MASTERS BY RESEARCH

Innovation & Design Thinking Practices in Industry

Parry, Jac

Award date:
2019

Awarding institution:
Bangor University

Innovation & Design Thinking Practices in Industry MRes.

Jac Parry
Bangor University
KESS 2

Index

Acknowledgments

Supporting Mentor

Dr. Iestyn Pierce
School of Electronic Engineering
Bangor University
Dean Street
Bangor
Gwynedd
LL57 1UT

Supporting Mentor

Dewi Rowlands
School of Education
Bangor University,
Normal Site,
Bangor,
Gwynedd,
LL57 2PZ

Supporting Organisation

Marco Cable Management
Unit 8, Bryn Cefni Industrial Estate
Llangefni
Anglesey
LL77 7XA

Supporting Organisation Mentor

Brian Pigott
General Manager &
Director

Abstract

Development and embedding of in house product development capability. Research within the business highlighted that there wasn’t a defined design mindset available. But after researching into various theories and detailing models of IBM and IDEO it was clear that the business should implement a human-centered approach to design considering the market characteristics and the changes needed for the business.

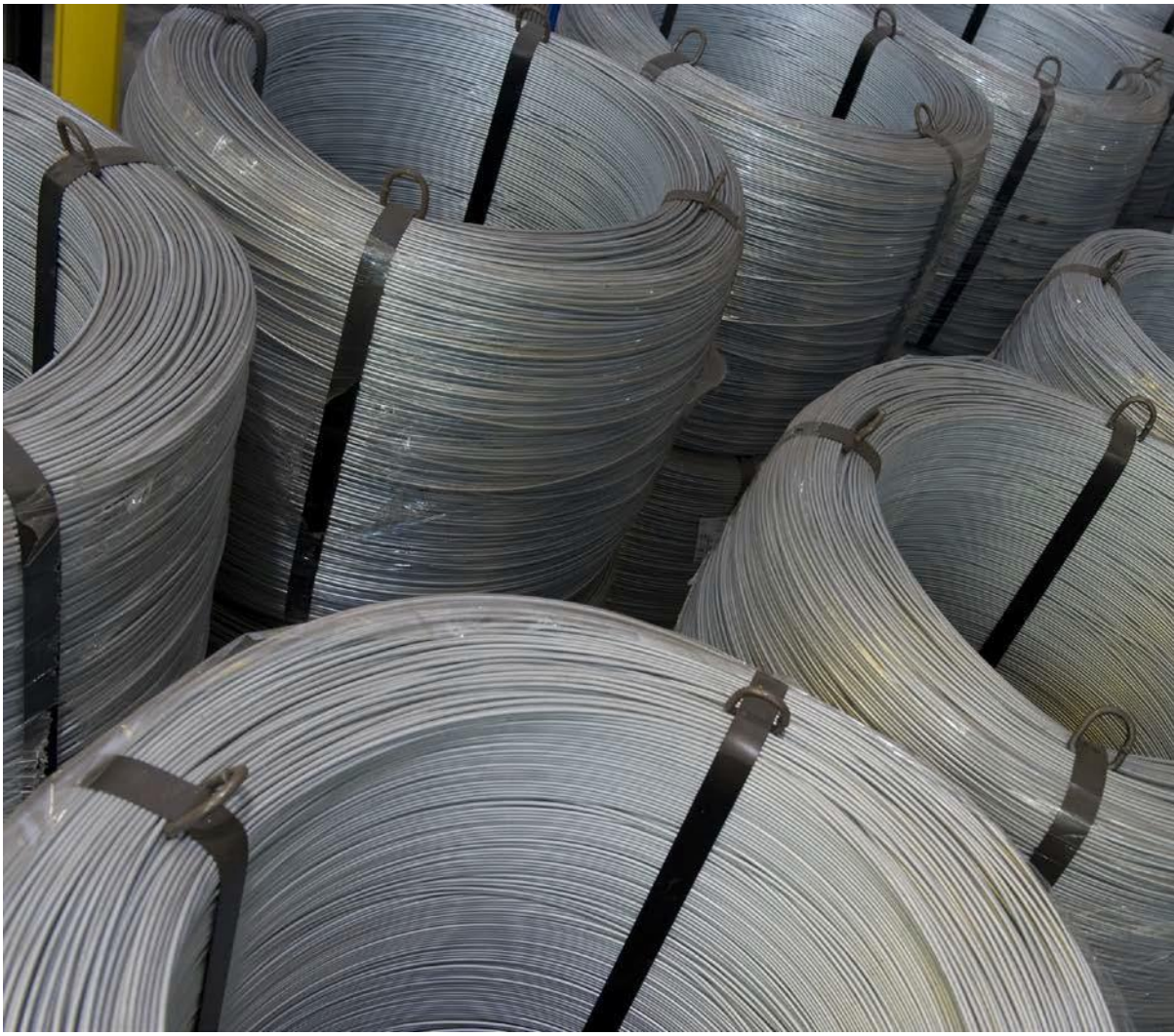
After further findings, it was clear that the business didn’t have any prototyping activities present hence creating a large area in which to implement various rapid prototyping technologies and a conceptualisation mindset.

Also, it was found from theory, that working with other departments can improve the accuracy of the prototype vastly for better performing solution at the end of the project, as discussed by (Dahan, E., Mendelson, H, 1998).

After highlight product development structures in Chapter 2, it was clear that Marco should implement project management resources along such as timeline management a further training for design team members to ultimately give senior members of the design team more authority and ownership of projects.

Chapter 1

Introduction



1.1 Introduction

Collaboration between Marco Cable Management and Bangor University first came to light with the author being tasked as part of a third-year undergraduate work placement module with developing a new innovative product. In the context of the third-year placement period, Marco approached Bangor University with the concept of developing the functionality of their steel wire cable trays. The experience served a prosperous opportunity, not only to build relations between the company and Bangor University but also to provide a good manufacturing placement for the student to experience first-hand valuable design and development projects with tangible consequences and tasks within the industry.

Receiving a list of specifications, the student developed multiple functioning prototypes, and after the eight-week placement, a final prototype was refined for the demonstration to Marco Cable Management. After many reviews and vigorous testing, the product has deemed a success and answered all the specification points, so much so that Marco was willing to patent the product using the student's name as an inventor.

This success spawned a stronger relationship between Marco and Bangor University. Marco was continually expanding year on year as a business; therefore, a natural development for the company was to develop their working procedures and structures within manufacturing and office-based departments. The emphasis on the structure development highlighted the need for facilitating and restructuring of an in-house design development capability. To enhance these capabilities, guidance was sought by Marco to ensure the most relevant theories and practices were researched and implemented for the most beneficial results for the company.

As the student was eager to continue working with the company coupled with Marco's need for improving their design development capability a large amount of research was needed and hence a Masters by Research project was developed headed by

Dewi Rowlands along with Iestyn Pierce. To facilitate the master's project, a partnership scheme was needed and hence the collaboration between KESS, Bangor University, and Marco Cable Management. Bangor University and Marco were able to officially approve a research project bringing knowledgeable contribution from both parties and the author.

1.1

To aid Marco in the research project, the following areas are being analysed;

- Current design thinking & innovation theories
- Researching into innovation management
- Design processes
- Prototyping methodologies
- Embedding in-house design development capabilities

A structure will be facilitated and implemented to accomplish the analysis of these areas above which will ultimately provide knowledge to enhance the product development and innovation processes within the company. While doing so, critically investigating the efficiency and relevance of design thinking & innovation theories will directly contribute towards the knowledge of the subject.

To describe Marco Cable Management's structure and area of business, the following sections will explain activities within the company. Within the dissertation, activities will then be critically analysed against current practices (described in chapter two) to highlight areas of development for Marco.

1.2 Motivation & Visions

Following the synthesis of the project, understanding the driving force behind the research for the project is crucial to create a brief to give context to the findings that follow. As Marco Cable Management was actively involved in the creation of the project, both KESS II and the company outlined various performance indicators in which to evaluate the outcome of the project for its feasibility. As briefly mentioned earlier the research would be based on the facilitation of implementing new design theories and practices within the company to deploy the design process efficiently and to address self-initiated new product ranges with market expansion potential. To highlight areas for improvement in design development environments at Marco the following table will list key stages that will be analysed:

Key Stage	Description
Analysis of design inspiration	As a crucial stage for design environments, the initial stage of inspiration for new products will be analysed against current practices to validate the effectiveness of the current context at Marco. From the findings of this section, specific areas can be adapted, or new theories implemented for the most effective outcomes and ultimately equip Marco with the clarity and vision to develop new innovative products with a clear focus on the design process.
Explanation of the design context.	To aid Marco's understanding of the design process and best current practices available, design thinking theories and case studies relevant to the company will be highlighted to adopt the most useful methodologies from them. This will give the design environment context within Marco and further structure their design process to integrate good ideas before they are disregarded and ultimately hone their knowledge of the design process for future projects.
Analysis of design considerations and people centric design	To utilise the findings of current design theories and practices, the importance the people-centric design will need to be established and analysed to coincide with these practices to establish systems and procedures that support people-centric design and its application in new product development.
Identification of design opportunities	Capitalising on inspiration in initial design stages by keeping current design practices with people-centric design in mind, understanding and highlighting the opportunities for innovation and how to capitalise on them will tie the theory of design thinking and best practices together for structured procedures.

Use of innovation development techniques & toolkits	A structured design process with procedures will be a testament to current design thinking toolkits and innovation techniques. As to further simplify and map a new design process for the company, design toolkits will also be analysed to produce the most useful design model relevant to Marco's business structure that can be applied in various departments.
Statement of design constraints and hierarchy of criteria for new design development.	Moreover, finally, with adopting new procedures and processes into the company's structure a clear system must be apparent and regimented to ensure its validity. To accomplish this, the management of the hierarchical design development process will be analysed against best theories of design management, with facilitation strategies to create a smooth implementation of the new design model into the business.

To analyse the areas mentioned in the above table the following sections will aim to gain a thorough understanding of the company's structure, activities and business strategy and production processes conducted on site while understanding the market requirements of the products due to development and innovation processes adopted.

Furthermore, coupled with adopting current theories and practices in the design process for Marco, current technological advancements in prototyping will aid the new process and help embed an in-house design process through the utilisation of prototyping methodologies, implementing new technologies to enhance the design development and innovation processes within the company for new product generation.

Following the vision by Marco to develop their product development capability the next section will begin by describing their current product range and their application.

1.3 Hypothesis & Research Questions

As research for the project will be based on areas Marco Cable Management intend to develop and restructure, an understanding of the business is crucial to identify areas to concentrate on further in the project. Firstly, it is important to gain further insight into the history and specific aims of the company.

Marco is one of the largest UK based cable management manufacturers of uPVC data containment systems and steel wire cable tray products. Marco has supplied electrical wholesalers, contractors, and installers for over 10 years.

Sales are increasing, and demand is climbing every year since the birth of the business. Marco has invested in a range of new machinery and equipment to increase its efficiency as a manufacturer. A large proportion of their products are manufactured in-house to reduce costs and lead times, and with extensive investment into the factory, the volume of products has increased drastically which can be met easily by the new advanced machinery in place with even greater capacity available.

With increasing demand and popularity of products, a bigger warehouse was needed to store the stock of the Marco range. All products manufactured and that are bought by Marco are stored at a second site which only accounts for deliveries and stock, whilst the main site is specifically structured for manufacturing, management, and sales.

Growing in sales and sites over recent years, the workforce has had to expand with the company. Having a workforce of over 60, including an external sales team who provide nationwide and European coverage, Marco has provided many jobs for the local community.

Manufacturing mainly uPVC and steel products ranging from U shape steel wire cable trays to multiple compartment perimeter trunking and selling aluminium pole and benchtop units, the breadth of products covers a large range of industrial cable management. The uPVC trunking and steel wire cable tray markets are very competitive, which is why Marco′s ethos is based on quality, so much so that in-house testing facilities and countless quality reports and checks have been implemented early in the expansion of the business ensuring that all products are fully compliant with all applicable British Standards Institution BSI standards, German Institute of standardization DIN regulations, European standards and not to mention International organization of standardization accreditations, ISO9001 for quality structures and ISO14001 for environmental best practices.

1.3

Advanced testing protocols such as deflection and configuration testing of various steel wire cable trays and accessories are carried out in-house. These specific tests are designed to replicate real-life installation scenarios. By doing this many defects or design errors are highlighted before products are launched into the market, this is a testament to Marco's consistent quality in their products and hence their popularity in the UK market.

In 2009 a new management team was appointed to help control the growth of the company. The team made up of industry experts, each had their own experiences in cable management or had been working in similar companies previously.

With such firm foundations and management to grow and develop, Marco has been growing, installing more machinery and employing more local staff. With higher demand and growth compared to their early production years, shift rotations and duration have also increased for longer hours of production.

With the investment in new machinery and change in factory layouts, production workflow efficiency has dramatically increased at both sites. Capitalising on lean management techniques has enabled the manufacturing and dispatch sites of the company to harmonise.

With the harmonisation of both sites and growing popularity, sudden influxes of large orders can be dealt with quickly and efficiently enabling quick turnaround of product and ultimately short delivery times compared to competitors in the market. Even more importantly, production capacity can be increased further utilising the advanced mass production machinery at Marco's disposal for additional expansion as the company grows relative to their share of the market.

To spread their coverage in the cable management market outside the United Kingdom, more recently Marco has begun to set up European contacts and wholesalers. This expansion will extend their reach in the market and ultimately their growth for the future.

Delving into new markets further afield and new product ranges, Marco is now working on applying formalised in-house lean management techniques coupled with trailing new quality countermeasure reporting and most recently and increased emphasis on product development. So much so that further collaboration between Bangor University and the company has been spawned to develop innovation and influencing change through the KESS II program.

1.3

To fully understand the company's design development situation, various aspects of the company need enumerating and discussing for context and further critical analysis against current practices and theories.

Brian Pigott, General manager and director of Marco Cable Management added;

"Marco Cable Management, established in 2003, has shown year on year sales and profit growth since the beginning. With sales more than £10M, we currently employ some 70 people and have a high-quality range of uPVC and steel wire mesh cable management solutions for our electrical installer customers in the UK.

In broad terms, we account for approx. 10% of the uPVC 3 Compartment Trunking market in the UK, and close to 20% of the Steel Wire Cable Tray market. Alongside our quality products, our flexibility, obsessive focus on our customers, and delivery promise, have created the culture that allows us to continue to grow into the next decade(s).

The challenge now is to be able to design, develop and then manufacture new products or ranges of products for our target market. We need to do this with clarity of vision, and with a clear focus on the design process to ensure that we are not continually re-inventing the wheel, nor letting good ideas slip because we are not as structured in our design process as we could or should be"

This will be the key output for Marco, of the KESS 2 Project, undertaken by Jac Parry. Through his design skills and his understanding of Marco, our capability, products, customers and markets, he will be able to embed a design and development process in Marco that is best practice, while still having the needs and limitations of an SME at its core. It is an exciting project, for the Company, and for Jac. This vision will include development and embedding of in house product development capabilities and a development review of products through consultation and implementation of new design thinking methodologies.

Also, to support the company in the implementation of professional design toolkits, design thinking, and design presentation skills to deploy the design process effectively and to address self-initiated new product ranges with market expansion potential."

1.3

The questions derived from this introductory chapter approach how current theories of design thinking, and development structures would benefit an established and growing business. As the topic of how and what within innovation can be broad, specific avenues will be researched, tailored towards areas in which the business is keen to develop and where initial areas for development have been highlighted in the Kess II bid. These questions discuss whether current theories within these overlapping subjects of innovation, management, product development, design thinking can be adapted and applied to the business to bene- fit its current working strategy. Consequently, from these questions sub questions can be derived to contextualise the main research question:

2.2 Are the most recent design thinking theories being used within the company structure?

2.2.1 What is innovation?
2.2.2 What is design thinking?
2.2.3 What toolkits, practices or policies are currently being used in industry?

2.3 How can prototyping capacity be increased?

2.3.1 What are the current prototyping practices?
2.3.2 What process workflows are there for standardised product development procedures?
2.3.3 How current technological advances are being used in product development for conceptual design and prototyping?

2.4 Which product development structures can be implemented?

2.4.1 What is management within the context of product development?
2.4.2 What influences change in practice and what can be used to improve the businesses to improve structure?
2.4.3 How can managing team role theories and facilitation of entrepreneurship benefit businesses?

As to investigate the questions above, the next topic will contain a critical literature review to open the research for further comparison of theory against Marco in latter chapters. Also, current new product development and innovation practices that are being implemented within then industry and current research will be used as a basis to outline could be implemented within Marco to answer the above question

1.4 Scope of Research

"Without change, there is no innovation, creativity, or incentive for improvement. Those who initiate change will have a better opportunity to manage the change that is inevitable"

It has been stated in the Harvard Business Review, "Despite beliefs spawned by popular change-management and reengineering programs, processes are not nearly as flexible or adaptable as resources are and values are even less so. So, whether addressing sustaining or disruptive innovations, when an organization needs new processes and values because it needs new capabilities managers must create a new organizational space where those capabilities can be developed. When a company's capabilities reside in its processes, and when new challenges require new processes that are, when they require different people or groups in a company to interact differently and at a different pace than they habitually have done managers need to pull the relevant people out of the existing organization and draw a new boundary around a new group." (Wheelwright and Clark 1992).

From the above statement, it is apparent that the management of an organisation's resources is crucial to cope with change and specifically how to change/facilitate new processes in interacting groups within the company for innovation.

To understand the processes and resources that will be subject of this change within Marco cable management itself, the next topics will detail the nature of the management structure and product application by analysing the company's current activities, procedures, business strategy, and product ranges.

Furthermore, innovation within the company will be analysed not only at the product level but throughout the company, a summary will highlight areas in which innovation stands out from one department to another, this will then be analysed further in chapter three against chapter two's research findings to ultimately highlight areas in which innovation can be improved and utilised for an efficient innovative capability.

The next section will discuss the missions and motives of Marco and the KESS II bid. The culmination of both academic and business requirements will briefly summarise the subsequent sections and chapters of the project to highlight the desired outcome from both parties.

William Pollard 1954

1.5 Contributions

The thesis makes three novel research contributions, as follows:

A review of design thinking theories along with prototyping technologies and their interactions between theories.

While many researchers have elaborated various design thinking theories and its adaptability into modern-day design-based business, but little if any have directly compared the benefits of a design thinking mindset linked to the implementation of emerging prototyping technologies. This thesis presents a new view of implementing design thinking along with new technology and how their synergies can benefit SME's.

The critical review of design thinking theories against influencing change theories and their potential impacts within and SEM's.

Along with prototyping technologies, the second contribution will address the crucial background techniques and methods that can be adapted to aid the implementation of such design thinking theories, and prototyping technologies. This thesis will aid further in explaining how the user of the findings can use influencing change techniques to bring relevant departments onboard through correct management leadership and steps need for an efficient implementation.

The review of design thinking theories along with management techniques to implement a new mindset.

To substantiate the benefits if influencing change tied with delivery a design thinking mindset, this thesis will also contribute to the importance of the knowledge of management. Specifically, the knowledge of management within the design and how influencing a management mindset within various design aspects of each department can add value to the business system once adopted.

1.6 Summary

Initial research and placement at the company highlighted areas of improvement in the use of innovative techniques. As can be seen in the flow chart above, product development is mostly based around external factors influencing the design of a new product either through Market "push" or experimental business ventures.

To capitalise on new design thinking techniques and prototyping capabilities to improve the product development structure at Marco, the development processes will be the initial part of the research project, this was part of the initial bid for KESS funding. Further research into current design theories and practices used in comparable businesses will support the implementation of new design systems for the business. Marco has approached this opportunity with the need to develop as a company within the field of design thinking, development and innovation. After the initial research was presented the following areas of development were summarised for the dissertation:

Research	Description
Awareness of Design Theory	To support the company in the implementation of professional design toolkits, design thinking, and design presentation skills to deploy the design process effectively and to address self-initiated new product ranges with market expansion potential.
Implementing Design Practices.	To integrate computer-aided design and finite element analysis to aid design thinking and professional presentation within the context of the following; • Analysis of design inspiration • Explanation of the design context • Analysis of design considerations and people-centric design • Identification of design opportunities • Use of innovation development techniques/toolkits • Statement of design constraints and hierarchy of criteria for new design development

1.6

In order to fulfil the areas for development the initial dissertation challenges to address whilst undertaking the research will include;

Research	Description
2.2. Background	Gaining an understanding of the company's structure, activities and business strategy and production processes conducted on site. Understanding the market requirements of the products due to development and innovation processes adopted.
2.3 Prototyping	To establish and embedded in-house design process through utilization of prototyping methodologies, implementing new technologies to enhance the design development and innovation processes within the company. To capitalize on existing advanced knowledge of prototyping (Currently unavailable to the business) through HEI to improve product development time-lines using current design thinking methodologies and advanced prototyping facilities with design development support staff.
2.4 Product System	To establish system and procedures that support people-centric design its application against new product development. Embed design functionality in new products to move the company forward, therefore commuting to looking at the efficiency of current product portfolios and development of new market offerings, ensuring the company remains relevant and competitive in the UK market.

As part of the research process, questions are posed to stimulate suitable research strategies derived from the KESS II research topics and Marco project visions. To initiate relevant research the following questions should be posed;

2.2 Are the most recent design thinking theories being used within the company structure?
2.3 What product development structures can be implemented?
2.4 How can Prototyping Capacity be increased?

Chapter 2

Literature Review

2.1 Introduction

In this chapter, a review will be made based on the three questions stated in the previous chapter as areas of research. It is important to conduct this research to gain further understanding of the subjects mentioned in the main questions. Following a summary of this understanding, a comparison can be made against theory and current practices within the company to conclude the project.

As previously mentioned there will be various areas in which to research within subcategories of the main topics. These subtopics will be substantiated and explained, and their relevance shown against the project aims.

To critique these questions the following structure will be implemented:

- Introduction with definition and context to the topic.
- Reviewing the literature
- Context to main research question
- Specific research subtopics related to the main head topic.
- Summarise important aspects of the literature reviewed.

Another major purpose of this investigation arose from a personal link between the student and the business. Prior to the research project, the student collaborated with the company on a 3rd-year design project following a placement. Other than what has been previously stated on the involvement and performance of the student, various aspects of the company structure or somewhat procedures within the design process were very relaxed or in some respects not present. As some subjects previously studied by the student very much applied the theory of design procedures and process being a structured step by step workflow, this sparked personal questioning such as why hasn’t business adopted these well-known theories? Or, do they even know of any theorised design processes?

Coupled with personal curiosity on the design environment of the business and areas of research mentioned in the KESS application the following keywords will be stated and clarified for context: Innovation, Design Thinking, Managing Team Roles, and Influencing Change.

2.1

Innovation and Design Thinking is the main driver of the research, innovation and design thinking will be discussed to define the subject for a clear understanding of its values. Along with these main topics, current procedures and policies will aid the research contextualizing what is currently being used in the industry. These values will be put into context what benefits it can offer to businesses and how businesses of today are adopting this theory in their structure and processes.

The summary of this topic will outline what processes in design for innovation and design thinking that can be applied or adapted to the business. Furthermore, other aspects of innovation applied to the structuring of the design process will lead to further connections between departments such as management and team roles in the next category.

Spawning from various strands of innovation, design thinking will detail a more modern and current picture of Innovation. Design thinking will be discussed because of its adaptation to businesses and why business is using such theories within their structures. These case studies will be discussed and evaluated for relevance to the research question.

Management for Change

As the second research questions suggest:
“What product development structures can be implemented?”
The research will, therefore, be made into current practices of product development structures and specifically how they are managed. To aid this, influencing change theories will also be researched as to detail methods of improving management structures within the business and how product development practices can be adapted into the company.

As influencing change will have a great deal of collaboration between departments within the business, current team roles practices and theories will be researched to link behaviors of teams within the business and how to improve them through influencing change towards product development and design thinking.

Product Development & Prototyping

Lastly, to link design thinking through innovation and the management of this through influencing team roles, current technology advancements and procedures of product development will be researched to highlight the correct methodology for new product development outputs linking design theory from research at the start of the chapter through to the final stages of working concepts.

The following topic will begin with by researching the concepts of innovation through to more advanced design thinking theories and practices.

2.2 Recent Design Thinking Theories

2.2.1 Innovation

"The idea for a new product may spring from in the mind of an individual, but only a collective effort can carry that idea through prototyping and launch. If innovation is to be integrated with both business strategy and work processes, as we believe it should be, it requires a broad network of social interactions" (Lafley and Charan, 2008).

Taking Procter & Gamble's A.G. Lafley's statement into context, innovation is very much at a standstill without the constituent driving cogs to help apply it to a business structure. After a study, and Lafely's newly appointed CEO status in 2015, they found that 85% of their people within the organisation believed they weren't working on innovation (Lafley and Charan, 2008). The employees were found to be stuck in their line management, marketing, operations, sales or administration ways. This high percentage of a misunderstanding of innovation rapidly promoted P & G to redefine their social system specifically geared towards innovation.

This example justifies to the importance of innovation and how a large company can quickly turn its overall structure and thinking towards a single methodology.

"Something different that has an impact" (Scott D. Antony, 2012, p.23) but what exactly? This perception of creating something different and new, encompassing the meaning of innovation has been agreed on for many years. First records of innovation date back to 1625 when F.Bacon wrote Of Innovations whereby people of those days would resist innovating. But in today's knowledge-filled digital era, Innovation is very much part of our knowledge base and understanding, with more and more businesses forging paths into implementing this way of thinking not only into their niche R&D (Research and Development) teams but to their entire structure of the organisation.

According to the OECD (Organisation for Economic Co-operation and Development), Innovation has grown substantially in recent decades due to a collaboration of departments within organisations such as R&D, marketing and ICT. Because of this collaboration, Knowledge of innovation and effective ways in which to innovate has become wider spread and cross-departmental. This growth of innovation can be narrowed down to four factors (OECD, 2010):

- "New innovation networks and clusters"
- "Stronger international linkages"
- "Knowledge-based capital and intangible assets"
- "Information and communication technologies"

2.2.1

Networks and clusters when referring to the public sector, innovation has become a greater pool of knowledge spilled over from one organisation to the next with the help of public research facilities such as universities and specific institutions. The combination of innovation knowledge outside these organisations has added a greater resource of useful information and hence encouraging a greater number of collaborations of innovation between business and higher education entities. Furthermore, as higher education facilities are partnered across the world, coupled with the reduction of communication costs, this has also added to the rise of open innovation. Being subject to greater global open innovation collaboration, businesses will have access to a greater bank of resources and knowledge at potentially a lower cost.

As opposed to physical capital such as machinery, equipment, and buildings, businesses now are invested in greater capital in knowledge-based assets. This can be seen in the output of patents or extensive market research projects. Coupled with this, the unstoppable rise of ICT developments has given a firm base in which businesses communicate and transfer knowledge efficiently to innovate. So much so this could lead to increased productivity, reduced production costs and effectively expanding the market for innovative products and services (OECD, 2010).

To elaborate on innovation further, the next subtopics will include a literature review of current theories and practices seen in the main Innovation topic. The aim of which will be to summarise research findings to compile along with the other main topics. This compilation will be further summarised at the end of the research project as part of an implementation guide to the company in question.

2.2.1

In order to substantiate individual variations of innovation against the research question posed at the start of the project, the following are examples of Procter & Gamble's four strategic processes and efforts they use to increase sales;

Find new and more efficient ways to market or promote existing products ranges. In the mid - 2000's Procter and Gamble ran a string of commercials based on their increasingly popular Swiffer product range, aimed at quicker cleaning methods for consumers. This campaign aimed at women "Breaking Up" with their traditional outdated cleaning products to use Swiffer. The commercial was cleverly aimed at showing consumers a completely new way of cleaning that could match any previous cleaning method, but much quicker. This type of innovation is known as 'commercial innovation'.

Introducing a breakthrough in product performance in existing categories. 2005 was the year P&G purchased the razor company Gillette and were instantly impressed with their innovation to the market of the 5-blade razor dubbed the "Fusion Razor". Because of the additional blades compared to the two or three-bladed razors currently on the market at the time, the fusion razor blade easily took the lead of the market and became P&G's first brand to reach $1 billion in sales. Their definition of this sort of innovation was 'transformational innovation'.

Incrementally improve existing services or products. For example, P&G's successful brand Tide that produces various laundry detergents in the 2000s realised to boost their revenue a change and improvement was needed in the brand and product. At the time only one type of the Tide detergent was available and their strategy to improve the brand was to introduce a much bigger range of similar products, in the form of dozens of new Tide scents and linking the products to their sister Downy fabric softener brand. P&G calls this 'sustaining innovation', i.e. three important "-er" better, faster and cheaper.

Creating a completely new category of product ranges or services. In the 1990s Procter and Gamble launched two new brands, Swiffer and Febreze. As mentioned, the Swiffer brand was the birth of quick cleaning product ranges for the consumers, whilst Febreze would enable consumers to remove any unwanted odors in various fabrics around the house. Both brands were the first of which in these categories and P&G states this as disruptive innovation.

2.2.1

To summarise, innovation generally before reviewing current practices it can be gathered that Innovation has many parts to its philosophy that aids the performance of an innovative product or service or even procedures and structures. These aids come in the form of open and collaborative innovation spawning from external organisation specialising in providing innovative services. Other than organisations, academic establishments are also becoming a crucial part of businesses that want to adopt innovation into their structure or product ranges. In the background one of the main driver of this increasing collaboration is the exponential growth of ICT and how it has spread across the world to build on open innovation with ever advancing technological tools. Also, being open, stronger international links between businesses and higher educational entities, communication costs are reduced severely, and a greater pool of knowledge is obtainable to develop. But in these instances of collaboration, innovation must be relevant to the stake holder in question and the professional either external or internal to the business.

The subject in which innovation is desired must also have a link to the business itself or to the individual, otherwise outcomes could be misled. Contrarily when correct relevance is met innovation can flourish in many ways. It can be said innovation can be a consequence of continuous development of a product or service to keep up with current market demands. Differently to developing existing products or services, innovation can also arise from completely new concepts in existing markets. Furthermore, adopting new procedures and policies with business structures such as production lines are strong non-obvious examples of innovation to the consumer. And finally, innovation can be in the form of facilitating a complete new product range or service, where it hasn't been seen before.

A newer approach to the innovation thought process is the adoption of Design thinking, whereby a designer's natural step by step process is expanded into a more nature like free-flowing continuous development processes.

2.2.2 Design Thinking

"*What we need is an approach to innovation that is powerful, effective, and broadly accessible that can be integrated into all aspects of business and society, and that individuals and teams can use to generate breakthrough ideas that are implemented and that therefore have an impact*" (Tim Brown, Change By Design, 2009)

This statement by Tim brown substantiates on how innovation and design methodologies have developed. This development or somewhat evolution of innovation has molded into what is now called 'Design Thinking'. As previously mentioned at the start of this section, innovation is most useful when applied by relevant experienced individuals or teams to a relevant environment or brief, i.e. when process designers are tasked with improving a manufacturing process. The method behind design thinking though is to eliminate the need for this relevancy to the project or brief in question and gives the "tools into the hands of people who may have never thought of themselves as designers and apply them to a vastly greater range of problems". (Tim Brown, Change By Design, 2009).

Design thinking, when compared to general innovation processes, is based on the method of opening a designer's perception of greater testing and experimentation through a non-regimented path. Design thinking is a process of "*overlapping spaces rather than a sequence of orderly steps*" (Tim Brown, Change By Design, 2009). These overlapping spaces exploit greater solutions and present further inspiration to the team or individual through ideation, generating processes development and testing of concepts and finally implementation. Because of this unstructured concept of designing, projects might move backward through the processes from development back to ideation to refine the concept further or even adapt the purpose of the design to different avenues.

Tim Brown states "Design thinking is fundamentally an exploratory process; done right, it will invariably make unexpected discoveries along the way" (Tim Brown, Change By Design, 2009). This spawns from the nonlinear nature of design thinking when compared to older innovation design processes.

2.2.2

As design thinking contains an exploration motive through its methods, many discoveries can be integrated into an ongoing project seamlessly or it can spawn suggestions for teams or individuals to re-imagine a part of the project, such as the performance of the brief or functionality of a prototype. Also testing prototypes and developing their mechanical function, for example, might lead to a change in market application hence the potential for greater profits and consumer exposure. This is possible by not regimenting a project to a structured plan but more so opening the original plan up and expanding each step to overlap each other to reduce a binding nature to the project for better productivity. "A nimble team of design thinkers will have been prototyping from day one and self-correcting along the way" (Tim Brown, Change By Design, 2009), Again this statement lends itself to the notion of a non-structured way of designing which is based more on processes of continual development through the project.
"Without constraints, design cannot happen" (Tim Brown, Change By Design, 2009), according to Tim Brown, embracing an enthusiastic approach to constraints is the foundation of design thinking. A crucial stage of any designer's project is stating the constraints of the product or service and ways in which to evaluate them during the project. This evaluation can be reduced to three criteria that harvest successful ideas;

- Desirability
- Feasibility
- Viability

Feasibility encompasses what is possible based on technologies or materials available now or in the foreseeable future. Without this important criterion, a product or service can be deemed as a nonstarter or essentially not possible. Viability of a product governs whether a project can be economically feasible or can be economically sustained, for example, manufacturing, material costs or profit margins dependent on market costs and fluctuations. And finally, desirability is a consequence of a product or service that is understood by the consumer and eventually wanted by the consumer. Without this, a product can quickly be disregarded by consumers and rejected.

2.2.2

As previously mentioned, design thinking is very much based around the ethos of opening a design project up from stringent step by step processes into a bigger overlapping process, but even so this structure can still be mapped, as each section of a design thinking processes will have its aims and outcomes, and through this a breakdown of actions can be detailed as follows;

Stage	Description	Key Factors
Empathy	For designers, a project is rarely based on your own desire but most commonly based on the needs of other people, and to design for them an understanding of their needs and what important for them is crucial. By carefully emerging one's self into the environment of the consumer, clues can be gathered into how they can think or feel and most importantly this will define one's knowledge of what the consumer needs. The study of the consumer/ human behavior with the environment in question will facilitate vital insights from the experiences gathered and hence create better solutions	Observation - View users and their behaviour in the context of the project. A lot can be said comparing to what somebody describes and what they do. Engage - Based on interviews, the use of key questions in this section can be used as a tool to elaborate the subject further to gain better insight into processes for example. It is also important to ask "why?" to uncover deeper meanings. Watch and Listen - And crucially for empathy is that a strong combination of engagement and observations must be used.
Define	Continuing from the empathy stage of the design process, the findings of which will help to create a context in this definition stage. Here is where clarity is needed with a focus on the challenge ahead. From this, a statement will be produced that highlights the insights gained from empathy stage and lists them for relevance. This inevitably expresses the problem into a more narrowly focused problem statement to yield greater quantity and quality of solutions.	Looking into any patterns that emerged from the Empathy stage, what clearly stood out to the observer. Create a point of view understanding of the problem. A point of view will need to provide a clear focus on the problem that inspires the individual designer or design team. A strong point of view will empower teams to make decisions independently and capture the imagination of individuals to focus on the problem at hand rather than diverging to a broader unfocused outcome.

Ideate	Progressing from defining the problem Ideation combats the next step of creating initial concepts for user to sample for initial feedback before further development of prototyping. This stage will naturally transition from identifying the problem to produce solutions. Here imagination is teased of individuals and teams, as links will be created from the defining stage into new concepts to hopefully answer the user's needs. It is good practice in this stage to manufacture as many prototypes as possible for a better range of selection in later stages after testing and feedback.	Here it is important to step beyond the obvious for a greater innovation potential. If there is a design team involved, ensure to harness their individual strengths in certain parts of the ideation stage for a more efficient concept creation. Accept all areas of exploration, don't be quick to diminish potential uncharacteristic areas of development that might not be obvious to the problem at hand.
Prototype	In the prototyping stage, the aim is to develop concepts closer to the final solution based on the findings of the definition stage. Initial concepts from the ideation stage should be of low value and in their simplest functional form. With the prototyping stage, a product or service or process will be further refined and valuable. It is important that whoever form the prototype takes, that it can be experienced thoroughly by the end user for the res feedback. Immersing the user in the potential new experience will bring out the best emotional feedback and responses. The purpose of the prototyping stage is to fail quickly and cheaply before final implementation. Here will be the best insight into how the new project will perform before committing to a full-scale release. Other than creating valuable concepts for the project, prototyping is also an excellent stage to look backwards on designs for continual improvement.	Ensure something is being built or laid out. Testing material and configurations for example is a great way to start refining the conceptual stage into valuable functional prototypes. Ensure a wide range or prototypes are tested instead choosing one early on in the project. Some prototypes might have various parts to them that would be better suited to others. Ensure something is learnt from testing the prototypes. Specific functions can be labelled a document for efficiency and general performance of functionality. Certain parts of the parts of the prototype might work better than others

2.2.2

Design Thinking is aimed at improving an organisations communications skills by bringing to light new insights in product development and experimentation. It's been classed as;

"The search for a magical balance between business and art; structure and chaos; intuition and logic; concept and executions; playfulness and formality; and control and empowerment." (Idris Mootee, 2013).

The benefits of Design thinking are considerable as it involves a great deal of logic but also creativity. It will force a business to keep a human-centered aspect to its designs and specifically the overriding needs of the user. Due to its experimentation nature, it also promotes the developing while doing an approach to increase a continual improvement nature, and even highlight that failure can bring new opportunities to create new concepts. Another crucial part of Design Thinking that will benefit large companies, is that a great deal of collaboration is a product of the whole system. Collaboration is promoted within the process to bring in specific knowledge from relevant departments into one project, using experiences and information for greater efficiency.

When taking the above advantages and the process of Design thinking into context, these 10 main principles can be derived;

- Supports Change
- Is Action-oriented
- Focuses on the Human
- Develops foresight
- Promotes Empathy
- Reduces Risks
- Is Dynamic and iterative
- Relies on an adaptable process
- Combines Logic and creativity
- Creates shared meaning

This process is specifically designed to promote learning while developing along the process, each stage of the project ensures that teams and individuals are constantly learning to better the product, service or the processes itself. While learning, the teams will have the end-users in focus and their specific needs at the tip of their goals adopting specialised techniques to depict any crucial data or information increasing knowledge constantly to complete the project to high performance and relevance. And furthermore, a well-implemented Design Thinking process is dynamic and nibble, as to keep up to date with ever-changing technology or materials for example and the best ways to utilise these developments for the project at a hand for the best possible outcome.

2.2.2

As design thinking processes are built to be easily adapted into industry, specific solutions within the dynamic design process can be applied to certain business aspirations and challenges such as;

Business Challenge	Design Thinking Solution
Standardisation	Humanisations
Relevance	Value Redefinitions
Growth	Storytelling

(PWR Media, Design Thinking)

Driven by costs, 'Standardisation' is necessary for every company as to reduce costs across major activities within the business, by reducing operational costs, increasing performance efficiencies through streamlining activities, adapting technology and overall maintaining and strong employee workflow. But streamlining and structuring these activities, a personal touch is lost within the business, with employees and the resulting end user. But because of this stringent structured business format, it can be of great detriment to innovation due to great ideas being subject to the standards of the business where new innovations are disregarded as they don't fit into their workflows processes or procedures. It ultimately restricts vision and reduces the need for empathy which in turn reduces the businesses' opportunity to develop potentially transformative concepts.

Maintaining a business's relevance in a category is one of the main activities that can elevate a company past its competitors in a market. A relevant business will establish purpose, visibility, meaning, and credibility within its category and using innovation will render their competitors irrelevant to consumers. But the difficulty with staying relevant is keeping up with consumer demand and their ever-changing lifestyle, and to do so, businesses must redefine and rethink their values they propose to consumers. It can be said from this observation that value propositions are increasingly getting difficult to satisfy consumers.

To combat this, Design thinking applies the Humanisation strategy. Humanisation counteracts the typical structure thought processes of products and services by reminding users of Design thinking that businesses are responding to human beliefs, values, and needs. (Idris Mootee, 2013). Within empathy stages, design thinkers are tuned into recognising the emotional feedback based on products, services or brands, and with this feedback, relevant concepts can be developed. With this thought, Humanisation is a way to immerse human touchpoints alongside Standardisation to ensure the business truly recognises that real-life customer experiences are what gives products, services, and brands their true value and meaning to the end-user.

2.2.2

A design approach to maintaining relevance is Value Redefinition. Capitalising on humanisation factors, design thinking promotes relevance by ensuring harmony with aspirations, identities, attitudes, needs, beliefs, and desires that people picture and outline value. (Idris Mootee, 2013). As interpretations of values within individuals are changing constantly, design thinking in this context is aimed to *"identify the underlying forces influencing this change"* (Idris Mootee, 2013). Hence for relevance, empathy is greatly promoted within people and brands and effectively businesses to observe and engage taking vital feedback from consumers establishing the best opportunities to gain insights that aid businesses redefine their value and inherently maintaining and increase their relevance within ever-changing categories.

Above relevance and standardisation is the push for business growth. Many business leaders will strive for growth consistently year on year and will adopt classic strategies to do so including *"new strategic partnerships, horizontal market expansion, vertical integration, product extension, and franchising"* (Idris Mootee, 2013). All being well-implemented methods for growth, it can be difficult to choose exactly which strategy to use and how to focus the business's resources to support the strategy and hence how this might affect the organisational design. Because of these varied strategies, a simple answer towards growth is difficult to pinpoint, but with Design thinking, it can help bring clarity to the best areas for the best results.

