, this conclusion cannot be made without having done research into more cases. One case study per industry is insufficient for these results to be generalisable. Other aspects could also have had an influence the success or failure of a frugal innovation, rather than the elements. The lack of data therefore affects the reliability of the outcome. Thus, with the interpretation of these results, it is important to acknowledge this limitation.

Moreover, M-Pesa is a system that is not in the mobile phone industry. While it is not directly part of the industry, it helps to analyse the industry. While it can help shed light onto the phenomenons, the results are not directly derived from the mobile phone industry. This lowers the reliability for this particular industry. The research into M-Pesa itself could affect the result, since the result could possibly hold for M-Pesa, but not for the mobile phone industry.

Furthermore, regarding the business model, the results stated that a start up would have a higher chance of selling a more frugal product than an MNC. However, this only has been found based on the internal infrastructure being cheap for start ups in combination with the success stories of INUKA and M-Pesa. Possibly, there could be other factors why a start up would or would not be successful in this. Thus, also with the interpretation of these results, it is important to acknowledge this limitation.

The result of a product needing to be modular in design for the mobile phone industry should also be interpreted with caution. While it could be taken from the medical case study, it was not evident from the mobile phone case study. M-Pesa is a system and not a product, therefore, it could not show that modularity is a large part of the elements in the mobile phone industry. M-Pesa serves as an aid for the mobile phone industry, but is not part of it, therefore, while modularity has not be shown in the case study to be an element, it cannot be excluded. Based on the term modularity and its effects, assumptions have been made based on logical reasoning. There is no proof from the case studies that it is an important part of the elements. Instead of modularity following from the case study, the reasoning has been reversed; the term modularity has been reasoned into the mobile phone industry. Since this did not follow from the case study, this results needs to be interpreted with caution.

6.3 Reflection on data analysis

The data analysis has been done based on questions that need to be answered. These questions consist of sub-research questions that are broken down into parts. These parts can be combined to be able to answer the sub-research questions. Based on the data collection, these questions guided towards answering the research questions. If more primary data was gathered, a tool such as ATLAS.TI could have been used to codify the data. This would make the analysis more reproducible and more scientific. While the questions asked also lead to reproducibility, since they have derived from the sub-research questions, there is no room for other questions to be asked in order to make the analysis reproducible. Asking other questions that could be derived from the research questions could lead to another analysis and potentially a slightly different outcome. However, due to the one interview and literature research, using a tool such as ATLAS.TI was not possible, thus guiding questions have been asked. While this is not an ideal data analysis method since the questions that needed to be answered have been derived by the researcher and could differ per researcher, it did help in reaching a conclusion.

7 Conclusion

In this section, the sub-research questions have been answered, which lead in answering the main research question: *How can frugal innovations have an impact on over-engineering in the mobile phone industry and in the medical industry?* Sub-research questions 1, 2 and 3 have been answered based on literature research. Sub-research questions 4, 5 and 6 have been answered based on case studies. Two case studies have been done, one for the medical industry and one for the mobile phone industry. With this, the research objective *to investigate the factors of frugal innovations that can affect over-engineering in the mobile phone industry and for the medical industry* has been reached. Therefore, this thesis closes the knowledge gap of the effect of frugal innovations on over-engineering. Furthermore, this research is highly societally relevant, since overly complex and expensive products are unavailable to the majority of the world's population, but can be made available to them. These products can vary from luxury products to products of medically importance.

Sub-research question 1: What is over-engineering and its characteristics?

Over-engineering is when a product or a solution to a problem is designed in an intricate or sophisticated manner when a simpler option can be proved to exist with the same efficiency and effectiveness as the original design. Over-engineering dramatically increases the costs of design, installation and operation.

There are two types of over-engineering:

1. to over-engineer to serve the existing demanding consumers with ever-improving products.
2. to over-engineer to comply with rules and regulations

The first type of over-engineering is happening, because incumbents often strive to give ever-improving products and services to their most profitable and demanding clients, while paying less attention to less-demanding consumers or non-consumers. The incumbents enable the feasibility of disruptive innovations by the fact that these innovations begin in two types of marketplaces that incumbents ignore: the less-demanding consumers and the non-consumers. In reality, incumbents' offers frequently outperform the latter's performance criteria. The less demanding customers will be provided with products that are good enough and non-consumers could be turned into consumers, which could disrupt the over-engineered product. This type of over-engineering is visible on the demand-side of the market, which means that the products are mostly not a necessity, depending on the context, however, there is a high demand for these products.

On the other hand, the second type of over-engineering belongs to the supply-side of the market and does not focus on improving their products and services to their most profitable and demanding clients, while paying less attention to less-demanding consumers, because they want to reach a broader market and make non-consumer consumers. The products and services on the supply-side are not luxury goods, but are a necessity.

Sub-research question 2a: What are the causes of over-engineering in the medical industry?

The causes and reasons for over-engineering in the medical industry is due to:

- Safety: There are several trade-offs between complexity and expense when designing devices to achieve desired safety performance. Cost, quality and time balance are never easy to achieve. Project costs and schedules are likely to be considerably exaggerated by placing a strong emphasis on design quality in an effort to account for all unforeseen eventualities. Additionally, machinery that has been unduly built for safety may operate slowly or with a limited range of motion. Some medical devices have safety mechanisms that enable them to function even in the event of failure.

- Performance: Regulatory bodies typically need specialised equipment performance testing. To cure the sickness or illness, equipment must be made that is also long-lasting enough to last the patient their entire life without compromising other aspects of their quality of life.

- R&D: Medical devices include a range of R&D procedures and ethical challenges that are unique to them because of how they interact with people. The need to address unmet clinical needs, the alignment of technological challenges with internal capabilities and available expertise, the infrastructure required to effectively distribute and support the product, the anticipated time to market, financial risks and rewards and the likelihood of market acceptance are just a few of the considerations that companies make when choosing R&D projects. The effects on development and research are substantial. These factors could increase the cost and complicate the product excessively.

- Testing: Medical device design requires careful planning and testing with known and unknowable variables that might effect device operation, such interoperability issues. For the gadget to be approved by a regulatory agency, thorough human and non-human investigations as well as significant trials must be conducted. As a result, the device's cost increases. If the tests are unsuccessful, the product could have been over-engineered to succeed.

- Other regulations: Sometimes low-income economies are unable to get affordable, effective equipment due to regulations, which might vary by country. Regulations could force manufacturers to over-engineer a product. For instance, safety comes under the regulations category. However, there are many additional rules that have an impact on the complexity and cost of the equipment.

Sub-research question 2b: What are the causes of over-engineering in the mobile phone industry?

The causes and reasons for over-engineering in the mobile phone industry is due to:

- Performance: Characteristics of the phone's brand name as well as social influence from peers and family have a significant impact on consumers' demand for phones and its features. Performance (battery, speed, etc.) is a key factor in this situation. It affects a person personally and socially. Performance is enhanced as a result for the demanding consumers.