Growth for business encompasses an executive's team's vision for the future and their drive to keep activities moving forward. These visions will need to be clear with defined actions, what to do? How to do? Where to go? And ultimately to show growth, progress must be measured against the organisations stated goals from the initial visions and design thinking's approach to this statement of visions for clarity across the business is storytelling. From a design thinking perspective, relying on statistical numbers to portray visions and future growth goals is inefficient as numbers cannot tell the whole story and so seeks other means of communications to define the desired goals. Storytelling has a unique ability to bring people into the same context and efficiently present and organize information in an accessible format. Often Business will struggle to portray their core visions across the entire organisation and define exactly what they are. Design Thinking's storytelling method is a technique to create clarity in the company's visions and translate their key factors of a strategy into a captivating and reachable narrative, connecting past and present and the planned future.

The issue of not being able to foresee the visions of the business is commonly seen in younger or newer employees compared to older experienced employees. Employees that have many years of experience for business will naturally have a longer view on the visions of the company as they've been immersed in the environment and mentality of the management for longer. This can create a divide between employees on the core understanding of the company's purpose. To counter this, storytelling is effectively designed to bring confused or miss lead employees up to date by illustrating the path in which the business has taken and where it has come from and what choices and challenges its faced during that time and ultimately what lies ahead for the company. (Idris Mootee, 2013).

2.2.2

An example of well-implemented storytelling techniques spawned from design thinking is that of Doug Dietz, head designer for GE healthcare. He learned that the advanced MRI and CT machines designed by himself, terrified children. To combat this, he employed design thinking processes along with parents and their children and hospital employees to collaboratively brainstorm new ideas. From this collaborative work, Doug solved the issue by introducing storytelling aspects to the machines and scan rooms. The large previously "scary" machines were turned into child-friendly adventures such as pirate ships, submarines campsites, and underwater scenes. Dubbed the "adventure series" scanners, these improvements were successfully implemented into hospitals by addressing human-centered elements and introducing them back into the process which also shares a further aspect of design thinking, continual improvement.

IBM is another large company who has now adopted design thinking into their thong process. In 2012 they employed one designer for every 80 coders, but today it has decreased to one per 15 coders. Their investment of more than $100 million has brought the business forward towards their goal of becoming a design-centered corporation. Charlie hill, chief technology officer of IBM stated for years "our teams had a much engineered centric culture" But in 2012, everything changed "We wanted to shift that culture towards a focus on users' outcomes". IBM is aiming to create a culture specifically for their software developers to be an intuitive working environment equaling the intuitiveness of the software they design themselves for day to day technology such as ATM's. Hill says check referencing protocols here, "To do their work really expertly across industries, it has to be just as intuitive as what they use in their personal lives". To do so, IBM has planned a companywide implementation of design thinking processes to impel a user-centered vision across the business and to establish IBM as a leader in an ever-going design lead companies. The company has developed their design thinking process to such an extent that they've published they're very own set of design thinking guidelines that include a variety of design practices they hope other companies can adopt into their structure. IBM is using this major advancement of implementing design thinking essentials to ensure their relevance in the computing category and most importantly cementing their vision of increasing their profitability in a rapidly evolving corporate market.

2.2.2

As seen below this is IBM's rendition of their design thinking principles better suited for their large organisational structure. Dubbed "The Loop", its design represents an infinity symbol mark with 4 dots, the yellow representing the user while the green dots represent the various activities of "observing", "reflecting" and "making". The loop itself represents the product creation process, initially with user-centered research throughout to prototyping to the final stages of launching and implementation. The true meaning of the loop comes into action when there is a realisation that the iterative process is never complete and hence compelling the users of the loop to emphasise on the importance of reflecting on what's been created and constantly improving it, for example, IBM's constant development of software with incrementally introduced software update versions. Roughly 10,000 employees have been through training on the principles of "the loop" and how to adopt them, and as a result of implementing this design thinking lead philosophy around a100 products have been developed, the most prominent being the "BLUEMIX" creating a cloud-based platform for developing apps. This is a clear example of how large successful organisations plan to remain relevant within ever-dynamic markets of computing and business. This striving for relevance is all based on focusing on good user experiences and therefore implementing an entire company restructures instead of possibly developing the user interface, all to ensure the products and services are perfect for the consumers.

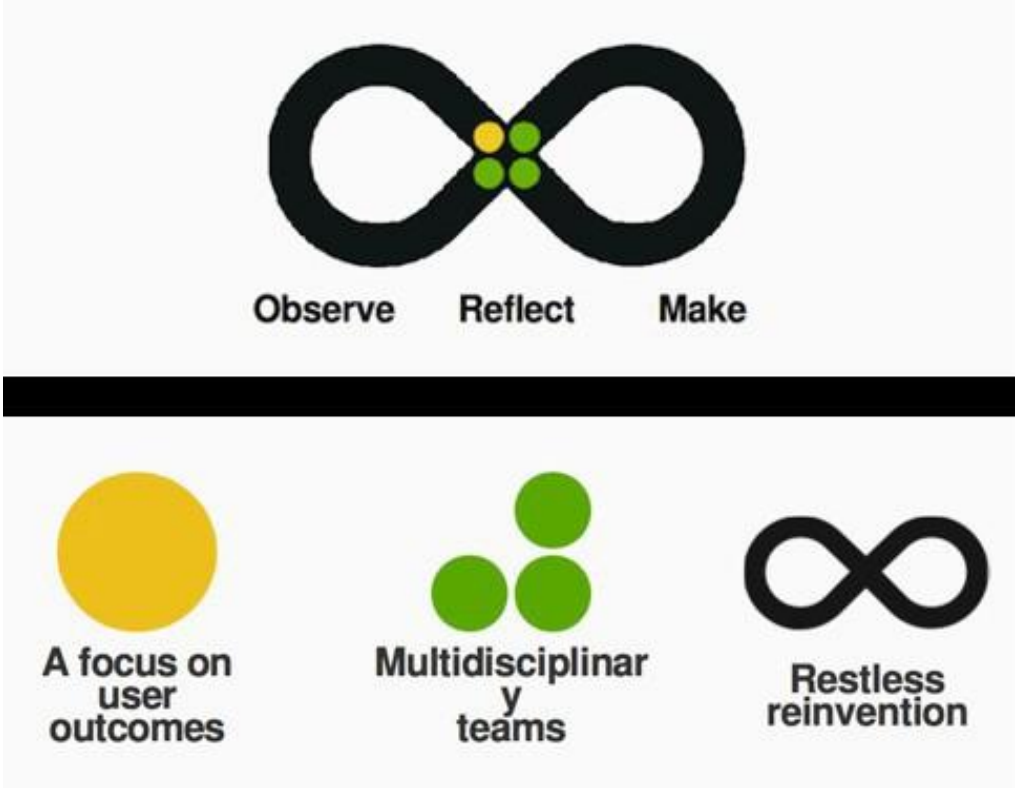


Figure 1.2 taken from (Explore IBM design Thinking Human centered outcomes at speed and scale guide, 2016)

2.2.2

IBM's design thinking loop is one of many developed toolkits of design processes that have been adopted by large businesses to create change in their structure or ethos. It can be seen more often than design thinking principles can be applied quicker and more efficiently by developing these principles into what is known as "Design Toolkits". As it can be seen, IBM has adopted a visual design process based around design thinking steps into a clear and self-explanatory symbol infusing sub-symbols within it, defining the constituent parts of their simple process for innovation.

Most toolkits share common features like what is seen in IBM's example, they usually include innovation models, a step by step processes and provide various templates in which to support these steps along the process (Soren Kaplan, Innovation Point, 2002). As they're also becoming increasingly open and readily available businesses whatever specific tools, can easily adapt them and even customise them to suit their needs and structure. And it's the crucial link between design thinking theory and design toolkits that create a general tool that can hold the true power in implementing business-changing design mindsets and create strong platforms for their employees to innovate further.

To explore this link further, various examples of design toolkits will be outlined and explained for their adaption to design thinking and hence a business culture and ultimate how it can benefit the company.

To combat these sluggish budget destroying product development processes a new wave of innovation or design toolkits are being invented and developed themselves. The principle of design toolkits is to approach product and service development to involve transferring need related product development tasks from the business to the users, essentially giving them a set of effective tools in which to complete these tasks (Eric von Hippel, Ralph Katz, 2002). Effective toolkits generally have five objectives to their structures and tools involved. They will allow the user to complete trial and error learning which is based on constant evaluation and continual improvement of the product or service. It will allow the user a free space applicable to their working environment, specific to the business economical and practical ability. The toolkit itself is intuitive and free of complex design structures, enabling novice designers the ability to quickly adopt the tools of the toolkit into their process. And furthermore, the fourth objective will allow the user to tap into a wealth of commonly used subjects that can be used to apply to a designer's individual knowledge.

In general product development processes, manufactures typically initially explore the needs of the user and create products to combat those initially stated needs. But ensuring a thorough understanding of the users' needs can be difficult, expensive and more-so time consuming when compared to the dynamic change of market demands for new product answering to increasingly "needy" consumers. (Eric von Hippel, Ralph Katz, 2002).

Finally, the fifth objectives ensure that users of the toolkit can produce new innovations completely producible in this manufacturing system reducing any need for new investments. (Eric von Hippel, Ralph Katz, 2002).

2.2.3 Design Toolkits & Practices

Adopting design thinking toolkits can be at a cost to many various departments of the business. Innovation needs to be fully understood throughout the process one follows. Consequently, partially understanding the process will result in many negative outcomes. The table below details understanding innovation as only certain conceptions can lead to various results;

Strong R&D Capability	Technology used might not suite the demands of the user and not accepted
The Knowledge of Specialists	Will lead to not benefit from collaboration of various knowledgeable groups that could actively contribute to R&D.
Understanding of consumer needs	Can results on products or services developed solely to answer the customer needs with no further development for a curling edge advantage in the market.
Advances in technology enhancements	Technology developed could be too advanced for the market and would be difficult to implement for end users
The knowledge of large organisations	Smaller more disruptive innovation apparent in smaller companies as they seize new technical or market opportunities
Breakthrough changes	Neglecting the power of incremental innovation. Difficult to harness radical changes in projects as incremental improvements are not implemented well.
Depending of Strategical targeted projects	Could miss out on “by chance” discoveries and possibilities
Associating with key individuals	Not utilising the entire team of innovators that could add their own inputs and insights for greater innovation
Being Internally generated	Potentially externally associated 3rd part concepts will be declined and with it the potential for breakthrough products or services.
Only Externally Generated	Innovation not filly adopted with little internal learning and development of technologies knowledge.
Applicable for single businesses	Excluding possible sharing of work between organisations to produce new concepts and streamlines processes.

Adapted table from Tidd, Bessant and Pavitt, 2005

2.2.3

As shown in the table above, many parts of innovation can be miss lead and resulting consequences can lead to major drawbacks including not developing products for the users' needs or not adapting appropriately to market change. To ensure this understanding of innovation and how to operate within it, toolkits are vastly becoming a well-developed path for consumers or businesses to adopt into their systematic way of working. The overriding benefit for users of design toolkits implements an innovation-friendly structure in which to exploit new insights and knowledge, ultimately increasing the potential for innovation exponentially when used correctly.

As to further answer the stated research question at the beginning of the project the following subsection will list and describe various design toolkits. From this subsection, a picture can be painted into what structure can be adopted by the company and specifically what stages should be carefully adopted for best results to spawn an innovative environment.

IDEO has been renowned in recent years for developing the human-centered analysis through design thinking approach to products, services, and experiences. They believe that "*human-centered designers are about believing that as long as you stay grounded in what you've learned from people, your team can drive at new solutions that the world needs*" (IDEO, 2015). In 2015 they published their "*The field Guide to human-centered design*", the guide perfectly details the three main sections of a performing design process, inspiration, ideation and implementation through a non-stringent linear process. By following these three steps, IDEO State "by taking these three phases in turn, you'll build deep empathy with the communities and individuals you're designing for". (IDEO, 2015).

The three steps;

Implementation - These final designs will then be developed for market launch for maximum impact.

Inspiration - the First stage to understand people and create empathy in the processes their apart of. Essentially an observation of their day to day lives and their needs hence to gain further knowledge on the challenge.

Ideation - What is concluded with the inspiration stage will be contextualised in the ideation stage. From this context, opportunities for designs will arise through testing and further continual development.

2.2.3

From the outset, the IDEO process bases human-centered design as a diverging and converging path. As innovation is rarely spawned from precise structures, the process allows the user to directly learn from people for a greater potential for creative opportunities and then hone in on what's most desirable, feasible and viable for the end-user. Along the process, concepts and thoughts will stray "out of the box" and back into the technical side of the project. IDEO's way of describing these wide and narrows thoughts, diverging and converging. Naturally, in an ideation stage, a great deal of diverging is seen as all possible ideas are considered and more even noted, but in following developing stages projects tend to converge as the only performing ideas will be chosen when considering further needs and aspirations noted form the inspiration stage by the users. The IDEO process compels diverging and converging continually through the process as all new insights and developments through these peaks and troughs will lead to market-ready solutions.

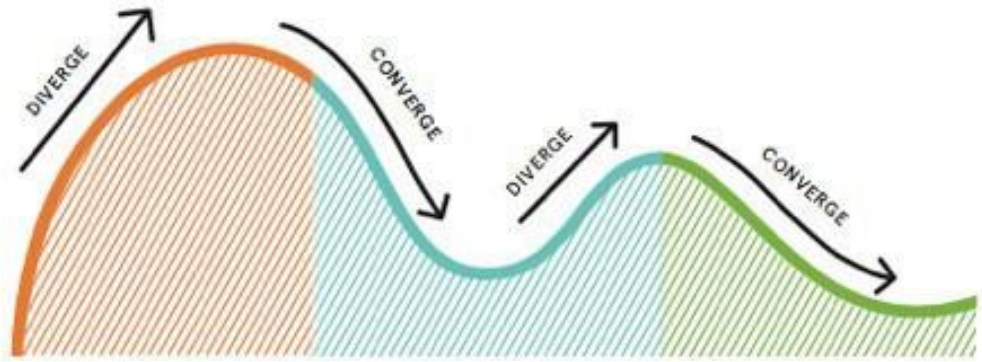


Figure 1.3 IDEO Diverging and Converging Model

2.2.3

Solutions are why human-centered design is developed as the mindset of the process is to arrive at are feasible, desirable and viable end goals. By keeping humans at the core, their hopes, fears, needs, and desirables are quickly uncovered. Once a range of solutions have been shortlisted that would benefit the target market under focus, the next steps would to home in on the technically feasible to implement and how to make the solution financially viable. This is somewhat a balancing act but is crucial to design solutions that are successful and sustainable.

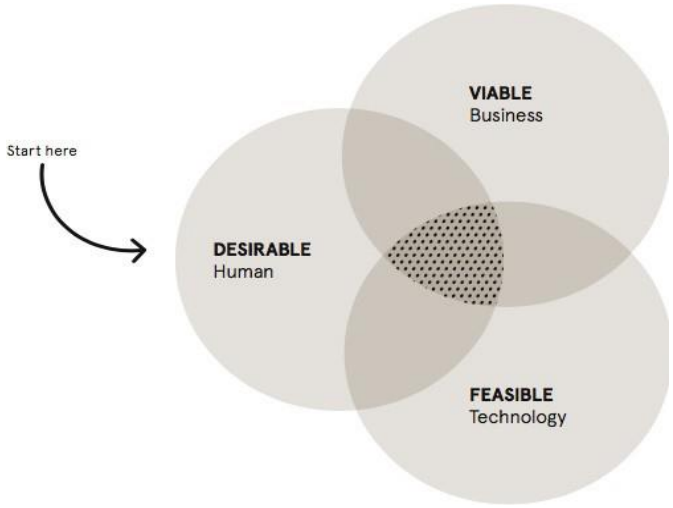


Figure 1.4 (Field Guide to Human Centered Design, IDEO,2015)

A well-structured mindset is crucial for effectively developed solutions. Without the correct deployment of ideas and methodical process behind a design process, an individual will fail to extra the potential breakthrough idea that could generate the ultimate solution. A good Mindset from a human-centered design point of view is a confident one, as stated by David “Creative confidence is the notion that you have big ideas, and that you have the ability to act on them” (David Kelley, 2015). A lot can be said of this statement anyone can approach a world like a designer.

Confidence is the key to unlock the potential as a dynamic problem solver to spark creativity, and that creativity isn’t artistic talent or fancy drawings or sculptures, but a way of understanding the design world. It is creative confidence that human-centered design relies upon when boundaries are met and trust in their intuition and chasing solutions that haven’t been completely figured out. It is the driving force that a person can and will figure out a creative solution for large problems and the confidence needed to do this. Creative confidence will drive the individual further to test new concepts to get it wrong and to continue knowing in their minds that along the way the concept will innovate and ultimately succeed. Building creative confidence is a lengthy process, but by using a human-centered approach, all manners of problems can then be dealt with. As human-centered design helps an individual to succeed incrementally through bigger projects, creative confidence grows and grows until the individual has adopted the mindset and proceeds to be a widely creative person.

2.2.3

"*You're taking risk out of the process by making something simple first. And you always learn lesson from it*" (Krista Donaldson, 2015). As mentioned by Krista taking a concept and trying the simple solutions first greatly reduces the risk out of the project. Human-centered designs are adopted by doers, tinkerers, crafters, and builders who build and fettle with this solution, using simple tools further and sophisticated digital tooling. Ideas are built so users and designers can test them for functionality but furthermore, it opens a whole new dimension in which a design can be studied thus potentially highlight further areas of development within the prototype that wasn't apparent in a 2D form. From studying a prototype, one can delve into its complexities, and by doing so developers can focus their thoughts on the feasibility of the design further analysing the concept for the best possible result. Another crucial benefit of physical designs is the ability to share the model with the target audience for the most accurate feedback, and this is one of the main principles of human-centered design whereby a whatever the design, materials used on the quality of the finishing, the goal is to always convey and idea, share it and learn how to make it better. The beauty of prototypes is that they are useful at any stage with various incremental changes as the concept develops throughout the project. A human-centered design approach is always pointed towards action, which means summarising the ideas in the designer's head and conceptualising prototypes for customers to give feedback. Further prototyping aspects will be discussed in the next subchapter.

Another tool human-centered designers capitalise on is Failure, or as Brown suggests "*Don't think of it as a failure, think of it as designing experiments through which you're going to learn*" (Tim Brown, 2015). An interesting statement in which human-centered design is very much based on, and it's the understanding in that not all of them are going to work. Relatively with great designs outputs, failure is inevitable at some stage but, if the right mindset is adopted designers will learn a great deal from these failures. At the start of each design project, a sense of not knowing what the solution will be is always present. Only by thinking, listening, building and refining a way to an answer that designers will create concepts that will work for the target market. IDEO's mantra states "Fail early to succeed sooner" which is powerful in its self, as it relaxes designers from focusing on the correctness of their concepts and more -so it's the permission it gives to get something wrong. As Thomas Edison put "I have not failed. I've just found 10,000 ways that won't work" which directly links to human-centered design as sorting through concepts that won't work will highlight those that will. Human-centered designers inherit failure as part of the process as a concept are rarely correct on the first attempt. IDEO state "*In fact, getting it right on the first try isn't the point at all, the point it to put something out into the world and then use it to keep learning*", continuing from this, designers can keep asking and test the concept further and more often than not, human-centered designers create useful concepts as they got it wrong first.

Empathy is another crucial tool used in human-centered designing. The effective use of empathy will allow a designer to conceptualise a product from the consumer's perspective. The processes stipulate that the people one's designing for will aid a designer or a team's vision for innovative solutions, all that is needed is to empathise with the target market and ensure they are immersed with the designing phases to ensure the most relevant final outcome. Empathising with the target group is the best route to understanding the context and complexities of their activities, but even more so it keeps the consumer you're designing for central within the design vision of the project.

2.2.3

In many design cultures in the modern era, designers are too focused on being the first one to the right answer. But it is essential to start a clear mind at the beginning and immerse one's self in the world and communicate to the people one is looking to serve. Through this scope, a greater aspect of creativity is seen as a range of different ideas can be drawn up to arrive at unexpected solutions. By embracing this ambiguity, it will serve a strong basis for innovation. Human-centered design qualities focus designers to believe that there always new and big ideas possible and that the turnover of new ideas are very frequently, constantly moving on to the next great idea! The addition of collaborative team working also adds to the generative process which makes discarding bad ideas easier as collective agreement and developing good ideas much easier. In some instances, it might be advantageous to not know the answer to the outcome, this can create innovation as it again can focus a designer's mind to all the possible outcomes instead of converging into the final answer without development.

"Optimism is the thing that drives you forward" (John Bielenberg, 2015) states John Bielenberg founder of Future Partners. A great deal of human-centered design is inherently optimistic. To management large projects and challenges a designer must believe that there will be progress as otherwise, people wouldn't try. Optimism in design thinking is the mindset that even if designers aren't aware of the answer yet, it is out there to find. Other than driving us towards greater solutions, optimism encourages us to be more creative especially when working through boundaries and pulling efforts within a team closer. When approaching a challenge with the mindset that a solution will be developed it combines the entire process with drive and energy to break through the toughest of problems. Because of these human-centered designers are persistent in there and focused on the possibilities within a project and not what barriers may lay ahead. Obstacles are always present within a design project and often they push designers towards unexpected solutions. But it's some human-centered designer's drive that has the mindset that every problem is solvable.

A human-centered design approach to solving problems is an iterative one, as it creates better quality feedback from the target market as to aid the evolution of the solution. By constantly iterating, refining and improving concepts it will improve idea generation and the speed of which ideas are brought to life. Correct iteration keeps designers focused and responsive in creating an idea and refining it. If a designer focused all their time regarding the perfection of their prototype, a lot of the time would be taken to refine these concepts while the relevance of the design is yet to be determined. But by simply building, testing and iterating once can develop their idea without wasting many hours and resources until the concept is proven successful and to be developed further. Human-centered designer iterates as they're fully aware that they won't succeed with the first concept. The essential use of iteration gives a designer the ability to explore various opportunities, to get initial concepts wrong and to follow their minds to greater concepts that will be adopted. Rather than conceptualising in workshops hoping ideas will counteract the challenge at hand, human-centered design spawns from the environment and the target people who guide designers to the outcome.

2.2.3

As to continue from design thinking, a lot of theories has been synthesised to better explain the idea of design thinking and innovation in general. These theories come in the form of "Toolkits" or practical guides in which participants or team's cam immerse themselves to generate the best ideas. Design toolkits are based on step by step practical exercises of steps one can take to ensure all aspects of a potential idea is researched and tested. By using a standardised design plan or guide, the user can ensure that they're working through the correct stages of designing a product or service.

Toolkits and design guides will be researched as this will aid comparing what current structure are in the business with regards to design planning and standardisation where applicable. Also, if no design structure is present then the conclusion of such research will serve basis to suggest a design toolkit of guide for the business.

Detailed in the little black book of innovation is Scott's should you reference this better / protocol – is this the same Scott as later as it is spelled a different way here? "Twenty-eight-day innovation program", where the reader is given a day by day 4-week-long program that one can use to spark innovation in any given applications. Each day begins with a question based on what that day is designed to answer which also includes a brief answer to the question. After the brief answer, the author of the book continues to describe the answer in greater detail by illustrating key points and giving examples. With the examples, each day includes how-to-tips to facilitate the central idea into action. The great benefit of using the twenty-eight-day innovation planner is its ability to be used out of order and not specifically in daily order.
To aid breakdown the structure of the planner each week has a specific goal as shown below;

Week 1 – Discovering Opportunities
Week 2 – Blueprint ideas
Week 3 – Assessing and Testing Ideas
Week 4 – Moving Forward

2.2.3

Week one is based on harvesting ideas from a disciplined process to discover opportunities to create something different that has an impact. The aim of the first week is to aid the user to Identify the target audience, identify the problem the customer is struggling to solve and to discover any signals suggesting that the customer id dissatisfied with the status quo.

Broken down further day by day the following table concludes each day;

Week 1	How do I know it is time to innovate?	Scot answers this central question by stating the early warning signs must be addressed as the urgency of innovation and the ability to innovate are inversely related. Spotting signals of change needs a trained eye and creativity and pushing efforts towards spotting such trends can be very lucrative and ensures a business is dynamic and not stuck in a paradox.
	How do I spot opportunity ties for innovation?	An innovator should be fully aware that the "consumer is boss" perspective and that they hold the final decision on the successfulness of the product or service. With this in mind, a designer would ensure they're immersed with the consumer is extensive and thorough. .
	What indicates an opportunity for innovation?	A good instance of opportunity for innovation arises is when there is a problem a customer cannot effectively address today. This will clearly show what the problem is and what could potentially aid the problem that hasn't been highlighted before.
	Which customer should I target?	Designers must seek "Non-consumers" that are currently facing barriers to complete their work. By doing so it will show clear markets where innovation is needed to break down these barriers.

2.2.3

	How can I find non-obvious opportunities?	To do so a designer should tune into the behaviour a consumer will put on to compensate for the in inadequate solution. This will clearly show opportunities for improvement even when a previous solution has been developed
	How should I investigate potential opportunities?	It should be started with clear and deep observational research in the target market without wasting time in focus groups by using time effectively with the consumers in the environment in which the existing solution is used.
	How can I confirm that the opportunity I have spotted is real?	Ensure enough time is invested in the target market you've identified a possible solution, and beg the question, why hasn't other innovator's also come across this opportunity.
Week 2	How can I get inspiration for an idea?	Designers should investigate the intersections, i.e. where various concepts have crossed over between various markets to create the best solutions and inspire from them.
	Where should I look for inspiration?	When developing initial concepts ensure that a broad range of avenues are researched and recorded for performance to gain the best insight.
	Is my idea high quality?	Quality of a solution can only be determined by the consumers or by the designers if what matters to the consumer is clearly understood.

2.2.3

	Is there such a thing as too good?	A designer can easily create other beneficial features for consumers when developing and implementing a new solutions, but the question should be asked, will the consumers see enough extra value to pay for it?
	What is disruptive innovation?	Disruptive innovation is when a solution doesn't simply benefit the consumers but also creates new markets and transforms existing ones through, convenience, affordability, simplicity and accessibility.
	What is a business model, and how do I innovate it?	A company's business model will describe its activities and process workflow to create value. By considering a range of business model options this will help business model innovation.
	How can I transfer my work into a concrete blueprint?	Ensure that the designers work is summarised concisely into a comprehensive plan, that can be used exhaustively to develop.
Week 3	How can I separate good ideas from bad ideas?	A designer should use various patterning tools create a directional sense to conclude whether an idea is good or not. Then experiments can be used to confirm the directional sense
	What is a quick way to estimate my idea's financial potential?	Designer can multiply penetration, population, price and purchase frequency to gain quick insight into and idea's potential

2.2.3

	How can I identify and idea's most critical assumptions?	Critical assumptions can be drawn by noting what will make the solution successful, then detailing the two things that would need to happen to accomplish this success.
	How can I learn more about my idea?	To learn form a solution, the best practice to gain further knowledge is to test the solution rigorously that could identify new solutions for development.
	How can I get people behind my idea?	Use creative ways to bring ideas to life to motivate potential consumers to invest.
	How can I get good at experimenting?	As a designer one should be constantly researching into the best and new experimental concepts to trail
	How can I learn the right things from my experiments?	A designer should be immersed in his or hers data gathered from these experiments and focus on the findings that weren't expected for potential improved solutions.
Week 4	How much should I invest in innovation?	Ensure the most relevant timelines are prioritised and embraced by all levels of a team and the decision making is narrowed and strategic choices are researched efficiently.

2.2.3

	Where can I find resources for innovation?	Look into new resources not previously considered and re-direct current committed resources towards these new areas.
	How can I avoid the sucking sound of the core?	Ensuring the correct leadership style is adopted with new voices, safe spaces and smart borrowing can help protect innovators from the sucking sound of the core.
	How do I manage interface s between a new business and the core business?	Designers should adopt a range of techniques that will ensure individuals don't accidentally remember what you are trying to forget.
	How can I motivate and reward innovation?	Ensure that individuals responsible for the innovate solutions or even teams are reward based on their behaviour instead of on the successfulness of the solution.
	How can I build Momentum?	An effective way to build momentum would be to complete the quick and simple wins before the time-consuming bigger jobs are started.
	How can I get systematically better at innovation?	A designer should put themselves in a situation where innovation skills must be learned to be successful.

Table adapted from Scot Anthony 28-day innovation planner breakdown, (The Little Black Book of Innovation, 2012)

2.2.3

The table above can be concluded at various points. Firstly, time spent with customers must be increased or emphasised when designers wish to innovate. By having greater contact time with the target environment and the customers, invaluable feedback can be recorded and developed to achieve a more relevant and successful solution. During the time spent with the customers and developing the potential solutions, innovators should ask why? why not? and what if? From these simple questions, one can create various conversations or research avenues that weren't previously made and from these avenues, insights can come to light that wasn't obvious previously.

Furthermore, experiments should be conducted daily in order to get the best insights from the solution. Either implemented solutions or current concepts must be tested as they can still give insights into mechanics in which the solutions work to potentially develop them further to greater solve the initial problem. Also, on the back of frequent testing, a designer will benefit from striving to learn more without spending money. Their knowledge can then grow quickly as it is not governed by budgets or 3rd party research reports.

Also mentioned in the table, designers will benefit from looking at the cross-references of features within current designs and learn from them. Various designs from various application swill intersect in many solutions and learning the nature of these intersections and why were they determined as useful will help to implement them into another possible solution or ultimately intersection.

And finally, a designer's mindset will need to be stimulated and sustained to innovate frequently and effectively. The ensure enough stimulation, individuals should teach their colleges key innovation lessons. By doing so, this not only creates a greater knowledge base of innovation in the immediate environment of the designer but also aids the designer's cognitive stimulation.

Coupled with the 28-day planner, Scot details his seven deadly sins which in short mention seven aspects that starve innovation from its successfulness and how to avoid them. Leading on from what a designer should be achieving according to the 28 planners, the following will be discussing from Scott's point of view what designers should be avoiding.

2.2.3

The first sin is Pride, more so forcing a view of quality onto the marketplace can often result in overshooting. Scot's example of this is the quantity of razor blades found of a Gillette razor. Shown in the graph below shows that the Gillette razor follows a hyperbolic curve compared to an exponential curve within a few years the razor will include over 10 blades compared to the 6-blade razor on offer today.

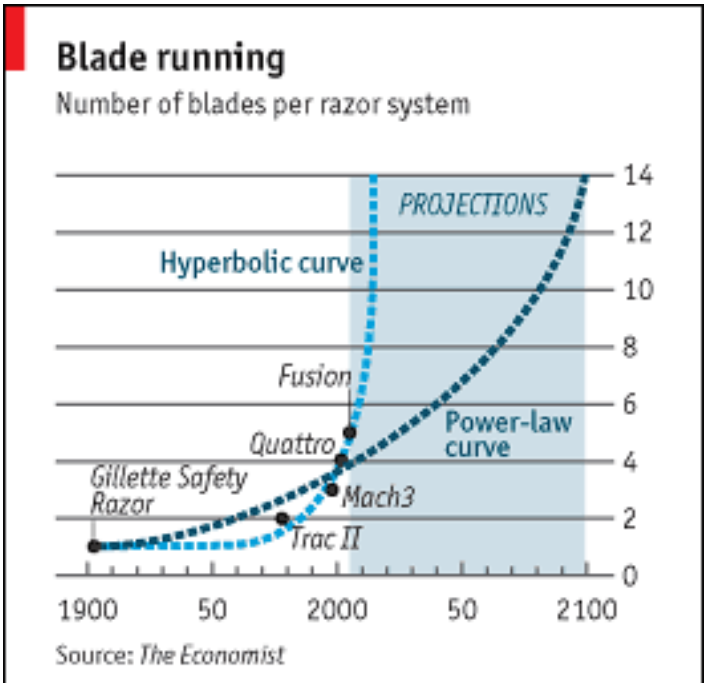


Figure 1.5 *The cutting edge article, A moore's law for razor blades, The March 2006.*

When given the choice of a 10 blade system consumers are naturally drawn towards the greater the number the better misconception, but are they willing to pay the extra premium for the additional blades? In most cases, consumers wouldn't as it would be too much performance for their needs. This is where the term "overshooting" (ScotD.Anthony,2012) is used within innovation and hence its link to the sin - pride. Whereas trying to continue to create better solutions in a designer's mind my not be what the consumer really wants or needs. The solution to overcome overshooting is to take an eternal viewpoint to ensure the designer understands how the consumers measure quality and ensure that research is grounded in what the market wants not what the designers want.

The second sin is when innovation efforts slow to a steady crawl. Activities can easily be prioritised in the wrong direction especially those who prioritise analysis over action. By filling the working day with to-do lists and finishing the smaller tasks or starting a detailed ninety-day planner, technically work is being completed but counterproductively as actions aren't being completed towards the raw innovation of trying and testing concepts

2.2.3

over and over, as the first concept will always have drawbacks, and these drawbacks can't be figured out precisely through analysis alone. As championed by Thomas Edison "If you're not sweating, you're not innovating".

The next sin describes what outsiders of a market can do to market leaders if innovation is found and directly attacks these leaders. Often these "attackers "are better equipped to innovate as they comprise of smaller more dynamic teams who move quickly to achieve the end goal. Large market leaders can be hindered by their abundance of resources. Compared to the small attackers, the market leaders will have a much greater budget for research and development, but this doesn't necessarily mean the market leader is innovating in the right direction.

The larger business will deploy large amounts of people or teams towards a specific strategy which is slows the process down, while the smaller teams typically move faster than large teams. Also, bigger companies are very patient to drive results without realising that these patients hinder their ability to find innovation. This concludes that big efforts and large teams shouldn't be task with creating the next big thing, smaller more agile teams should be set up to innovate quicker. And managing these dynamic teams should have tighter constraints with regards to deadlines or milestone to reduce complacency.

As importantly, the fourth sin aims towards the "*Bright, shiny object problem*" (Willy Shih, 2007). Where the innovator must learn to prioritise their efforts. Joseph Schumpeter 's idea of creative destruction lends itself to this theory whereas the ability to stop is as powerful as the ability to start, i.e. if one lusts after too many things, you'll find that you'll end up with nothing. Good innovators will carefully steer their efforts towards opportunities they can achieve without getting bogged down pursuing bright shiny objects.

A further sin can come in the shape of innovators inside and organisation proclaiming themselves as the chose one. It is essential to keep the core business relevant to the innovation strategy, without the core business, there is no corporate innovation. The Harvard business review of Vijay Govindarajan in 2010 talks about forgetting and borrowing. The review names "Stop the innovation wars" urged businesses to avoid internal sniping that can derail growth efforts. One way to ensure this problem does not arise, is to consistently celebrate both the core business efforts and the new growth efforts. Another aspect of this is when business start on their innovation journey, they often choose the most the best performers, give them start on their chest and given the status "Innovator". In some instances, this does work but people who previously had been involved in the core business can struggle to adopt into a new business role along with behaviours and mainly mindset to promote innovation.
Essentially companies should staff their innovation efforts with in different ways, ensure people have developed innovation skills and innovation backgrounds.

The other sin is developed from the fear of the "*failure is not an option*" quote. As mentioned in Daniel Pink's book (*Drive, 2009)* states that providing financial rewards for creative tasks are linked to a decrease in performance. Pink stats that to achieve good performance from innovators, one should provide enough opportunities in which to build on and create a sense of purpose to the activities. Along with rewards, leaders of innovation should be careful in which the ways they discipline failed innovations. Employees cannot be punished for failed innovation as failure is an inevitable part of

2.2.3

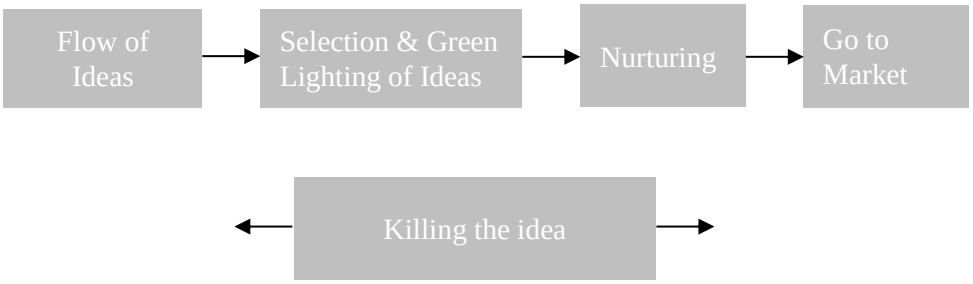
innovation and is crucial to building innovation further. Therefore, leaders should pay attention to people's behaviors as to the results they achieve. Venture capitalists will look to invest entrepreneurs who have a couple of failed projects on the CV, the crucial part is that those entrepreneurs have learned their lesson from these failed ventures and know what to do next time. Large business often punishes people who fail ventures, but the message that is given by punishing people who take well-thought-out risks that don't pan out is very negative and de-motivate individuals from taking any type of risk. To encourage innovation, one must think about what gets rewarded and what gets punished as both are equally as important.

The final sin is greed and impatience for growth. Yes, greed does have its advantages, but innovators need to ensure their greed is aimed towards to correct outcomes. Innovators can easily be sucked into the need for growth, i.e. they want something that is a big possibility. But looking for the big possible for quick growth will force a designer to look at what already exists. Which explains the fact that "it is hard to make the case that a market that doesn't exist will be huge" (Scot Anthony, 2012). And it's difficult for innovators to understand that creating growth in existing markets will depend upon the business within a market, the large businesses and market leaders will have a lot to lose and hence will fight for their dominant position and every pound of profit. Successful innovators would avoid the temptation to compete with the bigger business and big markets. They are patient for growth and are greedy for the best result but humble in the direction this result is driven.

2.2.3 The Game Changer - How Every Leader Can Drive Everyday Innovation

Another design framework is the 5 building block framework conceptualised by the chairman and CEO of Procter & Gamble A.G.Lafley & Ram Charan. Without the discipline of a system that constantly revises, reshapes an idea into various iterations a project can rarely reach its full potential. And because of this people see innovation for what it is, the half of its potential. A result of this is the support needed to maximise market share fast doesn't materialise which inevitably gives competitors the opportunity to get most of the profits.

A successful system ensures that many iterations of an idea are developed which in turn improves the chances of success. Also, this doesn't necessarily mean subjecting the ideas through a bureaucratic business system to be filtered through various teams. What is seen is that the most successful companies in the fast-moving markets are indeed the most disciplined at nurturing and bringing their ideas to market. Converting ideas into profits is very much a matter of practicality and it requires a well designed and flexible process that moves the concept set by step into the market place as shown in this diagram below;



In many businesses, innovation is a linear sequential process mainly starting with R&D then moving forward from department to department. But as we discuss design toolkits and methods further, the following breakdown of the 5-building block framework will describe other structures that a designer could adopt in their team or department.

The framework is based around ensuring constant stimulation and parallel working units which the following outline will discuss the key issues and the questions that are part of the various stages.

Flow of ideas

Initial stages of this framework consist of highlighting sources of ideas. They can either be created internally developed from the business itself or they can be generated from outside sources such as customers, alliances, suppliers or joint ventures. Many businesses with similar structures for sourcing ideas from outside include Lego Group and Nokia.

Ideas from such structures can range from incremental or disruptive such as the reinvention of a business model such as Apple with the iPhone and the iPod, which redesigned the value chain through the business through to the customer.

Additionally, a transparent system within a business is essential to receive and manage ideas, whether they are sourced internally or externally. The best practice is to ensure that these culminations of ideas are facilitated to the

2.2.3

correct departments within the business to get the most relevant attention. Equally during facilitating ideas within the business, middle managers should not wait for orders to come from higher executive leaders to continue the flow of ideas developing further. Therefore, designers and leaders should "Actively create the structures to ensure that ideas flow" (A.G.Lafley & Ram Charan, 2008). By doing so it will expand the capability of both the lead and people within the organisation.

Selection and Green Lighting of ideas

At this stage, there must be a clearly defined social mechanism for selecting ideas to be green-lighted. After the selection, a major dedicated effort is made to nurture the chosen idea to final concepts.

Within the structure, the mechanisms must operate on a disciplined orderly fashion. There must be a structure for employees to become part of the mechanism and be involved in the way decisions are made.

Further, the composition and direction of the mechanism must be considered and carefully chosen for the best performance.

The criteria of the mechanism must be clear and linked with the strategic selections of where to operate and the desired profits growth goals. Also, the strategic selections must be a balance of incremental and disruptive ideas, internal to external and ultimately high and low risk.

And finally, the mechanism must practice the outcome that the "customer is boss" attitude and use failure productively, striving to develop prototypes and recording vital customer reaction to the concepts, and if a prototype fails, then quickly develop another for further feedback.

Nurturing

For the green-lighted ideas to succeed someone must own and be accountable for its success or failure which usually would be a middle manager has part of his or her goals, such as top-line growth, gross margin, preventing prices drops or commanding premium pricing including budgets and performance.

The owner would also be responsible for funding the idea and moving it forward or canceling any further actions. Also, they would be responsible for both the team leader and members of the innovation team, allocating resources, ensuring to prioritise work when necessary while conducting reviews of the team's outputs, through using milestones to measure when certain stages are reached, where applicable rewarding success and dealing with failure.

A decision needs to be made as to whether the idea warrants a fully dedicated team to nurture it to fully market-ready.

Also, criteria need to be established in the selection of the team leader and the members of the team itself. The question should be asked such as, do the leader and the team have the

2.2.3

necessary skills to develop the idea through the entire process or will midterm restructures be needed? (For examples, somebody skilled in initial concepts and prototyping might not be suited for marketing or commercialisation).

Along with establishing the leader and the team itself, it is crucial that the team works together to achieve the common goal, i.e. to shape the idea to prove the concept will work or not. The team leader doesn't necessarily need to be a specialist in marketing or technology, their job is to ensure the day to day task are completed and on target, dealing with highs and lows and giving the team that creative platform and resources to ideate and conceptualise further.

The team leader will need to deal with various hurdles within the project, these will include; not postponing any activities and coming to grips with tough issues, nursing internal and external help is available when dealing with hurdles, set milestones agreed with higher management and has the discipline to deliver on the milestones, and ultimately takes the project onwards with his or her team by constantly analysis the following;

- Commercialisation potential,
- Margins,
- Price points,
- Scalability
- Appropriate methods to achieve the best growth goals.

Go to Market

When moving from the nurturing stage into the actual marketplace it is not sequential but more so overlapping. It is the manager's responsibility to take an idea to the market ensuring the idea is engaging during the nurturing process so that trade-offs and resources are allocated when the products need to be scaled up, including cost considerations and further reach into the customer's mind.

Up to this point, funding hasn't been significant. With going to the market being a major decision, significant investments are made along with major risks and rewards, for example, manufacturing facilities, advertising, and marketing campaigns and new potential development channels.

Once a design is completed from the innovation team and given straight with no hand over details to manufacturing teams or marketing will guarantee failure. Within manufacturing, it could be seen that a concept is not practical to manufacture at the correct costs and tolerances, and marketing teams might say that the design won't appeal to consumers. If the manufacturing team and marketing would have been part of the social process throughout, these issues would have likely been highlighted and dealt with sooner, making final commercialisation a smoother integrated process, not one with bumps and gaps. The executive managers would ensure that the customer is always perceived as the boss is making the right tradeoffs between the innovation team, what marketing is asking for, and what is feasible from a finical point of view, ensuring that the customer will buy it and

return for further purchases. All the activities need to take place without compromising the integrity of the offering, it is this skill a leader must keep central in making innovation an effective end to end process.

2.2.3

As always with innovation, not all ideas will succeed. Through the process of developing the concepts an evaluating milestone, the executive manager and the team leader will ultimately need to have intellectual honest conversations whether to proceed further or whether to assign a higher priority or even resources or to give the project a lower priority and extracting resources or possible killing the project.

Failure can be a consequence of many aspects, such as the wrong choice of team leader, poor team working, not using outside sources of ideas and help, not keeping the "customer is boss" mindset at the core of the team or bid timing. A third of innovation resources can be wasted due to executive managers letting their emotional commitment take over the project further past its best killing point. Which concludes just as there is a risk in funding ideas, so there is a large risk in killing an idea and canceling any further funding and possibly missing an opportunity.

2.3 Increasing Prototyping Capacity

2.3.1 Current Prototyping Practices

Continuing from the previous section where design theory onwards to design toolkits and practices where discussed, as to research further topics to answer the second question of the project, the author will discuss and carry out research on prototyping practices along with product development workflows and the use of technological advancements to help strengthen these topics.

The second research question; How can prototyping capacity be increased? Can be broken down further to various aspects of prototyping that can be discussed to be analysed further against the company in chapter three.

The discussion will begin with the background of prototyping. The idea of prototyping is to bring the user closer to the final product. Yes, sketches through portfolio work and 3D cad representations do create good basic visuals for the final product but it is the prototype that brings to life the final experience of the concept to the intended user. Yes, a 3D model can show functionality and movements or even just simply a render for a better clarity of visuals, but a designer won't know if a design is successful until a prototype is made, it is at this stage textures, feel, sound and all the senses can be determined off the prototype.

While prototyping can be skipped in the design processes, the time saved skipping this crucial point will be doubled during the development stages as certain aspects of the design would be highlighted latter on the design stages, instead of in the early stages where prototyping would have made it clear to the designer. This lends itself to the importance of interaction as this is how users access the design solutions on their problems.

2.3.1

The importance of prototyping can be broken down into five points as follows;

Communication & collaboration. A lot of concepts can be developed from specification documents alone, but a true perception of a concept comes from imaginative collaboration when teams can play with a prototype and explore its limitations and possibilities. When discussing specifications through documentation and face on communications or even sketching, concepts can be misinterpreted, but the experience of using a prototype can be invaluable and self-explanatory.

Gauge feasibility while reducing waste. Portfolio work, sketches and specification documents only live on paper and not as physical models. Creating prototypes allows teams to experiment, giving them freedom ensuring the cost of failure at this stage is cheaper compared to product failing after being launched. Adding prototypes to the design process can increase estimate accuracy by 50% while reducing requests for clarification by 80% (Todd Zaki Warfel,2009).

Sell your idea. Physical prototypes are exceptional processes to pitch and idea especially if clients are skeptical on the concept. Using a prototype can aid a designer to fully explain the concept at hand to the clients and prove the vision of the idea, which is more powerful than wordy descriptions or drawings.

Test usability earlier. By creating prototypes early on a user can spot any potential drawbacks or any problems in the design in the early stages of the project. This saves a lot of time dealing with the problems in the preliminary stages compared to rectifying problems when the product has been mass manufactured and so to the consumer.

Set your design priorities. Also, early prototyping will aid the designer to prioritise the design aspects to ensure the fulfillment of the concept. Certain parts or outputs of the design can be measured at this early stage for best performance to see whether the prototypes live up to the specification original stated and does the spec need changing because of the performance of the prototype.

To accomplish the above five points, the prototype does not need to be elaborate or contain every single final part need for a final assembly. A simple low investment prototype is all that is needed to prove a concept or a specific moving part for example. Which is why it is important to understand the benefits of prototyping, and resources should be devoted towards it in many a design project with specific attention to the number of resources needed depending on the needs of the design itself being basic or complex.

Prototyping can add balance to a design process. It is the phase in which conceptual ideas become reality, thus requiring creativity with practicality, rationale with intuition.

2.3.1

Philip van Allen, Professor, and designer at the Art Centre College of Design, Pasadena, United States, believes that prototypes help decision making, that cannot be described by parameters. From this statement, three advantages to the design can be listed;

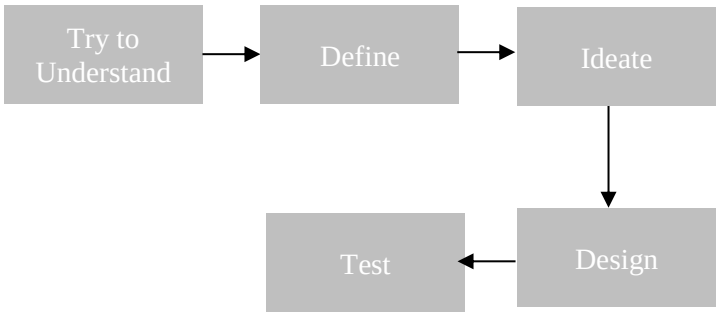
Decision Making. Crucial design choices within the product can all be derived from a prototype, this includes ergonomics, shape, function or production all at once. A working prototype can give feedback to a designer instantly during testing which allows them to make an educated decision with a reader potential for the correctness of the decision.

Focus. With firm feedback for all senses, prototypes will help the designer immerse themselves into the user's environment which helps to understand the users' needs better. As discussed in user-centered design within design thinking championed by IDEO's Tim Brown, human-centered design is essential to generate the most relevant and breakthrough innovations and coupling this with the extensive use of prototyping will ensure the designer achieves a more successful design.

Parallelism. Many a designer will go through the design processes sequentially. But for better efficiency gathering feedback, setting requirements and brainstorming new ideas with interactions can all happen at the same time during prototyping and if done correctly will complement each other.

Where design and development diverge and converge.

Prototyping is the phase in which creativity and feasibility are merged and is an essential part of any design process. The first prototype version of the product is produced, and features are either highlighted for performance or disregarded and developed further and thereafter the product comes to life. This typical process is shown below;



Being such a transformational step in the etc. design process there are a lot of different styles, methods, and processes to do it. To choose the correct styles and methods of your project it will be governed by the user-specific needs that will be appropriate for the project at hand. To understand how prototyping should fit into a design process compared to sketching and mock-ups certain points need to be discussed as follows;

2.3.1 When to start prototyping: 3 points of Convergence.

There is no definite time to start prototyping nor is there an obvious “light bulb” moment where the designer must begin to prototype. But when the time for prototyping does come there are various methods that can be introduced to at various levels the to begin analysis the performance of a concept. The traditional linear process found resembled this order;

Sketching. The first stages where designs are drawn up quickly and sporadically with no real process or thoroughness. Here initial concepts are thought of quickly and recorded through quick images on what the product might resemble or even how it will work i.e. mechanism or even the end goal to aid designers to contextualise the concept.

Wireframing. Depending on the product to be designed in question, but creating a simple framed product using basic materials can help the design get a sense of scale for the product and its interaction with the user.

Mockups. Developing further from wireframing, mockups add greater detail to the basic model such as colour, photos, typography, and other visual elements.

Prototyping. After the addition of visual aspects, prototyping adds certain interactive traits to the model, such as technology, the output from the model and a greater sense of feel for a user to truly use the product for its intended use.

Development. After analysing the performance of the prototype with the various users, further, development can be made for incremental changes or bigger improvements to bring the product or service to market.

But with the popularisation of rapid prototyping, the sequential method above is quickly being outdated and newer variations are being adopted which will now be discussed.

Rapid prototyping is structured to not be a separate process form prototyping but somewhat a more filtered process for greater efficiency. The “rapid” connect of this system is quickly revise any feedback gathered from initial prototypes and to continue to create multiple prototyping approaches based on etc. requirements. A rapid prototype is not designed to develop into a fully functional solution but mainly to aid the design team to visualise and craft the final product

2.3.1

Rapid prototyping can be broken down into the following steps:

- Scope the prototype. The designer should figure out what exactly to build. Any variations of functionalities or interactions, or changes to workflows including design will warrant prototyping.

- Craft personas & user scenarios. Once one is aware of the area for prototyping, the who, why and how also needs to be known.

- Iterate & gather feedback. One should start with breadth and then move onto depth. Beginning with possibly paper-based models, a designer should create a breadth of models iterate ideas and gather as much feedback to develop further. After the feedback is gathered then less breath and more detailed models can be developed.

- Repeat. A designer must repeat this process until the final concept is created and polished reducing any potential problems that might arise after implementing the product into the market.

Now, after stating the processes within prototyping further discussion will continue with the physical characteristics of prototypes. It can be said that prototypes can be analysed on four qualities, representation, precision, interactively and evolution. Each of these qualities vary for each method but can offer invaluable insights which can be helpful for the designer.

- Representation. The actual physical form of the prototype whether paper model or the materials.

- Precision. This includes the level of detail and realism of the model. This could include a very rough sketch or a highly machined real product closely replicating what the final product could resemble.

- Interactivity. How much a user can interact with the prototype, ranging from only a visible presentation or complete interactivity open to all the user's senses?

- Evolution. This part measures the lifecycle of a prototype, whether it has been designed to be quickly built and then thrown away (as with rapid prototyping), or whether further models will be built until the final product is agreed on.

2.3.1

Even though there are multiple levels and methods for prototyping, they all derive from a lot of common ground. Taking from what has already been discussed, ten principles can be stated that will aid a designer which covers all methods used;

1. **Know your audience and your goals.**

knowing who and why a designer is designing for will keep them on track an aid their decision making. What could work well for a brainstorming session within a team might not work well for the end user. As Todd Zari Warfel states, *"Prototyping accuracy is a sliding scale. Don't be concerned with hi-level or lo-level fidelity. The level of accuracy that matters is whatever is needed to help you accomplish you goal with the audience for your prototype"* (Todd Zari Warfel, 2009).

Low accuracy / detailed prototypes can help with presenting a concept in the earlier stages of design to ensure the context is correct. On the other hand, higher accuracy prototypes can be easier to understand for non-designers as they resemble the final product. Possibly a paper design model would be relevant to a senior executive who just needs to get a quick grasp of the product, or a higher accuracy functional prototype to share and collaborate on. This cannot be determined until the team is addressed on what would be most effective in getting the concept across to all the team.

2. **Prime Your Audience Beforehand.**

For designers who have been designing the prototype for a long period of time, it may seem strange to them that users don't know the finer details of the model. It is important to remind one's self that not everything is obvious, as it is likely the designer will have to explain the key features to the stakeholders or outside users.

As a designer prototypes, one should periodically review their work as if it was the first time they're seeing it, to give the best instructions to new users. Setting the context is key to a successful design presentation. Explaining the key features of the prototype, the desired business impact, and any further features still to be completed or trialed. If users can predict what they are going to see, they will act more productively.

3. **Involve the Users.**

Participatory design will build users input into the design process. This can be one in various ways such as including usability tests, brainstorming sessions or paper prototyping exercises. The concept is that a user can offer insights into how to improve a design that possible the design wouldn't have come across or thought of on their own. A great misconception of participatory design, is that a designer must reduce control of the project to inexperienced amateurs. Instead, participatory design is based on more of an observant collaboration through involving users during the ideation ad development process, a designer will naturally see what features are important and where the problems lie. This is different compared to usability testing as one is involving the user in the initial stages of ideation and concepts not specifically used for validation. The consequence of this is a product of one side or the other, but both.

2.3.1

4. **Focus on Flows and User Scenarios.**

Prototypes necessarily don't need to be a highly polished pretty model, but they need to work. Regardless of the detail, prototypes must include a good degree of functionality and interactivity. This is not always easy as especially when a design works hour after hour ensuring the detail of the model is correct. Therefore, ensuring user personas and user storyboards at the initial stages of the design process are crucial to help focus the designer on the journey and end goal not just the steps.

5. **Keep Interactivity simple.**

Related to the previous point of simplifying flow. The prototype should be interactive but not to the extent where a user must navigate or use multiple buttons or interfaces to complete and action. i.e. for example, the 3-click rule for web designing. David Hamill stated, "It was once believed that a web page should not be more than 3 clicks away from any other page on that site" (David Hamill, 2015). This statement lends itself to the product being interactively intuitive, the user made still need to a use a plethora of navigation tools of buttons, but if one knows how to navigate with minimal guidance then the prototype is successfully doing its job.

6. **Don't neglect effects.**

Certain effects within a prototype can be put off the end of the design process, but they must not be forgotten. Certain effects serve a vital role in the final representation of the product but might not be crucial in the early stages of ideation such as paper models or sketching. A designer's knowledge where and how the effects of the product will be implemented at whatever stage, will contribute to the designers understanding of the user's experience. The effects will have to be developed seriously at a stage, especially sooner when developing highly detailed prototypes, which is important for a designer to keep this aspect in mind during the entire design process.

7. **Sketching: Prototype for the Prototype**

A sketch can be a very simple outline of a prototype. A traditional design process follows a similar path like so; sketching, wireframing, mockups, prototypes and then development, but this often various based on the project needs, resources and limitations. Regardless of the method used, though starting with a rough sketch is a rapid and inexpensive way to help the designer drag ice their thoughts and turn a vision into an idea the onto something more concrete.

8. **Don't let a lack of skill hold you back.**

If a designer isn't proficient in a certain aspect in the functionality of a part of the prototype, one should not worry. There are other options possible to substitute that component the designer is unsure on such as paper prototyping, or even nonphysical representations such as presentations of a graphic based render representation. Furthermore, a designer can continue with less detailed prototypes to ensure the context is covered for users, until further assistance in greater detail can be facilitated to prove the concept to the end user.

2.3.1

9. Use Prototypes for Usability Tests.

As previously mentioned, testing a prototype allows a designer to find and gauge any problems early and record critical feedback to be addressed before progressing the product to market. A rapid prototyping strategy handles testing usability well. A basic prototype can be built quickly, tested and then scrapped if needed and then amendments are added to the next iteration of the concept.

10. Prototype only what is needed -Then stop.

Prototyping is a means to an end, not the actual end itself. A designer can easily try to create the perfect prototype and incrementally improve it constantly to create the perfect model, but this only postpones the development of the final product. While rushing the prototyping phase is in-efficient designing, iterating and refining should come naturally, a designer also does not want to hold onto the prototype too long. Some minor problems can be resolved during the development stages, thus designers should only prototype concepts to resolve the serious concerns.

2.3.2 Product Development Workflows

New product development by DFM (Design for manufacturing) and rapid prototyping (RP).

Along with prototyping to add further context to the research against question 2, How can prototyping capacity be increased? A common method that could be adopted to further structure the prototyping process. This could be moulded from the nature of the business and its business model.

As the business's business model is based around manufacturing, further research into designing for manufacturing through prototyping and processes will be highlighted and discussed.

In any manufacturing process, the design is the initial step where most of the decisions will be made while will inevitably affect the final cost of the product. The following discussion will provide analysis into the design for manufacturing through an example.

Production basis begins with a strong need for a product, which can be identified by customers or internally through market research. Through this process, the product will be subjected to two major processes from the initial conceptualisation to the finished part. These processes are the design process and the manufacturing process. Within the production process, these two key stages are important and, therefore the relationship between them always is of principal importance to any product designer. A DFMA (Design for Manufacturing and Assembly) process improves design effectiveness and integration is facilitated when:

- Fewer active parts are used through simplification, standardisation and group work to find information related to existing products or preferred processes.
- Overall manufacturability is increased as greater emphasis has been put into the manufacturing process of the finished part.
- Various design alternatives are evaluated, and design tools are used to develop a thoroughly validated design before released into manufacture.
- As the manufacturing processes are designed alongside the design of the product, a clear structure can be highlighted for balanced product quality and design effort and product robustness.

To obtain a high-quality product, prototyping plays a crucial role in any design practice and allows for the rapid creation and evaluation of a product concept. A prototype part is then tested under a certain criteria specification for approximate performance indicators. After testing, information is gathered and evaluated to account for possible variability in the tests, which is ultimately used to amend any detailed information about the part so further development decision can be made with greater confidence and reduce risk.

2.3.2

Cleber Willian Gomes, explained Rapid Prototyping as another tool that adds to CAD/CAM/CAE (Computer-Aided Design, Computer-Aided Manufacturing, Computer-Aided Engineering) facilitates new product development within household appliances, automotive industries, electronics, war, and medical equipment. (Cleber Willian Gomes, 2000). YAN Yonginan, L.I. Shengjie studied Rapid Prototyping and various manufacturing technology and various, techniques, principles, applications and development trends. Selvaraj introduced an approach to design for assembly and manufacturing based on reducing product development time and cost. (Selvaraj, 2009). Martin O'Driscoll discussed the use of DFM processes in industries and explained the approach to implement DFM in a manufacturing environment, (Martin O'Driscoll, 2002).

2.3.2 Design for Manufacture

As CAD/CAM technologies have improved vastly in recent years, DFM has been growing in popularity, (Wankhade Nitesh Prakash, V.G Sridhar, and K.Annamalia, 2014). The basic design process does to a degree of manufacturability into account within the processes, often DFM practices are not followed. It is commonly seen that the interaction between design and production functions is neglected. Recently CAD/CAM has forced a change in this approach as improvements in the product can be cost-effective only through design over an extended period. One would presume that in a CAD/CAM environment the design would need to be perfect from a manufacturing aspect, as computers can accommodate last minutes changes without any difficulty. But what is observed is that designers must now give closer attention to their concepts and drawings from the manufacturability point of view. A designer is expected to design what the available tools and personnel can produce. Designs, therefore, are adapted accordingly to the production and assembly facilities in which the final products will be manufactured. The great power CAD/CAM assistance is doing by providing designers with detailed information/data on the capabilities of existing manufacturing resources. (Vajpayee, s.k, 1995). it can then be said the term DFM emphasises design production interface more significantly in a CAD/CAM environment compared to a non-CIM (Computer Integrated Manufacturing) environment.

The concepts behind DFM are not new, however, its recent popularity within industries as helped propel its implementation further into the use of various software packages and modern techniques. DFM ensures the need, within the functional necessities of the product. Designers must consider the manufacturability of their design. Boothroyd and Dewhurst advised designers to apply DFM methodology. DFM will integrate product design, process planning and production with the outcomes of:

- Easily identifying product concepts that are easier to manufacture.
- Better focus on component-level design for ease of manufacture.
- And ultimately integrating product design with process design to achieve the best results.

DFM includes both productions an assembly of components. In large plants where the assembly is the core activity which is a common theme, DFM generally makes considerations well beyond the ease with which components will attach to also include assembling processes and other end processes functions. Regarding CIM (Computer Integrated Manufacturing), the designer would be expected to have extensive knowledge of manufacturing processes and of the service department’s requirements. Effective communication between marketing, service personnel and manufacturing are essential as well. A designer must be proficient in the cost analysis of raw material and their characteristics including the processes involved to shape and bend the products, machine, assemble and pack them. It's only after these stages that a designer can standardise the parts across all the models within the product range, to reduce any tooling and other fixed costs to get the most efficient design.

2.3.2

To follow DFM designers must follow a set of rules depending on the production process. These rules may vary among the process groups. Typically, guidelines to implement DFM to component design are, (Rajesh Parekh and Vasant Honavar, 2001):

- Minimise part variations.
- Attempt multi-functionality of parts
- Design for ease of fabrication.
- Design with as few parts as possible.
- Design parts for multiple uses.

Rapid Prototyping

In the design analysis stage, enough data on various design alternatives can be uncovered. Thereafter, examining the collected data is used to determine the similarities between the actual design and the initial design objectives and specification, this can be classed as one part of the evaluation process. Members of the engineering team will then perform examinations of the data and recommend suitable changes in the design. The nature of the design process makes it difficult to split engineering and design activities during the analysis and evaluation functions. This is where the main doctors of computer-based design software have its advantages as it will analyse and evaluate design quality based on various criteria depending on the user requirements. Therefore, the traditional method computer-based method in the evaluation stage is prototyping. Further, in the evaluation stage, Rapid Prototyping can be utilised to produce and analyse a new part quickly for further testing and functionality. These systems will electronically subdivide a 3D CAD model into thin horizontal layers and then transform the design, layer by layer, into a solid model replicating a real part. To replicate such accuracy for rapid prototyping powerful microcomputer systems must be used. Starting with the 3D CAD part file itself, the 3D CAD Software will convert the geometrical features into a file format in which the rapid prototype system can understand and decipher (Andre Pravas, 2003). FDM (Fused Depositing Modelling) systems, commonly used within rapid prototyping stages, use STL file formats. The prototypes purpose is to represent the original CAD model to evaluate operational features before continuing into further production.

Tools used for typical prototyping are conventional tooling that would be seen on production machinery. Prototyping parts would be machined from nonferrous metals or plastic. But with recent advancements into plastics and polymers, prototypes can now be injection moulded but with the process creates greater difficulty. Machining tooling for injection molding is complex, time-consuming and from a prototyping point of view very expensive and certain tooling steel and many man-hours would be needed to create the tooling. Furthermore, as markets grow and demand increases, requirements to cut lead-times to market are always prioritised and to do so require quicker prototyping technique.

2.3.2 New Product Development

Within this research stage of product development workflows, alternative product development processes, techniques such as DFMA (Design for manufacturing and Assembly) and rapid prototyping have been described to highlight optimum prototyping design solutions for low cost and good quality to represent functionality and a sense of scale. The first figures below show a generic product development cycle while the second figure shows a new product development cycle where the design for manufacturing and assembly and rapid prototyping techniques are used.

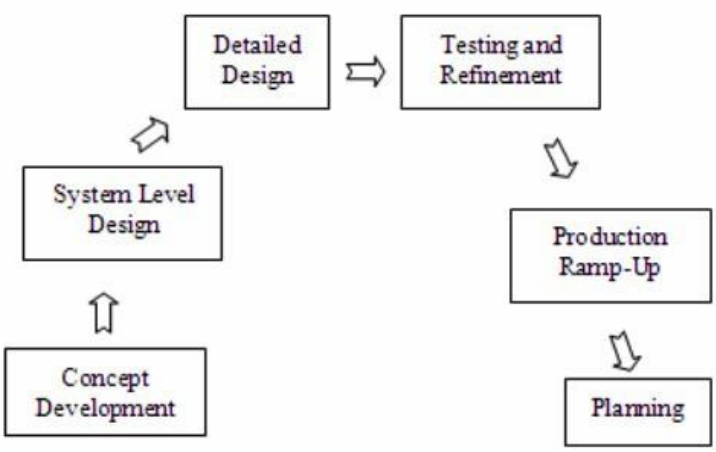


Figure 1.6 Traditional product development cycle.

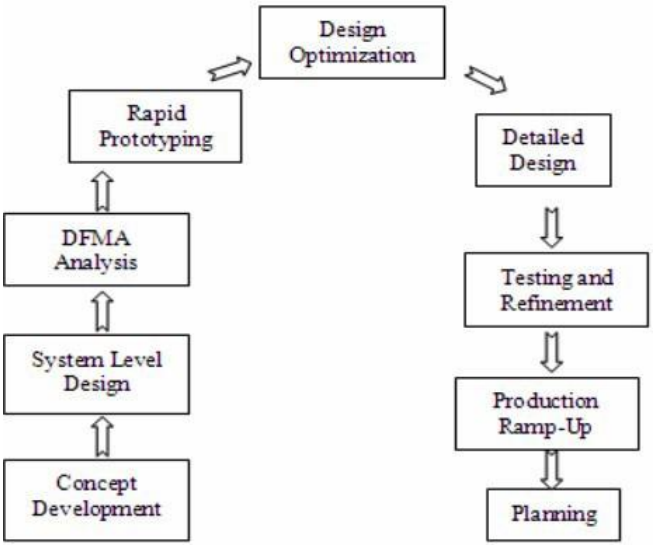


Figure 1.7 DFMA product development cycle.

Images taken from" New Product Development by DFMA and Rapid Prototyping", ARPN Journal of Engineering and Applied Sciences, VOL. 9, NO.3, 2014.

2.3.2 Concept Development

To further explain the process an example will be used to highlight at component level considerations for analysis when designing a ball operated flow control valve which is used in generic hydraulic systems. To ensure the most efficient design with the lowest number of part possible, three concepts of ball valve designs were developed. The first concept is designed in which the entry of the ball is from the center while assembling and thereafter only other components of the ball valve are assembled. In the second design, the entry of the ball is intended to be assembled from the side of the assembly, either from the left or right, while the last concept, the entry of the ball is from the top and all the constituent components are assembled after.

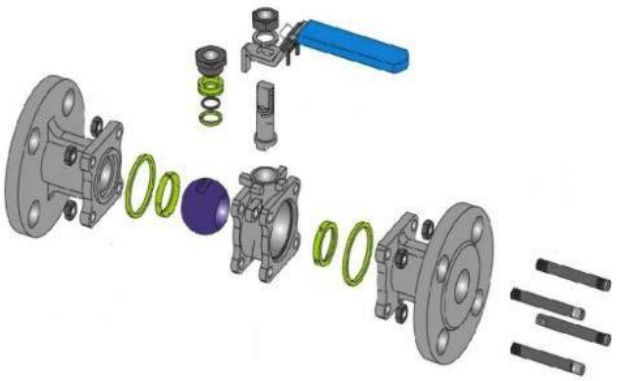


Figure 1.8 Existing flow control valve center entry design with 18 components.

Figure 1.9 DFMA of flow control valve center entry design with 8 components

2.3.2

Figure 1.10 Existing flow control valve side entry design with 18 components.

Figure 1.11 DFMA of flow control valve side entry design with 7 components.

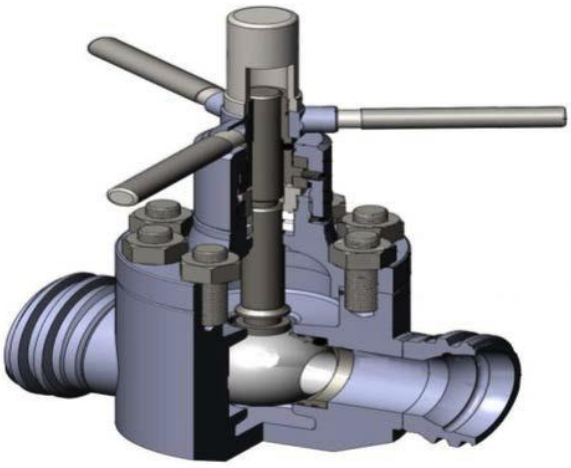


Figure 1.12 Existing flow control valve top entry design with 23 components.

2.3.2

Figure 1.13 DFMA of flow control valve top entry design with 6 components

Concept Selection

From the three concepts above, one concept was selected as it had the least number of component parts. This will relate to the final product having less cost as well as less time to manufacture it. The top entry ball valve was chosen for this example as shown in figure 8 as it only had 6 components.

Design Evaluation and Optimisation

The three designs were optimised with the implementation of the DFMA process (Design for manufacturing and assembly). Invented by Boothroyd and Dewhurst the DFMA concepts follow these specific outlines;

- Reduce the number of parts.
- Eliminate redundant adjustment.
- Test the need for each part.
- Eliminate technical fasteners.
- Multifunctional part design.
- Self-aligning.
- Reduce cost.
- Reduce assembly time.
- Assemble in single linear motion.

2.3.2

To further practice DFMA techniques various quantitive indexing can be used on the assemblies to rate the design of the product to gauge its performance from a design and assembly point of view. The DFA index or assembly is given by the ratio of theoretical minimum assembly time to the actual assembly time. The formula is given by;

DFA Index (E_{ma}) = $N_{min}.t_a / t_{ma}$

Where;

Nmin = Theoretical minim number of parts.
ta = The basic or average assembly time of one part equal to 3 seconds. tea = Estimated time to complete the assembly of the actual product.

Item	Number	Theoretical part count	Assembly time in (s)
Ball	1	1	3
Body	1	1	9
Bonnet	1	1	8
Stem	1	1	5
Bracket	1	0	4
Core Handle	1	0	6
Gland	1	0	5
Seat	2	0	6
Weco 602	2	0	8
Valve Cover	1	0	3

(Kruth JP, Leu M C and Nakagawa T, 1998)

2.3.2

By using the above technique, the number of components will be reduced which are shown in the table below and the DFA index was calculated using the above equation, for the existing design and most efficient design. The assembly time and part counts are shown in table 1 below.

The table below Details of parts and assembly time for existing design;

Item	Number	Theoretical part count	Assembly time in (s)
Stem nut	1	0	5
Key	1	0	3
Handle	3	1	9
Bearing	2	0	9
Filer	2	0	6
O-ring	4	0	8
Hex socket flat	1	0	4
Socket flat	1	0	4
Stud	8	0	16
Heavy hex nut	8	0	24
Total	43	5	145

DFA Index = 5 x 3 / 134 = 10.34%

Table 2 Details of parts and assembly time for modified design.

Item	Number	Theoretical part count	Assembly time in (s)
Casing	1	1	5
Ball	1	1	3
Sleeve	1	1	3
Cover	1	1	9
Stem	1	1	5
Handle	1	1	4
Total	6	6	29

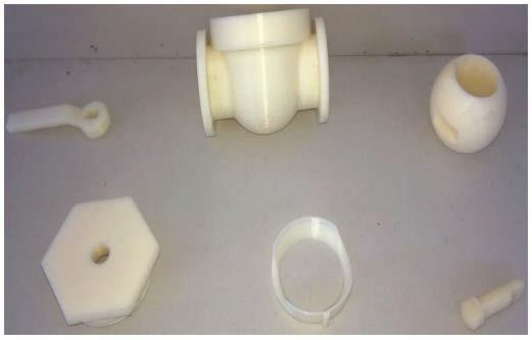
DFA Index = 6 x 3 / 29 = 62.06%

2.3.2 Design Validation

In order to validate a design within rapid prototyping, the above technique is used. In which the most efficient design has the least number of components was manufactured by the rapid prototyping technique. For this specific example, the rapid prototyping method used was fused deposition modeling (FDM) which is a type of additive manufacturing process using ABD (Acrylonitrile Butadiene Styrene) to create to model. Using a uPrint and Uprint SE plus, Figures 9 and 10 shows the product assembly and it constituent parts.

Figure 1.14 DFMA of the flow control valve top entry design manufactured by rapid prototyping.

Figure 1.15 Individual components of the top entry flow control valve manufactured by rapid prototyping.



Results

Through using DFMA (Design for manufacturing and assembly) techniques and the theoretical part count efficiency method as described previously, the number of parts been vastly reduced. The central entry design number of parts was reduced to 8 while for parts entering from the sideways reduced up to 7. The top entry design was selected as the most efficient design because the number of parts was reduced to 6 and the DFA index was 51.72%, increasing for the modified design which is shown in the table below.

2.3.2

Type of Design	No. of Components	
	Existing design	**Modified design**
Centre Entry Design	18	8
Side Entry Design	18	7
Top Entry Design	23	6

To conclude the techniques discussed, the product was re-designed by using the DFMA method and prototype product was developed by using rapid prototyping machines. The ball valve flows control valve itself is taken as an example to design, develop and evaluate the product using DFMA and rapid prototyping techniques. The combination of these both techniques has proven that they are a clever investment with significant observations to ensure the best quality, reduced number of parts, time to market, reliability, safety, lifecycle and customer satisfaction. Additionally, early consideration of manufacturing problems will decrease product development time, minimise the cost and ensure the smooth transition into full production for a better time to market. And finally, these techniques can be used to produce efficient and well thought through designs.

2.3.3 Product Development Technology Advancements

With technology advancing every day, businesses are always on the search for better ways to enhance and streamline their product development process. There have been numerous experimentally driven methodologies for the best concept generation process and manufacturing all to assist product designers. But even with many experimental techniques, there are few structured approaches to prototyping. As prototyping is an essential part of the design process that generates ideas for further realisation, it is important to discuss this subject along with current technological advancements in the sector to give further context to answer question two of this research project. This research will focus on methodologies to enhance prototyping during or with concept development along with current prototyping technologies available today. Also, during further discussion in this point of product development workflows and technological advancements, two structured studies will be used as case studies, one in which the method was employed in a business by various design teams, while the other will be a controlled experimental study that was used to evaluate the method's effect on performance.

The goal for the following research will be to provide generalised methodologies to enhance development, testing, and modeling of prototypes that were drawn from experimental and theory-based analysis as well as further research into best design practice and technology. The following points will outline what the project's research will contribute question two;

- Analysis that will provide a details approach to prototyping choices based on derivations from the best practices of prototyping.
- The formalisation of a methodology that provides a template for deploying the results of these analyses into any given engineering prototyping effort.
- Experimental evaluation of the techniques discussed including the correlation between performance such as effectiveness and efficiency and usage of the method.

2.3.3 Motivation

In the prototyping stage, designers will have concerns for the number of prototypes to be produced, the nature of the prototypes with regards to material, accuracy, and functionality, and the forms of testing which will be applied to the prototypes. In this case, study engineering prototypes will be discussed as supposed to marketing and manufacturing prototypes. An engineering prototype typically developed to analyse the functionality of the design along with layout and interfacing (Camburn 2013). These potential problems predominantly are resolved without using specific methodology, intuitionally by a designer or by the project manager based on cost and schedule or on historical precedent, hence why it is important to adopt a structured approach to design and prototyping. Such a structure methodology will consider basic quantification of key elements to be distributed across time and resources. It will also provide the best-suggested guidance for detailed techniques regarding constructing the prototypes themselves.

It can be said according to Wood, K "the set of choices that dictate the actions that will be taken to accomplish the development of the prototype(s)". It is simply a method for creating a plan for the development of prototypes. It is a consistent and repeatable method that converts design context characteristics (such as available or the uncertainty in modelling accuracy, etc.) into the crucial the decisions made during prototyping, such as the quantity of prototypes to build, whether the product will be to scale or not, functionally accurate or part accurate, or functionally isolated to various components outside the assembly.

For example, looking at the design of a transducer used in acoustic speakers, laptops, and headphones. the basic design of the transducer has been the same for many years, a rigid paper or cloth cone is attached on the outside of a metal frame, with an electrical voice coil wire glued to the center of the cone configured to be concentric to a permanent magnet. Many different concepts that implement this design, however with various cone sizes, angles, and profiles, coil diameters, attachments geometrics, materials and methods. In the center of the speaker cone many different geometrical pieces inside of the voice coil from hemispheres, inverted hemispheres, flat discs, spiral grooved discs, etc. Along with the designs and various assemblies there can be many materials, shapes, and features within the ring attaching the outer edge of the rigid moving cone to the rigid nonmoving speaker frame. However, speaker cones are made through using a stamping process that will change the thickness of the cone once its formed and basic material characteristics. Then by gluing these parts together this will also change their local masses and internal stresses. The outcome of all this is that the transducer natural frequency response and acoustic performance is difficult to analyse until a prototype is made to conduct such testing, complete with tooling for the stamping process or any other manufacturing processes that are needed.

Each unique geometry involves various specific tooling which can be very expensive. While several different materials can be tested for tooling at less expense, they are also fewer differences in dynamic acoustic performance results. Therefore, it can be concluded a key development process question in transducer design is to decide the number of geometries of prototypes needed as a part of selecting a concept before continuing the later/final design phases to create the final last concept.

2.3.3 Related Work

Each year the top global innovative businesses will average 141.8 billion dollars in product research and development costs. Of that money, estimations have been made that 40-46% is spent on stricken off products or those that will not provide the desired revenue as first thought (Cooper, R.G, 1993). In order to increase sales, companies will often focus on project management type logistics such as lead times, budgets and so on. Although focusing on these management aspects this does not correlate towards increasing the output of good prototypes. It was found that the literature exists in two areas, within management science and the engineering literature.

In-depth books such as e.g., by Thomke or Schrage, have suggested minimal, though very useful strategies, as for example the "purse parallel development prototypes" or "iterate prototypes, instead of initially including all features" (Thmoke, 2003, Schrage, 2000). On further research, there are several resources regarding the detailed implantation of various prototyping precise and methods developed specifically for certain prototyping technologies. Yet many of the prototyping literature is, as mentioned mostly focused on logistical management, cost, functionality and ultimately time. (Clark K, 1991, Moe R 2000).

Dahan and Mendelson found that sequential concepts are successful in cost-constrained environments, while parallel designs succeed in more time-constrained environments. (Dahan.E & Mendelson.H, 1998). Thomke and Bell have added that further savings can be made by focusing on less accurate prototypes. (Thomke .S.H & Bell.D , 2001). Furthermore, in-depth, studies over a forty-year period of prototyping these observations can be said: (Thomke .S.H & Bell.D, 2001),

- Ensure that the prototypes are developed to meet the minimum design requirements.
- The goal of the prototype must be ventured to prove the final product is viable in its final market place.
- Prototypes are used to determine the unknown quantities; therefore, adding non-critical features should be avoided.
- During the prototyping stage, there should be no concrete decisions made for further production or mass production of the product at hand.
- When the design process has begun, and prototypes are being produced, do not add any further design requirements or performance expectations.

2.3.3

Dahan continued to pursue a method/technique in order to determine the number of prototypes that may be the most efficient to pressure based on an equation for the uncertainty of success at this point in the design process of the prototype and the marginal increase in profit of that prototype. (Dahan.E, 1998).

Within the technical engineering Literature, it was found that engineers would often rely on their experiences and wealth of knowledge when prototyping. A few publications proffer anecdotal stories on the importance of prototyping. (Christensen, C.M, 2003, Dodgson, M, 2005, Verganti, R, 2009). Other engineers would go into detail explaining the importance of rationale (Martin. R, 2009), but not actually reach the level of outlining actual strategies. Respectively, it is possible that successful engineers must have some methodology, this could be in the form of a trade secret, intuitive or ad hoc (based on historical precedent).

Evidence has suggested that prototyping is one of the most crucial aspects of new product creation/development, but there is no apparent work that converts their findings within logistical management studies into and engineering framework. Otto and Wood address prototyping in multiple aspects that cover an array of analytical modeling techniques, physical prototype development processes, and suggestions, and concrete testing strategies to ensure that the physical models meet the intended requirements. The author recognises that while nonphysical modeling is extremely important such as CAD modeling, a designer must migrate eventually into the development and testing of physical prototypes at latter stages of the design process for garter justification of design. (Otto, K.N, Wood K, J., 2001)

Otto and Wood then continue the discussion further by suggesting a basic method for physical prototype design and a resulting case study that implements this method. Their suggestions mention for prototype design procedure, various guidelines for prototyping development and an example template to ensure any other design projects are kept on track for the best design decisions. While the information given in Otto and Woo’s theories are excellent examples of ways to strategies prototyping, the author will not be focusing entirely on their theories. (Otto, K.N, Wood K, J., 2001)

Ulrich and Eppinger, have provided detailed work regarding the benefits of physical versus virtual prototypes and focuses and specific approaches to prototyping. (Ulrich, K.T, Eppinger S.D, 2000). They highlighted general aspects to describe the prototyping process, like the observation that a prototype may be either a physical or a virtual design representation. They discuss further by stipulating that the model that is cost-effective should be generally pursued.

2.3.3

Yang also discusses further that prototypes that comprise fewer parts are correlated to more successful designs. (Yang, Maria C, 2005). Psychological studies on the effects of prototyping have shown that several aspects of a design process are enhanced and accurate because of prototyping, (Franck, C., Rosen, D, 2000);

- Failure of the prototype can be deemed as an opportunity for learning.
- Prototyping can be aid the feeling of development and foster progress.
- And successful prototypes will harvest greater confidence within the designers and strengthen their creative beliefs.

For this research, these studies are very informative yet to the point on management aspects and prototyping which will bring the readers onto further points in the dissertation. Based on the review of the literature on prototyping, it can be said there is a distinct need for broader and more specific methods to strategies and approach to prototyping.

A study from Moe, et. al. is a possible exception to this (Moe, R., Jensen, D., Wood, 2004), in Moe's work, three prototyping decisions are considered. These include:

- How many concepts to prototype in parallel.
- How many versions should there be in the prototyping plan for each of these concepts?
- Should there be an allowance for any alterations of the prototyping plan midway through the process?

This work by Moe, suggests that answers to the above points should be made based on the rigidity of costs, schedule, and performance expected for that specific design. But while Moe's work is constructive it only deals with these three questions highlighted.

Christie et al. have developed a number of heuristics, or various decision variables that could be considered in the development of a prototyping strategy, (Moe,R.,Jensen,D.,Wood, 2004, Christie, E,2012), which included whether prototypes are scaled, built internally to the business, outsourced or rapid prototyped. Although Christie et al. do not claim to provide a full list of prototyping decisions it gives a strong starting base to consider.