- Competitiveness/profit: Businesses are striving to make a profit and even survive in a very competitive environment. When there is hardly any competition, businesses can increase the price to generate profit. In case of a competitive environment, the prices will be kept low enough such that the demanding customers will not go to the competition, but high enough to generate profit or to survive.

- Demand: Voice dialling, colour displays and mobile Internet are just a few of the features that might significantly affect how happy customers are. Phones with mobile Internet are more popular with users than those without. Higher-resolution images should be produced by mobile phone cameras so that users may access visual information with more precision and clarity. The demand to enhance mobile phone features is growing. As a result, there is a demand for phones with these functions and the price is one that the demanding customers are willing to pay.

Sub-research question 3: What are the characteristics of frugal innovations?

An innovation manifestation called "frugal innovation" aims to reduce the cost of systems, services and products and are accessible to the Bottom of the Pyramid. It is often associated with affordability, low-cost production, low-cost materials and design that focuses on fundamental functioning and feature sets for the unserved end of the mass market while meeting or even exceeding certain pre-defined quality standards.

There are three requirements for frugal innovations:

- Substantial cost reduction: When compared to traditional products and services, frugal innovation has a substantially lower price or significantly lower expenses. Defining a threshold for 'substantial' is difficult. Therefore, a recommendation has been made, which is that the considerable cost savings from frugal innovation must be at least a third lower than comparable items.

- Concentrate on core functionalities: Core benefits, fundamental functions and decreased complexity are frequently connected with frugal innovation. As a result, frugal innovation involves a focus on the key features that provide the greatest consumer advantages, as well as a direct focus on user requirements

- Optimised performance level: Frugal innovation should achieve the performance and quality standards that are actually necessary while keeping expenses to a minimum.

Sub-research question 4a: What are the factors of frugal innovations to affect over-engineering in the medical industry?

The factors of frugal innovations and over-engineering are the same and have been take from their definitions. Hence, when changing one factor, it may have an affect on both frugal innovations and over-engineering (e.g. changing the price from expensive to affordable). When a factor of over-engineering will be affected by the same factor of frugal innovations, the product or service then will shift from being over-engineered to being less over-engineered and more frugal. One example is that when a product is complex in design (factor of over-engineering) and will be made less complex in design (factor of frugal innovation), the product will be less over-engineered and more shifted towards being frugal. Therefore, the most important factors of frugal innovations to affect over-engineering are the business model, price and design of the product/service. Not only these factors are important, but the elements that influence these factors are important as well.

Sub-research question 4b: What are the factors of frugal innovations to affect over-engineering in the mobile phone industry?

As with the medical industry, the factors of frugal innovations and over-engineering are the same. Hence, when changing one factor, it may have an affect on both frugal innovations and over-engineering (e.g. changing the price from expensive to affordable). When a factor of over-engineering will be affected by the same factor of frugal innovations, the product or service then will shift from being over-engineered to being less over-engineered and more frugal. One example is that when a product is complex in design (factor of over-engineering) and will be made less complex in design (factor of frugal innovation), the product will be less over-engineered and more shifted towards being frugal. Therefore, the most important factors of frugal innovations to affect over-engineering are the business model, price and design of the product/service. Not only these factors are important, but the elements that influence these factors are important as well.

Sub-research question 5: What are the elements that influence the factors of frugal innovations

Based on the case studies, the majority of elements that influence the factors of frugal innovations are the same. For both industries, the design and company's infrastructure influence the price factor; the target audience's environment, their demand/need, modularity and business model influence the design factor; and the target audience, target market, sort company and goal of the company influence the business model. In addition to the mobile phone industry, competition/profit influence the price factor and in addition to the medical industry, regulations influence the price and design factor.

Medical and mobile phone industry
For both industries for the price factor, the company's infrastructure is one of the elements.

This element likely will not change. However, while the company's infrastructure likely will not change, What can be changed, is the company that will be selling the innovation, which bypasses the the inability to modify this element. A start up has a higher success of selling a frugal innovation than an MNC. A start up will be able to sell the innovation for a lower price than a multinational, due to the company's infrastructure, which mostly is expensive for MNCs, as seen mainly for INUKA in the medical case study. Also, a start-up has more freedom in the sales of a product/service, because there are less costs involved in comparison to an MNC, while multinational will likely stop their production and will look for other opportunities. Furthermore, the structure of an MNC does not lend itself to frugal innovations for low-income economies as well as a start up would. The frugal innovations' pricing are beyond the range that MNCs would sell and they have a different target market, which is evident from the CHARM, INUKA and the Wind Up Fetal Doppler in the medical case study. However, the production can potentially be done by an MNC. As seen in the case study of the medical industry, a collaboration between an MNC and a start up is possible and could lead to success. Furthermore, the design of a product or service is an element of the price factor. The more advanced a product is being made, the more expensive the product can be and vice versa.

For the design factor, the environment of the target audience cannot be modified. The product or service needs to be altered to make it work with the infrastructure. The same holds for the target audience and their demand or need; this cannot be influenced as well. The products or service is meant to solve the demand/need problem, hence it cannot be influenced before the production of the product/service. Furthermore, modularity is important when manufacturing a product as seen in the case studies, mainly the medical case study. Once a product has been manufactured, it is difficult to remove features or components without affecting other features/components and it will be challenging to modify it to be more cost-effective. In case of an innovation being modular, its design can be modified and should not contain irrelevant components and features. Moreover, when the product or service can be used in an alternative manner that leads to less features or components, then this should be followed up with, since it will potentially lead to an decrease in product/service price. In case of a non-modular innovations, modifying its design to make it more frugal will remain difficult, as seen in the medical case study. While manufacturing products to be modular is an investment, in the long term, it is beneficial in costs. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management. Furthermore, the business model of a company for the product or service has an impact on the design factor. While the business model is also a factor, it has an influence on the design. For an MNC, the frugal products and services will differ majorly with the MNC's standard products. The business model therefore will also differ, which is evident from the medical case study. They must

reconsider their old business strategy in order to achieve long-term success for the product. Local companies or start ups do not have such problem, as seen for local company M-Pesa in the mobile phone case study.

For the business model factor, the target market and target audience will not change, since this is the market and audience that the company wants to engage in/with. Furthermore, the goal of the company can be influenced, however, a company likely will not modify it. These elements therefore cannot be influenced. The business model will change depending on whether the organisation intends to generate a large profit or a small profit/ give the audience a free product/service to their concerns. To prevent the innovation from going towards over-engineering, the profit should be low or potentially non-existent, at least in the beginning. However, this could be unrealistic, therefore, this element cannot be altered. Lastly, the sort of company that is producing or selling the frugal products/services matters. As seen mainly in the medical case study, a start up would be a better fit for selling the innovations. The sales of a frugal product is a disadvantage of an MNC, because they do not have a lot of freedom in this, their decisions are being scrutinised. When making wrong decisions, this could lead in large international backlash and has a high impact on their reputation. Furthermore, MNCs are not familiar with the target audience in low resource economies when comparing them to their usual target audience. Start ups do not encounter these issues as severe and as often, which is evident from INUKA in the medical case study. They have more freedom in selling products and in making decisions. They do not have that scrutiny and severe backlash and reputational damage. However, start ups could fail when making wrong decisions and possibly do not have a backup. Therefore, as seen in the medical case study, a product or service could be produced by an MNC, but sold by a start up. There is a possibly for collaborations, which has been successful for INUKA.