The second set of heuristics, which highlighted the best practices, was that of developed by Viswanathan (2009). Their experiment involved data collected over there semesters of graduates on a design course. These students intriguingly study design techniques and methodologies from Otto and Wood (Otto, K.N, Wood K, J., 2001), and apply to their design projects with a wide verity of backgrounds driven by corporate-sponsored projects to those based on issues common in the developing world. These teams of designers begin by evaluating the customer needs and continue through the design process up to the p point of developing and building a functional prototype. A testing strategy was used, and the data gathered was classified into general codes. The results included heuristics such as "support budding and analytical calculations" and use of standardised parts".

2.3.3 Synthesising the prettying design connect variables.

After examining the information from Moe, Christie, and Viswanathan a synthesised list of variables can be developed for a prototyping strategy, or a list of the minority of applicable choices a designer might face when developing there. The list shown is formed by extracting the decision variables embedded in the heuristics. For example, a heuristic "build a scaled prototype" becomes the decision to "build a scaled prototype or an exact size prototype". Additionally, the list not only represents the extracted decisions, but it also is the union of both sets with the added hierarchy to the decisions. In the end, each element has been re-phrased to be more general. They have also been reduced from specific ideas such as "avoid complicated machining" to general elements in a more hierarchical decision list such as "ad hoc or precise manufacture", which is under the embodiment category.

For the purpose of this research and specifically this research question two these are the chosen five heuristics (or dependent prototyping strategy variables):

- The number of design concepts.
- The number of iterations of each concept.
- Scaling.
- Subsystem isolation or design of an integrated system.
- Relaxation or rigid application of design requirements.

The above five points were chosen as a foundation to be developed for the prototyping strategy methodology. Used effectively, six independent design context variables can be derived;

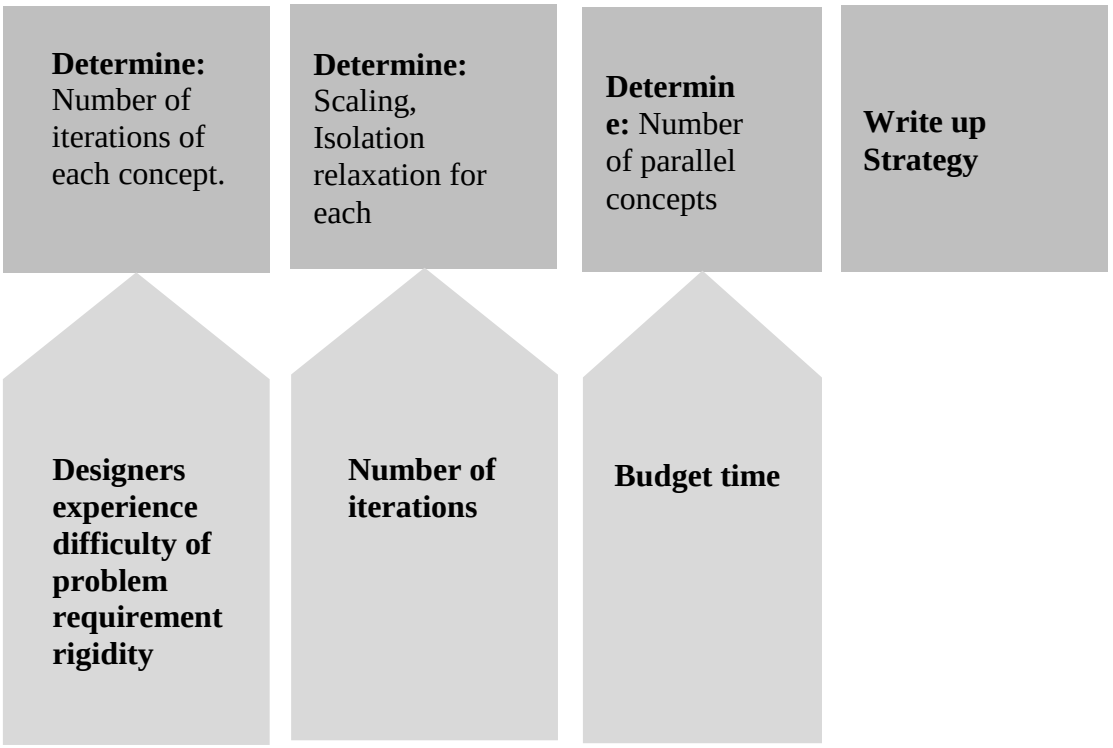
- Budget.
- Time.
- The difficulty of meeting the design requirements.
- Interactivity
- Designer's experience
- The rigidity of design requirements.

2.3.3

Table 1: Hierarchical List of all Decisions for a Broad Prototyping Strategy.

Scale	Scaled or actual boundary conditions / parameters	
	Scaled or actual function	
	Scaled or actual geometry (dimensions, shape, tolerances)	
Integration	Physical Integration or segmentation / subsystem isolation	
	Functional integration or segmentation	
Logistics	Allocations	Rigid or flexible scheduling
		Rigid or flexible budgeting
	Make	Number of design concepts (in parallel)
		Number of iterations of each concept
Embodiment	COTS (Commercial Off- the-shelf) or custom parts	
	Material	Actual or easy to manufacture
	Method	Ad Hoc or precise (formal or systematic)
	Virtual of Physical	
	Outsourced or in-house	
Evaluation	Relaxed or stringent parametric design requirements	
	Exploration or verification	
	Testing	Dynamic or static
		Run conditions or failure conditions.
		Multiple test conditions or single condition.
		Continuous or discreet variation or parameters.

2.3.3



Furthermore, along with the researched prototyping structures as outlined in the previous point within chapter 2, further research will now be a focus on the technology itself. By first outlining the most useful methods and techniques to prototypes, outlining the most effective technology to coincide with these methods will give a whole overview that the Company can learn from.

Previously mentioned, Rapid prototyping in simple terms refers to a class of technologies that will automatically construct three dimensional models from CAD (Computer-aided design) data or can be described as a group of techniques utilised to quickly mock up a scale model of a physical part or an entire assembly depending on the complexity of the product, using three dimensional computer-aided design (CAD) data. Also known as "Three-dimensional printers", allow designers to rapidly create tangible prototypes of their one design rather than basic two-dimensional drawings, and because of the rapid creation and tangibility, they have many uses. Most important of which they make excellent visual aids to communicate a concept with fellow colleagues or even customers apart from design testing. For example, an aerospace engineer might mount a model airfoil in a wind testing tunnel to measure the amount of lift and drag generated on the wing through force. It is a common concept and goal through engineering to "Improve the Quality of Life" of mankind without any restrictions.

2.3.3

To create this much-needed change, engineers are required to work on challenges that face them today and to do so will involve great collaboration. India has ample opportunities and various challenges and massive advances made by us in science and technology are constantly transforming by the frantic pace of market dynamics and customer demand. What is needed is “Change leader” to harvest innovation, growth and manifest a totally new culture of design. Rapid Prototyping is one such method of technology that is perfectly designed for products within dynamic markets.

Prototyping techniques can also be used to make tooling referred to as rapid tooling and furthermore into final quality parts i.e. (rapid manufacturing). Good designers have always use prototypes to strengthen their concepts along with rapid prototyping also allows them to be made faster and less expensive.

For smaller production runs and complex parts, rapid prototyping can often be the best manufacturing process available because of this flexible 3D process. “Rapid” being the relative term, most prototypes require from three to seventy-two hours to build the art or assembly depending on the size and complexity of the product. It might seem slow but in the grand scheme of things t is much faster than the weeks, months even years required to make prototypes by traditional methods such as machining tooling for pressed parts. This dramatic time-saving method allows the manufacturing of the product to be brought to market much quicker and effectively cheaper. In 1994, Pratt and Whitney achieve an order of cost reduction and time-saving of roughly 70 to 90 percent by introducing rapid prototyping into their investment casting process.

In essence “Rapid prototyping” is an additive process i.e. combining layers of paper, wax or plastic enough to create a solid object as suppose to (milling, drilling, turning and grinding, etc.) are methods called “subtractive Processes” as they remove material from a solid block / blank or rod. Rapid prototypes' additive nature allows the design used to create complex objects with internal features that cannot be manufactured by other methods due to the nature of the manufacturing process and order in which the shape is created. For specific applications, particular metals, machining will always be useful manufacturing process and hence why rapid prototyping will not replace machining, but rather complement this traditional method instead.

As we have discussed the general purpose of rapid prototyping and its overreaching advantages of traditional machining methods, the author will continue to further research into specific rapid prototyping methods and their distinction between each process. This will aid the reader to further distinguish the best methods for their needs and more so for the company itself.

RP stands for rapid prototyping, which in turn refers to the group of techniques used to quickly fabricate a scaled model of a physical part or assembly using CAD (computer-aided design) software ran by a computer. It is also known as a call of technologies and is defined as a diverse set of technological tools and resources that construct three-dimensional models from computer-aided design raw data. There are at least six different rapid prototyping methods commonly available, each with their own individual’s

2.3.3

advantages. Rapid prototyping is being increasingly used in prototyping applications; these methods are often referring to as;

solid free-form fabrication, computer-automated manufacturing as layered manufacturing. Layered manufacturing explains the process used by all manufacturing commercial techniques.

The CAD (computer-aided design) software used for rapid prototyping will slice the three-dimensional model into 0.1mm thick layers which are then built up one atop another. This is an "Additive Process" compared to machining processes that are "Subtractive Processes" as previously described. The six popular processes can be listed as follows;

- Stereolithography (SLA).
- Laminated Object Manufacture (LOM).
- Selective Laser Sintering (SLS).
- Fused deposition Modelling (FDM).
- Solid Ground Curing (SGC).
- 3D ink Jet Printing.

Description

As to outline the differences between the above rapid prototyping methods, the following processes are breakdowns of the initial, in-between and final stages of rapid prototyping. All rapid prototyping techniques employ the same basic five steps. These steps are as follows broken down:

(A) Basic Process

- Create a CAD (Computer-Aided Design) model of the design.
- Then convert the CAD model into an STL format/file.
- After convert into an STL file, the model is then sliced into thin cross-sectional layers.
- Construct the model one layer atop another.
- Clean and finish model.

(B) CAD Model Creation

As the first step, the concept needs to be built using a computer-aided (CAD) software package. Many software packages are available such as SolidWorks, Autodesk Inventor, PRO/ENGINEER. These will represent 3D models more accurately than the wireframe modelers such as AutoCAD and hence will produce detailed and accurate results. The designer can create a new file expressly for prototyping or may use the existing CAD model file. This process can be the same for all the rapid prototyping techniques.

2.3.3

(C) Conversion to STL Format

With various CAD packages, they use several different algorithms to represent solid objects or extensions. To ensure consistency, the STL (stereolithography, the first rapid prototype technique) format has been adopted as the standard of the rapid prototyping industry. The second stage, therefore, is to convert the CAD file into an STL file. This format is designed to represent a three-dimensional surface as an assembly of planar triangles, like the precise cuts on a jewel. This file contains the coordinates of the vertices and the direction of the outward normal of each triangle. Because STL files use planar elements, they are not able to represent curved surfaces exactly. But by increasing the number of triangles this will improve the approximation of the dimensions, but at the cost of bigger file sizes. Large, complicated files will require a lot more time to process and build, hence the designer must balance manageability and accuracy to produce an efficient STL file. Since the STL format can be universally used, this specific process is identical for all rapid prototyping build techniques.

(D) Slice the STL File

After converting the 3D file into an STL file a pre-processing program/software is needed to prepare the STL file to be built. To do so there are several programs are available, and many would allow the user of the programs to adjust the size, location, and orientation of the model, i.e. if the scale of the model needed to be changed depending on the size of the rapid prototyping machine.

First properties of rapid prototypes vary from one coordinate direction to another. For example, prototypes are usually less accurate and weaker in the Z (vertical) plane than in the x-y plane. Furthermore, the orientation of the part will specifically determine the amount of time it will require to build the 3D model. By placing the shortest dimension in the direction will reduce the number of layers, thereby reducing the build time needed. During the pre-processing stage within the software, slices of the STL file will be made into several layers varying from 0.01mm to 0.7mm thick, depending on the prototyping technique used. Also, the processing program might also generate an external structure to the actual model itself to support the object during the build, this is can be seen for many complex and intricate products. Furthermore, supports are useful for objects with delicate features such as overhangs, internal cavities, and thin-walled pieces. Each rapid prototyping machine manufacturer will supplier its own specific pre-processing software suite.

(D) Layer by Layer Construction

The fourth step involves the actual construction of the parts itself. By using one of many techniques possible which will be further explained in the future points, rapid prototyping machines build the object layer by layer one at a time from either polymers, paper or powdered metal. The majority of prototyping machines is autonomous and will need little human intervention.

2.3.3 (E) Clean and Finish

The final stage of the post processing is to remove any residual material from the prototype and then the prototype itself from the rapid prototyping machine and detaching any supports if necessary. Depending on the prototyping process, some photosensitive materials require full curing before they can be detached from the machine and used. Other post treatments might include sanding, sealing and painting depending on the accuracy of the model and the desired aesthetics and durability of the user.

Rapid Prototyping Techniques

Today they are roughly six common types of rapid prototyping machine used commercially as will be described as follows;

Stereo Lithography

This technology was patented in 1986 and essentially started the rapid prototyping revolution. The process involves building three-dimensional models from liquid photosensitive polymers that will solidify when exposed to ultraviolet light. As shown in the figure below the model to be created is built upon a platform situated below the surface in a vat of liquid epoxy or aryl ate resin. Then a low powered highly focused ultra violet laser traces out the initial layer, then solidifying the models cross selection while leaving excess liquid in some areas when the UV was not intentionally focused.

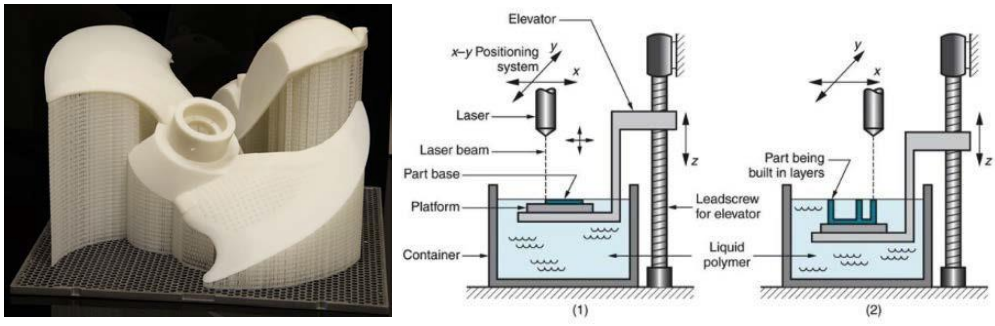


Figure 1.16: Schematic diagram of a Stereo Lithography process.

After the initial process of defining the first layer, a hoist slowly lowers the platform into the liquid polymer and as the object gets lowered slowly into the liquid the laser / UV Light beam traces the second layer atop the first. This process of tracing atop each layer continues until the desired object is complete. After the object is completed it is removed from the liquid vat and rinsed thoroughly clean of any excess liquid or semi solidified polymers. Furthermore, supports are then broken off, again depending on the complexity of the object. Then the object is placed into an ultraviolet oven to complete the curing process and completely solidify the part or assembly.

2.3.3

Stereolithography machines have been made since 1988 by 3D systems of Valencia C.A.

3D Systems is a well-known industry manufacturer of rapid prototyping machines as they developed the first technique of stereolithography and is regarded as a benchmark by which other technologies are judged against. Early stereolithography prototypes were prone to be very brittle and could distort during the curing process, but recent modifications have developed the technology much further correct these issues.

Laminated Object Manufacturing

Laminated object manufacturing (LOM) is a method of 3D rapid prototyping or as more commonly known as 3D printing. It was initially developed by Helisys Inc now known as Cubic Technologies. During this process, different layers of either paper or plastic are fused/laminated together by using heat and pressure, and then simply cut into the desired dimensions and shape with computer-controlled laser or blade or cutting head. LOM (Laminated object manufacturing) is not regarded as the most popular method of rapid prototyping but it is still one of the fastest and affordable ways to manufacture three-dimensional prototypes.

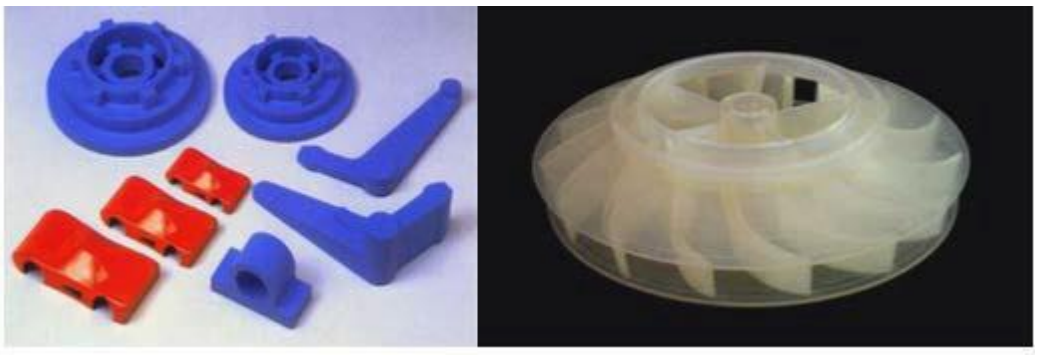


Figure 1.17: Laminated Object Manufacturing (LOM): Turbine blade created from sheets of PVC plastic patterns for molds.

Selective Laser Sintering

This process is designed to build three-dimensional parts by using a laser to specifically sinter (heat and fuse) powered material into any given form. As described previously the process begins with a three dimensional CAD file which has been mathematically sliced by the pros processing software into numerous two-dimensional cross-sections. The object to be manufactured is then built up layer by layer until it is complete. It can be created from a range of different materials ranging from plastics to metal in powdered form or even carbon fiber in recent years to enhance its physical properties. SLS (selective laser sintering) prototypes material properties can be similar to traditional machining manufacturing methods. While this technology production began to produce early concepts, non-accurate prototypes in the initial stages of design processes, it is now being utilised to manufacture end-use parts because of its accuracy and range of materials possible. It has application in ECS (environmental control systems) ducting 7 plenums, final production parts without tooling, file tanks, control surfaces, and flight control systems to mention a few.

2.3.3

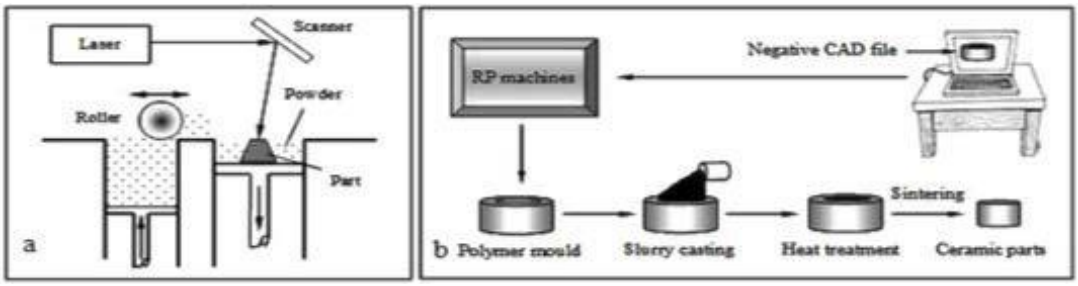


Figure 1.18: Selective Laser Sintering

Fused deposition modeling (FDM).

In this process, certain filaments of heated thermoplastic are extruded from a base that moves in the X and Y plane. Similar to a baker decorating a cake, the controlled extrusion will deposit material thinly from the head of the extruder onto the base/platform to form the first layer of the object. The platform is maintained at a lower temperature to the head of the extruding to ensure the etc. base of the object cools and stick to the base when moving in the X and Y plane. As the process continues to create the object the extruding head will deposit layer by layer the desired material on the previous layer also while adding supports to the object if applicable. FDM machine such as Stratus's makes a variety of FDM machines ranging from fast concept modelers to slower higher profession-based machines. Materials that can be used in the FDM process includes ABS (standard and medical grade), elastomeric (96durometer), polycarbonate, polyphenol sulfone, and investment casting wax.

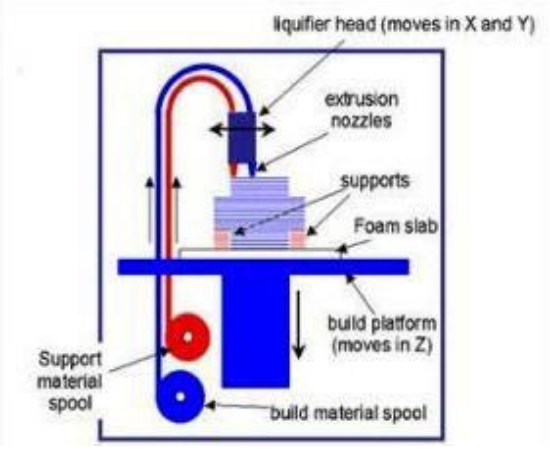


Figure 1.19: Schematic diagram of FDM curing.

Solid Ground Curing.

This process is developed by Cubical, solid ground curing, unlike SLS (Selective Laser Sintering), SGC (solid ground curing) cures an entire layer at a time. The figure below portrays SGC, which is also known as the more solid process. Firstly, the photosensitive resin is scattered on the build base. Thereafter, the machine will develop a photomask similar to the stencil of the layer to be built. Then the photomask is printed on a glass plate above the

2.3.3

construct base using an electrostatic process similar to that used within photocopiers. The photo mask is then susceptible to UV light, which will only pass through the transparent sections of the mask, which in turn will selectively harden the shape of the current layer. After hardening the shape of the current layer and the layer has dried, the machine will vacuum the excess liquid resin and sprays wax in its place to support the model during the build acting as an external supporting exoskeleton. Then to continue with the next layer, the top surface of the previous layer is made flat ready for the next layer. This process will repeat until the object is complete, and after its completion, the model will be Immersed in a solvent bath to de-wax the object realigns the final cleaned part.

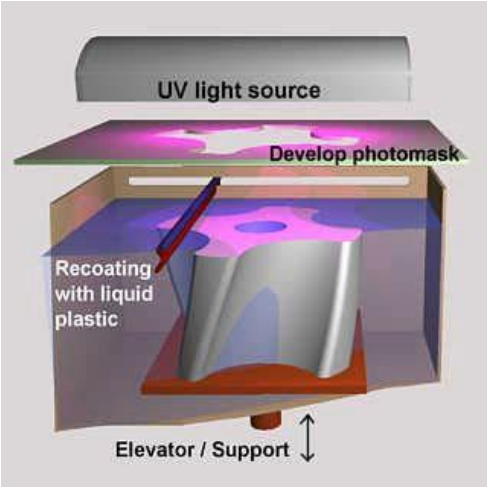


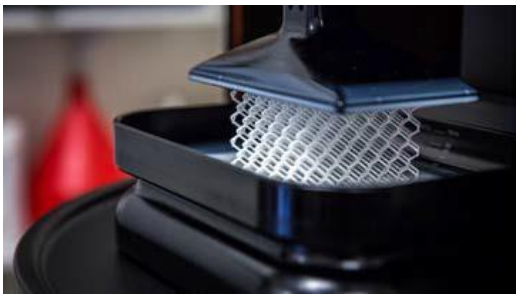
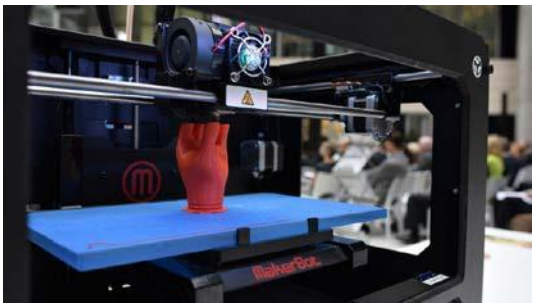
Figure 1.20 of Solid Ground Curing 3D printing process.

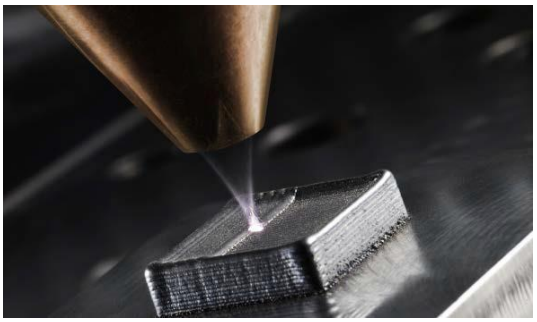
Applications of Rapid Prototyping Technologies

As the possibilities are endless using these various rapid prototyping techniques many models or final products can be manufactured for many fields such as medical, textile, electrical appliances, footwear design, architectural interior design, and furniture design, etc. Rapid Prototyping technologies have the potential to reduce costs through the reduction of manufacturing time needed to move concepts prior to market release roughly 15%-20% (Chua and Leong, 2004). These processes discussed have the ability to enhancing and product development within businesses while reducing costly time factors due to amour breakthrough in manufacturing. Although it can be said that many of these processes create poor surface finishing on the product because of their layer by layer techniques, limited strength and accuracy are the limitations of rapid prototyping models, it can deposit a part of any degree of complexity theoretically. Because of this RP technologies are successfully used by many industries like the automotive, jewelry, aerospace and coin making industries;

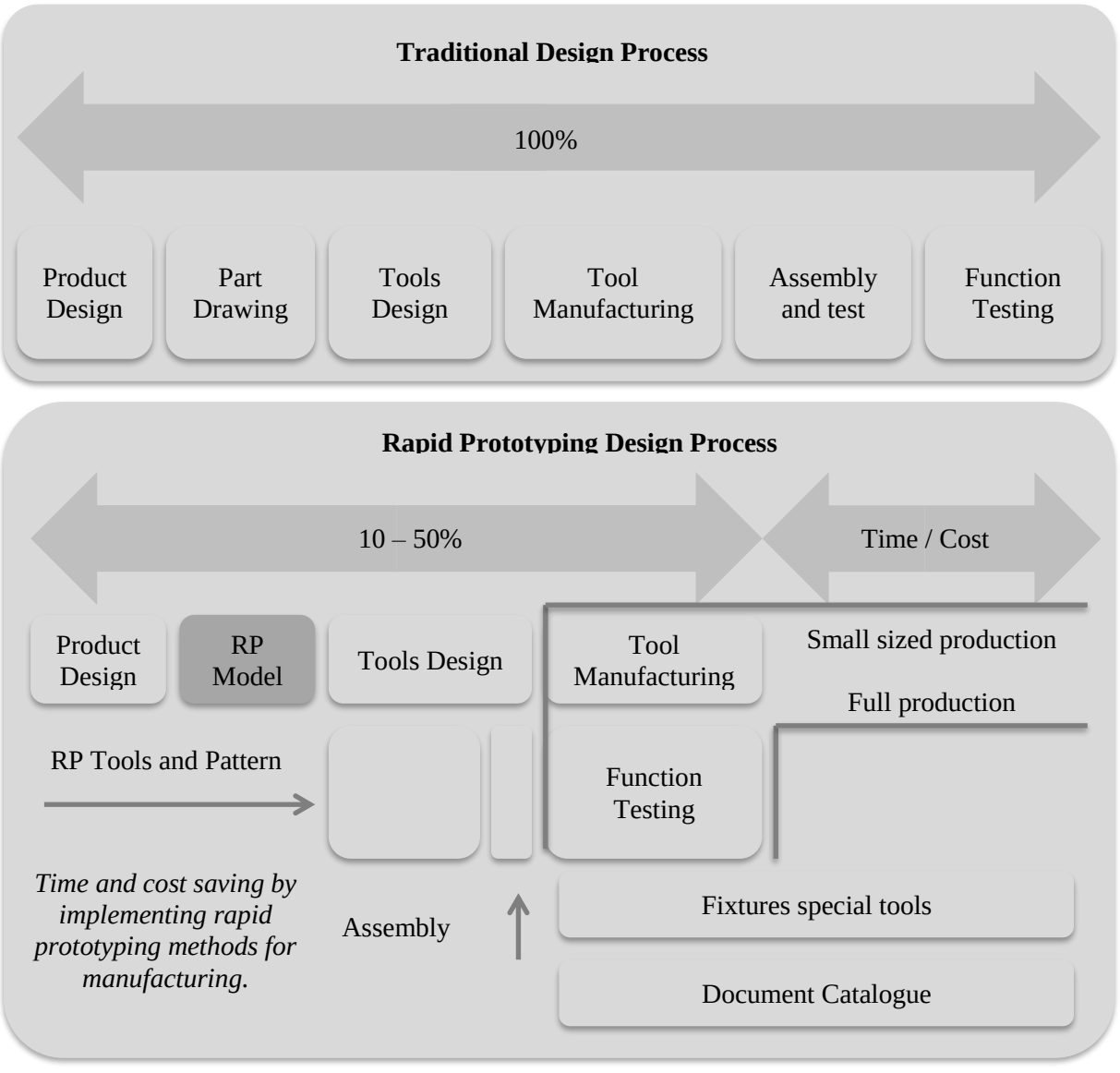
- Design and further development of instruments and medical devices.
- Created a revolution in rapidly creating prosthetics and implantations.
- Creating accurate models to aid planning and explanation of complex surgical operations.
- Development and manufacturing of highlight complex biocompatible and bioactive implants and tissue engineering.
- General concept modeling for various design applications.
- Finite Element Analysis.
- Presentation Models for product justification and feasibility in the user environment.

2.3.3



The time saving and cost cutting advantages of using rapid prototyping process can be summarised in the following diagram:



Time and cost saving by implementing rapid prototyping methods for manufacturing.

2.4 Product Development Structures

2.4.1 Managing Product Development

It can be said that the following are the associated challenges that can be seen with rapid prototyping. The RP models are manufacturing directly from a computer-generated model (CAD) coupled with automated machines. Hence the following points are to be carefully considered for developing a rapid prototyping system;

Develop automatic recognition of appropriate geometric features from the STL file such as minimum wall thickness. Develop rules appropriate to metal components relating to prototyping. Research into which method of delivery would best suit the needs of smaller companies and who would be responsible for its upkeep.

Previously discussed in point 2.3, prototyping is an essential part of the design process. Not only does the rapid prototyping save time but it also saves costs as the final product is quicker to market compared to traditional design processes. But crucially without the correct management structures and steps, rapid prototyping could be miss-aligned within the design process and affectingly slow down the final product to market.

To further research building innovation within a business the following points will discuss methods and theory to further answer question three previously stated in chapter 1 as shown below;

- Are the most recent design thinking theories being used within the company structure?
- How can prototyping capacity be increased?
- Which product development structures can be implemented?

2.4.1 Introduction

Many businesses must manage a range of portfolios of product development (PD) projects that are driven from a common pool of resources the business has. Even if the size of the resource pool is sufficient for the average needs for all the projects, they will always contend for specific resources at particular times, which will cause delays to various projects and portfolios. In some cases, these situations can be foreseen and therefore managed, but the notoriously iterative nature of PD (product development) projects (Kline 1985: Smith and Eppinger 1997a) fraught with unplanned and undiscovered rework (Cooper 1993b) worsened the situation. Furthermore, the novelty and ambiguity of PD projects make it difficult to specify their activity networks, a priori (Pich et al. 2002; Anderson and Joglekar 2005; Levardy and Browing 2009). In the context of this project, PD project managers most often rely on the most accurate projections and resources needed. Hence, it can be said, resource contentions within other product development projects in PD portfolios can be very difficult to predict and overall manage; they can often occur as a surprise that can easily derail projects from their desired plans. Also, managers of their individual projects, who ensure their own projects to be completed on time, and sometimes might find themselves at the odds with the portfolio manager, who intern wants to advance the entire portfolio instead of individual portfolio here and there i.e. what is best for one project may not be best for another or indeed the entire portfolio of projects.

Therefore it can be said that research in this area is important for various reasons. First, most existing research on project portfolios focuses on project selection (and sometimes initial resources allocations), but this does not include the ongoing adjudication of resources contentions. Practicing managers will need guidance on this aspect. Secondly most of the research on resource-constrained (single and multi-project) and scheduling addresses only networks and approaches; it does not clarify the iterative nature of the PD projects, which will call for different managerial approaches. Thirdly, the existing theory does not clarify the differences between the multi-project and single project perspectives (e.g Dilts and Pence 2006), this could also cause tension between project and portfolio managers. Fourth, the reality is that most projects do not actually build detailed activity network models (Liberatore and Titus 1983; Besner and Hobbs 2008), even though these models are essential for applying the methods developed by research to find the most efficient solutions. In product development projects noted for their novelty, ambiguity and complexity-building such networks correctly with foresight are especially problematic. Hence product development projects and portfolio managers are inhibited from applying entire streams of research because of disconnect with practice. Instead, when managers are faced with resource connection situations, many will arbitrate locally with basic and affective decision rule based on activity project attributes such as “which activity has more slack time?” or “which activity is holding up the most other critical activities?’’. However, the effectiveness of these approaches can vary vastly depending on the properties of the project and the portfolio.

2.4.1

But with shorter life cycles and demand for greater product variety, continual pressure is put on NPD (New product development) team to produce a wider and varying portfolio of new concept opportunities and further to manage the risk associated with processing these from initial ideation, to development to eventual launch to market. In simple terms to minimise the most risk of failure, to deal with this potential failure, both effectively and efficiently attention has been focused on systematics, monitoring, screening and various progression frameworks for examples such as Cooper's stage are approach (Cooper, 1988,1994). Many of these ideas can't be classed as new; for example, Lawerence and Lorsch (1967) focused on cross-functional team working and coordinating mechanisms back in the 1960s, and Cooper (1994) reported on NASA's 'phased review process' as a stage-gate process also dating back to the period.

But, despite the importance of new product development, for the present and future generations and businesses, great deals of new products fail when released into the target market. Research (Liberatore & Stylianou, 1995) demonstrated that the majority of the concepts that enter the NPD process fail to grow into commercial successes; it can be said that only fourteen percent (14%) succeed (Owens, J D, and Davies, J (2000). Ultimately because new product development costs are generally high, and their failure rate is also high, businesses generally hesitate to provide further resources associated with NPD projects (Cooper, 1998). On the other side, the other argument can say that there is a growing consensus based on integrating the various tools and techniques available to the designing team specifically designed for 'new model of good practice' such as IDEO's and IBM's design thinking processes outlined at the beginning of this chapter.

Below is a table containing a list of key features of the emerging model;

Subject	Characteristics
A structured process for developing new products.	Using a stage-gate model. Close monitoring / screening & Evaluation at each stage of the processes.
Ensure early involvement of all relevant functions.	Ensure to involve the correct team members and design perspectives early in the process to influence the design, which adds preparation for downstream problems that might arise. With early detection of problems this will lead to less undoing and less reworking.

2.4.1

Overlapping and Parallel Working.	Ensure to plan concurrent and simultaneous engineering to ensure faster development while raining cross-functional involvement across all the departments or individuals relevant to the project.
Applicable project management structures.	Ensure the choice of structure is appropriate to the project e.g. matrix/line/project/heavyweight project management- to suit the conditions and the task at hand.
Cross-Functional Team Working.	By involving various perspectives to the project and using team building approaches to ensure efficient team working which will develop capabilities in flexible problem solving.
Advanced supporting tools.	Ensuring the use of tolls such as CAD (computer aided design), rapid prototyping and computer supported collaboration tools e.g. (Slack) to assist with the quality and speed of developing the product.

The table above, Key features of 'new model of good practice' model in NPD.

Table based on Cooper, 1994; Crawford, 1991; Johne & Snelson, 1988; Lilien & Yoon, 1989; Mahajan & Wind, 1992; Maidique & Zirger, 1985; Rothwell, 1992; Smith & Reinertsen, 1991; Thomas, 1993; Wheelwright & Clark, 1992.}

Therefore, it can be said, if properly managed new products can create a powerful injection in growth into business which cannot usually be matched by existing products already within the market (Griffin, 1997). A result of this is important for business to not adopt the 'Not Invented Here (NIH) syndrome.

2.4.1 Measuring the Success

It can be said that new product success cannot be measured in absolute terms. A product's success should be defined and interpreted according to its realistic goals and objectives that will reflect the specific new product situation.
The studies of new product success (and failure) have been a preoccupation of academic researches for several years. These various studies have used various measures to report back from a great range of industrial and market sectors, hence drawing valid comparisons and thus conclusions are difficult. A result of this is deciding on the common factors that lead to new product success, but it can be argued it is possible to draw two fundamental points from the multiple studies undertaken which include;

- New product success is highly situational.
- No one factor can be clearly defined for new product success.

New product development is highly circumstantial, and a few actions can be taken to assure NPD success. Hence, business developing new products must ensure they carefully analyse their situation and therefore recognise the multiple factors that might determine the successfulness of their NPD.

2.4.1 The Foundation of Success

Identifying the key factors that lead to new product development success is now an extremely topical area of deep discussion for both academics and industrialists. And therefore, questioning what the essentials between success and failure and the reasoning behind these factors are is important, and in some cases vital in order to fully understand the development of new products (Twigg, 1998).

Research by Cooper and Kleinschmidt, (1995b) illustrated in the figure below, highlighted the three key segments of new product development success; Process, Strategy, and Resources.

The following thee critical success factors were found to be the main drivers of new product performance at a business level. This research discussed and considered different performance measures (Cooper & Kleinshmidt, 1995b) and they can be summarised into the following points:

- Having a good product innovation strategy for the business that ties product development to the company strategy, that identifies areas of focus for general product development, that also has a long-time drive, and finally is clearly enunciated to all in the company, is likely to lead the company towards success.

- Relevant and adequate spending and resources is another contributing factor to a company's NPD success, by having the necessary people and research and development spending confirmed.

- And lastly and most importantly is having a high-quality new product process to guide product innovation within the business from idea to launch. And of the three points it is the least appreciated, but inevitably can have the biggest impact on the business's NPD performance.

Figure 1.24. The new product performance triangle and the key elements of performance (Cooper & Kleinschmidt 1995b)

2.4.1

*"There are no defining rules on the contents of a critical list of factors which might aid NPD success, only an integration and balance of best practices and tools which are essential ingredients of the process (*Cooper et al, 1998*).*

Time Management of the NPD Process

What are the best drivers for time efficiency? There are many factors that can be considered which can consist of advantages such as the forming of collaborative teams and having a team working both effectively and efficiently, doing the research beforehand and hence determining what the customer really is after and the quality of execution of the new product process. In a study conducted by Cooper & Kleinshmidt, (1994), ten factors of time efficiency of the new product development process were of high importance and in turn, were found to reduce the overall introduction time of a new concept across various studies undertaken. The drivers with a summarised description are shown in the table below;

Driver.	Description.
Project Organisation	Projects that are organised into cross functioned, dedicated and accountable teams with a strong empowering leader and with senior top management would harvest better time management.
Early, Sharp product definition.	Projects that began with clear and defined focus prior to the development phase can be found to move their concept to the target market quicker.
Up-front homework.	Projects that had thorough and credible research completed before the development process were found to give fewer problems further through the new product development process.
Strong Market Orientation.	Projects that are focused around their target market and customers, budding relationships with the customers while in the development process from start to finish have been found to progress more quickly.
A strong Launch.	Good promotion through good advertisement with product availability are key ways in moving product to the target market quickly.

2.4.1

Technical Proficiency.	The undertaking of the technological / technical activities in quality departments through the development process leads to cycle time reduction.
Synergy	This is the ability to utilise the businesses' in-house technology resources, production and marketing skills to an advantage with regards to improving timelines.
Familiarity	A project that is more familiar to a business in respect to the product type and market idling technology used also means impede timelines.
Market attractiveness	Products that are designed and aimed at popular increasing markets with good economic climates will feature a better cycle time.
Market Competitiveness	Markets that have many competitors, intense and aggressive competitors with easily switchable customers will provoke quicker and dynamic product development.

Figure 1.25 Ten Divers of time efficiency of the NPD process (Cooper & Kleinschmidt, 1994).

Assembling a NPD team

Gathering an effective team and getting them to work efficiently and productively together is essential (Urban et al, 1987). Depending on the experience of the company this may be a simple or complex situation to implement (Olthius, 1997). Certain procedures would need to be introduced to ensure teams participate in vital activities throughout the NPD process. As previously discussed, rapid prototyping, incremental new product development, process modeling, e-mail, group collaboration platforms e.g. (Slack) and video presentations are a few methods that be utilised to enhance both the process and ultimately the product itself. Furthermore, using these tools greatly simplifies the potential challenges of maintaining clear and effective communications within the whole work environment. Therefore, keeping assists in view ensures that the relevant information about the NPD activities is constantly under observation (Bessant & Caffyn, 1997). Also making, effective decisions quickly is crucial to the success of the NPD process. Likewise, it is also important that everybody who is contributing to the process is fully aware of how to make the process swift, accurate decisions or knows hot get them complete. The techniques and how it is adopted within a particular environment is the base for efficient decision making. (Edstrom, 1998). To attempt to ideate a new product with a wealth of talent within a team is inadequately prepared, or ultimately will lack the skills needed to apply the knowledge they possess efficiently and effectively, is an exercise in futility (Cooper, 1999). In summary, the author believes that within an NPD team the following factors need to be true; adaptability, creativity motivation, competitiveness, and initiative.

2.4.1 Developing a NPD process.

The step-by-step process as shown in the figure below is the most basic and traditional rendition of a new product development process. Once each stage has been completed the information gathered is then given onto the next activity in the process. However, the challenge with the traditional approach to NPD is that the information flows sequentially from team to team or department to department and can form a problematic 'over the wall' scenario.