Addition mobile phone industry

In addition to the mobile phone industry, the competition and profit the company wants to generate influence the price. When there is hardly any competition, businesses can increase the price to generate profit, as seen with M-Pesa. In case of a competitive environment, the prices will be kept low enough such that the demanding customers will not go to the competition, but high enough to generate profit or to survive. The influence over-engineered products to become less over-engineered, or to prevent an innovation from going towards over-engineering, the profit should be low or potentially non-existent. However, this could be unrealistic, therefore, this element cannot be altered. Furthermore, the demand of the target audience can also not be altered.

Addition medical industry

In addition to the medical industry for the price and design factor, regulations also influence these factors, as seen for the Africa Innovation Hub. In theory, these regulations cannot be modified by the company manufacturing a frugal product/service. However, it is possibly to bypass regulations. This raised ethical questions. On the one hand, regulations have been created for a reason, such as safety. On the other hand, these regulations may be too strict

and could deprive people from having medical care. As per the case study of the medical industry, regulations increase the price of the product or a product being rejected, which can lead to inaccessibility of these products for certain people, while the product potentially could safe lives. Furthermore, these regulations differ per country. A products needs to meet the requirements of the regulations of the country it is being produced as well as the country the product is being sold to.

Sub-research question 6: How can the elements of the factors of frugal innovations be used to influence over-engineering?

Not all elements that influence the factors frugal innovations and over-engineering can be modified. As seen in the case study and in the previous sub-research question, the elements that can be altered to influence factors of frugal innovations and over-engineering are the modularity (design factor), sort company that is selling the innovation (business model factor) and regulations for the medical industry (price and design factor) .

Modularity
Once a product has been manufactured, it will be challenging to change it to be more cost-effective. For instance, because of how the design is built, removing more features will be challenging, such as a belt or lever for the Wind Up Fetal Doppler and the CHARM in the medical case study. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management. Therefore, it is essential to bear in mind that the design must be frugal from the beginning of the process. Only when a product has been produced to be modular, it could potentially become easier to modify features. Since they need fewer parts and make the product easier to alter, modular products are in the long term more affordable.

Sort company
As seen mainly in both the medical case study and mobile phone case study, a start up, or in the case of the mobile phone study, a local company, would be a better fit for selling a frugal innovations. The sales of a frugal product is a disadvantage of an MNC, because they do not have a lot of freedom in this, since their decisions are being scrutinised. When making wrong decisions, this could lead in large international backlash and has a high impact on their reputation. Furthermore, MNCs are not familiar with the target audience in low resource economies when comparing them to their usual target audience, as evident from the CHARM, Wind Up Fetal Doppler and INUKA. Start ups do not encounter these issues as severe and as often. They have more freedom in selling products and in making decisions. They do not have that scrutiny and severe backlash and reputational damage. However, start ups could fail when

making wrong decisions and possibly do not have a backup. Therefore, as seen in the medical case study, a product or service could be produced by an MNC, but sold by a start up. There is a possibly for collaborations, which has been successful for INUKA.

Regulations (Medical industry)
When medical equipment are manufactured, they need to comply with national and international regulations, which have been the case for mainly the CHARM and the Wind Up Fetal Doppler. Regulations raise ethical questions, since regulations have been made for a reason, such as safety reasons, however, if it is at the expense of the people who are deprived of medical devices, should the regulations still be upheld? Sometimes, it would be better to have access to medical equipment to save a life rather than adhere to regulations, which can be too strict. As per the case study of the medical industry, regulations increase the price of the product or a product being rejected, which can lead to inaccessibility of these products for certain people, while the product potentially could safe lives. As seen in the medical case study, regulations differ per country. A products needs to meet the requirements of the regulations of the country it is being produced as well as the country the product is being sold to. For high resource economies, these regulations are more strict as the healthcare in these economies is more developed and advanced than in low resource economies. Therefore, it would not make sense for low resource economies to also adhere to the regulations of the high resource economies. Hence, when producing medical equipment in high resource economies, the company producing the product should only focus on regulations of the low resource economy since the product only will be used there. Selling the product for an MNC such as Philips, will be difficult to do, since their decisions are scrutinised and will lead to large international backlash when selling products that bypass regulations. A start up has more freedom to do so, due to less scrutiny and less attention to their decisions.

In case the regulations in the low resource economies are too strict too, trade-offs need to be made in order to provide people with the best care they could get. The safety of the product and the people should still have a high priority, while in other areas, trade-offs could be made. What the regulations are and what areas can be bypassed are unclear, since these differ per country and need to be research upon extensively before reaching conclusions. Therefore, an advice I would like to give to the Ministry of Health in low resource economies is that the regulations regarding medical devices need to be reanalysed to see how the citizens can have access to medical devices while still adhering to most regulations. This could mean that some regulations need to be more flexible, while still putting safety as the main priority. More people could be saved by bypassing some regulations and providing them with care, rather than not giving them the care at all.

Research question: How can frugal innovations have an impact on over-engineering in the mobile phone industry and in the medical industry?

Based on the sub-research questions, the main research question can be answered, frugal innovations and over-engineering have three factors in common that results from their definitions: price, design and business model. Therefore, the factors of frugal innovations can impact over-engineering by modifying one or more factors they have in common. For example, when a product is complex and will be altered to be less complex, potentially easy in design, the design factor has been affecting the over-engineered product to becoming more frugal and therefore less over-engineered. These three factors are influenced by elements. The most important elements to influence the factors of frugal innovations that can affect over-engineering for the medical industry and the mobile phone industry are the modularity (design factor) and sort company that is selling the innovation (business model factor). For the medical industry, there is an additional element, which is regulations (price and design factor).

Modularity - design factor
Once a product has been manufactured, it will be challenging to change the design to be more cost-effective. For instance, because of how the design is built, removing more features will be challenging. The operations and effectiveness of a business that makes items are impacted by the modularity of products in many different ways. Increasing commonality between products without sacrificing variability is the goal of modularisation. Customer benefits from modularity include simpler repairability, refurbishment and extended product lifespan. Increased design reuse through modularisation minimises the required design work per product delivery and may have positive effects on cost, quality and time when taking into account product development and product data management. Therefore, it is essential to bear in mind that the design must be frugal from the beginning of the process. Only when a product has been produced to be modular, it could potentially become easier to modify features. Since they need fewer parts and make the product easier to alter, modular products are in the long term more affordable. Therefore, modularity also affects the price of an innovation. When a product is being made modular, a product will be more frugal and therefore less over-engineered.