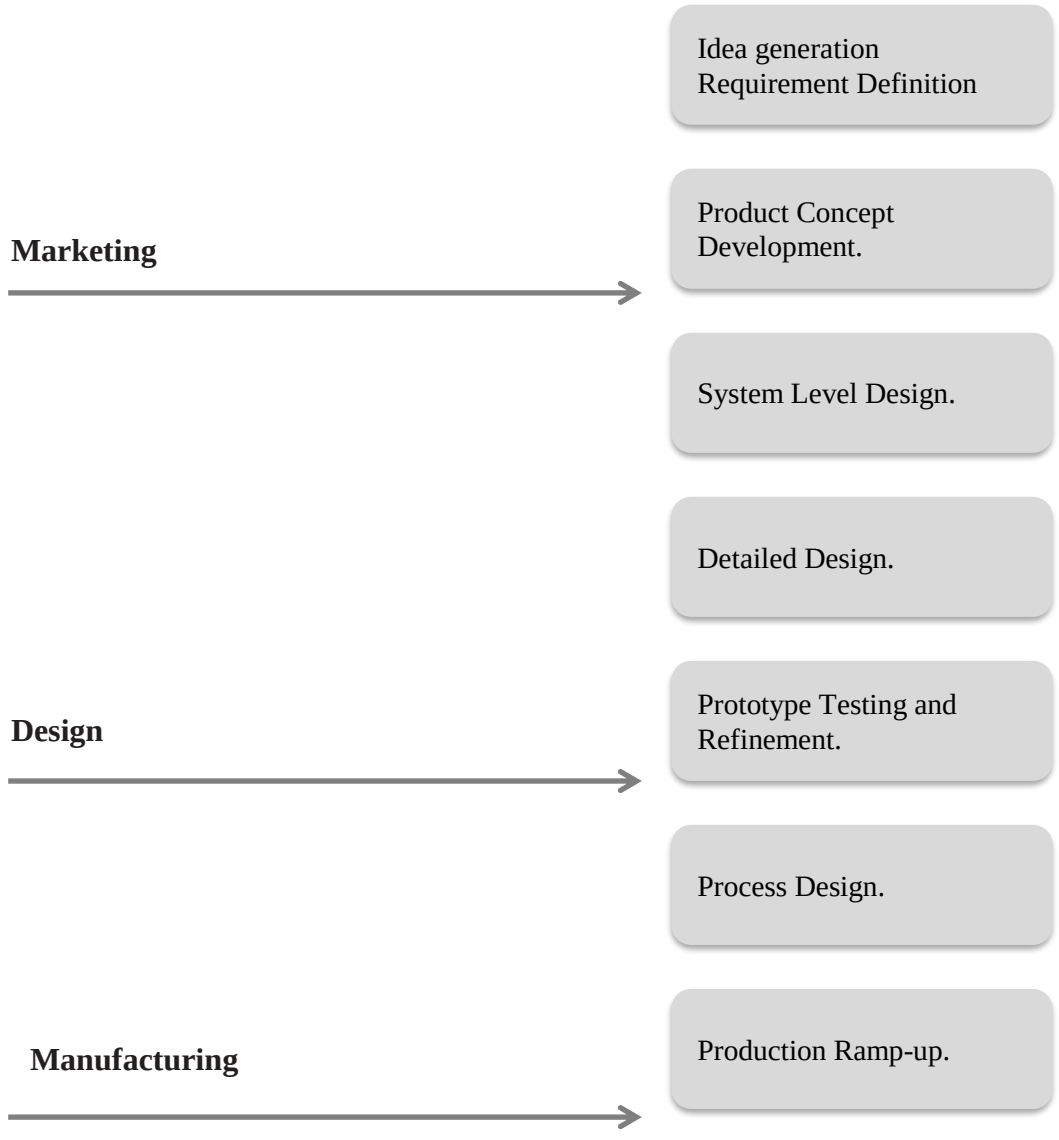


Figure 1.26. Sequential NPD process. (Elrich & Eppinger, 1995; RUSSELL & Taylor, 1995).

2.4.1

This style of scenario as demonstrated in the figure below. This both increases the time from product concept to product launch and effectively increases the number of formally documented engineering changes later in the process. Both these problems will delay the time to break even and the start of making a profit. Also implicit in the term "over the wall" engineering activities will lack the team working and understanding of the department's problems, which can result in poor quality products, over sending and ultimately late results concepts.

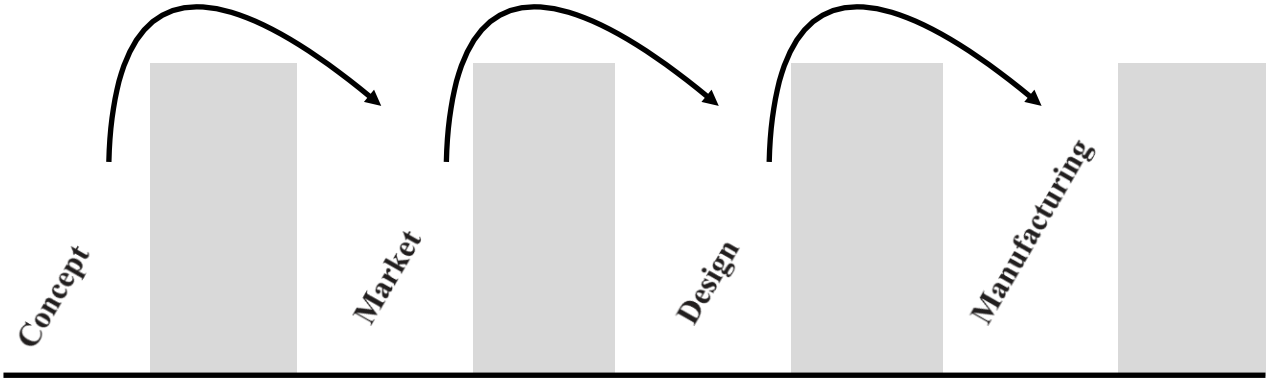


Figure 1.27 Typical "Over the wall" Engineering approach.

The effect seen because of these late changes to the product is compounded, as it will take longer to evaluate each incremental change the further down the development process it is (Rush & Hansen, 1998). Consequently, it is often too late to action a large proportion of the proposed changes due to the excessive cost that is related to these late changes. It is often seen where appropriate these changes are designed out on the next new generation model (Cooper er al, 1998). The table below highlighted how the costs of changes roughly will increment if changes needed doing as the design progresses. The example used is of the electronics industry, but the general increase in costs will be a similar pattern for other high-tech industries.

Stage	Relative Costs (£)
Concept	1
Detail Design.	10
Tooling.	100
Testing.	1,000
Post-release.	10,000

Figure 1.28, The Increasing cost of design change in the electricity industry (Olthuis, 1997).

The typical result of a sequential NPD process with a large number of late changes is that the development budget is drastically exceeded, and the product cost hence is too expensive to make an acceptable profit (Cooper, 1993). The figure below demonstrates a conceptual and operational model for progressing a new product development project from ideation to launch to the target market.

2.4.1

As mentioned previously, the stage-gate system breaks the NPD project into smaller identifiable stages, five of which are being illustrated. This number can be increased or decreased to suit the NPD team it's applied to, there are no specific individual R&D or Marketing stages. Instead, they have been included in stage 1,2 and 3. Each stage has been developed to gather the important information required to progress the project to the next stage/gate. Each stage will include a set of parallel activities competed by different personnel in different departments within the company, but essentially working together as a team. In order to manage and minimise the risk using a stage-gate theory, the parallel activities within the theory must be designed to gather vital information, in order to reduce technical and business uncertainties (Cooper, 1998).

Also, it can be said that each stage costs greater than the previous stage so that the fundamental plan is an increment of commitment to the project. To speed products to launch into their target markets, stages can overlap each other. Long lead time activities can be adapted and brought forward from one stage to a previous or driller one; projects can continue unto the next stage, even though the previous stage hasn’t been complement finished, and the stages can be adapted and merged to suit each individual project.

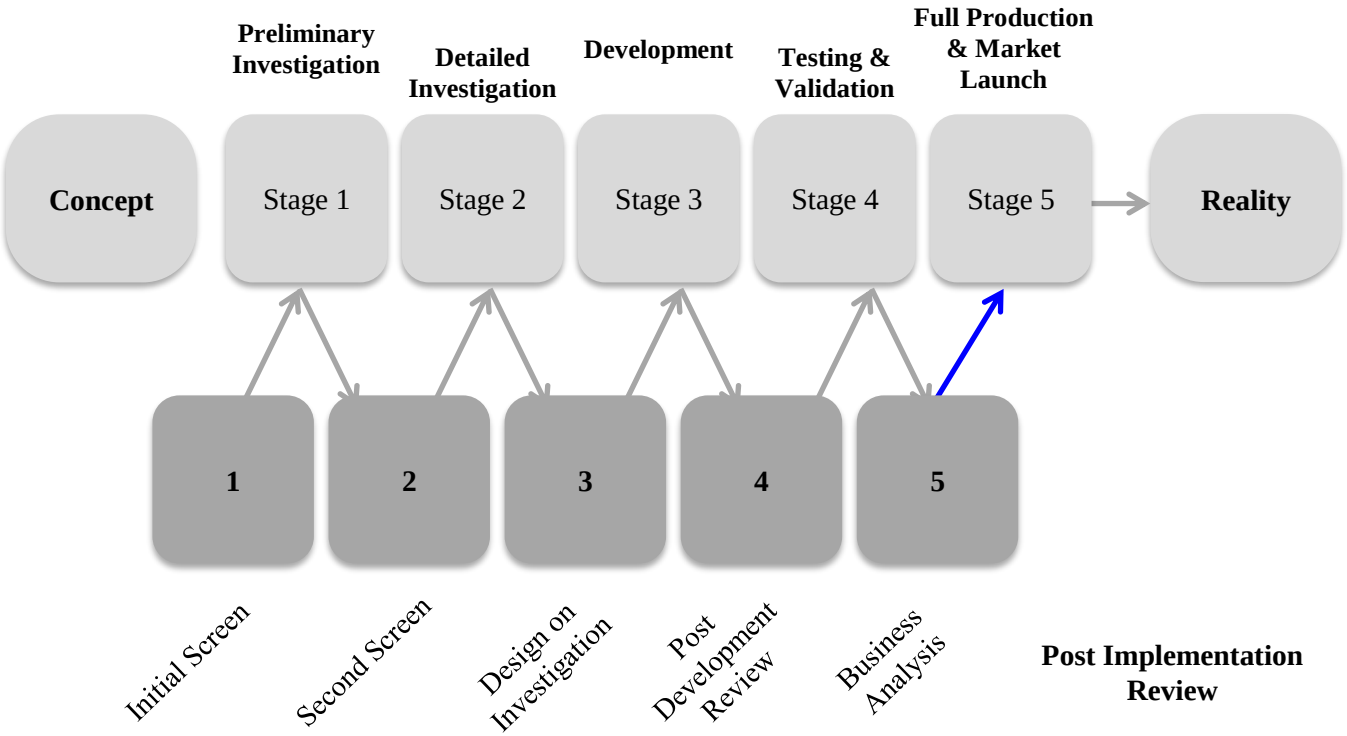


Figure 1.29 Overview of a typical stage-gate NPD process. (Cooper,1993).

2.4.2 Influencing Change in Practice

Discussed in the previous section, the management of product development go hand in hand with utilising resources such as rapid prototyping and various other prototyping facilities available to a business. But as a part of this specific research, the author will discuss the specific factors that can aid influencing change within a business to adopt such prototyping processes and design methodologies that weren't present in the company previously.

In this point, the author will continue research with the element that influences and are influenced by change projects and the various techniques that can be used to adopt within the business of this project.

In today’s organisational change projects, it is common to find a project manager who focuses on the overall task and a change manager who will look after the relationships and the requirements requested by the stakeholder. Other than the outlined task the projects need to achieve and the stakeholder's relationship requirements, there can be organisational factors that will both influence and are influenced by how the project is executed. Some examples of these factors include the experience of people with the organisation with previous changes, support from leadership with regards to the changes, the extent in which various processes or system are changed and the companies’ ability to work as an effective team. All organisation will contain a range of these types of elements that influence and are influenced by the project activities.

Despite the work of the change and project manager to achieve the project goals, there are many examples where businesses may still fail to achieve their goals, and in some cases it can be attributed to characteristics of the ay the organisation operates, which could be described as organisational factors. Organisational factors can either aid the execution of the project or expedite its potential success or make it difficult for the project to achieve its goals. In a lot of projects, organisational factors are planned for and therefore managed through change management. The need for efforts in change management can decrease when the organisational factors are supportive of the project changes.

For a project to achieve its goals, it is crucial that the controlling team, including both the change manager and the project manager, clearly understands the context of the project. Both teams and managers need to understand the organisational factors that may influence the project and how the project could be influenced by these factors. Furthermore, they also need to understand what potential negative and positive impacts these factors might have on the project that will affect the project goals. While discussing this point further, three in-depth case studies of change projects will be discussed to identify those organisational factors that will have the most influence on the projects and its outcomes, including its impact, whether positive or negative and ultimately the implications for the management of changes project

2.4.2 Background

Organisational changes can be a result of internal and/or external factors and can come in various sizes and forms that will affect all the organisations in all industries (Carnall, 2003; Luecke, 2003; Burnes, 2003; Burnes, 2004; Balogun & Hope Hailey, 2008). Within the organisational change and development literature, a great deal has been accepted of the importance of context in influencing attempts to change individual and organisational practices (Dopson, Fitzgerald, & Ferlie, 2008). But context can be complex to understand and thus must be broken down into components attributes, which can be referred to as 'factors'. Authors on the subject tend to focus on the specific elements of the context and how these will influence change initiatives. The nature of which they influence is well recognised. As Fitzgerald, Ferlie, Wood, and Hawkins (2002, p.215), points out, "the behavior of the stakeholders and the features of context are interlocked. The combination of multi-layered, two-way influences, multiple stakeholders with interpretative schemes, innovation-seeking behaviour by individuals and groups, and differing absorptive capacity in organisations, produces a situation in which context is an actor." Within this section, the author will focus on the importance of context as defined by Pettigre, McGee, and Ferlie (1992) as organisational structures, corporate culture/environment, history, and political factors can affect the outcomes of change.

Within the project literature, Pellegrinelli (2002) and Pellegrinelli, Partington, Hemingway, Mohdzain & Shah (2007) dealt with the organisational context, considered the influence of organisational elements on a project's success rate. Pellegrinelli (2002) detailed that programs and projects may have a specific role in shaping the context and aligning also embedding the project or program work to fit within the business's general needs or goals. Not only do the projects or programs influence the organisational factors but also there is the significant influence of organisational factors on the project success, hence it can be said that the relationship works both ways. Pellegrinelli et al (2007) stated that the greater the project looks for greater impact on the influencing o the organisation, the greater the importance of dealing with the organisational factors and their influence on the project success. He also suggested can be rare to find a project that will take advantage of the organisational factors for its purpose to utilise these factors to achieve the best results. His findings suggest that most project managers will be intuitively aware of the influence of these factors and crucial they are to the success of the project, but he also states that this awareness is not, according to Pellergrinelli, enough. The specific factors that need to be adapted to the goals of the project and project managers are rarely systematic or proactive about understanding factors as part of their projects (Pellegrinelli, Partington, Hemingway, Mohdzain, & Shah, 2007).

As highlighted previously, organisational factors that influence change in projects include organisational structure, culture, history and politics (Pettigrew, McKee, & Ferlie, 1992), of these points, one of most critical factors for projects is culture, but according to Morrison, brown and Smit (2006) along with Pellegrinelli et al (2007), project management theory has taken a superficial view of culture and thus not dealt with the significance of influences on a

2.4.2

project's overall success of failure. Similar to context, culture is complex and Morrison et al., while examining the implications of culture for project management, suggested that twelve dimensions together construct a company's culture. These dimensions highlighted by Morrison are as follows;

- Organisational Direction
  Competitiveness Orientation
- Decision-making rationale
- Cross-functional integration
- Communication Philosophy
- The focus of decision making
- People Management Style
- Flexibility
- Philosophy about people
- Personal Competence
- Process and system support
- Performance Management

The authors mentioned that rather or not behavioural change is required, but somewhat part of fetch project depends on the fit between these twelve dimensions and the desired project outcomes.

In a study of CRM (customer relationship management) implementations in three financial businesses (Shum, Bove, and Seigyoung (2008) identified six organisational factors that highlighted as influencing the conduct and outcomes of these worldwide enterprising companies. These six factors were organisational culture, facilitative leadership, cross-functional integration, training, communication, and technology. Despite the scale of these changes to a business processes and workflows, only one of the businesses mentioned treated the implementation as a major transformation and focused a large part of their efforts on project budgets "on change management and organisational factors critical to the implementation" (Shum, Bove and Seigyoung, 2008, p.1365). Hence this was the most successful of the three change projects.

Organisational factors and how they are managed will have a significant influence on the performance of project being success or failures. As mentioned previously, context is a crucial theme within change management and further business development theory but has been given little attention in the project management field. This research draws on analysis of three case studies with the aim of contributing to knowledge and practices the organisational factor on the management of organisational change projects.

2.4.2 Methodology

Three in total case studies were studied of organisational change projects in three organisations. Both the organisations and change project themselves were specifically chosen to give as much control as possible over variation. The three organisations were as similar sizes but from different industry sectors:

- A large telecommunications company that had 9,000 employees (Telco)
- A large financial institution with 12,000 employees (before merging with another business which grew the total to 30,000 employees (bank).
- A public university with 10,000 employees (university).

In order to provide as much control as possible over the type of change project, its influence, and its measurability, these change projects were also chosen based on a range of criteria:

Type of change - All change projects are implementing a wide IT-system as these are the most common changes found in business today.

The number of influenced staff - Each organisational change implemented must be for a minimum of 1,000 employees and a maximum of 3,000 within the business.

Project Expenditure - The cost of implementing these changes range from £5 million up to £20 million.

For all the projects studied the change were already underway, the project had been completed and then the results of the particular change measured and estimated if applicable. The change project was chosen on the principles that there was a successful implementation. Crucial to the choice of the project studied was that one was managed by a change manager, one by a project manager and the last by botch change and project managers.

For each project, various interviews were arranged with the leader(s) o fetch change project, either being the project manager the change manager or both if needed, the sponsor of the change project, three employees directly influenced by the organisational change and a project team member as shown in the figure below;

2.4.2

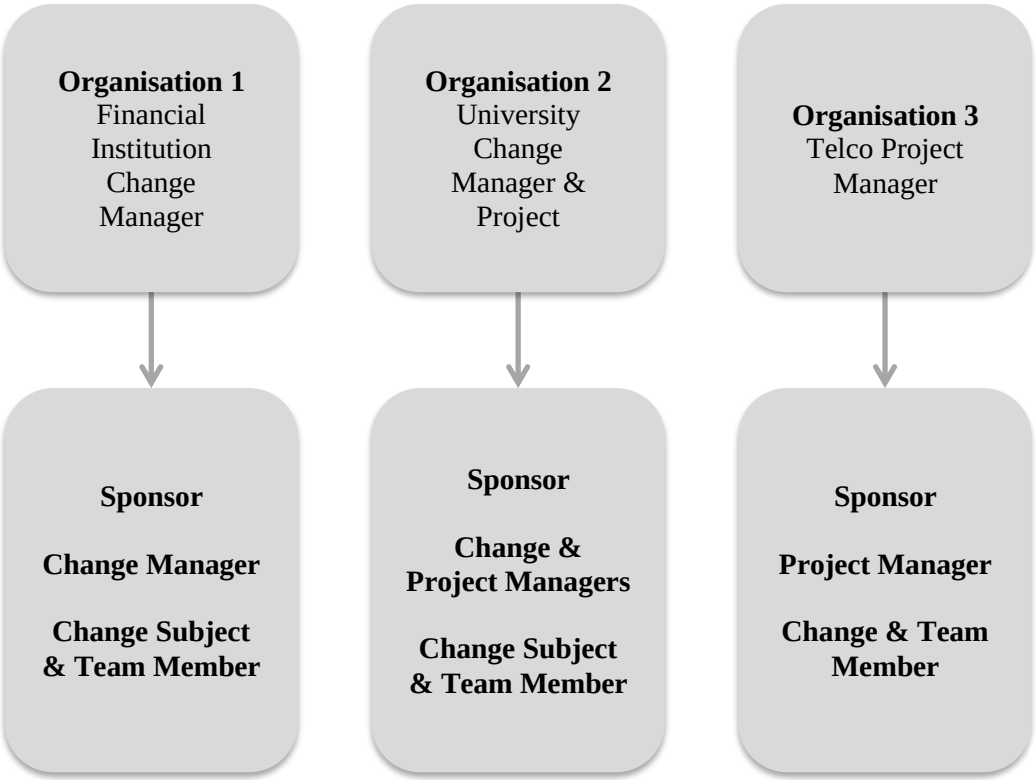


Figure 1.30 Participant Structure

People being interviewed were asked to participate in each organisation's project sponsor. Semi-structured meetings were conducted, minutes taken and then analysed using grounded theory techniques (Stratuss, 1990) along with the aid of NVivo qualitative software. The goals of the analysis were to identify and highlight emerging themes concerning organisational factors that would influence the outcomes of the projects, either positively or negatively.

Results

Organisational Factors Influenced and Influencing the Project

As previously highlighted in the literature review, there is a range of organisational factors that can influence business change projects such as the organisation's structure, size, project capabilities, customer, leadership, competition, culture, teamwork and change readiness. These organisational factors will both influence and are influenced by the project at hand.

2.4.2

There was good evidence that the three projects that were studied all had been influencing and or were influenced the organisational factors, being in a positive or negative way. The basic nature of the influence itself was analysed by how well the factors were planned for and managed. The organisational factors that were found to be the most significant in the case studies were to those identified by Shum et al. (2008), which adopted similar mythology and dealt with an information systems project. Each of the factors that were highlighted as significant in the analysis of the case study interviews is shown in the table below that includes a brief explanation of the details of the influence.

Factor	Nature of Influence
Organisational Culture	The organisational culture refers to the way employees behave in the business towards their specific jobs and each other. This factor has a strong impact on the ease of difficulty for the project to succeed or not.
Resistance	A common theme can be seen with implementing new changes into an organisation as often staffs are distance to change. The resistance can influence the way in which the project is run as it needs to be planned for and addressed for projects to succeed. It can also be influenced by the project itself as the project implementation is likely to either increase or decrease resistance depending on how well the project change is managed.
Teamwork	The greater the teamwork within a business, tech more lily it is that employees will help each other throughout the change process.
Degree of Leadership support for the change	All change efforts in projects should increase leadership support in any situation. Leadership support is vital for successful implantations. Some change projects may be driven by leadership. Other projects or employees may need to enlist and nurture leadership support.
Organisational communications	The project could be very proactive about explaining the change to the organisation or it may focus more on the specific task within the project. In any case, the organisational communication in general and specific to the project can be influenced by the project it will also influence the amount the project needs to ensure the correct people are across the project change.
Organisational systems and processes	As explained, a project will have a degree of decision making in with regards to how many systems and process are affected by the change. Processes and systems will also influence the way in which the project implements its solutions as it would need to work with and adapt to certain systems and processes.
Organisational Strcture	Finally, the organisational structure can also effect the influence the why in which the project is run. If the organisations are based around a hierarchical structure, the project will need to be considered was to communicate to the various levels. Alternatively, if the structure of the organisation is flat, the project will need to consider what as the influence necessary to assist the project in achieving the project goals. Some projects are designed to change the structure by adding/removing organisational levels.

2.4.2

Furthermore, the author will now discuss in garter depth the top three organisational factors form the table above being, organisational structure, resistance, and teamwork (while will be discussed in point 2.4.3).

Factor: Culture

An organisation is a social construct that operates beyond the project and has many characteristics that influence the success of the projects regardless of how well the change or behavioural component of the is handled. As explained earlier, organisational factors are reflexive. They will interact with each other and with the change goals. In this aspect, organisational culture can be a superior factor as it influences and is influenced by all other factors, which in turn are often adapted as attributes contributing to the understanding of organisational culture. Morrison et al (2008) for example, used 12 various factors to define what they describe as the organisational culture construct.
Based on the information in the study reported here, it was decided to treat culture as a factor as its own while recognising its interaction with all other factors identified.

Schein (1992) described organisational culture as being a pattern of assumptions that a group has invented, discovered or developed in learning to deal with its challenges of external adaptation and internal integration. Trice and Beyer (1993) also linked culture with the environment, looking at organisational culture as a collective response to uncertainty and miss-alignment. According to Deal and Kennedy (1982) culture is dynamic and comprehensive subject and can be placed in a system of informal guidelines. Managing Successful Programmes (Office of Government Commerce (OGC) 2007) refers in detail to the over goal grams will have in implementing the change strategy. The theory discussed here suggests the organisational culture components need to be addressed as part of implementing the change within the business.

In the study mentioned, participants in the interview mainly reared to culture as either being supportive or unsupportive of the change that was done. This was the case study that did not include a change manager in the process and according to interviewers, the change was successful because of a supportive culture, including good leadership, teamwork and organisational aid for the project.

2.4.2 Culture Factor Table

Reported Culture Factors	Positive Influence	Negative Influence
Good Leadership	Telco University	
Teamwork	Telco	
Organisational Support	Telco	Bank University

Within the case study, a member of staff expresses appreciation for the culture, which was supportive and encouraged everyone to work together and give extra effort to achieve a common goal for the business.

Examples are as follows;

Telco affected staff: "(There was a) whole (Telco) team environment and everyone willing to assist". Telco affected staff: "(The project) could have ended very poorly but we had a very professional team which is why it didn't go bad as it could have".

In the bank and university case studies, the culture wasn't concluded as being as supportive, and more-so there was a large demand for change management to plan and manage any cultural interference to the project. The sponsor of the bank project expressed disappointment with the culture created, which in turn allowed people to ignore the culture change and revert to back to their previous way of working before the change and did not provide enough support for the change.

Bank, sponsor. "Of the fears we had was that managers would revert back and ignore the information the information helped identify who were the incompetent managers."

The last project within the University case study suggested that although the dean was supportive of moving forward because the basic culture of the organisation would allow the managers to respond to him to resist the project and the amendments required for the implementation.

University, sponsor. "(Change Manager) spent a lot of time around difficult people. The Dean would agree to move forward but the faculty didn't move it forward".

But it can be said that culture is the sum of many other factors; however, it can also stand on its own. When there is a healthy, positive and supportive culture of the project goals, it is easier for the project to achieve its outcomes. An example of this can be seen in the telco example case study, where it suggested that without the culture the entire project change would have failed. However, if a culture is unsupportive, there will be further requirements for greater planning and management factors throughout the project.

2.4.2 Factor: Change Resistance

It can use say that change resistance is directly associated with culture as mentioned by Morrison et al. (2006). When the key cultural aspect of the change is not addressed correctly, great resistance can be seen against the change to be implemented. Researchers of culture view culture as balancing forces inside organisations and use the concept of culture to explain the resistance of change. Resistance against change can be seen spewing from threats to traditional methods of working previously used within the business (Senge, 1992). Within the three case studies mentioned in this section, there were various mentions of staff resistance to change when interviewed further. This was consistent with the indicators of supportive culture at the Telco, a reference to staff resistance was highlighted in the bank and the university projects. For both projects' interviewers would discuss the issues that affected the project itself and were caused by people's resistance to the project changes.

Reported Change Resistance Factors	Positive Influence	Negative Influence
Extra work to implement change		Bank
Disturbance in day-to-day work		Bank
Additional Accountabilities		Bank Telco
New reporting relationships		Bank
Large degree of change		Bank
Culture of Talking, then doing nothing		University
Minimal involvement of affected parties.		University

2.4.2

Bank, sponsor: “The negative influence on staff was, additional work in implementing the system, resistance to change, disturbance to day-to-day work and they were worried about the additional accountabilities.”

Bank, IT Manager: “IT staff resisted the system in greater due to the fact it was a greater chance for their specific work and processes. Also, they found the change more like a changeover scenario i.e. they had to change workflow, personal reporting, etc. and they wanted to be different”.

University, change manager: “The stakeholders weren’t engaged enough to make the project successful and thus didn’t work well as a team.”

University, sponsor: “If staff were readier to engage it would have been an easier process, but there is strong passive resistance in the university so agree they sit around a table, then they leave and do nothing”. Another quote the same interviewee regarding change resistance: “If we were more mature we could have adapted more. Partly because of this project, as a team, we understood more about we needed and could to facilitate that change.”

University affected staff: “These sessions were organised by the change manager, the university people don’t participate or volunteer, its cultural thing. A number of sessions were facilitated across various campuses but only a small number of people showed up”.

The only point worth mentioning attributed to change resistance as part of telco projects is made by the telco sponsor, where he suggested that staff were unhappy by the change and that they needed to take ownership of the new roles and responsibilities.

Telco, sponsor: “The negative feelings people are experiencing as a result of the project are that the can no longer blame the vendor and the need to work longer hours.”

Although the Telco project doesn't mention any behaviours that accompany these negative feelings, from what the sponsor mentions one the reader can assume that there was somewhat of a “blame” mentality that the project had to change. An interesting difference here (where culture was considered as a positive environment), however, is that the negative feelings about the consequences of the change to be done did not convert into resistance to the change. It was also seen in other areas that the people involved in and affected by the change project all understood the change process and activities and agree that it was necessary to progress the business and innovate even though some might complain about the consequences.

The positive influence of a supporting culture is even more significant here, as the Telco change project was a more detailed and extensive undertaking than this in the bank and the university, which involved greater changes to roles and overall structures. When taking the significance of the changes involved and the lack of crucial change management efforts, practices employed on the Telco project, it may consider surprising that the project was successful especially as there is evidence to suggest that the probability of success declines as the level of personal and environmental threat perceived by staff increases (Gray, 2001).

2.4.2

The point that resistance to change in the Telco project was hardly mentioned may be better explained to the overall culture in the Telco. As mentioned by Alas and Vadi (2006), commitment to the business, which can be a result of the business culture, decreases change resistance. As so this is further evidence of this commitment through the “working as a team” factor.

2.4.3 Managing Team Roles and Facilitation for Change.

As previously mentioned the final section for this chapter will be to discuss the efforts of the managing team roles to aid facilitation of change within a business and actives one can implement to accomplish such changes.

The type of team dynamics within a business is also a crucial symptom of its culture and its ability to achieve project goals (Morrison, Brown & Smit, 2006). Through the case studies detailed in the previous section, there were very clear distinctions between organisations that had healthy team dynamics and knew how to work in teams to achieve the project set goals and those that did not. This can best be illustrated by the differences between the Telco and the University.

Team Dynamics Factors	**Positive Influence**	**Negative Influence**
Number of existing teams	Telco-environment of teams	University - few teams
Stakeholder engagement		University

The university project sponsor explained that as not every staff in the organisation was committed to the project and hence supported it, they had to continue with their own work and activities despite this behaviour. The team dynamics in the organisation in total did not fully support the project, and the project needed to rely on the few teams that did support the project to help progress the project change activities further.

University, sponsor: "On thing to do is continue when things are moving and round them up later. You would win over those who to have a direct part. And in turn, the ones that don't come on board will eventually do so when they see the rest of the colleagues join."

The university change manager also agreed with the university project sponsors' view that the team environment was lacking in influencing and pushing the project forward as much as they could.

University, change manager: "The stakeholders weren't engaged enough in making the project successful and it wasn't working as a team".

2.4.3

At the Telco, there was no change manager present and interviews included numerous references to issues such as “not having processes”, “not being communicated to” and “not receiving proper training for the change”. But efficient team dynamics and team’s ability to pull together and work through their specific change management issues assisted in making the project successful. These positive factors of team dynamics in the telco project were directly mentioned by several affected employees as the reason for the eventual success of the project.

Telco, affected staff: “There was a whole team environment and everyone willing to assist.” Telco affected staff: “The positives team effort.”
Telco affected staff: “The project could have ended very poorly but we had a very professional team which is why it didn’t go as badly as it could have.”

As shown in the previous quotes, in the university, the organisation did not work best as a team to achieve the project and this reduced the progression of the project down and made it more difficult to achieve the overall change. But to argue against this, in the Telco project, the team dynamics were supportive of the project. According to the interviewees, the main reason for the success for the Telco project, and it is the only apparent explanation for the project, even after the lack of attention from the change manager or management issues. This finding is also supported by Campobasso and Hosking (2004), who also said that the decision of the members of the team can make a difference between success and overall failure of a given project, and commonly it has distinguished projects that progress quickly to completion compared to some projects that seem to wallow for months or even years.

As described previously in this section various key members of the change process are vital for the performance of the change itself. To understand the influences these key individuals will have on the change management the author will explain further their impact on the change system.

Being individuals or teams, the change process can depend on them at any stage of the change process depending on which stage the business is at in the change cycle. And thus, individuals or groups can fill more than one role also during this process. The following will be a breakdown of certain individuals or groups that play their part in the change cycle;

Change Initiator

It is commonly seen among organisational development consultants that successful change is underwritten by a deep “crisis” or need within an organisation, for example, loss of a key leader in the organisation, dramatic reduction in sales, warning signals from a major investor, or unforeseen actions from a competitor. It is not uncommon then that an individual within the organisation will need to react to these changes i.e. internal or external to the business and suggest the need for a large or major change actions. Often the person who champions the changed needed is not the person who is the primary change agent.

2.4.3 Change Agent

The change agent is the individual that is responsible for organising and facilitating the overall change effort. This change agent role can be given to different people and different stages during the project. For example, an external consultant might be the first appointed change agent. After the development of the change project plan and implementation is underway, the change agent could, therefore, merge into an implementation team comprised of people from the organisation. If the change implementation stalls, the change agent might be a higher leader within the organisation who intercedes to ensure the change reprocess continues as planned and on time.

Champion for Change

The effort of the change often will require an individual or team who will continually improve and sustain strong enthusiasm about the change. This will include constant remaining of employees of the reason for the change and why it's occurring in the first place and the great benefits that will follow because of the huge. In some occasions, the champion for change might be the same person as the change agent.

Sponsor of Change

Also, in most cases, there will be one key internal individual or department that is officially the “sponsor”, or officially responsible for coordinating the change process. Within a large organisation, the sponsor can often be a department such as HR (Human Resource), Strategic planning or information technology. within smaller businesses, the sponsor could be a small team comprising of senior leaders to ensure that the change activities are completed on time and outstanding actions are on schedule through ongoing supervision and updating of resources and further training if needed.

Leadership, Supervision, and Delegation

Leadership within many guides can be defined as setting direction and influencing people to follow that direction. A person can indeed lead themselves, other people, other groups or an entire business. Supervision is helping and guiding the development and productivity of people in the organisation. Effective survivors will be able to achieve goals by guiding the work of other people through delegation.

It is important to note that supervisors exist throughout an organisation, that depends on the structure of the board of directors and employees. For example, the board of Directors will supervise the chief executive officer (CEO), the CEO will intern supervise their executive assistants, and thereafter managers will supervise their entry-level supervisors.

2.4.3

The leadership topic within management literature has become a popular area of discussion. Hence it is difficult to find a general management book that does not include frequent mention of the topic leadership. There can be found many reasons for this and one of the most important beings that successful organisational change will require strong, visible and ongoing leadership in support of that change. The leadership model must imitate that type of behaviour that they want to see in their organisation. Other reason can include the following;

- Leaders that will work with others within the organisation to clarify the desired results define the vision and goals, or desired results, for change.

- Leaders within an organisation must also “practice what they preach”, i.e. they must behave according to the same values and general behaviours that are to be accomplished by the change effort.

- Leaders must also ensure the ongoing accountabilities, support, and resources to ensure that the correct actions are taken to complete the overall change cycle.

It can be said that there is simply no substitute for the role of that leadership and supervision play in accomplishing successful organisational change. Hence, it is important that all leaders and supervisors within a business must have a strong understanding of the basic principles of successful change in organisations.

Chapter 3

Methodology

3.1 Introduction

In order to investigate the research questions to adequate depth and to ensure the relevant methodologies are adopted. The following sections will outline, philosophies, strategies, and methods on how the author will research the question topics previously stated. The initial details of this section will discuss the overall objectives of research as a whole while keeping the specific research end goal in mind.

The following headings will outline specifically the approach in which the research itself will be structured and what research theories will be adopted to further extract enough information in order to answer the pre-defined research questions and giving the thesis its context and output. Specifics such as ensuring quality for search and various data collection resources and processes are detailed to further explain the routes of the conclusions.

3.2 Research Objectives

The aim of this research is to discover design thinking methods and current design theories that can be critically analyzed against design practices used in a sample of the industry. It will investigate how theories can be applied to various departments within the 3rd party business, and what technologies current and merging could be adopted to increase productivity and streamline processes within the sample business system. The thesis will also investigate what useful structures can be provided to help managers within the business evaluate the design stages of a project/product and how to ensure increased efficiencies across the process. This will be demonstrated by creating an implementation plan highlighted findings from the literature review against the business critiques and where processes and methodologies can be adopted/improved.

These aims will be achieved through the following objectives.

Objective	Description
OBJ1. Design Mindset	To research and outline main design thinking theories to currently used and expose their inner processes for business implementation.
OBJ2. Conceptual Design	To outline and detail conceptual design practices and links possible with further initial prototyping for a quicker route to market.
OBJ3. Market Research	To highlight the importance of correct and relevant market research and its crucial tie within the design process, along with how research could change vital features within a product throughout the project.
OBJ4. Product Development	To suggest various prototyping techniques and technologies that could be adopted in the business with a breakdown of benefits depending and the nature of prototypes needed.
OBJ5. Management Skills	To detail management techniques with regards to design mindsets and design management processes that the business could implement. These techniques could then be transferred to various departments relevant to new product development.
OBJ6. Influencing Change	Detail various influencing change strategies that could be used to implement all of the above objectives. This will ensure the smooth change of procedures and processes for each department.

3.3 Research Approach

This thesis is specifically designed to help the 3rd party business to understand the current design thinking and technologies currently use within industry and to potentially apply them to their processes and mindset. Therefore some parts of this work will be broad. Especially such subjects as prototyping and managing change due to the complexity of the subjects. But other parts of the thesis will need to discuss in more detail such as when discussing design thinking as this is the main topic of the thesis.

Within each chapter a range of methodologies and processes will be discussed specific to the desired out of the thesis and the outcome needed, and hence will be detailed as required. How the research, which is shown in this thesis, follows two general principles, first traditional research, discover and reporting methodology will be used, and second and business-based research approach will be used to aid the critique at the end of the thesis of industry against the theory. This will highlight the areas for improvement for the business and potential opportunities.

The traditional research methodology.

There are many design thinking papers and statements to read. Therefore, journal articles, published papers, conference papers, white papers, and books will be searched and utilised through reading and summarising the relevant content needed for this thesis. For this research, several online archives will be utilised such as Google. Scholar, Bangor University Online Library Portal, Academia.edu and a general search engine (Google) along with physical books bought or loaned from the University Library. These research methods will be demonstrated through the output of the material that will be present in the main related work chapter 2 (Literature Review). This methodology is principally used in the first few chapters of the thesis.

Case Study research methodology.

As the scope of this thesis is to compare a sample of industry practices against what theory states, the content of chapter 4 (Data Analysis) will be only of the businesses in question through a case study approach. Details of the business will outline inner processes and structures along with management styles, prototyping techniques, and overall design processes. The details of which will be gathered through various probing research methods. This will include interviews with management, document reviews of stated procedures and processes within their management systems and a general overview of works seen during new product development projects.

This thesis will be broken into 4 parts, as shown in the figure below. The main first stage will use research methodology and includes background and related work, with the last stages analysing the business itself and critiquing both research streams at the end of the thesis.

Stage 1

The first stage (1) will contain the background information and literature review in chapter 2, and critical thinking in chapter 4 as follows:

- **Literature Review – Chapter 2**

  The literature review is achieved through researching to investigate different materials and theories and how they are applied in business. They will be discussed on their benefits to a business adopting such a theory.