Sort company - business model factor
A start up would be a better fit for selling frugal innovations. The sales of a frugal product is a disadvantage of an MNC, because they do not have a lot of freedom in this aspect, since their decisions are being scrutinised. When making wrong decisions, this could lead in large international backlash and has a high impact on their reputation. Furthermore, MNCs are not familiar with the target audience in low resource economies when comparing them to their usual target audience. Start ups do not encounter these issues as severe and as often. They have more freedom in selling products and in making decisions. They do not have that scrutiny and severe backlash and reputational damage. However, start ups could fail when making wrong decisions and possibly do not have a backup. Therefore, a product or service could be produced by an MNC, but sold by a start up. There is a possibly for collaborations. When a start up

sells a frugal innovation, due to the business model, the price can be kept low of the innovation. Therefore, due to the business model of a start up in comparison to an MNC, an innovation will become more frugal and therefore less over-engineered.

Regulations (Medical industry - price and design factor)
When medical equipment are manufactured, they need to comply with national and international regulations. Regulations raise ethical questions, since regulations have been made for a reason, such as safety reasons, however, if it is at the expense of the people who are deprived of medical devices, should the regulations still be upheld? Sometimes, it would be better to have access to medical equipment to save a life rather than adhere to regulations, which can be too strict. As per the case study of the medical industry, regulations increase the price of the product or a product being rejected, which can lead to inaccessibility of these products for certain people, while the product potentially could safe lives. As seen in the medical case study, regulations differ per country. A products needs to meet the requirements of the regulations of the country it is being produced as well as the country the product is being sold to. For high resource economies, these regulations are more strict as the healthcare in these economies is more developed and advanced than in low resource economies. Therefore, it would not make sense for low resource economies to also adhere to the regulations of the high resource economies. Hence, when producing medical equipment in high resource economies, the company producing the product should only focus on regulations of the low resource economy since the product only will be used there. Selling the product for an MNC such as Philips, will be difficult to do, since their decisions are scrutinised and will lead to large international backlash when selling products that bypass regulations. A start up has more freedom to do so, due to less scrutiny and less attention to their decisions.

In case the regulations in the low resource economies are too strict too, trade-offs need to be made in order to provide people with the best care they could get. The safety of the product and the people should still have a high priority, while in other areas, trade-offs could be made. What the regulations are and what areas can be bypassed are unclear, since these differ per country and need to be research upon extensively before reaching conclusions. Therefore, an advice I would like to give to the Ministry of Health in low resource economies is that the regulations regarding medical devices need to be reanalysed to see how the citizens can have access to medical devices while still adhering to most regulations. This could mean that some regulations need to be more flexible, while still putting safety as the main priority. More people could be saved by bypassing some regulations and providing them with care, rather than not giving them the care at all.

8 Discussion

This research aimed to derive the link between frugal innovations and over-engineering in the medical industry and mobile phone industry and how frugal innovations could impact over-engineering. To date, most of the literature on over-engineering were described with a focus on other contexts, such as software, rather than products and services as found in this thesis. Furthermore, hardly any literature could be found on the impact of frugal innovations on over-engineering. It is important to derive this impact, because it could be a remedy for over-engineered products and services, leading to make non-consumers consumers and serving the underserved. In the medical industry, this could mean saving a large amount of lives that otherwise would not have been saved. In this thesis, I explored the link between over-engineering and frugal innovations and how the latter could impact the former.

In this research, it was found that the link between over-engineering and frugal innovations lies in the factors they have in common. The factors of over-engineering and frugal innovations are the same, thus by influencing one or more factors of a product or service, over-engineering could be influenced. Influencing the factors is possible by modifying the elements that influence these factors. Both industries have a majority of the elements in common that could influence the factors. This has been researched by doing two single case studies; one per industry. For the medical industry, one interview has been conducted in combination with literature research and for the mobile phone industry, literature research has been conducted. Multiple companies have been contacted multiple times for the interview, however, due to lack of responses, only one interview could have been conducted, hence the lack of primary data collection. The lack of response could potentially be explained by lack of incentive to cooperate or lack of time to cooperate. Another explanation could be the fear of backlash for the company when their answers to questions in this thesis put them in bad light. As discussed in the thesis, MNCs have scrutiny and could expose themselves to large (international) backlash. The lack of primary data for this research affected the reliability of the research results.

One part of the results of this research shows that three factors, price, design and business model, of frugal innovations can influence over-engineering. This result followed from the definitions of frugal innovations and over-engineering rather than from the case studies, which means that despite the low reliability due to lack of primary data, this result still holds. While these results about the factors may hold, these factors rely on elements. These elements followed from the case studies in this research. However, due to lack of primary data and due to the low sample size, the reliability of this result is low. This result cannot be generalised from the case studies to their respective industries. Therefore, the results should be interpreted with caution. Other elements could also have had an influence the success or failure of frugal innovations and could differ per context within the industries. One case study has been done per industry. The lack of data therefore affects the reliability and generalisability of the outcome.

Furthermore, the research question is about how frugal innovations can have an impact on over-engineering in the medical and mobile phone industries. It does not state that over-engineering has to be removed completely. This has the implication that when changing one

factor of the over-engineered product or service, over-engineering has already been impacted. Therefore, not all three factors of over-engineering have to be influenced by frugal innovations. For example, when a product is complex in design and is being made less complex, the product is becoming less over-engineered and more frugal. The over-engineered product is therefore being impacted by only changing one factor. Note that it could be possible that by changing one factor, another factor may be changed indirectly. A less complex design could potentially influence the price to be cheaper. While changing one factor may not result in a product that will switch from being over-engineered to being completely frugal, it lowers the characteristics of over-engineering and therefore has impacted over-engineering.

While the question on how frugal innovations can affect over-engineering has been answered, there could be other solutions to the problem of over-engineering. One other solution could be reverse engineering. Over-engineering would not be influenced directly, however, it can limit over-engineering by avoiding it from happening from the start of the manufacturing process. As seen in the case studies, it has generated success for M-Pesa and INUKA. Furthermore, regarding the business model factor, the results stated that a start up would have a higher chance of selling a more frugal product than an MNC. However, more research needs to be done into the role of a start up, because this study only focused on start ups with relation to their business model and internal infrastructure based on the success of INUKA and M-Pesa. There could be other factors that have has an influence on the success or there could be another reason why start ups would be more successful or unsuccessful than MNCs in selling frugal products. For this, further research needs to be done. Specifically for the medical industry, this research advised on reanalysing the regulations of low-income economies in order to provide them with medical devices. The Ministry of Health in those economies should be advised to make their regulations on medical equipment more flexible, while adhering to safety. It is unknown how realistic this is when an MNC is to give this advice. Potentially, it should be discussed with the Ministry of Health and Foreign Relations in the high-income economies the innovation is being produced, which could talk to the low-income economies about this issue.