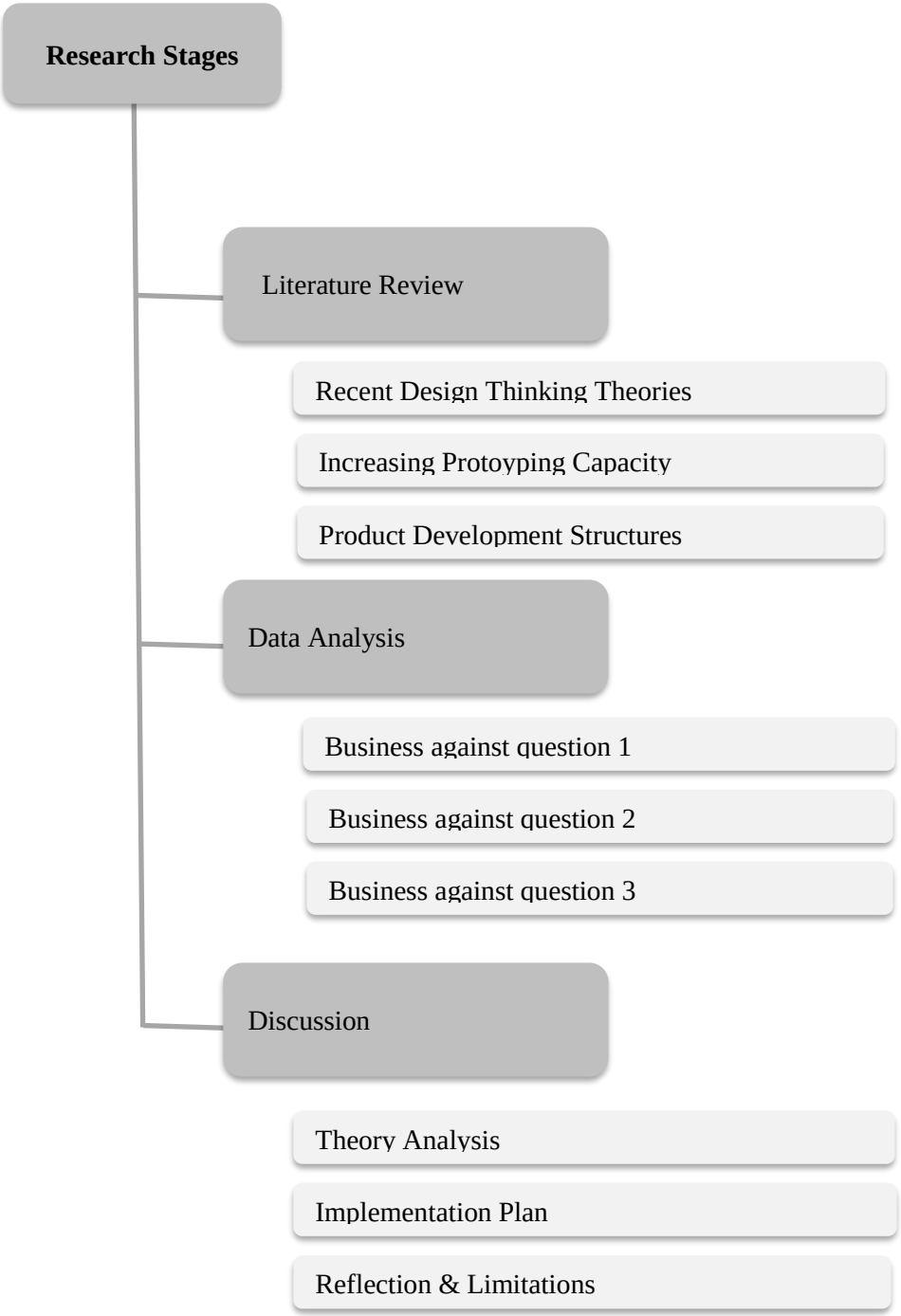


Figure 1.1 Research Methodology. A diagram of the whole thesis showing the three main research and conclusion parts.

Stage 2

- **Data Analysis (Chapter 4).**

Related subjects within the business are gathered applicable to research stated in chapter 2 (Literature Review). The content of the information gathered will then be critically analysed against the research question to highlight what the business in question does compare to the fields of study (Questions). This will involve asking questions to the relevant managers and people directly related to the design process on how their stated processes are applied and fulfilled.

The output of this chapter will directly feed to the tent of the following chapter 5 (Conclusion & Future Work). Along with an evaluation of the information gathered against the research questions and limitations, a proposed implementation plan will also be outlined to begin a potential process the business would want to follow.

Stage 3

- **Discussion (Chapter 5).**

The final section will collate both stages 1 & 2 (Chapter 2-3) and compared the findings against the research questions initially stated in chapter 1. This will highlight the key areas the sample business in question is using or not using current theories that could be beneficial to them.

After highlighting the key benefits that could be implemented, an implementation plan will be drafted. Sections from the theories researched will be developed into a single process by process method in which the business can clearly see where and how adopting the outcomes of the theories shortlisted will benefit them.

Furthermore, limitations to the research conducted will also be highlighted. This will outline where further research will be needed to confirm or address further related topics that could be beneficial to the implantation plan

3.4 Research Methods and Strategy

Throughout chapters 2 to 3, specific methodol1ogy and processes will be used and followed that will be appropriate for the outcomes needed judging by the nature of the research questions. The following components of the research will be described further regarding the specific qualities and various data resources that will be harnessed to ensure that correct and relevant information is produced in order to base final assumptions against the research questions.

Key Stage	Description
Quality	**Credibility –** Through undertaking activities that make it more likely that research will produce credible findings including engagement with relevant members using the systems within the case study. **Transferability –** Ensuring interpretations of the author / researcher are in harmony with the experiences that are shown in the researched peers and case study. **Dependability –** Ensuring that the research is easily understood with other researchers or relevant parties. This will be upheld through creating the research with the case study party as it produced to ensure dependability. **Confirmability –** Ensuring information is both produced from eth researcher and relevant individuals in with the business. **Authenticity –** Will be upheld through gaining viewpoints from management and lower-level individuals to ensure various viewpoints are taken into account.
Qualitative	Qualitative research methods will be used as it is best suited for describing, interpreting and gaining in-depth insights into specific concepts and theories, along with overseeing current practices. Through using a qualitative approach, research will conduction through interviews within focus groups and individuals, various participant observation and analysing existing data from the case study. By using qualitative methods, the analysis will be based on; **Content –** looking at various categories within the case study that is linked to defined research questions.

	Narrative analysis – Looking through pre-defined structures in the case study and interpreting their meaning. **Discourse analysis –** Further looking at communication linked to the structures seen, and how teams interact with each other through the management and change analysis.
Research Design	The design of the research will be based on the quality and qualitative aspects listed above. They will be taken into account during specific research into the case study and the activities within it, then along to the theories defined from the research questions.
Data Collection/ Process	Data collection will be in the form of shortlisting theories and infographics of proposed processes and guides. Equally data collection from the case study will incorporate the breakdown of organizational structures, along with quality processes and procedures. Analysis of various design stages and steps within the case study will add value to data collection when discussing against theories gathered.
Questions / Interviews	Questions will be asked to relevant people within the case study that will be relevant to the processes and departments that fall under the themes of the defined research questions. These questions will either be conducted in an interview format if possible or on an ad hoc basis when the research stages dictate when and where information is needed.

3.5 Research Philosophy

To back up the research methods to be implemented, a research philosophy will also be included to hone the overall approach to the research within the thesis. The philosophy approach will be based on Interpretivism (Saunder et al, Research onion, 2009).

Interpretivism refers to approaches emphasize the nature of people's participation in social and cultural life. Researchers working within this tradition analyse the meanings people confer upon their own and others' activities and take the view that cultural existence and change can be understood by studying what people think about, their ideas and the meanings that are important to them.

Advantages	Disadvantages
By adopting the use of interpretive research it can bring May advantages to the case study. First, it is well-suited for exploring underlying reasons behind complex processes, such as inter-firm or inter-office politics, where quantitative evidence may be biased or otherwise inaccurate and there difficult to obtain. Also, they are often useful for theory building in areas with little or no prior theory. Thirdly, they are appropriate for studying context-specific, unique events or processes. And lastly, interpretive research can also help uncover interesting and relevant research questions and issues for follow-up research.	But, interpretive research does have its limitations and challenges. First, this research method will tend to be more time and resource-intensive compared to positive research during data collection. Thus collecting little data can lead to false or premature assumptions, while too much data may not be effectively processed by the researcher. Also, all participants or data sources may not be as equally credible, knowledgeable or unbiased about the interest of the research. Thus inadequate trust between participants and researchers may hinder full and honest self-representation by participants, and such trust-building takes time.

All interpretive research must adhere to a set of principles as described below;

Principle	Description
Naturalistic Inquiry	Potential phenomena must be studied within their natural setting. Thus contextual variables should be considered and observed in the research of interest, even though connect sensitivity may limit this.
Researcher as Instrument	Researchers must consider themselves as part of the data collection if relevant within the framework of the case study. Further, their personal insights, knowledge, and experiences of the context are critical to accurately interrupting the research of interest. At the same time, the researcher must be aware of their personal biases and preconceptions, and not let such biases interfere with their ability to present a fair and accurate portrayal of the research.
Interpretive analysis	Initial observations must be made through the eyes of the participants embedded in the context. The first stage involves viewing or experiencing the case study from the perspective of eth researcher. The second stage is to understand the meaning of the individuals working within the case study, in order to provide a rich narrative of the participants of the processes being researched.

Being part of interpretive research, action research is a qualitative but positivist research design aimed at theory testing rather than theory building. Action research will be used within the overarching interpretive research as it best understood and used by introducing changes, interventions, or "actions" into those areas and observing the outcomes of such actions and common end goals. In this method, the researcher themselves is usually a consultant or an organizational member embedded into the eth case study, who initiates an action in response to resolving a problem, and examines how the author's actions can influence the case study while also learning and generating useful insights for the case study. Good examples of adopting action research are those that may include organizational change programs, i.e. introduction of new organisational processes, procedures or managing change through people that have been initiated with the goal of improving an organisation's performance or profitability in its business environment. The researcher's choice of resulting change to the case study must be based on theory, that will explain hose it will provide and action eth desired business change.

3.6 Conclusion

To conclude this chapter a range of research design and directions will be aligned to ensure the author will be using and applying to the case study.

The research will in a broad sense investigate the theories that can be applied to the departments within the case study, through using new technology and various design thinking theories. Researching into theory will begin through discussing design mindsets and conceptual design, then onto current market research theories, product development and finally influencing change through researching various managing skills.

In order to research these fields, two research methods will be adopted as being a traditional research method and a case study method. The traditional research side will be used specifically for research into journals and library-based media, while case study research methods will be adopted for when a critique is needed for the case study. The outcomes of these specific research methods will be coupled within the final chapter to create a final outcome of findings and further recommendations.

Furthermore, the quality of the research will be ensured through adopting a qualitative approach within traditional and a case study research approach. 5 key pillars will use being, credibility, transferability, dependability, confirmability, and authenticity will be used to ensure all the research including data collection and questions/Interviews undertaken and outputted will be of sufficient quality for the final outcomes and findings.

All the above is a framework of research angles that will sit within the thesis's interpretive overarching research method, and being action research they will be best suited for eth nature and of research needed and what specifically will be researched i.e. people and processes.

Chapter 4

Data Analysis

4.1 Managing Team Roles and Facilitation for Change.

Following the findings of chapter two, the next section will begin to deduce exactly what the business does including all the internal design procedures and how departments link to them.

Chapter two was subdivided into three questions serving as the base of the research for this dissertation. The questions are repeated as follows;

- *Are the most recent design thinking theories being used within the company structure?*
- *How can prototyping capacity be increased?*
- *Which product development structures can be implemented?*

The first question was designed to explore current design thinking theories and to give a broad understanding of useful and recent design practices by giving examples and for context. By explaining various definitions of innovation and design thinking a clear overview of these subjects could be noted and further evaluation of the business practices in this section.

Secondly, prototyping was added to the research as the use of prototyping practices are becoming increasingly used within the design process.

Finally, the last section within Chapter 2 was to further detail what current product development structures can be used and how certain management structures within design environments can benefit the effectiveness of applying design thinking theories coupled with recent prototyping technologies.

The following points will continue to critically analyse firstly the design theories used within the business against what methodologies were found in the first question of chapter 2.

4.2 Marco Against Question 1

(Are the most recent design thinking theories being implemented within the company structure?), OECD (Organisation for Economic Co-operation and Development) narrowed innovation down to four factors in 2010;

- "New innovation networks and clusters"
- "Stronger international linkages"
- "Knowledge-based capital and intangible assets"
- "Information and communication technologies"

Marco Cable Management; the business understudy can be directly compared against the above values. As the theory states, networks and clusters is a greater pool of knowledge glued together from one organisation to another sharing this knowledge through the use of research facilities such as universities and various institutions. The availability of knowledge specifically innovation knowledge outside the organisations have added greater resources of information to capitalise from. Because of the growing pool of knowledge, business is now continuing to invest in knowledge-based assets instead of machinery, equipment or buildings. This also can be linked to the greater output of patents and market research seen by large businesses.

Comparing the business (Marco), with the above statements gives an initial background to their design thinking progression. It can be said by studying their current design thinking activities, there is a deficiency in opening their design projects for assistance from external resources. Taking theories detailed by OECD, currently, Marco does not facilitate further (It may be worth citing OECD again as a point of reference) design projects with external resources such as universities or designing institutions. Simply put, open innovation is not practiced by the business which is reducing their potential for external design knowledge and guidance.

To detail further, many factors of in house design at Marco will currently be at a disadvantage as they cannot capitalise on pure design thinking/design practices used by experts from external sources. By not fully taking advantage of the pool of open innovation, the business will be less productive from a design point of (this sentence needs rephrasing for better understanding) this could even be detailed down further to their efficiency of product development and design for manufacturing which could ultimately lead to greater manufacturing and prototyping costs.

The initial drawbacks of Marco's current system of design thinking will be discussed further throughout this chapter by directly comparing the activities within the business with what theories were analysed in chapter two.

4.2

As discussed above, Marco's design thinking activities and basic operations within the department, "Innovation" isn't solely broken down into various versions, i.e. the business only focuses on Innovation from the design office and no other areas of innovation such as commercial, transformational, sustaining and disruptive innovation.

Proctor and Gamble describe these innovation steps clearly. Commercial innovation is that of producing or adapting an existing product to create a completely new method of completing a task. If we compare this to Marco, their generation of new products are for existing tasks carried out by the customer/fitters who install the product. The products in which they design are for problems that already exist in the market, this is typical of reactive instead of proactive design. By designing products for existing problems, they accomplish the task at hand to solve the issue but the design itself of the product does not constitute breakthrough ideas, which highlight answers to problems the customer never thought they had, this is where transformational innovation can make a big difference within a market place.

Currently, Marco is not practicing any transformational innovation as they design for products other competitors already have on the market. Their initiative for breakthrough ideas is currently low but this could be linked to not making the most of open innovation and the design resources around them.

Sustaining innovation acts for the incremental changes within products as shown in (Figure 1.4 Issue No.8 of their Quality manual ISO9001 21/06/2016) to ensure the design is current within the target market. Marco currently is focused on small incremental changes to products for a better manufacturing efficiency compared to greater customer relation. With the nature of the product the business produce, many factors can be changed to increase their manufacturing efficiency and turnaround times. But the crucial drawback to focusing only on manufacturing efficiencies is that customer/installer's ever-changing needs within the products change and are ultimately overlooked as the market progresses. as mentioned in chapter one, currently the cable management market especially within steel wire cable tray products, the customer is using more and quicker fitting accessories to reduce the installation times on sites. Marco is currently changing existing products for quicker manufacturing times but in fact, greater effort needs to be placed on adapting or revising these accessories for quicker installation or user friendless for the customer or installers in the site.

The final innovation type that Procter and Gamble's practice is a disruptive innovation. Similar to commercial innovation, the effects of disruptive design is to design completely new products or ranges for the market. This can give a shock factor to a Market and give "something new" for the customer to explore and use. When comparing this to design output from Marco, there hasn't been much disruptive innovation as all of the products are for specific

simple tasks and new disruptive products could only come from developing a complete new range of product type.

By continuing innovation and delving further into the topic design, design thinking is an increasingly popular and well-theorised methodology of design thinking THE theory by Tim Brown of IDEO stands out strongly. Design thinking can be described as a method of opening a designer (and managers) mind to greater testing and experimentation through a non-structured process, in essence, a series of overlapping steps instead of orderly stop-start

steps. The process of overlapping steps can release solutions and generate inspiration for individuals or teams by linking ideation, further development and testing or evaluation through the implementation. As Design Thinking ensures a free-flowing process of generating incepts through the design process, individuals or teams might find themselves going from evaluation at the end of the project back towards development and ideation to incrementally change a concept for better adaptability to the brief in question.

From research at Marco their process workflow of designing new products is structured and not open to change as it's based on a standard design workflow as follows;

Stage	Marco Process Description
Market Research	Minimal market research involved. Currently patents and from various competitors are recorded and analysed for design restrictions or possible infringements.
Ideation	Once market research is completed and justification for the product or range is signed off, initial concepts are created through various sketches or 3D models.
Development	After first concepts have been created, further development of the concepts is put forward for prototyping.
Prototyping	Once developed concepts have been signed off, prototypes are made for further development and proof of concept.
Final Samples	Final functional samples are made for further sign off project.
Implementation	Stock quantities of the product are ordered and any further technical details for the products are added to the catalogue.

4.2

As Tim Brown stated, "Without constraints design cannot happen" (Tim Brown, Change By Design, 2009). Constraints in a design process workflow are crucial to ensure the process is well structured but also gives the ability for individuals or teams to overlap these constraints to critically and continually evaluate the design from start to finish throughout the project.

IDEO's Change by Design (Tim Brown, Change By Design, 2009) book breaks down design thinking evaluation into three criteria as stated in chapter two;

- Feasibility
- Viability
- Desirability

Marco's design process as detailed above does have elements of the above evaluation points. By comparing Marco's design process against the three evaluation points stated by IDEO the following findings deduced.

Feasibility is well used within the business in the initial stages of the design process. As previous projects have been developed within the business and past design or market researcher have been archived, the feasibility of new product ranges can be judged initially from the previous information. The initial judgments of new projects from previous information is good to start initial concepts and decision making for the higher management, but after further analysis of the market researcher activities at Marco, information gathered isn't detailed enough for a true feasibility study for new products. Market research within the business involves basic website searching of competitors of either current 'live' or 'pending' patents and basic outsource market research.

Viability, within the design processes of Marco, can be seen from the ideation and development stages. As there his great emphasis on design for manufacture within the business and because of its high-volume products, viability is a crucial part of any new product. Within the initial conceptualisation stage, a rough cost in the analysis will be made at Marco to get a brief overview of what the costs will be involved before any further work is done within the project. If the initial costs analysis is approved further viability actions will be carried out throughout the development stage to get detailed costs.

Viability is a crucial part of a project to understand its economic feasibility. Researching into Marco's strategies to ensure correct viability show's not enough detail in their costs projections and potential sales forecasting. Also, profits margins and product pricing isn't discussed until the last stages of the project which can lead to significant downfalls when product is manufactured and sold.

Lastly desirability. A desirable product or product range is a must for businesses as their customers will understand the brand and products installing faith into the design or usefulness of the product. Accomplishing

such a level of confidence with customers takes time and excellent quality and service from the business. A degree of desirability can be seen within the Marco product's as their customers are loyal and fully understand the brand. But it can be said that some products are suspect of downfalls within their design ultimately their use on-site by installers. Due to the nature of the design environment within the business, products are designed in a microenvironment i.e. design engineers will design and prototype their concepts in the house without immersing the design into external final installment environments, this is where the true evaluation of a product can be gathered. Because of the lack of external testing of concepts products can fall short of some customer expectations. By taking the initial findings from the business above a clear distinction comparison can be made by taking a design thinking structure detailed in chapter two and critically result areas to improve at each stage of the design process.

4.2

The following table will show the comparison from a design thinking aspect as detailed by Tim Brown of IDEO

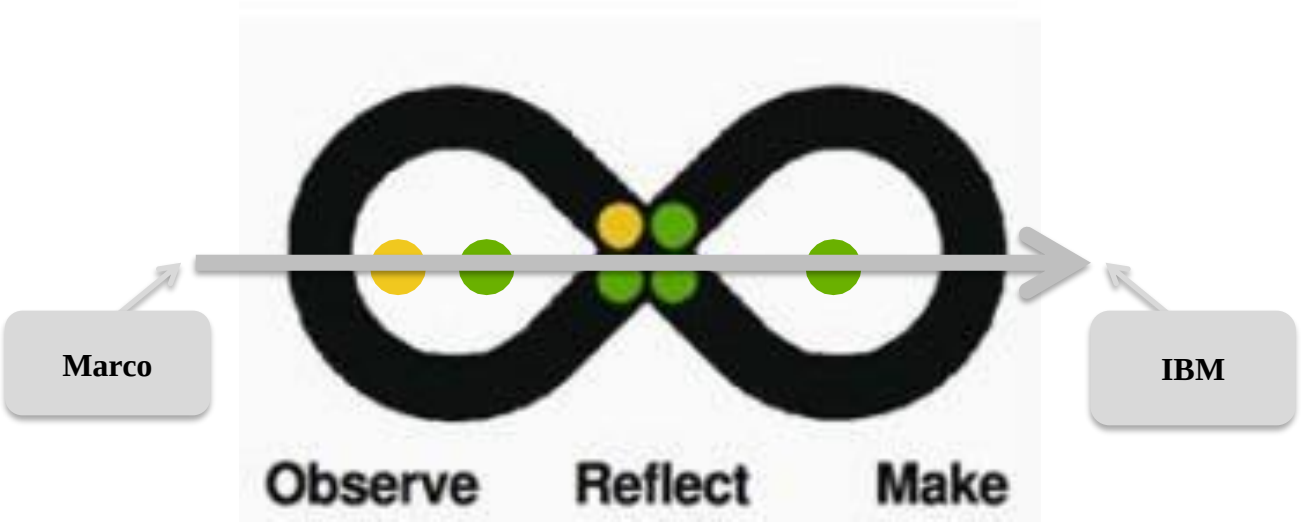
Stage	Key Factors	Marco Findings
Empathy	Observation - Comparison of what is described and what is done. Engage - Interviewing activities / questions to gain better insight. Watch & Listen - A strong combination of engagement and observations.	Described applications for new products interpreted internally and acted upon. External questioning and interviews are not used to fun potential or not recorded for best results.
Define	Look for patterns from Empathy studies. Generate an overriding point of view with strong focus and inspiration.	Minimal end user-based research used at empathy stages thus creating unclear patterns that can't be analysed nor creating a point of view.
Ideate	Stepping beyond the obvious for the best inventions. Harness individual strengths of team members for an efficient concept. Ensure all areas are explored and analysed for possibilities.	Concepts are derived from basic requirements of the customer. Being a small design team, individual strengths are not broad enough. Concepts aren't fully explored for other applications.
Prototype	Ensure enough prototypes are being built for trials. A wide range of various prototypes will need testing for the best outcomes. Ensure information captured from the prototypes are recorded and acted upon for efficient developed designs. Certain parts of the prototypes might work better than others.	Minimal prototypes are made because of the nature of the product ranges. Detailed recorded system is not used to ensure the best aspects of each prototype are recorded for further development and utilisation.
Test	A better representation of the product is given when under test. Users need to interact with the prototype for initial feedback. From the initial feedback, it is important to record any questions raised repetitive questions might highlight underlying issues. Numerous final prototypes will also help compare the best aspects of them all.	Products are tested within the business and externally but not extensively and in final installation environments thus less interactions with the users for crucial initial feedback. One or two final prototypes are made for inspection not giving the potential breadth of products that could be commissioned.

4.2

Design thinking stages as stated above against Marco suggests that there are various aspects within each stage can be improved or honed for better results (these will be discussed further in Chapter 5). By also comparing Marco's activities against the 10 principles stated by Idris Mootee, (2013) adopting design thinking principles within the business will indefinitely best learning practices. Even in a small team as the business starts to adopt a design thinking approach will ensure individuals are constantly learning to produce better products, service, and processes themselves. While learning through the project they will keep the customer point of view in mind to give context to the project and end goal. Along with context, individuals of teams will complete projects to high performance and relevance whilst being dynamic and agile to changing external factors such as technological advancements and material changes.

Other elements of design thinking can also be adapted or developed to suit a business. For example, as described in Chapter two, IBM's "The Loop" clearly and easily represents their belief in continual development and evaluation throughout the design process. The loop has centralised activities being observing, reflecting and making while keeping the focus of the user outcomes close to these activities. The underlying principle of the loop is in the name of the theory, i.e. the relation of the iterative process is never complete and hence forcing individuals or teams to emphasise on the importance of continual reflection of what has been created and to strive to always improve it.

Below is IBM's "The Loop". To analyse the further difference in Marco's design strategy, a reflection of the business activities will be made against the following diagram for representation.



4.2

As shown above, the develop diagram represents a comparison against IBM's loop design thinking concept against Marco's current design process. It can be said that during the observation stages within the business as highlighted in the above table activities are short and not accurate. This is true because of the lack of immersion of building a design context and point of view with the end-user, and any user-focused outcomes are held low in the hierarchy of design constraints as costs and manufacturing performance are held at greater importance.

During the reflection phase, multi-disciplined teams are utilised to ensure the best development activities are accomplished during the IBM process. When comparing this to Marco the multi-skilled teams are used sooner in the process for initial feedback and then disregarded further through the development and reflection stages.

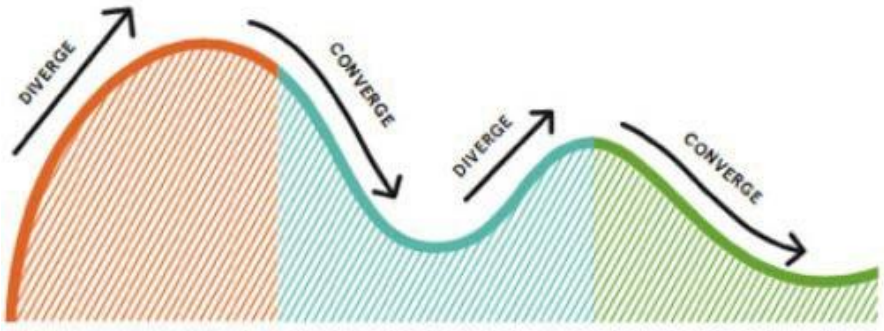
Onto the production of new products, from Marco's point of view multi, skilled teams are also used at this stage but haven't previously been subjected to the initial ideation and development stages. This can lead to complications as certain aspects of the new product or product range might not be possible in the making/implantation stage and these complications were not highlighted in the crucial ideation stage where any potential future issues should be raised and overcome.

The major differences between the two models are Marco's "One -Way" design process pattern. "The Loop" is clearly designed for continual evaluation of every stage from initial concepts to after implantation to create the best performing products. As findings suggest from Marco, once a product or product range is imprinted it is rarely revisited or continually developed for better performance.

To couple with IBM's loop theory, IDEO also uses a model of design thinking based more on human-centered design. Human-centered design details that innovation is an uncommon result of precise and structured design procedures. Users of design thinking principles through human-centered design can allow a designer to directly from the people within a team and the customer themselves to create a greater potential for creative output. Taking IDEO's model into account, creative concepts and thoughts will verge from out of the box and back in for further development, this is what IDEO calls "diverging" and "converging".

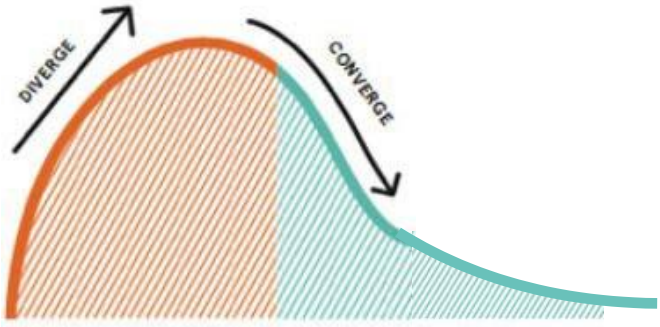
4.2

As shown below, the model shows how at the first stage of ideation, divergence is high as many concepts are naturally thought of. As further specifications and initial prototypes are made activities and concepts will converge. These two processes will be repeated until the best performing concept is developed.



IDEO

The following develop model is a comparison of what activities where found at Marco;



Marco

As shown in the amended model and also reflected in the IBM Loop model comparison, continual diverging and converging processes are not present within the business. Initial concept creation in the diverging stage is high as commonly seen within the first steps of a project. But when comparing the following converging stage, specifications are final details are signed off sooner within the Marco design system and leave no opportunity for further refinement and development for better-performing products.

Along with an explanation of their model above, IDEO also stereo the importance of a designer mindset and their confidence in their ability. A designer should approach his or her work with a large degree of creative confidence as this can spawn breakthrough ideas for the best solution to a problem. Having creative confidence within the human-centered design will ensure designers can meat barriers and easily rise above them with the efficient product or design alternatives. Furthermore, it will drive individuals or teams to test new concepts to fail and to develop further

concepts through diverging and converging continually throughout the process. Installing such creative confidence within team members of Marco will be beneficial not only within the design team but into other departments of the business, as departments would challenge and contribute to development phases if a looping design process is adopted replicating that of IBM's design strategy.

The human-centered design will capitalise on failure. Based on this principle, elements of the human-centered design some concepts will not succeed at the first try but it's what designers learn from this failure and how to move forward. As with every project, it is difficult to be fully confident in the successfulness of the results after the first iteration, only by thinking, listening, building and refining the initial concepts to the final answer will create the most efficient products. As IDEO states and as explained in chapter two, "Fail early to succeed sooner", design individuals within Marco will benefit from creating a vast number of initial concepts during the "diverging" stage to highlight any potential issues early before moving to converge stages where changes may be more difficult.

To aid design in general along with adopting various design mindsets such as design thinking, and human-centered design, individuals or design teams can adopt design toolkits through these processes to ensure the entire design strategy is well structured using divergent and converging activities. More so a design toolkit can aid through giving teams or individuals activities to follow or to be guided by to be used within the design process, i.e. creating a tangible process to create results from while keeping a design mindset. The couple both design thinking mindsets and design toolkits can be highly effective result in the best solutions if used correctly.

Design toolkits such as Scot D. Anthony's 28-day innovation program are useful tools that can be used to heighten the output of efficient solutions. This toolkit, initially describes the importance of designers immersing themselves within the customer's environment to ensure the correct context for the project is set from the very start to and to get the best feedback. Then by moving through the design process from creating several initial concepts, the designer should test their concepts regularly for performance or test incremental changes as they progress. At this point, it is important to learn as much as possible as trying to learn any new insights from concepts later within the design stages will be costly as time and equipment would have been invested prior to the later stage. Towards the end of the 28-day innovation plan, Scot mentions the importance of continual stimulation for designers through teaching collages around them to ensure intern the designer mind is also stimulated for innovation.

Along with the 28-day innovation planner, Scot D. Anthony details innovation signs to accompany the design toolkits as listed below;

Pride - Creating a solution in a designer mind might not be the best solution for the customer.

Crawling Innovation - Prioritising in the working direction, i.e. prioritising analysis sooner in the design processes.

Attacking Outsiders - Dynamic smaller business creating concepts flooding a market quicker than market leaders with their hindrance of many available resources.

4.2

Not Prioritising - The ability to stop is as powerful as the ability to start. If a designer is after a lot of things within a concept the final product will not be successful.

"The chosen one issue" - Ensure that internal innovation is a team effort if more than one designer is present in the department, instead of doing individuals taking ownership, which will hinder innovation growth.

Fear of Failure - Employees cannot be punished for their failed innovation attempts as it's a part of the innovation process and failure can be used to build upon in later stages.

Impatience for Growth-Innovators need to ensure their want for growth is steered towards the correct outcomes, as rushing innovation growth will force the designer to compare and use innovation that already exists.

When comparing the above "Sin's" and toolkits it can be said that Marco falls into some of the areas Scot D/Anthony highlights in his study. Currently, designers at Marco don't fully immerse themselves in the environment of where their products are used. This is where the first sin can be seen which is "Pride", as the designers within the department will create a general conception of hoe installers, for example, will install the products thus creating a limited perspective of the final use of the products. This can create a poor relationship with the final user as and the business as potentially crucial pieces of information during the installation stage could be missed which would make a great difference to customer satisfaction.

Through comparing specifically, the concepts Marco produce, testing of them aren't as frequent as they could be. As described in the findings incepts should be tested on a regular basis at the start of the diverging stages of the project to learn from any defects that might be highlighted. Marco does test their products within the initial concept stages, but the only brief test is made in which not much can be learned from the test itself. Tests aren't in-depth enough i.e. concepts aren't sent to the customer for invaluable feedback and insights. This can be linked to the impatience growth sin, as designers within the business are impatience to grow and hence do the minimal test to progress age project a quicker pace.

And finally, Sot mentions the importance of stimulated designers in the business. When comparing this to Marco, designers often split their work between design development and other activities within the business such as quality and other operations-based work. This can be linked to two sins being "Not prioritising" and "Crawling innovation" as design work within the business is not prioritised efficiently and thus potential innovation engagement of the designers are wasted completing other tasks.

4.2

Other toolkits can be used to analyse activities at Marco. A popular design toolkit created by the CEO's of Procter & Gamble, A.G. Lafley & Ram Charan. As mentioned in chapter 2 the '5 building blocks framework' of designing are broken down as follows;

- Flow of ideas - The source of ideas need to be transparent within the business and sources should range from external and internal influences.

- Selection and green Lighting of Ideas - There must be clear instructions or procedures in place to develop solutions and to select concepts or ideas within concepts.

- Nurturing - In order to pass the green light stage, individuals need to take ownerships of concepts for accountability for success and failure. Hence grown leadership within teams for better growth and successfulness soft the product.

- Go to Market - Ensuring all critical information of the new products are correctly passed forward to the next department for correct and efficient implementation into the market.

- Killing Ideas - As with innovation not all ideas will work for the end goal, thus it's important to evaluate at this stage and priorities resources to her projects with a better potential.

Closely linked to Scott D.Anthony's theories as mentioned above, the 5 building block framework has overlapping aspects to its theory. By comparing these against Marco, firstly the flow of ideas is somewhat limited to in house operations and outsourced knowledge or concepts are rarely conditioned. As most of the design work is in house at Marco, their green lighting system is generic i.e. if a concept answers a brief specification se sentence does not make sense?! at the part of etc. project, the concept is deemed successful, but this is done without feedback from the market. During the conceptualisation and development stage, designers within the business take ownership of the project to ensure its successfulness but this can lead over control of the project and crucial in-house feedback might be disregarded. During hand over stages at Marco, very little important information is passed over, or if enough information is passed through then it would be at incorrect stages i.e. packing information would be passed down when the product is already in stock for example. And finally, if ideas aren't successful they are stopped for any further design work as detailed in the building blocks model.

4.3 Marco Against Question 2

(How can prototyping capacity be increased?)

Briefly mentioned in point 3.2, prototyping is a crucial part of any design process as it can aid vital decision making during the process and at implementation stages. As a detailed point 2.3.1 chapter 2, the importance can be broken down into the following points;

- Communication & Collaboration. many ideas can be taught of on paper, but when teams are collaborating and evaluating prototypes, this is when the best designs are created.
- Gauging feasibility. Creating prototypes give the designer the opportunity to review a concepts successfulness and hence failing at this early stage can be cost-benefit.
- Selling a concept. A physical prototype is well used? for bringing a 3D representation for infant? of other team members for review and give a sense of scale.
- Testing usability. Designers can quickly find any drawback to a design with a functional or scaled prototype to develop upon.
- Prioritising design aspects. Prototyping will aid the designer to prioritise the design aspects to ensure the fulfillment of the concept.

As shown above there are many advantages to creating prototypes and as this has been highlighted at the start of the project to discuss current prototyping techniques used within the designing industry and how it can be implemented into Marco, the author in this section will continue to compare techniques highlighted in chapter two against activities at Marco to highlight areas for improvement.

There isn’t a specific time to start prototyping within the design process but when it is time to do so various modes of prototyping have been highlighted;

- Sketching
- Wireframing
- Mockups
- Prototyping
- Development

4.3

Comparing Marco to the simple five versions of prototyping stated above; when a design process is started within the business some sketches are briefly used to give an initial representation to what is needed. These can be basic sketched drawings or detailed part artwork. Even though sketches are made, there isn't a clear pattern of initial development from idea to idea or "why we can make it like this?" recording of information on the sketches which could be a crucial step further down the project. Wireframing is not used within the business as the product in which they manufacture aren't suited to this sort of prototyping. Mockups, again a crucial part of the prototyping stage is not used much in the business again due to the nature of the product and the end manufacturing techniques used. For example, it is difficult to replicate many of the metal accessory brackets for the steel wire cable tray range of the business as many of the accessories are made of spring steel and are rough 1.0mm in thickness which would be extremely brittle in a plastic mock-up prototype. Prototyping wise, depending on the project at hand, a degree of prototypes is made in the form of samples but they tend to represent the final product and are created at a very late stage in the project. And lastly, development-wise, Marco do develop their concepts ate really stages of the project and not extensively as projects are mostly fast-paced and quick to market.

4.3

Prototyping Principles	Marco Findings
Know your audience and your goals	The business has a basic idea of what their customer need in their products, but markets and trends change regularly, and a previous conception might change.
Prime your audience beforehand	Marco doesn't send their prototypes to end users when any samples are made thus losing any potential feedback.
Involve the user	As mentioned ends users rarely get the opportunity to review any new Marco products.
Focus on flows and user scenarios	If any prototypes are made functionality is a key point that is driven in Marco but other points such as aesthetics aren't priorities that could be a detriment to the whole prototype.
Keep interactivity simple	Samples that are made at Marco do often have a good degree of interactivity to them, as they need to be interested with the work.
Don't neglect effects	Also, as mentioned simple prototypes are made at Marco but important affects such as finish quality and colours aren't portrayed.
Sketching/Prototype for the prototype	Sketching is used within the business to quickly show potential concepts.
Don't let a lack of skill hold you back	As there are a limited number of designer within the business, skill is hard to increase within the team, as there is minimal collaboration to learn off one another.
Use prototypes for usability tests	Comparing this to the business, due to the nature of some products it's difficult to create fully functional prototypes until the final stock samples are produced due to the technical manufacturing process.
Prototype only what is needed, then stop	Marco does not produce final samples of their products until a design is fully signed off as successful.

4.3

As it can be seen there are many opportunities for improvements judging by the findings of Marco's activities against various stages of prototypes. Furthermore, two benefit prototyping design processes and from a manufacturing point of view, design for manufacturing is an essential design aspect that can be implemented to not only early design stages but into the prototypes themselves as it is crucial to overcome any potential design/manufacturing issues during the prototyping stage compared to further down the development or implementation stage. Because of this crucial design model, the author will continue to describe further design form manufacturing against what Marco currently do. By implementing DFM (Design for Manufacturing) techniques it will integrate product design, process planning and production with the outcomes of;

Being easily identifying concepts that are much easier to manufacture.
Detail and focus on component-level design for ease of manufacture.
Combining product design with process design for more efficient solutions.

Design for manufacturing techniques is simply to implement as they are processed that can be changed quickly within a design process and that a designer can quickly focus on. For example, Rajesh Parekh and Vasant Hon var in 2011 detailed the following guidelines for DFM;

- Minimise part variations
- Attempt multi-functionality of parts
- Design for ease of fabrication
- Design with as few parts as possible
- Design parts fort multiple uses

When comparing Marco to the above guidelines and taking a sample for better analysis the following can be said; Marco Product (MCFB370 Cavity Floor Box)
When considering the parts of the floor box in question as the size of the product grows in depth there are additional dividing fillets needed, can these dividers be made from one material and cut down on-site if needed? I.e. manufacturing one divider at Marco instead.

- Taking the design of the floor box lid as an example, where cables come out of the floor box when plugged in, the cable outlets are separate parts and have handed version RHS and LHS. Can the floor box lid have the cable outlets already built-in?

- When analysing the cavity floor box metal base, there are multiple complex bends involved too and multiple setups. Can the design of the metal base be changed for ease of fabrication? Can knock and extrusion forms be changes to ensure less set up times?

- Currently, the floor box has a plastic trimmed lid with a metal insert for strength. Obviously being separate parts, can a completely metal lid be manufactured instead of having two separate parts of two different materials?

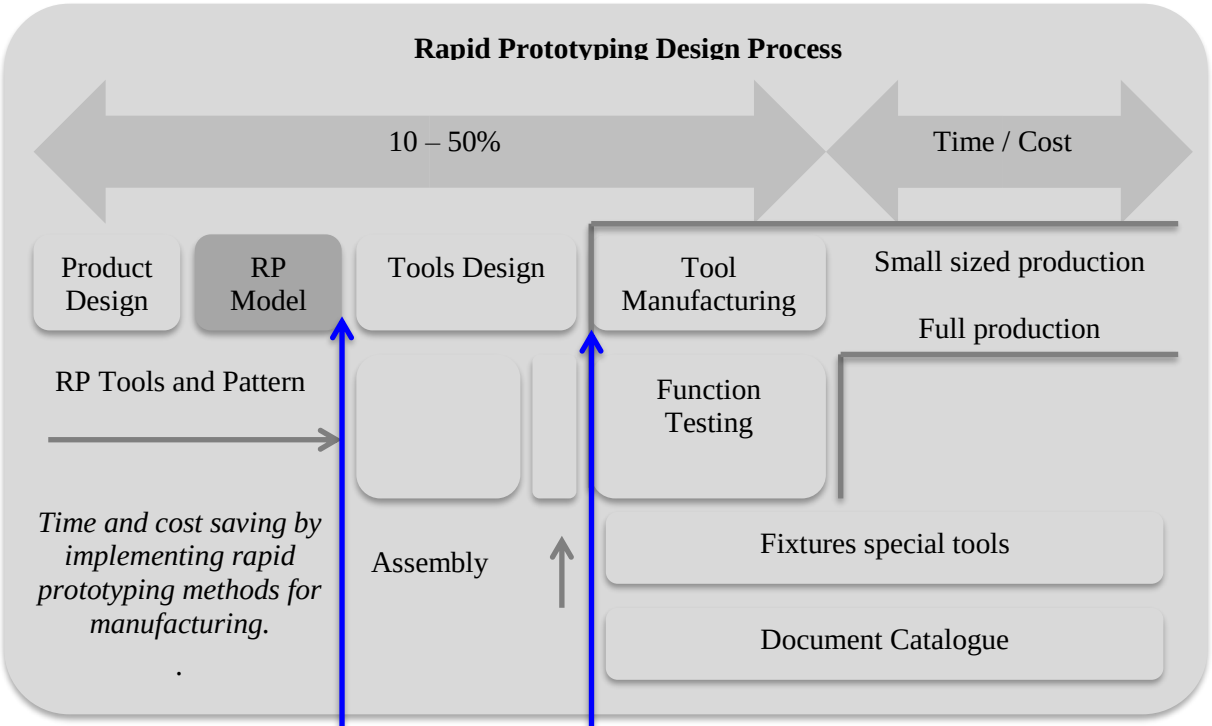
- Currently attaching the floor box lid to the metal base is done so by screwing the lid down using two screws. Can the lid by screwing it down also fix the floor box to the raised floorin

4.3

To aid trying all the above potential concept and solutions for DFM as described in the chapter there are various techniques possible to aid the design to prototype quickly to prove a concept and reduce time to market drastically. Rapid prototyping is a group of techniques used to quickly fabricate a scaled model of a physical part or assembly using CAD (Computer-aided design) software ran by a computer. As with growing technologies, there are multiple variants available which are listed below;

- Stereolithography (SLA).
- Laminated Object Manufacture (LOM).
- Selec.ve Laser Sintering (SLS).
- Fused deposition Modelling (FDM).
- Solid Ground Curing (SGC).
- 3D ink Jet Printing.

Currently, Marco does not use any rapid prototyping techniques or machinery to use within three design process. This is one crucial area for improvement for the business. As also covers din chapter two the .me and cost-saving of implement.ng rapid prototyping techniques is vast as shown in the model below;



Currently the rapid prototyping stage is missing from this model when comparing it to the activities found in Marco's design process.

As there are not rapid prototyping machinery present, stages further down the design process can have issue such as Tool manufacturing and final function testing, which can create costly delays and delay the entire the project.

4.4 Marco Against Question 3

(Which product development structure can be implemented?)

Product development structures are as important compared to prototyping techniques and design thinking methodologies as previously discussed at the start of this chapter. The author will continue to describe the differences between theories found in Chapter 2 based on product development structures against activities found at Marco. This final section will tie in design thinking theories and prototyping stages to ensure a well-structured design process can be implemented.

To begin research found that up to 14% of concepts reaching product development stages fail to achieve commercial ability, but with merging design models such as highlighted previous by IDEO and IBM's design thinking theories, concepts are benign to merge into great performances and are reach commercial statuses quicker and easier as concrete structures and design steps are benign utilised more efficiently. As highlighted in chapter two these merging models most key features. The author will continue to discuss these key features against activities found at Marco;

Subject / Characteristics	Marco Activities
Structured process. Using stage gat models, monitoring and screening of each design stage.	Currently there isn't a developed and implemented design structure at Marco, other than a basic guide listed in the ISO9001 QMS manual but this isn't followed.
Using relevant functions. Involving the relevant team members getting vital design perspectives solving problems earlier.	it is difficult to involve team members at Marco as there is only one design engineer within the business.
Overlapping and parallel working. Ensuring simultaneous working and engineering for quicker development.	Currently a design project at Marco is segmented in a stop start fashion. For example, once a design is signed off, then production staff contribute towards the project.
Project management structures. Ensuring the choice of structure is appropriate to the project itself.	Currently there is no use of project management software or guides within the business.
Cross-Functional team working. To ensure efficient team working and team building.	As team members at Marco aren't fully trained in respect of engineering to design, their contribution would not be constructive or relevant.
Advanced supporting tools. Ensuring to use CAD and rapid prototyping technologies.	The business does extensively use CAD software's but are lacking in coupling the software with rapid prototyping technologies.
Learning and continuous improvement. Ensuring lessons are learnt during the project for continual improvement.	Various aspects are learnt within the business during projects, but they are not recorded to address in the future if projects are re visited.

4.4

As can be seen from the table above there are various aspects of a development structure that can be improved within the business. As detailed by Cooper & Kleinshmidt in 1995, they are key factors that can be implemented to ensure the success of a development structure. The factors in which he detailed can be compared against Marco as follows;

- Having good pa product innovation strategy for the business.

As Marco don't currently have an innovation strategy, implementing such a structure can bring many advantages. It can tie product development to an over company strategy that will bring an area of focus for product development activities driving success within the business.

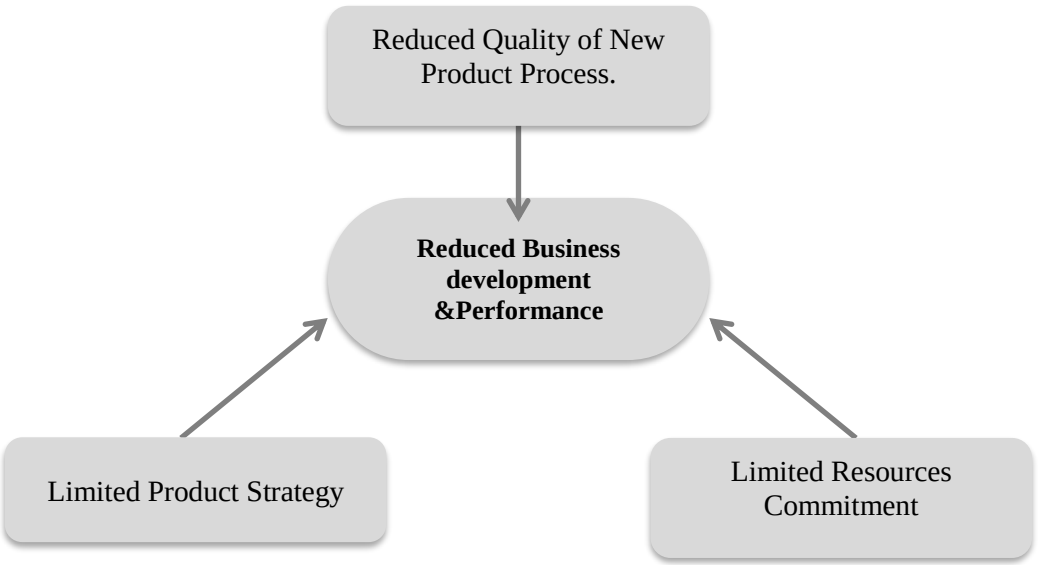
- Relevant and adequate spending and resources.

This can directly contribute to a business's new product development. From finding at Marco, there isn't any specific spending tracker in place or time trackers of resources liked to product development structures. If the business would delegate to correct stages of a project to the correct resources, it can vastly increase the tracking of activities and spending of a project to ensure no overspending.

- Having a high-quality new product process.

As seen from findings at Marco, a product development structure isn't fully implemented in the business. Implementing such a strategy will be discussed in chapter 5.

By taking the three factors above against Cooper & Kleinshmidt's model against Marco the following diagram can be drawn to describe the current situation within the business;



4.4

Along with analysing new product development structures within the business, which ties in design thinking theories with development resources such as prototyping, time management is equally a crucial aspect within a design project and can give large consequences if not managed correctly. As also theorised by Cooper & Kleinshmidt in 1994, the following ten factors can be discussed against Marco for relevance;

Driver.	**Description.**
Project Organisation	Cross integration of team and departments are rarely used within design project within the business. This can overrun projects by not taking advantage of parallel working.
Early, Sharp product definition.	New product development project at Marco will change their specification regularly portraying a non-structured way of working.
Up-front homework.	Minimal market research is done for a new project, which can be a detriment to etc. final solutions.
Strong Market Orientation.	Also, as market research when it is done is based on reports found online crucial information can be miss interpreted or is of no relevance to new emerging markets.
A strong Launch.	When new products are developed at Marco, a good degree of promotional work is completed but this is normally done towards the very end of the project and information can be miss interpreted.
Technical Proficiency.	Minimal technical product development is used, as there are no rapid prototyping facilities available.
Synergy.	Again, as the business do not utilise any prototyping techniques, improving timelines is difficult.
Familiarity.	Depending on the project at hand, with the business growing new products are being innovated within new product ranges not familiar to Marco again increasing time to market.
Market attractiveness.	The products that Marco develops are aimed at large target markets again decreasing time to market but this can often be a detriment to the quality of the product.
Market Competitiveness.	With the cable management growing with the construction sector a quicker product to market time is needed which Marco do accomplish but are sometimes hindered by the timely sample creation.

4.4

In order to implement such differences within the business to accomplish what theories have already been discussed including design thinking, prototyping, and design development structures, a great deal of in house influencing for change will be needed to ensure the efficient changeover of processes and an overall mindset within the business.

To discuss effects within the business that could potentially hinder influencing change, the author will describe findings against theories by Shum et al in 2008 as follows;

Factor	**Nature of Influence**
Organisational Culture	The culture of the business is very much a quicker product to market is always the best "mantra". Changing this way of thinking will be difficult as design thinking process are based on methodical timely innovation processes.
Resistance	As with any business there are individuals within various departments who have been in the business for some time and will oppose changes to their job or department depending on which level of authority they command.
Teamwork	As Marco does have good team working aspect within the business from a process change point of view the business would be in a good situation to change and to help one another.
Degree of Leadership support for the change	Currently there aren't many managers within the business nor would supervisors thus showing leadership within different departments to drive changes be difficult.
Organisational communications	Communication for office-based staff would be easy to delegate changes to processes but comparing this to factory staff would be much more difficult because of the lack of technology used and number of managers and supervisor are much lower.
Organisational systems and processes	Decision making within the business isn't delegated to the relevant departments and can be quite sporadic. This will be difficult to make changes to the decision-making processes as there isn't a clear structure at the moment.
Organisational Structure	Being a hierarchical structure, Marco may have issue implement changes within different departments as some managers might implement the change better than others.

After comparing product development techniques theory against the activities of the business the author will continue to summarise the findings to further review in chapter four.

4.5 Chapter 4 Summary

From the first findings of the activities within Marco, it was clear simple aspects of design thinking such as ensuring the use of external resourcing were not used within the business. Currently, they do not facilitate any external design resources to aid their project in any stage of a project such as university projects or machinery. But by comparing this to the types of innovation found within the business against that of Proctor and Gamble's it's clear why Marco don't source any additional design help outside of the business.

Their innovation style is clearly aimed towards what is easy to create for the customer. But the solutions created are aimed towards issues that have previously been outlined within the industry, thus not creating breakthrough ideas or transformational innovation as Proctor and Gamble describe. New products created by the business are for existing markets or issues and don't necessarily stand out from competitor's products highlighting a somewhat reactive designing style instead of a proactive drive for change style. Furthermore, the incremental changes the business adds to their products are based on ease of manufacturing. As highlighted this perspective is good for increasing product manufacturing efficiencies but with markets constantly changing the customer's needs might change rapidly and focus on manufacturing techies and efficiencies might not meet the customer's needs. And ultimately this is the defining reason why business is currently stuck in innovating for efficiency and not concentrating on degrees of disruptive innovation where breakthrough ideas can vastly change the cable management market.

Coupled with prioritising design for manufacturing efficiency and not creating breakthrough ideas, Marco's market research capabilities aren't used to their full potential and thus giving little or no information to base design solutions upon. This affects the three main factors that need addressing at early stages of a design project being, feasibility, viability and desirability as mentioned by Tim Brown (Tim Brown, Change By Design, 2009). Marco's findings highlighted that within early costs analysis their breakdown of costs wasn't detailed enough to make a concrete decision on the project viability. Furthermore, little time is spent with market research and manufacturing techniques when researching a new project those affecting the feasibility judgment of, etc. project. And finally, Marco's product desirability isn't at its full potential as design within the business is very much limited to the business itself i.e. external customer testing isn't facilitated, and thus invaluable customer feedback isn't recorded which might highlight better design solutions for an overall more desirable product. As for feasibility, viability and desirability are crucial for initial stages of a design process the design mindset behind the process itself is equally as important in order the increase these three points. Comparing Marco's design mindset against IBM's "Loop" mindset highlighted that as a business Marco would rarely re-visit a product or product range for continual evaluation to continually increase their performance within the market. And as highlighted Marco when compared against the diverging and converging stages throughout the IDEO mindset/process there isn't a distinct lack of continual diverging and converging throughout the design process at Marco.

It can also be said if there isn't enough diverging and converging steps within a design process as IDEO stated, “Fail early to succeed sooner” concepts might be taken further to more detailed development stages without enough testing and diverging stages beforehand which could lead to inefficient or failed solutions at the end of the project, which can be seen at Marco and their failed product attempts in the past.

Furthermore, the failed new product attempts also can be linked to the “Sin’s” as detailed by Scot D.Anthony. It was clear after further research into Marco’s design process that designers would not familiarise themselves with the environment in which they are designed for and therefore rely on their perception of the environment instead which highlighted why major aspects of the designs previously created weren’t successful and ultimately why customer didn’t fully adopt the new solutions. Along without designing their products with the final environment in mind, sufficient testing is a drawback for the business. During development stages concepts aren't tested enough for functionality or on a regular basis, test results aren't recorded for future use and further decisions are rarely made after the results of the tests if tests are made. And finally, as designing within the business is a small department, business development is prioritised within this department and on regular occurrences designing individuals would be moved to complete operations-based tasks such as quality or continual improvement instead thus making engaging design individuals difficult as they don’t have a clear structure or work pattern.

Along with not having a clear structure of design work within the business, a lack of prototyping can also be concluded from findings at Marco. From early stages of the design process, there are basic sketches, but they are sporadic and don’t record any detail of why some aspects of design would work and why others wouldn’t which could cause issues further down the development process. Mockups are also rarely used because of the nature of the products the business offers and the material characteristics linked to them. Further one to prototyping itself, if any prototypes are made they are generally seen later within the design process as there aren't any prototyping resources available in the house. This could cause issues as any changes to the final prototype could be costly when regarding machinery tooling. Because of the reduced prototyping, general product development within the business is at a low frequency as projects are generally pushed by managed for a quicker route to market reducing any potential diverging and converging stages.

Product development within the business can also be linked to their innovation strategy and how the business approaches developing their products from a structured and process perspective. Their current innovation strategy doesn’t have a clear structure for development giving the designer no guidelines in which to project or time management any new concepts. Along with an unclear structure, there are unclear spending trackers or recording abilities within the business to ensure a project isn’t running over budget for example. Also, it is difficult to judge a products final cost for viability reasons as previous development costs haven’t been recorded accordingly. And finally, without a fully implemented development structure, product quality and efficiency can be affected as crucial steps within the design process might be missed i.e. reviewing and evaluation stages that could ultimately determine the successfulness of the product in the market.

Chapter 5

Discussion

5.1 Chapter 5 Introduction

To continue with further analysis of design strategies at Marco Cable Management the author will begin this chapter by highlighting the strengths and weaknesses of the business gathered against the theories summarised at the end of chapter three which are most relevant to the business. Following further analysis of area by area, an implementation plan can be drawn to highlight the main areas in which the business would need to concentrate on in order to embed best practices from a design point of view and then to ensure influencing these changes within the business is efficient and successful.

5.2 Theory Against Marco Analysis

By taking findings summarised in chapter three, a final analysis can be deduced to clearly highlight, strengths, weaknesses, opportunities and threats of the business if new strategies would be implemented. This is discussed in the following table;

Strengths	**Weaknesses**
▪ Marco is driven to produce products quickly for shorter route to market. ▪ They do accomplish some in house testing where applicable. ▪ There is evidence of initial conceptualisation. ▪ Also, some evidence of a development stage with the design process.	▪ No use of external sourcing of design aid in initial and development stages. ▪ Innovation strategy is aimed towards quick turnaround of new product. ▪ Not fully immersing themselves in the customer working environment. ▪ Not going crucial customer feedback. ▪ Reactive designing style instead of proactive. ▪ Innovating for manufacturing efficiency instead of customer satisfaction. ▪ Minimal market research to substantiate project and design. ▪ Minimal extensive cost analysis for project viability. ▪ Customer needs are assumed by internal designers and not confirmed. ▪ No continual improvement of current and existing products. ▪ Not enough product testing throughout the design stage. ▪ Design not a priority within the business.

	▪ No clear design and innovation structure for designer to follow. ▪ No Prototyping capability. ▪ No use of external prototyping facilities. ▪ No mock ups being created for visual or scalable checks. ▪ No clear structure for product development for designers. ▪ No clear spending trackers used for project spending.
Opportunities ▪ Adopt design thinking practices such as human centered design and theories detailed by IBM and IDEO. ▪ Analysis design / innovation structures for implementation. ▪ Facilitate more site visits for greater customer interaction and valuable feedback. ▪ Take advantage of project management resources. ▪ Ensure team working within the design department is engaged. ▪ Facilitate a full market researcher action plan for each new product. ▪ Implement full testing techniques. ▪ Invest in prototyping resources or technology along with training. ▪ Ensure substantial information is gathered from initial research and feasibility studies are conduced and recorded efficiently to be reviewed in detailed for feasibility and viability reasons. ▪ Ensure influencing change within the business is systematic and relevant to various departments of individuals.	**Threats** ▪ Departments of individuals might oppose the changes needed. ▪ Resources within the business might not can produce results needed for new changes. ▪ Management might not agree with aspects of new design mindsets. ▪ Cable management market might change at a quicker rate than implementing changes within the business. ▪ Prototyping resources might not be applicable to products Marco manufacture.

Figure 1.30 Theory against Marco SWOT Analysis

5.2

As it can be seen from the above SWOT (Fig 1.30) analysis there are many opportunities for improvement as highlighted in the weaknesses and contras-ng opportunities section along with what could potentially hinder these opportuni.es. As to further breakdown, the route of the weaknesses found within the business with regards to design a route case analysis will be created to result in core areas in which to concentrate the implementation efforts of this chapter.

By using problem solving techniques championed within Six Sigma of Toyota a DMAIC (Define and Measure, Analyse, Implement and Control) model will be used to further deduce findings from the SWOT analysis above.

Define and Measure the Problem

- No structure of a design mindset from initial conceptualisation to final implementation.
- Lack of structured management of design process.
- Not utilising full potential of current design resources and potential additional resources.
- Not prioritising the importance of market research at initial stages of projects.
- Not fully implementing product development strategies within the design department.
- Currently no initiative for influencing change and leader for better performance.

Analyse Cause and Effect Relationships

- No previous training or exposure to design mindset models.
- Size of business according to management didn't warrant a dedicated structure.
- Again, no extensive training on in house resources and initiative to source external design aids such as rapid prototyping technology or aid from design consultancies.
- Team members not familiar with market research techniques towards new product development.
- Design not prioritised within the business and hence time for detailed structures aren't allocated.
- Management of current design process isn't delegated fully to an individual to project manage.

Implement and Control the Best Solutions

- **Design Mindset**. Introduce a common design mindset to adopt and to stick to.
- **Conceptual Design**. Facilitate further training for on in-house resources such as CAD packages and implement other forms of concept making for better detail and testing.
- **Market Research**. Ensure marketing departments are trained in market researching techniques using credible information for results.
- **Product Development**. Implement greater prototyping capabilities along with training along with greater in-house testing and design for manufacturing analysis.
- **Management Skills**. Implement project management process such as management software's and giving authority to team members.
- **Influencing change.** Implement a need for change strategy highlighting to end-users the importance of the change and steps or aspects about various departments that will change.

5.3 Theory Benefits to Implement

As highlighted in the previous section, there are many opportunities for implementation for the business and what initial activities can be done to facilitate the changes needed. Before discussing a full implementation action plan, the authors will continue to highlight the key benefits of implementing changes to the six key areas mentioned in the previous section. The benefits will be broken down stage by stage to better substantiate their importance for Marco. The benefits involved will also be analysed per department linked to design processes within the business.

Key Solution Factors	Overall Benefits	Design Department Benefits	Operational Benefits	Sales Team Benefit	Marketing Benefits	Finance Benefits
Design Mindset	Produces a common methodology that can be be adopted by all departments.	Designers will keep all aspects of the design project in mind including the customer.	Parallel working will allow crucial operational feedback to be translated into a new products design.	Feedback from sales teams and early / accurate forecasting will allow for accurate and competitive costing's.	Also parallel working will allow marketing teams to quickly prep work ready for quicker launch.	Project costs will be recorded accurately to be tracked against budgeting.
Conceptual Design	Greater generation of initial concepts for reviewing with better relevance to customer needs.	Being able to create prototypes for detailed testing and recording for further accurate development work.	Allowing for better feedback during diverging and converging ro reduce errors during manufacturing.	A breadth of initial concepts can aid design teams with feedback from sales teams in the environment.	Initial concepts can be pre released to preempt customers of new ranges to come.	Reduction in costly prototypes further along the design process.

Market Research	Generating accurately and constructive information in which to build design specification from.	Allows for a greater degree of accuracy when design in a human centered design aspect.	Reduction of any changes within manufacturing activities as market trends change.	Allowing sales teams to give a greater deal of feedback to the design process giving a sense that they're valued in the business.	Also gives marketing teams individuals to add value to the design process while also learning about the market.	Will give a better sense of market value and hence profit margins when analysed.
Product Development	Structured approach to generate prototyping for better solution results.	Allows the designer to create more mock ups and concepts for reviewing at early stages.	Very useful to iron out any issues earlier in the design stage instead of costly re making of tooling at manufacturing stage.	Gives sales team the opportunity to use functional prototypes with customer for better feedback.	Also gives marketing teams or individuals the ability to interact with prototypes to prepare marketing material.	With scaled prototyping it will befit financial teams by getting a better representation of costs for a scaled model.
Management Skills	Ensures the overall management of the design process is well structured and clear.	Will allow design teams to head a new projects while managing there and other department's time allocations.	Working with the design team and parallel working, time / project management will aid getting resources ready for full manufacturing,	Sales teams will be able to gauge project timelines easier updating customers on realise dates with greater accuracy.	As operational teams, marketing will also be able to work along side the design team in better order.	Finance teams will have a better understanding of costs related to a project and will table to allocate new budgeting if need for example.
Influencing Change	Will ensure all departments are clear on the changes ahead and how their activities will change in which order.	Aiding the design team to ensure all activities are aligned during a new project after changes are made.	Operational activities will be aware of working with design teams earlier on the converging and diverging stages.	Sales teams will be aware of giving greater feedback into the design team for a better insight into the market and customer needs.	Marketing teams will be aware of the need of increased market research and greater pare all working with the design team,	Finance teams will be aware of a greater detail of product cost and project costs and will amend costing documents where applicable.

5.4 Strategic Implementation Plan

As to further discuss implementation strategies, this section will detail an implementation plan that incorporates what has been discussed and highlight in this chapter. The table below breaks down the results of the SWOT analysis, DAMAIC route causes analysis with changes to be implied along with key factors to address for influencing change within the business when making the stated changes. The following is also linked to the key objectives set at the beginning of the thesis. The table will discuss these points against each of the six key solution factors, as these are the areas that have been highlighted as opportuni.es for Marco based on the theory findings in Chapter 2.

	Cause & Affect of Marco Findings	Opportunities of Theories Findings	Changes to be Implemented	Influencing Change Implementation
OBJ1. Design Mindset	No clear evidence of design mindset theories in place.	A clear and central bespoke design mindset tailored to Marco's product range and target market.	• Addition of mindset model. • Training in new mindset model. • Example project drawn up for reference.	Highlighting to employees the benefits to customer by adopting a new mindset and easier working within the business.
OBJ2. Conceptual Design	Design within the business was not prioritised and conceptualisation was shorted for a quicker product to market.	Increase of accurate and relevant concepts with input from various departments for best parallel working.	• Project check list based on timeline to discuss each stage with the relevant department.	By highlighting the value of many iterations of concepts and how they can bring value to a design process and the business.
OBJ3. Market Research	Very little market research within projects. Designer relaying on their assumption of market needs.	Producing constructive market reporting to base specification judgments on for relevant solutions for the target market.	• Training on market research techniques. • Buy cable management market research reports. • Conduct market experts feedback database.	Ensuring the marketing is at ease with looking for information in new areas compared to previous researches.

OBJ.4 Product Development	Minimal use of product development techniques and prototyping technologies	Utilising prototyping technologies for early generation of many possible concepts for review throughout departments and with customers.	• Buy prototyping machines. • Utilise external prototyping capabilities. • Training on model working. • Training of materials understanding for accurate prototypes compare to final solutions.	Using additional prototypes and highlighting the invaluable insights a designer can use from feedback given by the customer.
OBJ5. Management Skills	Delegation of designing authority not clear along with poor project and time management facilities / resources.	Clear and balanced project / time management system to ensure efficient actions are being completed.	• Integrate project managing software along with time management techniques for management and relevant departments to use.	Highlighting how management individuals can overlook the projects at hand and their ability to change activities where needed.
OBJ6. Influencing Change	No leadership for change within the business regarding design giving no direction to work to.	Each department will be fully aware of the changes to be implemented. Departments will can also completed pre actions ready for when changes are implemented.	• Create implementation plan for employees to review and sign off to agree for change before major changes are issued.	

5.5 Evaluation Against Research Questions

After creating and implementation plan for the business the author will evaluate the research efforts against the initially stated research question at the end of chapter one as shown below.

Are the most recent design thinking theories being used within the company structure?

- After further research within the business, it was clear that there wasn't a defined design mindset available. But after researching into various theories and detailing models of IBM and IDEO detailed in his book (Tim Brown, IDEO, 2015, Field Guide to human-centered design) it was clear that the business should implement a human-centered approach to design considering the market characteristics and the changes needed for the business.

How can prototyping capacity be increased?

- As the business after more findings didn't have any prototyping activities present there was a large area in which to implement various rapid prototyping technologies and conceptualisation mindset. Also, it was found from the theory that working with another department can improve the accuracy of the prototype vastly for better performing solution at the end of the project, as discussed by (Dahan, E., Mendelson, H, 1998).

Which product development structures can be implemented?

- After highlight product development structures in Chapter 2, it was clear that Marco should implement project management resources along such as timeline management a further training for design team members to ultimately give senior members of the design team more authority and ownership of projects.

5.6 Limitations

There are different challenges that this research has faced, and while there have been clear knowledge gained and added from correlating theorized design thinking against what sample of industry is doing, are have also been limitations to the research. We will follow the order of the thesis to discuss these limitations.

Literature Review

In the core research section many theories were discussed. While the review of these theories was comprehensive and includes several references, there will always be further references that could further reviewed and added to the research. It is clear that Design thinking is a subjective topic and is open to interpretation and therefore manipulation by various authors depending on its application. Therefore one could argue whether other references of design thinking could have been more valid to the research in question. Also many of the papers were unclear on how the theories were outlined, i.e. not enough detail in the core principles in which the papers were stating.

Also at the time, research of design thinking was limited due its limited popularity within design processes used within industry. But, as the thesis was completed there would be further research conducted that could have been added to the literature review.

Critique

The critique was usable to evaluate what stage the business was in its current state at the time. The process and design stages were outlined and described in detail, but the way in which these detail were researched was limited.

Details of the business processes where taken only from management minutes or from what was inspected from their management and quality systems. This did not paint the full picture of the business as not all the system were discussed further afield from the management system and managers.

Detailed research into the individual task and processes taken within their new product development stages would have been a succinct process of clearly outlining what the business achieves. This would have been a stronger foundation to discuss different between the critique and the literature review in the last chapter, evaluation.

Implantation Plan

Due to the timeframe of the thesis a brief overall implementation plan was outlined. Considering the breadth of research in prior chapters, a great and detailed implementation plan could have been developed. The implementation plan could have been developed to be lifted out of thesis and serve as a framework for the business to following to introduce the theories shortlisted to benefit the business.

5.7 Further Discussion and Reflection

After creating an implantation plan for the business there are other areas of the entire project that can be continued for further research and overall detail such as the following;

- Creating time studies of creation of concepts currently compared after implementing a new design mindset.
- Cost analysis studies on design for manufacture product after implementation.
- Team breakdown and employee satisfaction studies after influencing change
- Overall customer feedback after implementation of new human centered design mindset with new products.
- Creating an entire case study analysis. After implementing a new design mindset, prototyping facilities and product development structure, on how activities within the business has performed from start to finish. And ultimately how product development has evolved for improved concepts for the market.

*"*Taking into consideration the background of the business detailed at the beginning of the research and theories of prototyping, design for manufacturing and influencing change, the business could vastly improve their overall workflows and productivity, with improved solutions for the market specifically aimed at new issues that end users haven't engaged in yet. Implementing the theory finings not only within the design and manufacturing department, but other departments will also help the leadership team to tie in all the departments within the business to untimely create a collaborative working environment*"* *– Author (2018).*

Bibliography

(A.G.Lafley & Ram Charan,2008) “Actively create the structures to ensure that ideas flow”

(Scot D.Anthony,2012) “overshooting”

(Willy Shih, 2007) “Bright, shiny object problem”

(Scot D.Anthony, 2012) “it is hard to make the case that a market that doesn’t exist will be huge”

(Todd Zaki Warfel,2009)

(Todd Zari Warfel, 2009). “Prototyping accuracy is a sliding scale. Don't be concerned with hi-level or lo-level fidelity. The level of accuracy that matters is whatever is needed to help you accomplish you goal with the audience for your prototype”

Andre Pravas, “CAD, CAM and rapid prototyping”, SEA Technical series, 0301003, 2003.
Bessant, J & Caffyn, S (1997). High Involvement Innovation through Continuous Improvement. International Journal of Technology Management, 14, 1, pp 7-28.
Boothroyd G. and Dewhurst, P. Design for Assembly: A designer’s Handbook, Wakefield RI, Boothroyd Dewhurst, 1988.
Burnes, B. (2003). Managing strategic change: a strategic approach to organisational dynamics. Harlow: Prentice Hall.

Burnes, B. (2004). Managing Strategic Change: A Strategic Approach To Organisational Dynamics. Harlow: Prentice Hall.

C. K. Chua, K. F. Leong, K.H. Tan, F. E. Wiria, C.M. Cheah, Development of tissue scaffolds using selective laser sintering of polyvinyl alcohol/hydroxyapatite biocomposite for craniofacial and joint defects. J. Mater. Sci . Med., Vol 15, No. 1,2004, pp. 113-1121. 2004, Ppaer No. 151e63.

Camburn, B., Dunlap, B., Linsey, J., Viswanathan, V., Jensen,D., Crawford, R., Otto, K., Wood, K.L. “Using Design Problem Characteristics to Build a Prototyping Strategy,” ASEE Annual Conference, Atlanta, GA,2013.

Campobasso, F. D. & Hosking, L. E. (2004). Two Factors in Project Success. Journal of Healthcare Management, 49, 221–225.

Christensen, C.M, The Innovator’s Dilemma, HarperBsuiness, 2003.

Christie, E., Buckley, R. Zeigler, K., Jensen, D., Wood, K., “Prototyping strategies: Literature review and critical variables”, DETC 2012.

Clark, K. Fujimoto, T., Product Development Performance: Strategy, Organisation and Management in the World Auto Industry. Boston: Harvard business School Press 19991.

Cleber Willian Gomes, “Rapid prototyping”, Journal of SAE Technical Series, 2000-01-3274, 2000.

Cooper, K.G (1993b) “The Rework Cycle:Why Projects are Mismanaged,” PMNET work (Feb).

Cooper, R.G Winning at New Products:Accelerating the process from Idea to Launch, Cambridge, MA: Preseuse, 1993.

Cooper, RG & Kleinschmidt, EJ (1988). Resource Allocation and the New Product Process. Journal of Industrial Marketing Management, 17, pp249-262.

Cooper, RG & Kleinschmidt, EJ (1994). Determinants of timeliness in product development. Journal of Product Innovation Management , 11, pp381-396.

Cooper, RG & Kleinschmidt, EJ (1994). Determinants of timeliness in product development. Journal of Product Innovation Management , 11, pp381-396.

Cooper, RG & Kleinschmidt, EJ (1995b). Benchmarking Firms' New Product Performance and Practices. Engineering Management Review, 23, pp112-120.

Cooper, RG (1993). Winning at New Products – Accelerating the Process from Idea to Launch. Perseus Books.Carnall, C. A. (2003). Managing change in organizations. (4th ed ed.) Harlow: FT Prentice Hall.

Cooper, RG (1998). Product Leadership: Creating and Launching Superior New Products. Perseus Books.

Cooper, RG (1999). From Experience: The invisible success factors in product innovation. Journal of Product Innovation Management, 16, pp 115-133.

Dahan, E., Mendelson, H., Optimal parallel and sequential prototyping in product design, published mauscript, Stanford University Graduate School of Business, Stanford, CA, 1998.

Daniel Pink's (Drive, 2009)

David Hamill stated "It was once believed that a web page should not be more than 3 clicks away from any other page on that site" (David Hamill, 2015). , http://www.uxbooth.com/articles/stop-counting-clicks/

David Kelley, IDEO, 2015, Field Guide to human centred design

Deal, T. E. & Kennedy, A. A. (1982). Corporate cultures: the rites and rituals of corporate life. Harmondsworth: Penguin Books.

Dilts, D.M. and K.R. Pence (2006) "Impact of Role in the Decision to Fail: An Exploratory Study of Terminated Projects," Journal of Operations Management, 24(4): 378-396.

Dodgson, M., Think, Play, DO: Technology, Innovation, and Organisation, OUP Oxford, 2005.
Dopson, S., Fitzgerald, L., & Ferlie, E. (2008). Understanding Change and Innovation in Healthcare Settings: Reconceptualizing the Active Role of Context. Journal of Change Management, 8, 213–231

Edstrom, A; Jonsson, S & Ask, U (1998). Joint Plat forming: Learning from difference and differences of learning. Proceedings form the 5th International Product Development Conference, Brussels, European Institute for Advanced Studies in Management, May, pp349-367.

Fitzgerald, L., Ferlie, E., Wood, M., & Hawkins, C. (2002). Interlocking interactions, the diffusion of innovations in health care. Human Relations, 55, 1429.

Franck, C., Rosen, D., "Measuring value of prototypes during product development", ASME Design Engineering Technical Conference, Baltimore, MD 2000.
Gray, R. J. (2001). Organisational climate and project success. International Journal of Project Management, 19, 103–109.

Griffin, A (1997). Drivers of NPD success. The 1997 PDMA report Chicago. http://www.industryweek.com`articlesvisualize_this_20809.aspx

John Bielenberg, IDEAO, 2015, Field Guide to human centred design.

Kline, S.J. (1985) “innovation is not a linear process,” Research Management, 28 (2): 36-45.

Krista Donaldson, CEO, D-Rev, 2015)

las, R. & Vaid, M. (2006). The employees' attitudes and their connections with the organisational cutlure in the process of change in the Estonian organisations. Baltic Journal of Management, 1, 4966.

Lawrence, P & Lorsch, J (1967). Organisation and Environment. Harvard University Press.

Liberatore, M.J. and G.J. Titus (1983) "The Practice of Management Science in R&D Project Management," Management Science, 29(8): 962-974.

Liberatore, MJ & Stylianou, AC (1995). Expert Support Systems for New Product Development Decision Making: A modelling framework and applications, pp1296-1316.

Martin O’Driscoll, “Design for Manufacture”, Journal of Materials processing Technology, pp. 318-321,2002.
Martin, R., The Design of Business: Why Design Thinking is The Net Competitive Advantage, Harvard Business Press, 2009.

Moe, R., Jensen, D., Wood, K “ Prototype partitioning based on requirement flexibility”, ASME-DTM,2004.
Moe,R.,Jensen,D.,Wood,K”Prototype partitioning based on requirement flexibility”, ASME-DTM, 2004

Morrison, J. M., Brown, C. J., & Smit, E. V. D. M. (2006). A supportive organisational culture for project management in matrix organisations: A theoretical perspective. South African Journal of Business Management, 37, 39–54.

Morrison, J. M., Brown, C. J., & Smit, E. V. D. M. (2006). A supportive organisational culture for project management in matrix organisations: A theoretical perspective. South African Journal of Business Management, 37, 39–54.
Olthuis, G (1997). Production Creation at Phillips Electronics. R&D Management, 27, 3. pp 213-224.

Otto, K.N, Wood K,l., 2001, Product Design : Techniques in Reverse Engineering and New Product Development, Upper Saddle River, N.J.: Prentice-Hall.

Owens, J D and Davies, 1st European Conference on KM, Bled School of Management, Bled, Slovenia. 2000.

Pellegrinelli, S., Partington, D., Hemingway, C., Mohdzain, Z., & Shah, M. (2007). The importance of context in programme management: An empirical review of programme practices. International Journal of Project Management, 25, 41–55.

Pellegrinelli, S., Partington, D., Hemingway, C., Mohdzain, Z., & Shah, M. (2007). The importance of context in programme management: An empirical review of programme practices. International Journal of Project Management, 25, 41–55.
Pettigrew, A. M., McKee, L., & Ferlie, E. (1992). Shaping strategic change

Pich, M.T., C.H Loch and A.D. Meyer (2002) “On Uncertainty, Ambiguity and Complexity in Project Management”, “Management Science, 48 (8): 1008 - 1023.

Rajesh Parekh and Vasant Honavar, “Learning DFA from simple Examples”, Journal of Machine Learning , 44, pp. 9-35, 2001.

Rush, H & Hansen, K (1998). Hotspots in Complex Product Systems: emerging issues in innovation management. Technovation, May.

Saunder et al, (2009) Research Onion, Outside of the Onion

Schein, E. (1992). Organisational culture and leadership. London: Jossey Bass.

Schrage , M. Serious play : How the World's Best Companies Stimulate to innovate, Harvard Business Press, 2000.

Senge, P. M. (1992). The Fifth Discipline: the art and practice of the learning organisation. London: Bantam Doubleday Dell Publishing Group, Inc.

Shum, P., Bove, L., & Seigyoung, A. (2008). Employees' affective commitment to change The key to successful CRM implementation. European Journal of Marketing, 42, 1346–1371.
Strauss, A. L. C. J. (1990). Basics of qualitative research: grounded theory procedures and techniques. Newbury Park, CA: Sage Publications.

Thomke, S.H Experimentation Matters: Unlocking The potential of New Technologies for innovation, Harvard Business Press, 2003.
Thomke, S.H., Bell D., Sequential testing in product management science, 2001.

Tim Brown, IDEO, 2015, Field Guide to human centred design

Trice, H. M. & Beyer, J. M. (1993). The cultures of work organizations. London: Prentice Hall.

Twigg, D (1998) Managing Product Development within a design chain. International

Ulrich, K. T., Eppinger S.D., 200, Product Design and Development, NY :Mc Graw-Hill.

Urban, GL; Hauser, JR & Nikhilesh, D (1987). Essentials of New Product Management. Prentice-Hall.

Vajpayee, s.k., "Principles of computer Intergrated Manufacturing", 1995.

Verganti, R., Design-Driven innovation: Changing the Rules ofCompetition by Radically Innovating What Things Mean, Harvard Business Press, 2009.

Viswanathan, V.K., and Linsey, J.S., "Enhancing Student Innovation: Physical models in the Idea Generation Process," ASEE/IEEE Frontiers in Edu lion conference, San Antonio, TX, 2009.

Wankhade Nitesh Prakash, V.G Sridhar and K.Annamalia," New Product Development by DFMA and Rapid Prototyping", ARPN Journal of Engineering and Applied Sciences,VOL. 9, NO.3, 2014.

Yan Yonginan, LI Shengjie et al., "Rapid Prototyping and Manufacturing Technology: Principle, Representitive Techniques, Applications, and Development trends", Journal of Tsinghua Science and Technology, pp.1-12,2009.

Yang, Maria C. "A Study of prototypes, design activity, and design outcome. "Design Studies 26.6 (2005): 649-669.

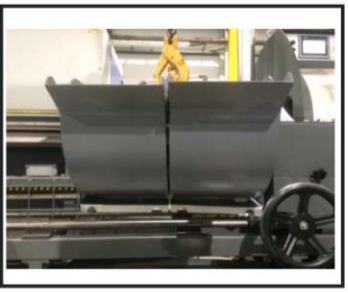
Appendix A

marco cablemanagement

KAIZEN

ORIGINATOR:	Tony Meyer	DATE:	16/03/2016
AREA:	SWCT - VITARI		
PROCESS:	Lifting Cradles	SHIFT:	

BEFORE:
When lifting two cradles together from the Vitari the galv support bases pinch together. You have to force them apart which cause damage.



ACTIONS TAKEN:
Design a spacer that sites between the bases or something to stop them pinching/locking together.