The knowledge gap of this research was about the effect of frugal innovation on over-engineering. This research has made several contributions fulfilling parts of this knowledge gap. The theoretical knowledge on frugal innovations and over-engineering provided the knowledge on the factors of frugal innovations that can impact over-engineering. This knowledge, together with the result of the elements that the factor rely on, which followed from the theoretical knowledge and primary data regarding several frugal products and services, fulfilled part of the knowledge gap. Unfortunately, due to the research method used and the lack of data, the gap was not fully closed, since only two case studies have been conducted. While a conclusion could be made of the research, more research needs to be done on the previous mentioned topics in this discussion. Due to lack of practical data, this research was designed to be providing theoretical knowledge and gain information from case studies with relation to the theoretical knowledge, rather than to have an extensive data collection to analyse. However, this research provides a basis for the knowledge gap to be filled. Further research upon this topic needs to be done to have more reliable data.

9 Recommendations

Based on the reflections and discussion, recommendations have been made. A product needs to be modular in order to be able to remove or replace components. This is useful if an over-engineered product needs to be more frugal. Then, the design factor of frugal innovations can be applied on the design factor of the over-engineered product. During the manufacturing process, it needs to be kept in mind that the product/service needs to be frugal, since otherwise extra features and functions potentially could be included that will increase the complexity and price of the product/service. The product/service then would be manufactured towards being over-engineered. when keeping this in mind, it can be avoided that unnecessary features will be included. If the product has not been made modular during the manufacturing process, it will be difficult to influence the design factor of over-engineering. As said, the product needs to be produced to be modular. When a product is modular, components can be replaced with less expensive or less complicated parts. While this is an investment, in the long run, the modular products will be cheaper and have a lower cost. One recommendation therefore is to invest in manufacturing modular products, thus manufacture products to be modular.

When the design factor cannot be influenced as much, the business model factor needs to be looked into. It could be better to let the product be sold by, and potentially be produced by, a startup, since at least one factor of over-engineering would be affected. In this case, the business model would be more fitting with the product and the price would decrease due to the less expensive infrastructure, which can keep the price of a product/service low. Especially, since the product/service is meant to be non-high tech, i.e. not over-engineered, which refers to an other business model than an MNC uses. Thus, the innovation needs to be sold by a start up rather than an MNC. MNCs on the other hand could manufacture the innovation. The case studies showed success for collaboration of start ups and MNCs in selling and manufacturing a frugal innovation. This, however, needs to be researched upon further. While this research shows this as a result, it has been concluded based on a small sample size. Another recommendation therefore is to do further research in the role a start up could take in selling frugal innovations and collaborating with MNCs.

As for the medical industry, one recommendation would be given to the Ministry of Health in low-resource economies to reanalyse their regulations regarding medical equipment, since it is an ethical dilemma to deprive people from medical care due to (potentially) strict regulations, while these equipment could have saves lots of lives. Possibly, the regulations are too strict and should be alleviated for the citizens' sake. Therefore, the regulations regarding medical devices need to be reanalysed to see how the citizens can have access to medical devices while still adhering to most regulations. This could mean that some regulations need to be more flexible, while still putting safety as the main priority. More people could be saved by bypassing some regulations and providing them with care, rather than not giving them the care at all. While it could be non-realistic for an MNC to give advice to the Ministry of Health in low-resource economies, MNCs could talk to the Ministry of Health and Ministry of Foreign Affairs in their own country, which could talk to the low-resource economies to discuss the issue and advise

upon it.

As for the mobile phone industry, M-Pesa is not part of this industry. It helps in shining light onto the phenomenons in that industry, however, to increase reliability for the mobile phone industry, research should be done into innovations in the mobile phone industry rather than doing research on something that acts as an aid for the industry.

Furthermore, as for the research, rather than one interview, more primary data can be gained for a higher reliability by means of multiple interviews. Preferably, the interviewees need to have an equivalent function within the company they work for, because then the results of the interviews can be compared. This comparison could be used to gain more insight in different contexts and offers more opportunity for generalisations. To avoid the problem of lack of primary data, ensure that corporations first agree to do interviews and based on that, create the interviews. Preparations are important, however, it can limit the research if the researcher is dependent on these corporations. Switching interviewees will otherwise become more difficult and it will save time that can be spent on the research. By having a list of general questions first and after a company has agreed to an interview, this could be expanded with company specific questions. Note that it is still needed to know about potential products/services that is needed for the interviews. Another recommendation based on the interviews is to not investigate large corporations. Either do extensive research within one large company, or try to interview small corporations. It is difficult to find an interviewee within a large corporation without a good incentive for them to participate. They have a large image that they are afraid to affect by cooperating in the interview. Furthermore, employees of large corporations potentially have little time to help with an interview.

This study serves as a basis for further research, therefore this study can be used to further investigate the topic of frugal innovations and over-engineering. Therefore, further research into this topic needs to be done with this thesis as a basis. One topic of future research that should be looked into, is diffusion of innovation. The reason behind it, is because innovations can be produced, however, need to be diffused as well. This is an important factor in success of the adoption of an innovation. The more is has been adopted, the more successful it is. Therefore, it relates to the topic of this thesis. Literature research has already been done for future work, which can be found in Appendix C - Diffusion of Innovation.

Another topic of future research of future research that should be looked into, is reverse innovations. This research has focused on one potential solution to influence over-engineering, however, while not directly influencing over-engineering, reverse innovations could indirectly have an influence. There is a potential link, because the innovations start as frugal and make their way into wealthier economies. Since it has shown to be successful for two products/systems in the case studies, it is worth to look into.

To increase generalisability, multiple case studies per industry could be conducted in different settings. A higher sample size is needed. Different situations need to be included in the research. However, due to it being time consuming, the case studies should be done without time constraints to avoid leaving out certain case studies.

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A Human Research Ethics

Before data gathering can happen by means of interviews, it is important to identify risks for the interviewee and interviewer, minimise those risks and creating communicating these risks and measures to the interviewee.

A.1 Research Design: Risk assessment and mitigation plan

Based on TU Delft (n.d.), a risk assessment has been done for the data collection, followed by a plan to mitigate these risk.

A.1.1 Potential risks for interviewee

During the interview, the potential risks for the interviewee are:

- Personal Data: personal data, such as name and position within the company, could be known to the interviewer, since the interviewer knows who he/she needs to interview to collect information required. It is also possible that during the interview, personal information results from follow-up questions or anecdotes within the interview.
- COVID: due to the current COVID-19 pandemic, a potential risks could be for the interviewer to (accidentally) contaminate the interviewee with COVID-19.
- Emotional harm: when sensitive matters are discussed and the interviewee is asked to recollect those experiences, i.e. personal experiences, it could induce emotional harm. Emotional harm can also come by conducting the interview for a longer period of time (Perri, Jagan, Sandhu, & Salas, 2018).
- Autonomy: due to the continual nature of the consent process, there is also a potential of inadvertent injury to the interviewee's autonomy. The procedure of obtaining consent must take place throughout the interview. For example, in circumstances when vulnerable populations are involved, such as elderly persons and those with mental illness, their medical conditions may make giving informed permission voluntary difficult. These individuals may forget that they had agreed to take part in a research (Perri et al., 2018).
- Wrongly interpreted data: the interviewee could be wrongly interpreted when the interviewer does not understand what the interviewee is trying to say or when the interviewer only takes partial notes.
- Bias: it could be that the interviewer has a certain bias which is forced onto the interviewee, while the interviewer has a different perspective. For example ask a lot of questions about product 1 about only on how great it is, while asking a lot of questions on product 2 on only how bad it is.
- Power imbalance (Perri et al., 2018): the interviewer asks the questions and can stir his/her narrative, such that the interviewer's narrative will becomes the interviewee's narrative,

without them actively knowing to do so. Word could be put into the interviewees mouth without them purposely doing so.

After the interview, the potential risks for the interviewee are:

- GDPR (General Data Protection Regulation): when personal data of the interviewee is saved, a security breach could have negative consequences, such as identity theft, fraud, damage or reputation loss, loss of livelihood or investigation by the authorities, depending on information shared during the interview and notes taken during the interview.
- Identification: When the personal information has been revealed in the study, colleagues or other staff members of the company and personal relations of the interviewee are possibly aware of the interviewee having done the interview. Therefore, if the results are out and available to the company, it will be known what employee conducted the interview and what his/her answers were.

A.1.2 Potential risks for interviewer

During the interview, potential risks for the interviewer are:

- COVID: due to the current COVID-19 pandemic, a potential risks could be for the interviewee to (accidentally) contaminate the interviewer with COVID-19.

After the interview, potential risks for the interviewer are:

- Failure to protect personal data: legal sanction could be taken against the interviewer. Not only against the interviewer, but also against the research-performing organisation. On top of the legal sanctions, reputational and financial consequences could follow.
- Data interpretation: the interviewer could be unable to interpret the data gathered from the interviewee due to for example contradicting information.

A.1.3 Mitigating potential risks for interviewee

First of all, agreements and possible risks will need to be shared with the participants of the interview via informed content. Furthermore, per risk, mitigation measure will be taken to minimise the risks.

- Personal data: the name, company and position within the company will be made public in the research. This is needed for reproducibility. If the interviewee is not comfortable with this information being shared, either another interviewee will be asked or the interviewee will remain anonymous. While this is not ideal, only the interviewee and supervisors will know the identity of the interviewee. For either scenarios, the interviewee will receive information on informed consent and has to sign it to ensure that the interviewee is aware of the risks involved.

- COVID-19: preventive measure will have to be taken. When one's feeling ill or have symptoms, it would be best to delay the interview. Moreover, one could get him- or herself tested for COVID-19 to ensure that no contamination will happen during the interview, even without symptoms. The measure of keeping 1.5 meter distance from one-another could be enforced and no physical contact such as shaking hands.

- Emotional harm: the interview needs to be done in a limited time-span. The interview will be finished within 30 minutes to one hour maximum. Furthermore, the interview will focus on the products of the company. If any personal recollections need to be done and the interviewee is not comfortable with recollecting those memories, the question will be scrapped and potentially be asked to another interviewee.

- Autonomy: since the interview will take up to one hour maximum, asking consent multiple times is not necessary. The interviewee will remain his/her autonomy.

- Wrongly interpreted data: when an answer is unclear, follow-up questions need to be asked in order to gain a better understanding of the content. When the interviewer thinks he/she knows what the interviewee is saying, repeating the answer in the interviewer's own words can help confirm the interpretation of the interviewee's answer. Furthermore, audio recording the interview can help in mitigating the risk of forgetting information and taking partial notes and it can be listened back if needed.

- Bias: the main questions need to be thought of beforehand and must not contain leading (e.g. "Product X is the best, is it not?") or loaded ("Do you really think that product X is best?") questions. The interviewer may not assume or lead the questions, such that the interviewee cannot disagree. Observing, listening and asking neutral questions (thus non-loaded or -leading) reduces the bias induced by the interviewer.

- Power imbalance: the mitigation strategy for this risk has overlap with the risk 'Bias'. The questions need to be neutral and not be assumed.

- GDPR: the only personal data that will be saved is the name of the interviewee, his/her position within the company and the company's name the interviewee works for. This information is available online. No more personal information is needed. While the name of the interviewee and his/her position within the company falls under the GDPR law, the interviewee needs to read and the informed consent paper in order to accept or reject with regards to the consequences of the GDPR. Furthermore, the interview will be recorded and transcribed. The recording of the interview will be deleted after the data has been analysed, which is the latest on August 9 2022. With these measures, the Ethics and Data Protection legal document of European Commission (n.d.) can be fulfilled.

- Identification: informed consent would be the mitigation strategy. The interviewee has to read about the interview and its risks before participating in the interviewee. By reading and signing the informed consent paper, the interviewee has been made aware of the consequences of the identification and interview.

A.1.4 Mitigating potential risks for interviewer

- COVID: preventive measure will have to be taken. When one's feeling ill or have symptoms, it would be best to delay the interview. Moreover, one could get him- or herself tested for COVID-19 to ensure that no contamination will happen during the interview, even without symptoms. The measure of keeping 1.5 meter distance from one-another could be enforced and no physical contact such as shaking hands.

- Failure to protect personal data: this risk can be mitigated by just asking for the name and position within the company. Since this information can be looked up online, there is no need to ask for other information. Personal information therefore cannot leak, thus the interviewee will be protected from leakage of personal information. Data interpretation: by recording the interview, answers can be listened back, Furthermore, during the interview, if something is unclear, the interviewer can ask follow-up questions for clarifications. Repeating the answer in the interviewer's own words can help confirm the interviewee's answer or interpretation.

A.2 Research Design: Communicating

These risks identified and the mitigation steps that will be taken need to be communicated to the participants of the interview. This will be done through the process of informed consent. There are two kinds of informed consent (TU Delft, n.d.):

- Research participation: in order to get consent to participate, researchers must identify any potential physical, emotional or other dangers to which their subjects may be exposed as a result of the study method or findings. It should clearly state what the study wants to accomplish, what participants are expected to undertake, what risks may occur (including identification), and what efforts you will take to reduce those risks.

- Data processing and privacy: informed consent is the most prevalent, but not exclusive, legal basis for gathering personal data from Human Research Subjects under European Privacy Law, the GDPR).

Due to the mitigation steps for gathering personal data, the GDPR risk is minimised. The informed consent for this research and the participation information inform the user of all potential risks and agreeing with them is accepting the use of personal information (name and position within the company) and accepting that the interviewee knows the potential risks of participating in the interview. The participant and the interviewer need to come to an agreement on what the participants can do for this research and what the possible risks are that the participant is exposed to, together with the mitigation measures that will be taken.

A.2.1 Participation Information

You are being invited to participate in a research study titled "Affecting over-engineering with the mechanisms of frugal innovations: The case of mobile phones and medical equipment for

the Bottom of the Pyramid". This study is being done by Vanisha Jaggi from the TU Delft.