Layout	
Process Change	
Trolleys/ Aids	
Material	
Facilities	
Future Eng Kaizens	

AFTER
Photo showing the revised design

BENEFITS / IMPROVEMENTS
Improve the safety and prevent the bases from being damaged

SAFETY	QUALITY	DELIVERY	COST	MORALE	ENVIRONMENT

IMPLEMENTATION DATE: 18/03/2016

Added to Kaizen Brochure	WIRE	PLASTIC

KAIZEN REFERENCE NUMBER: 0013

WASTE OF UNUSED TALENT

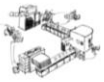
WASTE OF SCRAP/REWORK

WASTE OF WAITING

WASTE OF INVENTORY

WASTE OF MOTION

WASTE OF TRANSPORTATION



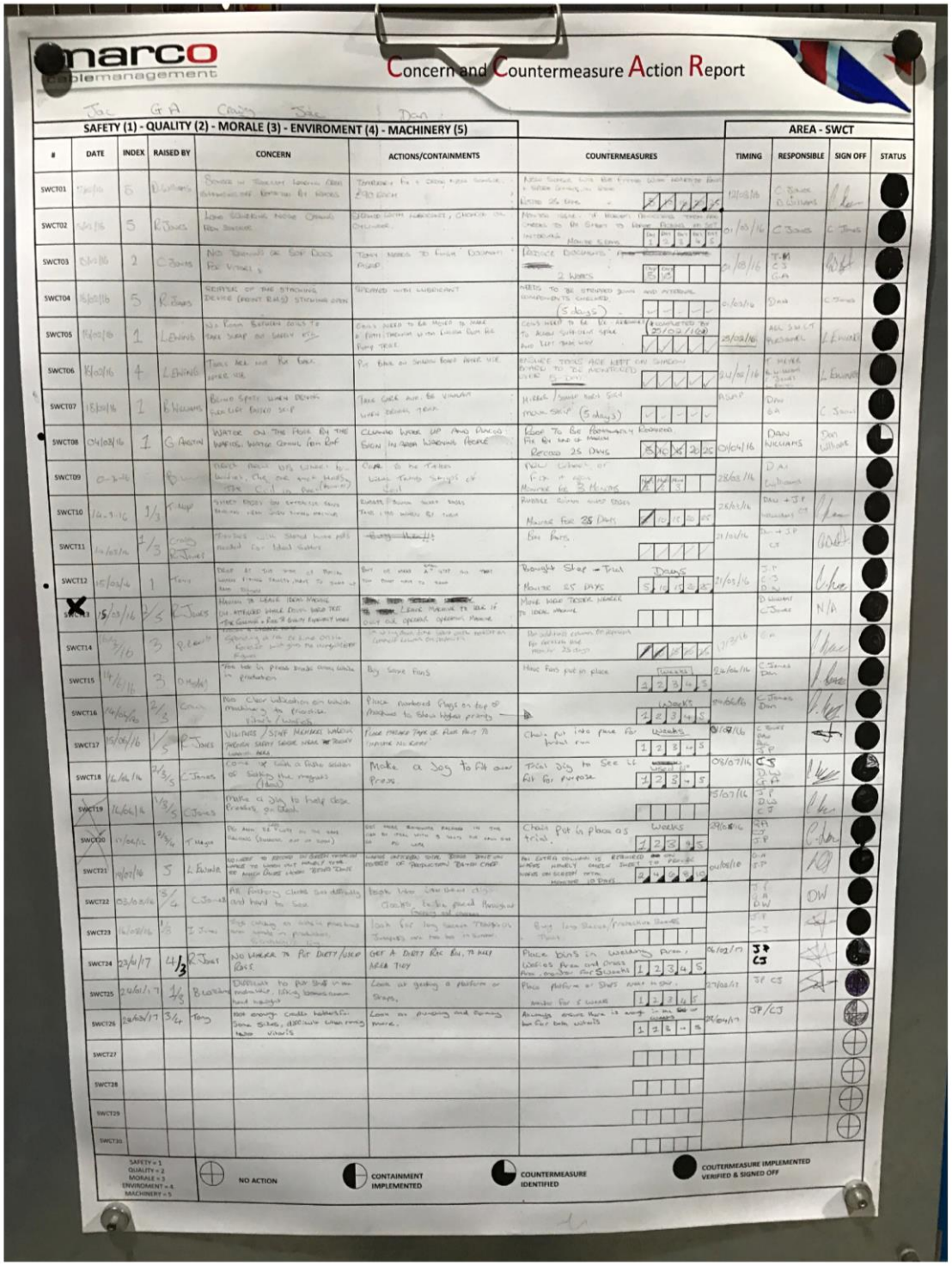
WASTE OF OVER PROCESSING

WASTE OF OVERPRODUCTION

Originator: G AUSTIN

G:\Grahame Austin\QUALITY\KAIZEN REPORTS\Wire\[0013 - Tony Meyer 160316.xls]KAIZEN Issue 1 Date Issued 15/02/16

Kaizen extract from Marco Cable Management Continual improvement system. 2016



CCAR extract from Marco Cable Management Continual factory improvement system. 2018

marco cablemanagement

WIRE PRODUCTION QUALITY CHECKS
IDEAL CHECK SHEET

Date :-	ARTICLE:		1	2	3	4	5	6	7	8	9	10	11	12	13	Comments
	CHECK															
1	Long wire Length (2998mm) when cold **+- 0.5mm**															
2	Tray front & back long wires overhang **under 1.5mm**															Check using MCSP
3	All 4 corners in spec - between top line wires (MC55 & 106 Range). 3.9mm= 20.40-21.40mm. 4.4mm & 4.9mm = 20.00-21.00															
4	Internal measurement between cross wires consistant. 1mm difference max.															
5	Internal measurement between all line wires. Check using MCCL on all spacings.															
6	Chamfers are consistant															
7	ross wire overhangs are equal on both sides and both trays must be the sam															
8	No Twist - Product is Square, Crosswires are welded/positioned square															
9	Straightness - Product is Square when flat & when bent															
10	No weld splatter on weld points on outer edges of tray															
11	Press Break Bend Test - Sides Even. (Measurement in mm) **+- 1mm**	LHS Front														
		RHS Front														
		LHS Back														
		RHS Back														
12	Weld Check - Height Check in mm on all wires across the width of the tray															3.9-3.9mm = 7.32mm MAX. 4.4-4.4mm = 8.27mm MAX. 4.9-4.9mm = 9.21mm MAX.
13	Visual check on weld heights & check to make sure all welds are centralised and even.															
14	Weld check using Testometric machine - print outs to be filled correctley															Tests every 3 hours. Test on full tray width and side wires
15	Two trays joined together with MCQC. Must be between 5999mm & 6001mm. Trays to be fitted together from both sides to ensure fit															If any changes are made to the machine settings in relation to these measuremnets then please carry out these tests again to ensure fit.
16	Two trays joined together with MCSSC & MCSSCL. Ensure correct fit from both sides. MC55 & MC106 Range															
17	Two trays joined together with MCFJC RANGE. Check fit on all 4 corners.															MCFJC - MC5550-MC55200. MCFJC-M - MC55300, & MC106100-MC106200. MCFJC-L - MC55400-MC55600 & MC106300-MC106600.
18	Three trays joined together. Ensure all line wires are aligned and no twist in the trays															
19	M+C stamp is clear		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
20	Trays produced per hour															
21	Total Trays Produced															
22	Scrap Trays produced per hour															
23	Time of check															
24	Number of Cycles															
25	Operator Signature															
26	Supervisors Signature after check															

If for any reason that you are unhappy with any of the checks on this sheet then **DON'T** sign the checks as complete and get somebody of higher authority to sign them. Counter signatures **MUST** be filled in, this is the operators responsibility.

Form 2 G:\Production Files\QUALITY CHECKS\Wire Department Check Sheets Issue 8 - 02/05/2017

Quality Form extract from Marco Cable Management QMS system. 2018

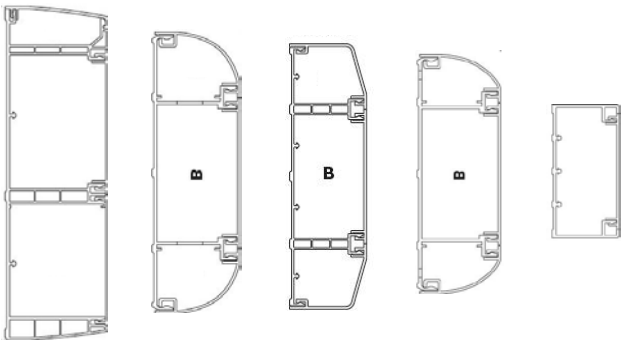
Appendix B

The Product Range

Marco's products apply to a wide range of applications specifically designed for the management of cables in areas such as offices, education and predominately large buildings with vast amounts of service runs.

Typical Installation of perimeter trunking.
Marco Elite 3 range
175 x 50 mm

Most of the products are designed and manufactured in house, while some product ranges are sourced overseas. Products manufactured include a range of 3m uPVC one, three or four compartment perimeter trunking and aluminium bench trunking / power poles. Each range includes pre-fabricated or moulded fittings to accompany the trunking profile, fittings including socket boxes, flat tees, internal, external angles and joint covers and accessories.



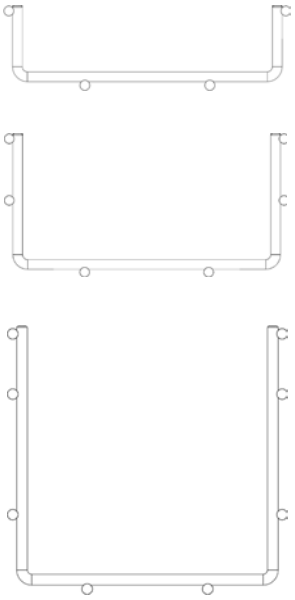
In addition to the uPVC and aluminium products, Marco have a steel wire cable tray range which couples with the perimeter trunking and aluminium ranges for a complete cable management catalogue of products. The trays come in standard 3m lengths with widths ranging from 50mm to 600mm and heights ranging from 30mm to 106mm. Four finishes are available including (EZ) electro-zinc plated, (HDG) hot-dip galvanised, pre-galvanized and powder coated.

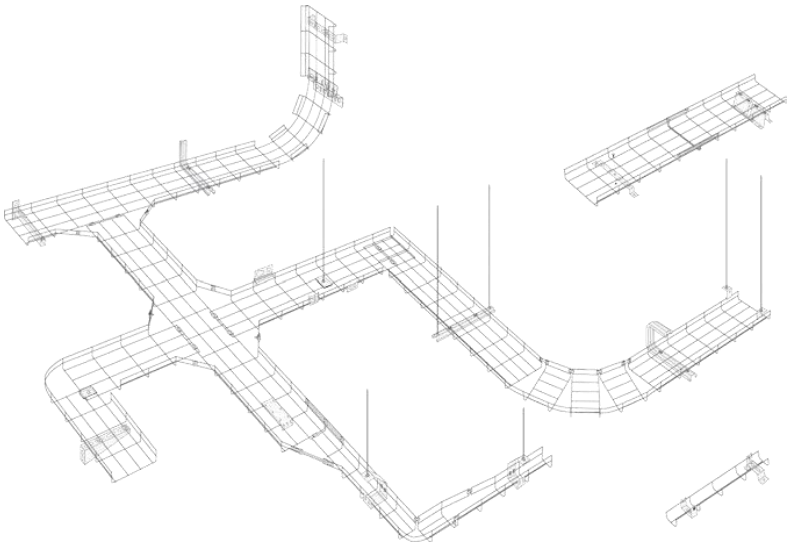
Typical Installation of steel wire cable tray containments

30,55,106
Heights (mm)

50-600
Widths (mm)

Marco steel wire cable tray is also produced in house using a state of the art automated resistance welding machine. To accompany the SWCT (steel wire cable tray) product family, various brackets and accessories are produced using CNC (computer numerically controlled) punching and bending machinery. Some brackets within the accessory range are made of sprung steel and hence are sourced overseas due to the expensive pressing machinery and plating facilities needed to make such parts.





One of Marco's innovative trucking systems, the "Elite" is designed for the high specification data cable management market. A profile the size of 145x50mm with its symmetrical design allows many cables to be enclosed in installations where space and area is restricted. The curved design allows for the installation of high density and power structured cabling systems including CAT cabling short for "category" such as CAT5E, CAT6, Shielded, CAT7 and most recently the new CAT6A 10 gig solution. CAT 5 -6 data cables are generally used for high traffic data capabilities commonly seen in offices and classrooms for Internet and networked areas, various constituent accessories relevant to the different ranges of trunking systems available also allows the installer to install a greater number of cables within internal, external, flat angles and tees. Furthermore, by using high quality uPVC various colours are possible other than white which is important for DDA compliance (Disability Discrimination Act 2005) whereby the differentiation in colours between areas of the trunking where power sockets would be located will help visual impaired individuals, this is small part of the standards in which Marco comply to within the market.

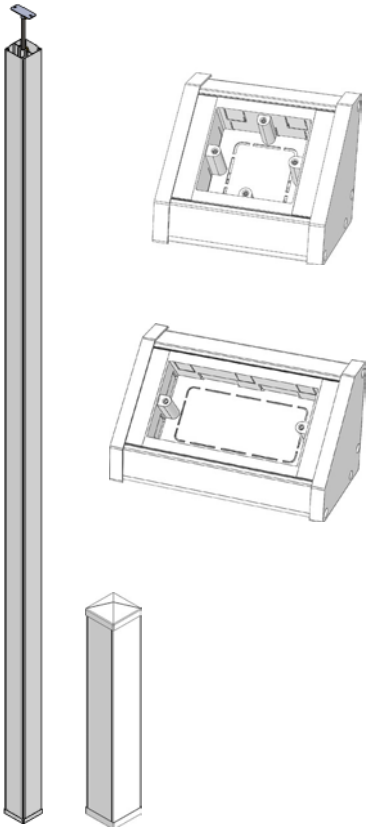
To ensure no time is wasted when installing the product, pre-punched holes are added to the compact base and internal walls. For ease of feeding the wires, a hinged lid is added to the design to allow the cables to be positioned correctly. For the easiest fitting to any sort of wall or flat surface, a wide range of accessories and fittings is also available. These include moulded flat angles and tees and a two-piece adjustable cover which bends to installation needs where 90-degree corners are unobtainable.

Use of flat angles with internal and external bends

Marco Elite 3 range

As an additional service, Marco also offer the design and manufacture of special units of the main 3 and 4-compartment uPVC trunking ranges cut to specific lengths that includes various sockets boxes at certain centers. Once the customer confirms a design, the trunking and respective lids are cut down to size to a specification with additional socket boxes were needed. Once completed these units are sent out fully assembled ready for the customer to disassemble and wire quickly on site without the need of cutting and assembling additional lids. This method of purchasing special trunking units is commonly used in school refit projects or large modular office projects.

Marco Power Poles are sold at a standard length of 3.6m with a range of finishes including anodised aluminium and powder coated, being made of aluminium the design is simple but rigid in all installation situations and being a simple design, its length can be modified easily with a height adjusting mechanism. Also, for the ease of quick installations of accessories, the poles have 35mm deep accessory boxes to provide the user a base to add specific plates and connections. Depending on customer demand Marco can supply power poles from 3.6m up to 5m in length. Each pole is supplied with six accessory boxes, a ceiling shroud, floor boot, accessory spacers to help speed installation and six meters of uPVC divider to aid segregation of various cables, commonly for power and data cables



Power Pole

3.6, 5
Heights (m)

Power Post

0.65
Heights (m)

Bench Units

2, special
Length (m)

Similar to the power poles Marco also produce Power Posts. These are used in a similar way to the power poles but transfer wiring up from the floor rather than down from the ceiling. This helps to conceal cabling effectively and positions the sockets conveniently, which is particularly beneficial in offices and other workplaces. Housed inside the post is a strong steel rod that extends from the floor to the top of the product adding extra strength to its structure. Each pole is made to order with a range of sizes with the largest being 1m. The power post is capped with a pyramidal top, and is supplied with a floor boot, six accessory boxes, uPvc divider and accessory spacers. The accessory spacers, are fitted between the socket boxes, to help reduce installation times. For customers wanting the installation of cables along working tops Marco produce and supply bench trunking lengths and bench trunking units to duct cables on a horizontal plane rather than vertical. This type of trunking is most commonly seen in IT or science classrooms where large amounts of power and networking cables are needed at desk level. Made of the same material as the Power poles and posts being anodised aluminium in silver or white, one-gang or two-gang socket boxes can be used with this range similar in design to sockets boxes used within the uPVC trunking range. To speed installation and cutting of products on site, bench trunking units come pre-assembled to 8 different standardised configurations with further configurations possible when re- quested. Customers can also decide to increase the cable capacity of bench trunking by using back to back configurations also available in a standardised range, whereby two regular bench trunking lengths or units are welded together back to back, these back to back units are commonly use d in the middle between two desks.

Recently to add to Marco's catalogue of products, a range of raised suspended flooring cavity floor boxes have been developed and implemented. Cavity floor boxes are used specifically in raised access flooring environments, in which offices for example are raised above the solid flooring to add a space to duct various cabling efficiently around the office. Cavity floor boxes can be placed anywhere within the raised floor as a rectangular cut out is all that is needed to fit them in place. Once the floor box is placed into the cut out, cables will be fed into the product using 20 or 25mm diameter conduits systems that are commonly used for ducting cables within the raised suspended flooring installations. With a range of accessory plates available to accommodate a breadth of potential power and data configurations that include sockets and data modules, the cavity floor box is very effective in open areas that need isolated services such as office desks away from walls or conference tables. There are 3 different depths available
all in either three or four compartment configurations, the cavity floor box has greatly expanded Marco's product range with the intention of further expansion soon.

Raised floor cavity floor boxes

70,100,130
Heights (mm)

3,4
Compartments configurations

Cable Management Market

Being based in the United Kingdom, the company command a small percentage of the market, roughly 20% in the UK alone in uPvc perimeter trunking and steel wire cable tray. Considering the size of the cable management market, there are numerous other competitors far bigger than the company with greater product ranges to offer.

As previously mentioned new products within the market are very much inspired by another company's innovative development ability to create new and time saving concepts. Various businesses throughout the cable management market have innovative product within their ranges such as OBBO Betterman and "magic basket" steel wire cable tray allowing fast installation of multiple lengths together reducing the need for couplers. Marco have also approached this new market avenue with their integrally coupled MCFJC fast fixing coupler supplied with or without steel wire cable tray attached.

It can be said here that the company currently bases their product development creativity from the market push of newer products coming through and developed by other companies. Additionally, these major companies are quick to protect their new products through patents and design rights that restrict any further development of similar products by other companies. New product ranges developed within the company currently are products that are sold by many other competing companies. The main reason of new products currently at the company is the drive to answer their customers need of a wider range of cable management products and hence the development of similar product ranges to their competitors.

To summarise this, because of market influences, new products emerging from the company are based on what standardised cable management products are needed for large projects. Or to fill a product range "gap" that wasn't previously available and has been available by other competitors for some time.

£40Million

Approx uPVC trunking UK market value

£5.5Million

Approx uPVC trunking Marco share of UK market
13.75% of total market

£25Million

Approx steel wire cable tray UK market value.

£3.5Million

Approx uPVC trunking Marco share of UK market
14.00% of total market

£10Million

Approx aluminium power pole and bench trunking UK market value.

£1.0Million

Approx aluminium trunking Marco Share of UK market 13% of total market.

£75Million

Total Value of cable management market in UK.

£10Million

Approx total value of Marco share of the cable management market. 13% of total market.

Business Approach

Structured around their quality management system the company follows their business strategy for product development can be seen within this section coupled with additional meetings and various other activities.

The most prominent activity within the company that facilitates its business strategy of continual development is the annual new product development (NPD) meetings. In these meetings, directors, managers supervisors and engineers attend with material and thoughts collected prior to the meeting. By sales managers, popular product ranges within the cable management market are discussed for possible further development within the company. The manufacturing, investments and justification for potential products are discussed and agreements are put in place with departmental actions if needed to start the project. Actions from the NPD meetings can be directly traced to new ranges within the company's catalogue of products such as the Marco fast joining coupler (MCFJC) as shown below. To cover all possible topics of discussion within the meeting, three main subtopics are covered, theseinclude;

- Reviewing Feedback on new product ranges.
- Updates on current projects
- Potential new product ranges / products.

MCFJC

Quick fixing integral coupler
Used pre-attached or separate.
55 / 106 SWCT Heights

The first sub topic is aimed at ensuring any new feedback from customers or testing experiments are reported for further discussion on potential new projects discussed in the previous NPD meeting. From the feedback given at this stage of the meeting, potential product ranges can be efficiently concluded to either close or develop it further to a potential new product range. Following the first sub topic, current projects that have been agreed to develop further are discussed on their performance and timescale, furthermore prices and potential investment of machinery and equipment is also discussed for further justification and viability. From this second subtopic new product ranges deemed suitable to the company answering all the stated criteria for that specific project is signed off informally and further actions delegated to bring the product or product range to market in the given timescale. Towards to end of the new product development meeting, any new potential products that have arisen in the time between the present and previous NPD meeting are discussed for eligibility. At this stage minimal justification material is used as to quickly decide on the relevance of the potential product or product range has to the company coupled with rough sales values and equipment costs available to the individuals of the meeting at the time. If deemed eligible, the product or product range is also delegated into the actions of the meeting minutes to develop further and reported ready for the next NPD meeting.

Additionally, to NPD meetings, Marco also practice specific design development procedures outlined in their ISO9001 accredited Quality manual under product realization as discussed in the next section.

Product Development

As the company works to a stringent ISO 9001(Quality management) & 14001 (Environmental management) standards, various departments and product related activities are specifically described within their quality management system within the quality manual (Issue 8, 2016). As this is a part of the inner workings of the company this will directly contribute towards understanding the natural tendencies the company has towards products and development.

Specific points within the company's product development section of the quality management system are aimed at the general performing requirements of the products sold by Marco coupled with the management and planning of design changes and customer specifications for custom products and legalities when manufacturing the products for selling, for example all products according to the low voltage directive Marco fall under, must have a full address of the main business headquarters clearly shown on each product where applicable (The low voltage directive (LVD) 2014 / 35/ EU). Marco's statement of product development is as follows;

"*Design and Development at Marco cable management is concerned with taking a Customer's enquiry for a potential product and converting this into an ex stock order. The Company does not strictly practice Conceptual Design, as all products are based on existing Technology, but Design and Development is included in the Scope as an 'Interpretive', Product Development Process is documented and applied to translate Customer Enquiries into Orders*" (Marco Cable Management Issue No.8 Quality manual ISO9001 21/06/2016)

Design and Development is also closely linked to Marco's continuous improvement ethos aimed towards efficiency of products through market performance and manufacturability in mind. Existing designs are tested and areas for improvement are developed to ensure products perform to a high standard.
Ultimately this results in increased customer satisfaction and increased market performance. Product development in the business is also closely linked to market "push" where new products developed by competing business quickly captures the customers attention and ultimately sales, depending on the success of the new competing products, the drive by Marco to be a leading manufacturer can result in the company choosing a similar path of product ranges to their competitors in specific products or entire ranges, . Also, as part of their continual improvement and key points within their ISO9001 quality manual, during product realisation the company ensures that all new projects are planned and controlled as defined in their operating procedure. The key input stages in their product development procedures are as follows:

1.Design & Development Inputs

- Functional and performance requirements
- Statutory and legal requirements are defined and are reviewed for adequacy and any conflicting requirements resolved

2.Design & Development Outputs

- Design outputs are verified against the Design inputs.
- Output documents are approved prior to release.

- **3.Design & Development Validation**

- Design validation is performed to ensure that the product can meet the requirements for the intended use.

4.Control of Design & Development Changes

- Design changes are identified, documented and controlled.
- The changes are reviewed and approved prior to implementation.
- The review of changes includes evaluation of the effect of the changes on constituent parts and delivered product.
- The result of the review of changes is documented in the design change no archiving folder for future reference.

Management Structure

"To facilitate a procedure led product development department within the company, the management of the employees and resources available must efficiently delegate such rules and work processes to be successful. Within recent years Marco have adopted various new methods of managing the business to accomplish this through Lean management". (Toyota Production System, 1988)

The basic process of lean management is to maximise customer value while minimising wastage. An organisation using lean management understands customer value and will focus its key processes to continuously increase it. The ideal goal to achieve using this management technique is to provide perfect product to the customer through a good value creation process with minimal wastage.

To achieve lean management Marco have adopted the following changes:

Key Changes	Description
Focus of Management	Changes in the focus of the management through optimising separate technologies, assets and vertical departments to ensure good flow of products and services through the value stream that flows horizon- tally through these factors. The recent appointment of the operations manager has helped to streamline the management between product manufacture and final dispatch while facilitating applicable product and business standards for formalised working practices.
Waste Management	Working alongside the operation manager, eliminating waste within value streams, a factory-based supervisor ensures the correct waste segregation and management from all manufacturing processes to decrease the need for human effort, less space, less capital and less time to produce products and services, at less cost, compared with traditional business systems.
Flexibility	Tied to their business strategy, being flexible to customer demand has allowed Marco to be able to adapt to certain spikes in sales and larger orders or customised products on certain quantities. Lean management allows businesses to respond with high quality, low cost and with fast throughput times. Also, information within this system is much more accurate and simpler to understand.

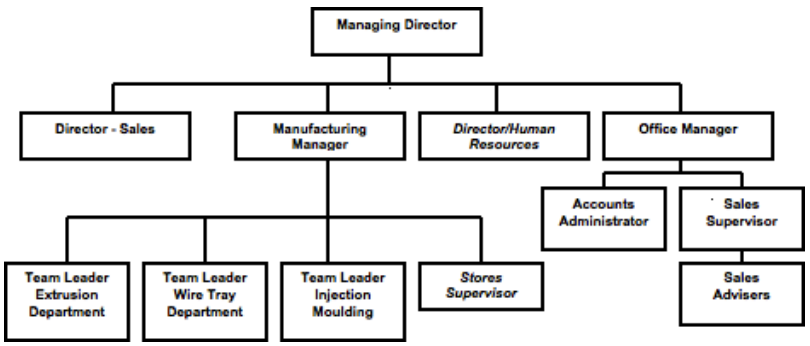
Coupled with changes aimed at lean management Marco have also changed their organisational structure since the business was born. But even through a drastic re structure when comparing the current structure against the initial outline of the business the basic layout of organisation has always been a hierarchical structure. For example, all employees are ranked at various levels each being above the other. At each stage a person may have multiple workers directly under them. This method of management clearly defines each employee's role within the organisation.

The structure clearly defines responsibilities within Marco by spreading the work across defined managers, but also it gives employees a clear promotion path encouraging increased productivity and initiative. As the structure is relatively small, this aids decision making as there are shorter paths to man- agreement level.

Additionally, a small organisation structure benefits cross-departmental work-flow. Projects and day to day working are shared from one department to another depending on the work at hand, because of this cross-collaboration of work the general efficiency of work output is much higher.

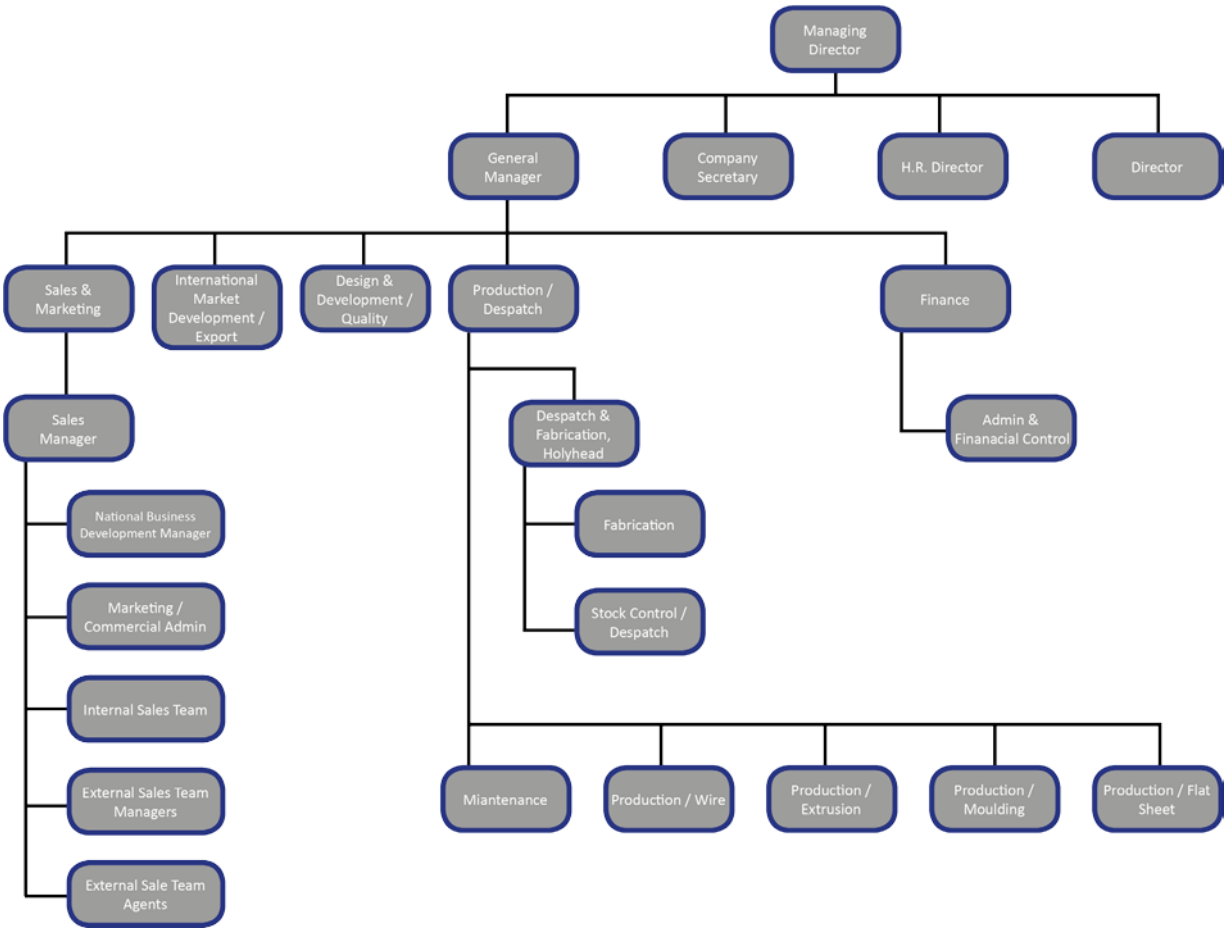
Driven by their ethos of continual improvement, their quality management systems and documentation within their quality manual has incrementally changed eight times in total. Below are two organograms showing the difference in the structure of Marco's management system with the past fifteen years.

Marco 2005 The Management Structure



Organogram taken from Issue No.2 of their Quality manual ISO9001 01/07/2005.

Marco 2016 The Management Structure



Organogram taken from Issue No.8 of their Quality manual ISO9001 21/06/2016.

Since 2005 it can be clearly seen that the management structure at Marco has changed in various departments, mainly to show a clearer path of management through the hierarchy of command in the company. Also, since 2005 a design development and quality department has been naturally created and is linked to the expansion of the company in this period. When compared with the expansion of other departments, design and development hasn't expanded further only to a couple of new employees.

Linked to the KESS II bid statement "Identification of design opportunities" it can be initially said that the differences between both management structures is the justification for the dissertation, as growth of design and development within the business has been less prominent compared to other departments which in turn serves a clear identification of design opportunities for the business to explore and develop.

Marco's recent management structure (Issue No.8 Quality manual ISO9001 21/06/2016) is reminiscent of an organisational structure theorised by Henry Mintzberg (Mintzberg and Mintzberg 2007). One of which perfectly encompasses the business environment is that of an entrepreneurial organization, whereby the business has a simple flat structure and only contains few top managers. The structure follows a relatively informal style compared to other organisations but allows the company to be more flexible than others and being flexible they can also be very lean in their model and fast to react. But as organisations with entrepreneurial structures grow it can quickly become irrelevant as top decision makers can be so overwhelmed that they make bad decisions, and as main decisions are left to only few key staff, this can come with a high risk if the business decide to move on or key individuals retire.

Mintzberg's model broke down the typical organisational structure into six generic components. Whereby top-level management sectors are split into strategic apex areas in which;

"*Their role is to interpret or define the mission of the organisation and ensure that its objectives are consistent with this mission*" (Mintzberg and Mintzberg 2007).

Further down the hierarchy the middle line provides the crucial link between the strategic apex and operating core. This aids consistency of work and clear communication between managers, line managers and supervisors. To the left of the structure, Technostructure departments include individuals dedicated to human resources, technical, sales and marketing. Support staff will include finance individuals and further research and development output. Due to the high degree of standardisation, the tasks performed by the operating core can be rigid, offering little discretion for the individual. For this reason, Mintzberg observed that motivation can be difficult and the organisation can be unreceptive to the need for change. However, Mintzberg warns that the simple structure is vulnerable, stating 'one heart attack can wipe out the organisation's prime coordinating mechanism (The Academy of Management Review, Henry Mintzberg, 1984).

Quality Control is the process of reviewing the quality of the product in question at each stage of its manufacturing process. These reviews can include, Job management, controls, defined and well managed processes, identification of records and performance and integrity criteria.

Competence; such as skills, knowledge, experience and qualifications.
Soft elements including, integrity, confidence, personnel, organisational structure, motivation, quality of relationships and team spirit.

These controls will include the inspection of the products whereby every product is examined visually and often using high accuracy equipment such as probes or microscopes. Commonly within the examining process inspectors or employees will be given lists and descriptions of unacceptable product defects such as cracks or tensile load minimum values and so on. An example of a quality control document used within Marco's manufacturing process is the IDEAL check sheet (Issue 8, 02/05/2017, Sample shown in Appendix B). The quality control document includes checks such as "Long wire length (2998mm) when cold +/- 0.5mm for the operator to conduct every hour of production.

Through the process of quality control, testing is emphasised to uncover defects or results below standards that then can be reported to management teams who make decisions based on the problem at hand.

Quality control is important as all companies have a minimum set of standards and quality that their products or service must meet. If the products do not meet the minimum requirements, quality control committee meetings are held to discuss changes in procedures or settings that will improve product quality. Marco work to a range of high quality standards all of which are driven by high specification in-house testing programmes that ensures their products are compliant with BS EN61537 (Cable man-agreement and cable tray systems and cable ladder systems standard). This standard only applies to Wire cable tray ladder systems used within the services departments and electrical management. All business selling these products need to work to this standard within the market to ensure their quality control and assurance.

Other quality standards Marco adhere to include ISO 9001, this ISO Standard is designed to help organisations ensure they meet the needs and expectations of their customers and other interested third parties. This standard is a recognised quality management principle set out by the international standard organisation. The standard includes quality policies, systems and principles that link together business objectives, customer needs on the market and marketing plans. Approaching quality in this method ensures recognition of quality standards across the business. This then reflects on each employee and their understanding of the quality needed which in turn creates a better customer experience and processes can be implemented to continually review the customer satisfaction. ISO 9001 is also a generic standard which entitles any organisation big or small for application to the standard.

Along with ISO 9001, ISO 14001 is used to set out a criterion for an environmental management system that can be certified. This standard does not state any requirements but outlines a framework that a business or organisation can follow to start an effective environmental management system. Again, being a generic standard, it can be used by any organisation regardless of which activity or sector, the use of this standards by Marco show customers and stakeholders that environmental impact is being measured and improved within the company. The benefits of the standard include reduced cost of waste management, savings in consumption of energy and materials, lower distribution costs and improved corporate image.

Recently Marco have adopted further quality and manufacturing continual improvement methods. These methods come in the form of Kaizen and CCAR forms spawned from Toyota's production system.

"*A philosophy that helps to ensure maximum quality, the elimination of waste, and improvements in efficiency, both in terms of equipment and work procedures. Kaizen improvements in standardised work help maximise productivity at every worksite. Standardised work involves following procedures consistently and therefore employees can identify the problems promptly*" (Toyota,2013).

In Marco's production factory, Kaizen reports are created daily. Operators have access to blank forms in which they detail possible improvements within their area of work, to reduce various wastage such as time, money, material, movement and so on. Once approved actions are delegated to the correct individuals to facilitate new process or machinery in order to close off the Kaizen Improvement. This method of continual improvement is a very efficient way of recording changes and benefits to a productions process, and ultimately give middle or higher management the chance to fully control improvements within the system. Along with Kaizen reports CCAR boards are placed around the factory for staff to complete.

With multiple rows to fill in CCAR poster, employees can clearly give their thoughts on a current working process and opinion on how they think it could be improved along with relevant staff needed to complete the tasks given and sign off period.

Structuring all the quality aspects of the company is their “Quality Management System” as illustrated below. From this process work-flow diagram it can be said that most of the processes and activities within the business is driven by the quality management system from sales and administration through to continual improvement and planning to despatch and ultimately customer satisfaction. Also, as many processes overlap, the flow in which tasks are managed and delegated can be seen by following the specifically styled arrows. Segregating the work-flow in this fashion clearly divides how general processes are dealt with compared to more specific continual improvement practices and sub process flows.

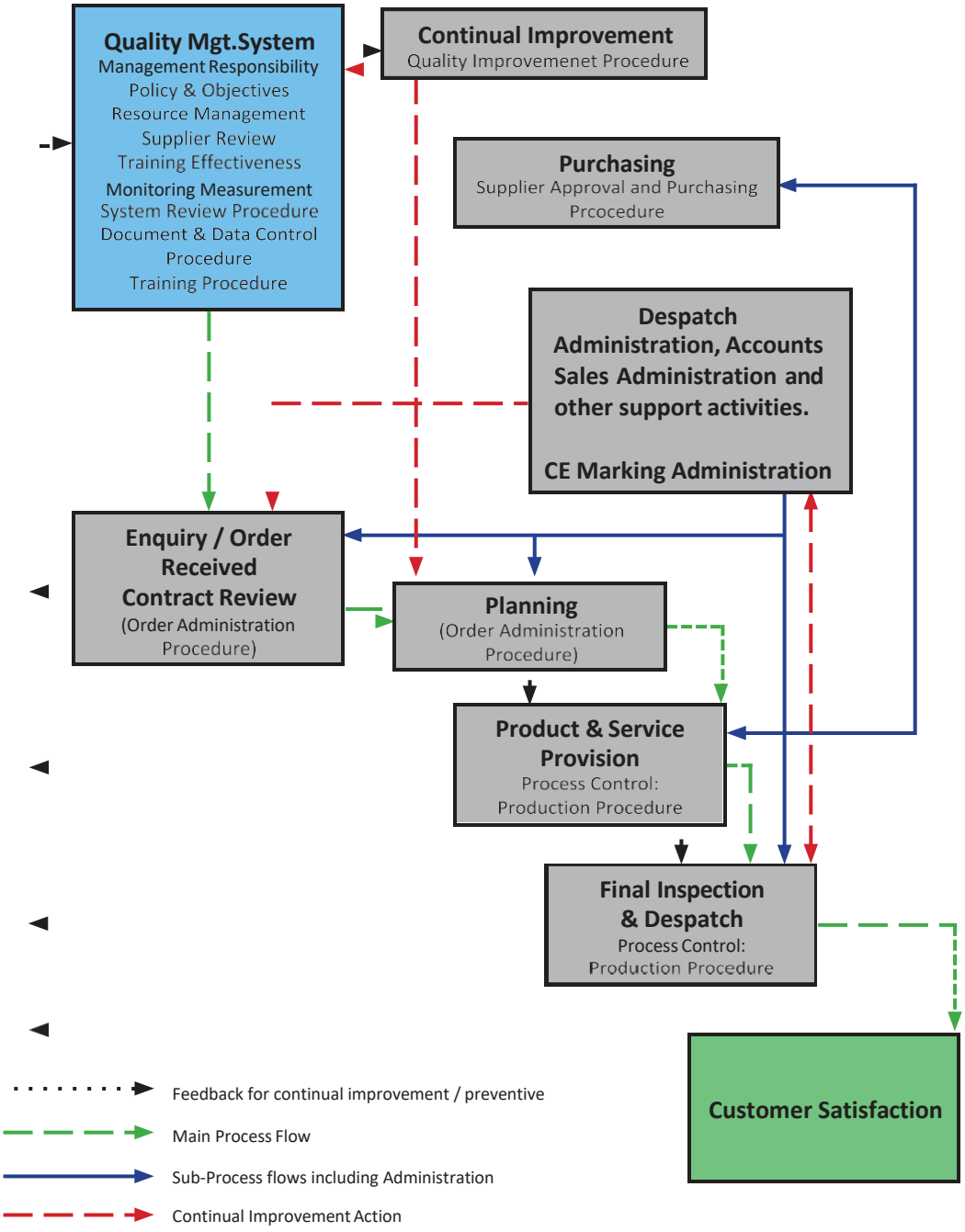


Figure 1.4 Issue No.8 of their Quality manual ISO9001 21/06/2016.

Business Development

Gaining an in-depth view of the company is crucial towards to later chapters of this research and to give overall context. Thus far Marco has been outlined and structured from initial face value research. It is evident to see with the history of the company that there has been vast expansion of growth within the past ten years and is currently ongoing. This increase was due to a substantial investment in machinery for more efficient manufacturing processes, the appointment of additional staff has also contributed to this expansion regarding improving management and further sales coverage across the nation.

With additional management and real visions for the company, the way in which Marco was operated has changed since its birth. Incrementally "Lean Management" process and techniques have been brought in and implemented slowly. These methods include improving the control of stock levels and inventory. Furthermore, waste management and recording of figures have also improved and facilitated across the company with the internal audits in ISO9001 and ISO14001. However, on top of a newly implemented lean management process, Marco has still been able to keep their flexibility for next day delivery despatch and straight to site individual orders.

When taking Henry Mintzberg's organizational structure theory into account, it was clear that Marcos' structure mirrored Mintzberg's model split into the top level, strategic apex, technostructure, middle line, supporting staff and the operating core. Because of this similar and clear structure, management was clearly defined throughout the company, which aids decision-making and problem-solving. Additionally, this structure type supports segregation in the enterprise. Staff can clearly understand team roles and departments which assist the flow of work and various projects.

Marco's early beginnings has managed to grow into a formidable business within the cable management market, so much so that they roughly command about 13% of it in the UK alone in PVC perimeter trunking and steel wire cable tray. This part of the market supplied by Marco is largely down to the contributing factors of, quality, current product ranges, manufacturing capability and quick turnaround to customers.

Their products have naturally evolved with the demands of the market. Once smaller CAT 5 data ca- bling products have now been adapted for thicker CAT 6 cabling, or even completely newer ranges have been produced to accommodate these new data and power cables. With a strong construction market in the UK, the market has grown and hence the need for cable management products has grown with it. Because of this not only Marco′s products, but comparable products from other companies have seen a degree of standardisation within the market, this is because of the nature of the products themselves. The products purpose of simply ducting various sources of cabling around, above, through or under rooms within buildings have made them a basic product within construction projects. However, even though the products are classed as standard construction items, Marco have developed an extensive range of goods to ensure their customers are saturated with choice. Products which include PVC perimeter trunking ideally used within large rooms wanting broad power and data connections, other products such as steel wire cable tray SWCT containments can be use injunction with PVC trunking.

Steel wire cable trays can be employed above suspended ceilings or below raised floors to feed into PVC trunking runs. Steel wire cable trays can also feed aluminium power poles and bench trunking units for greater flexibility of power and data access. Most recently cavity floor boxes have also been added to the range to further add power and data points capability within difficult areas or large rooms, such as existing offices and so on.

All the products have derived from product development over time at Marco. The product development is driven by customer inquiries and outside "Push" influences to add new products to their portfolio. As the company does not practice conceptual design processes, it can be said that there is not much opportunity to develop new ranges or products any further than they already have, due to the nature of their applications and function. Other than customer driven inquiries for product development, internal continuous improvement reporting can aid in design changes not only for customer benefits but for better manufacturability and a greater product output.

To clearly highlight the product development structure at Marco the following flowchart will list all the inputs and influences of design and new projects within the business and the general pattern of work processes during a project.