The purpose of this research study is to be able to find out how expensive and complicated mobile phones and medical equipment can be simplified and made cheaper for the Bottom of the Pyramid, the poorest people in the world, by applying the mechanisms frugal innovation. Besides that it needs to be help the Bottom of the Pyramid, it also needs to remain profitable, for example by means of a competitive advantage, for the company. This will be done through an interview and will take you a maximum of 60 minutes to complete. The interview will be audio recorded and deleted the latest on August 9 2022. The data will be used for this research only and this research will be published on the TU Delft repository. I will be asking you about a few of your company's products, your company's profit regarding the products, expenses to produce the product, possible regulations, the market for your product and your company's vision.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. I will minimise any risks by just asking for your name and position within the company. No other personal information will be asked. With this interview, you can be identified.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. Rectifying data can only be done until one week after the interview has been conducted.

For this interview, I will come to your office to minimise the burden for your travels and time.

If you have any questions and wish to contact the responsible researcher, you can contact Prof.dr. C.P. (Cees) van Beers on his email-address c.p.vanbeers@tudelft.nl.

B Interview Questions

B.1 Philips Healthcare

Background information products:

- **Philips' wind-up fetal heart rate monitor**: the wind-up fetal heart rate monitor allows for basic monitoring and troubleshooting in the absence of electricity or even batteries for the device (Philips, 2017).
- **Philips' Children's Automated Respiration Monitor**: the Children's Automated Respiration Monitor allows for precise pneumonia diagnosis (a complication accounting for 15% of all deaths in children under 5) (Philips, 2017).

B.1.1 General

1. What is your position within Philips Healthcare?

B.1.2 Target and price range Philips Africa Innovation Hub's devices

2. Could you please tell me about what the Philips Africa Innovation Hub is?
3. Two of the products in the Philips Africa Innovation Hub are Philips' wind-up fetal heart rate monitor (Philips Wind-up Fetal Doppler) and Philips' Children's Automated Respiration Monitor. What is the target group/target market for the Philips' wind-up fetal heart rate monitor and the Philips' Children's Automated Respiration Monitor?
4. What are the price ranges of the Philips' wind-up fetal heart rate monitor and the Philips' Children's Automated Respiration Monitor?
5. What are the factors that keep the price range of the Philips' wind-up fetal heart rate monitor affordable/low for the target group in developing/emerging economies?
6. If different, what are the factors that keep the price range of the Philips' Children's Automated Respiration Monitor affordable/low for the target group in developing/emerging economies?

B.1.3 Features Philips Africa Innovation Hub's devices

7. What are the most important features of the Philips' wind-up fetal heart rate monitor?
8. What are the most important features of the the Philips' Children's Automated Respiration Monitor?

B.1.4 Decisions and influences Philips Africa Innovation Hub's devices

9. What have been the objectives of selling Philips' wind-up fetal heart rate monitor and the Philips' Children's Automated Respiration Monitor to the target groups in developing/emerging economies?

10. How does the environment of the target group in developing/emerging economies influence the production and sales of Philip's wind-up fetal heart rate monitor?

11. If different, how does the environment of the target group in developing/emerging economies influence the production and sales of the Philips' Children's Automated Respiration Monitor?

12. Are there competitors regarding affordable medical devices such as the wind-up fetal heart rate monitor? If so, how does/did it influence the decision making in producing/selling the products in terms of price, quality and design?

13. How did regulations influence the decision making for Philips' wind-up fetal heart rate monitor in terms of price range, complexity and design?

14. If different, how did regulations influence the decision making for Philips' Children's Automated Respiration Monitor in terms of price, complexity and design?

15. Are the production and sales of the wind-up fetal heart rate monitor and Philip's Children's Automated Respiration Monitor still ongoing? If not, why not?

C Diffusion of Innovation

The diffusion of innovation theory was popularised by Everett Rogers in his book 'Diffusion of innovation' Rogers (1995). He suggested 5 attributes of innovation:

- Relative advantage: The degree to which an innovation is perceived as being better than the idea it replaces is referred to as relative advantage. Economic profitability, social prestige, and other perks are frequently used to represent the degree of relative advantage. The sort of relative advantage that is essential to adopters is determined by the nature of the invention. Although the qualities of potential adopters have an impact on which relative benefit sub-dimensions are more essential.

- Compatibility: The degree to which an invention is regarded to be compatible with current values is known as compatibility. Potential adopters' previous experiences and requirements.A more suitable notion is less ambiguous to potential adopters and fits better with the individual's living condition. Such compatibility aids the individual in giving meaning to the new concept, allowing it to become familiar. And innovation might be consistent or incompatible with (1) sociocultural values and beliefs, (2) previously presented concepts, or (3) the innovation's customer demands.

- Complexity: The degree to which an invention is seen as being particularly difficult to understand and use is called complexity. On the complexity-simplicity continuum, any new thought may be classed. Some innovations are apparent to potential users in their purpose, whereas others are not. The rate of adoption of an invention is adversely related to its perceived complexity by members of a society's social structure.

- Triability: The degree to which a new idea can be tried out on a small scale is known as triability. New ideas that can be tested on a payment plan are adopted more quickly than non-divisible innovations. Some inventions are more difficult to separate into test groups than others. Personalising an innovation is a means to give it significance by seeing how it works in one's own circumstances. The purpose of this experiment is to eliminate any doubts regarding the new concept. The rate of adoption of an invention is inversely proportional to its perceived ability by members of a social system.

- Observability: The degree to which the outcomes of an invention are visible to others is known as observability. Some ideas' outcomes are simple to notice and express to others, but some innovations are harder to notice or define. The rate of adoption of an invention is positively related to its observability as regarded by members of a social system.

Furthermore, he demonstrated that individual receivers' views of these characteristics determine the rate of adoption of an innovation.

C.1 Frugal innovations

The primary problem for entrepreneurs once their items are ready for commercialisation is how to get them into the target market. The diffusion patterns of low-cost goods differ from

those of high-cost goods. Frugal items are initially launched to the general public, then to other markets. Because they were designed expressly to address local demands, they are easily marketable in local markets. These items can spread to other geographically adjacent markets if they are effective at a local level. Some low-cost items may spread to adjacent nations through commerce if cordial economic links exist. Many entrepreneurs, on the other hand, use internet marketplaces and set up dealerships in other countries to offer their products to a global market. Some low-cost goods may even be viable for export to Western countries, a process known as reverse innovation (Hossain, 2020).

C.2 Diffusion for frugal innovations

The nature of the innovation, its effect, its pace of diffusion, local demands, communication channels, poor institutional setups, a lack of sophisticated and particular skills, time and social settings are all factors that influence the diffusion of innovation in developing nations. It is yet to be determined how these features change in the case of frugal innovation (Hossain et al., 2016).

Because certain clients are price sensitive when it comes to frugal product and service improvements, pricing is a key concern. Customers interested in frugal innovations, in other words, are looking for items that are both inexpensive and excellent enough to suit their demands. While the bulk of customers in underdeveloped nations are price sensitive, a rising percentage of customers in developed economies are becoming price sensitive as well. As a result, innovation diffusion patterns are changing (Hossain et al., 2016).

The spread patterns of frugal innovation are still a black hole in the academic literature due to a lack of investigation. However, new developments necessitate a thorough examination and discussion. If Western corporations continue to disregard the increasing middle class in developing and emerging nations, they risk losing market share. Frugal Innovation caters to a variety of clients. Because developing nations face their own limits in terms of cash, technology, and skill, their inventions are typically aimed at addressing local issues. Because frugal caters to price-conscious clientele, pricing is a major problem. Customers who choose frugal innovations are looking for affordability as well as value. They go on to say that frugal innovation patterns are changing as customers in developed economies become more price sensitive; yet, the diffusion of innovation across nations is generally driven by comparable socioeconomic factors (Ashfaq et al., 2018).

Diffusion patterns

Still, 4 patterns of diffusion for frugal innovations have been identified by (Hossain et al., 2016): local diffusion, proximity diffusion, distance diffusion and reverse diffusion (Ashfaq et al., 2018; Hossain et al., 2016):

- Local Diffusion: Only a small portion of the potential of 'Local Diffusion' is realised. It has a restricted distribution and does not even spread nationally.
- Proximity Diffusion: This refers to the spread of frugal innovation to similar socioeconomic

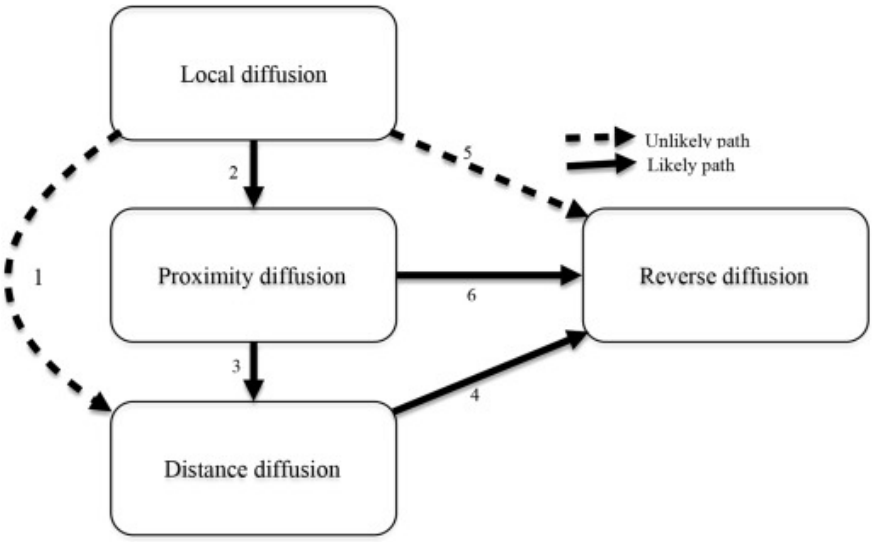

Figure 9: Frugal innovation's diffusion patterns (Hossain et al., 2016).

settings. It mostly spreads to certain neighbouring nations with socioeconomic situations that are comparable to those in the original country.

- Distance Diffusion: It is the spread of innovation not just to surrounding nations but also to other countries that are not developed
- Reverse Diffusion It refers to the diffusion of innovation in industrialised countries.

These patterns, however, do not have to be the only patterns that exist. Furthermore, of these four patterns, some are likely to be taken than others. Figure 9 shows the paths of the diffusion that can be taken and how likely the paths are to be taken. Local diffusion can extend to proximity diffusion (path 2). If the innovation spreads further, it will eventually reach other distant nations with similar socioeconomic conditions, achieving the status of distance diffusion (path 3). Distance diffusion can sometimes result in reverse innovation: the innovation spreads internationally, i.e. to developed nations (path 4). After the proximity diffusion phase, frugal innovation may become reverse innovation in some, albeit unusual, instances (path 6) (Hossain et al., 2016).

In terms of implausible diffusion choices, an invention may skip neighbouring nations and diffuse directly to distant regions after local diffusion (path 1). Local diffusion may also become reverse innovation without passing through the two intermediate stages of proximity diffusion and distance diffusion (path 5). However, it is believed to be a very unusual occurrence (Hossain et al., 2016).

C.3 Healthcare

Diffusion in healthcare are in line with Roger's diffusion of innovation theory. For example, consumer e-health service diffusion and acceptance are influenced by elements such as innovative characteristics, time, communication channels, and social systems. The impression of personal health records usage and its value are both influenced by innovative qualities highlighting the

relevance of innovative traits for innovation diffusion. The pace of diffusion is influenced by several factors, including relative advantage and compatibility. For the spread of Radio Frequency Identification in the healthcare business, the role of innovation is critical. The speed of telehealth adoption can be accelerated by factors such as user preferences, innovative qualities, and hospital staff input. Organisational context variables like as resources and capabilities, as well as hospital employees and administrations, all have a role in preventing or supporting diffusion (Arshad, 2021).

Finally, the literature reveals that innovative qualities, user preferences, networking, and hospital personnel and administration all play important roles in the diffusion of healthcare innovation. Furthermore, the diffusion of healthcare innovations is influenced by organisational culture, technological attributes and legislation (Arshad, 2021).

C.4 Mobile phone industry

The mobile divide, which is one of the most prominent parts of the digital divide, is defined as the disparity between mobile phone consumers and non-consumers. Globally, mobile technology has the ability to close the digital gap. The diffusion of innovation hypothesis has been utilised in a number of studies to investigate the spread of mobile phones. They do not, however, distinguish between low-cost phones and high-end phones, which target distinct customers and have different diffusion patterns (Zhang, 2018).

Low-income people's primary Internet access device is frugal digital ICTs such as inexpensive cellphones, which may meet people's demand to utilise the Internet. In China, 91.5% of people use smartphones, 10% use laptops, and 19.5% use desktop computers to access the Internet. Clearly, low-cost digital ICTs boost Internet adoption since more people can buy these low-cost items. Most people in the world would not have Internet connection if only high-end digital ICTs were available (Zhang, 2018).

Low-income people are slow to adopt new technologies. The fast adoption of smartphones has radically altered the pattern of Internet adoption, since they have become the vehicle of choice for billions of people to access the Internet. This shift is mostly due to low-cost cellphones. When cellphones initially became available, their price (about $1000) rendered them unaffordable for the majority of people throughout the world. If only high-end cellphones like the iPhone were available, the adoption rate of smartphones would be quite low. Frugal cellphones have made this breakthrough accessible to the majority of people, with the lowest models currently costing less than $40. The fast spread of low-cost smartphones is aiding in the bridge-building of the digital divide between rich and underdeveloped countries (Zhang, 2018).