



# INVESTIGATING THE STAGE-GATE MODEL AS A RESEARCH AND DEVELOPMENT IMPLEMENTATION PROCESS IN MODERNISING THE MINING INDUSTRY

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## EXECUTIVE SUMMARY

In recent years, innovation in the mining industry has shifted from being a non-essential business activity to a necessity. Key challenges in the last decade (such as declining ore grades and increased mining costs) have forced companies to focus on innovative business initiatives in order to gain incremental cost and productivity improvements. These key challenges have placed the mining industry in a difficult position – they are substantial and in many cases, complex in nature.

In order to ultimately solve (and not merely mitigate) these challenges, fundamental innovation step-changes are required. The success of the potential implementation of these changes is to rethink the “starting point” of innovation, namely the research and development (R&D) strategy and process. Contrary to popular belief, innovation does not occur spontaneously. It is, in the majority of cases, a product of meticulous planning, thinking, testing, iteration, and implementation.

This study investigated the Stage-Gate model as a potential R&D implementation process in solving the aforementioned challenges, and ultimately modernising the South African mining industry. The study focused on firstly deriving a skeleton Stage-Gate model, in order to conduct further research into the associated key gate criteria, stage activities and critical success factors. The research findings were used to develop a proposed Stage-Gate model, which was then assessed at the hand of a South African mining case study (Missing Person Locator System).

From the research findings, proposed Stage-Gate model and the case study evaluation, it was generally concluded that the Stage-Gate model has the potential to assist in the successful modernisation of the South African mining industry (SAMI), through focused R&D efforts into the industry’s key problem areas and challenges. The study further recommended that in general, the outcomes of the study should be used to conduct R&D in the SAMI, in order to more effectively and efficiently conduct R&D in the SAMI (and ultimately modernise the SAMI).

Lastly it was suggested that the outcomes of the study (and in particular, the proposed Stage-Gate model) be tested through conducting an actual R&D effort into a new value proposition. The actual application of the proposed model will reveal the degree of value that the Stage-Gate approach could deliver, and could serve as proof that the Stage-Gate model and approach can work as a tool in modernising the SAMI.



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## LIST OF ABBREVIATIONS

<b>\$</b>	:	American Dollar
<b>3D</b>	:	Three Dimensional
<b>AEMFC</b>	:	African Exploration Mining and Finance Corporation
<b>AIDS</b>	:	Acquired Immune Deficiency Syndrome
<b>B2B</b>	:	Business-to-business
<b>BBBEE</b>	:	Broad-Based Black Economic Empowerment
<b>BAH</b>	:	Booz, Allen and Hamilton
<b>CAD</b>	:	Computer-aided Design
<b>CAM</b>	:	Computer-aided Manufacture
<b>CCTV</b>	:	Closed-circuit Television
<b>CoE</b>	:	Centre of Excellence
<b>CSF</b>	:	Critical Success Factor
<b>CTA</b>	:	Call to Action
<b>DFA</b>	:	Design for Assembly
<b>DFM</b>	:	Design for Manufacture
<b>DFP</b>	:	Design for Producibility
<b>ECV</b>	:	Expected Commercial Value
<b>EVA</b>	:	Economic Value Added
<b>GPS</b>	:	Global Positioning System
<b>HIV</b>	:	Human Immunodeficiency Virus
<b>IRR</b>	:	Internal Rate of Return
<b>MHSC</b>	:	Mine Health and Safety Council
<b>MIGDETT</b>	:	Mining Industry Growth and Employment Task Team
<b>MPLS</b>	:	Missing Person Locator System
<b>MPRDA</b>	:	Mineral & Petroleum Resources Development Act
<b>MRRC</b>	:	Mining Resilience Research Centre
<b>MVP</b>	:	Minimum Viable Product
<b>NASA</b>	:	National Aeronautics and Space Administration
<b>NPD</b>	:	New Product Development
<b>NPS</b>	:	New Product Strategy



## LIST OF ABBREVIATIONS (continued)

<b>NPV</b>	:	Net Present Value
<b>NVS</b>	:	New Value Strategy
<b>OECD</b>	:	Organisation for Economic Co-Operation and Development
<b>OEM</b>	:	Original Equipment Manufacturer
<b>PI</b>	:	Profitability Index
<b>PESTLE</b>	:	Political, Economic, Social, Technological, Legal and Environmental
<b>PPP</b>	:	Phased Project Planning
<b>PRP</b>	:	Phased Review Process
<b>QFD</b>	:	Quality Function Deployment
<b>R</b>	:	South African Rand
<b>R&amp;D</b>	:	Research and Development
<b>ROI</b>	:	Return on Investment
<b>S&amp;P</b>	:	Standard and Poor
<b>SA</b>	:	South Africa
<b>SAMI</b>	:	South African Mining Industry
<b>SBG</b>	:	Standard Bank Group
<b>SWOT</b>	:	Strengths, Weaknesses, Opportunities, Threats
<b>TIA</b>	:	Technology Innovation Agency
<b>TOR</b>	:	Terms of Reference
<b>US</b>	:	United States (of America)



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## CHAPTER 1: MOTIVATION FOR THIS STUDY

Chapter 1 firstly aims to provide an understanding of the concept of innovation – by providing the most fit-for-purpose definition for the term. It further explores the different types of innovation that may be possible for any given enterprise, and how innovation will be interpreted in terms of this study. Secondly, Chapter 1 motivates the need for general innovation in the mining industry. The key challenges facing the industry are addressed; key role players' opinions on this need are discussed; and the potential positive impact of innovation and Research and Development (R&D) is highlighted.

Thirdly, Chapter 1 discusses the need for a systematic R&D and innovation process, what processes are available, and on what type of technology cluster the process should focus. Lastly, the problem statement is given, as well as the objectives for the study and how those objectives could be achieved. Figure 1 displays an overview of Chapter 1, along with key questions for each section.

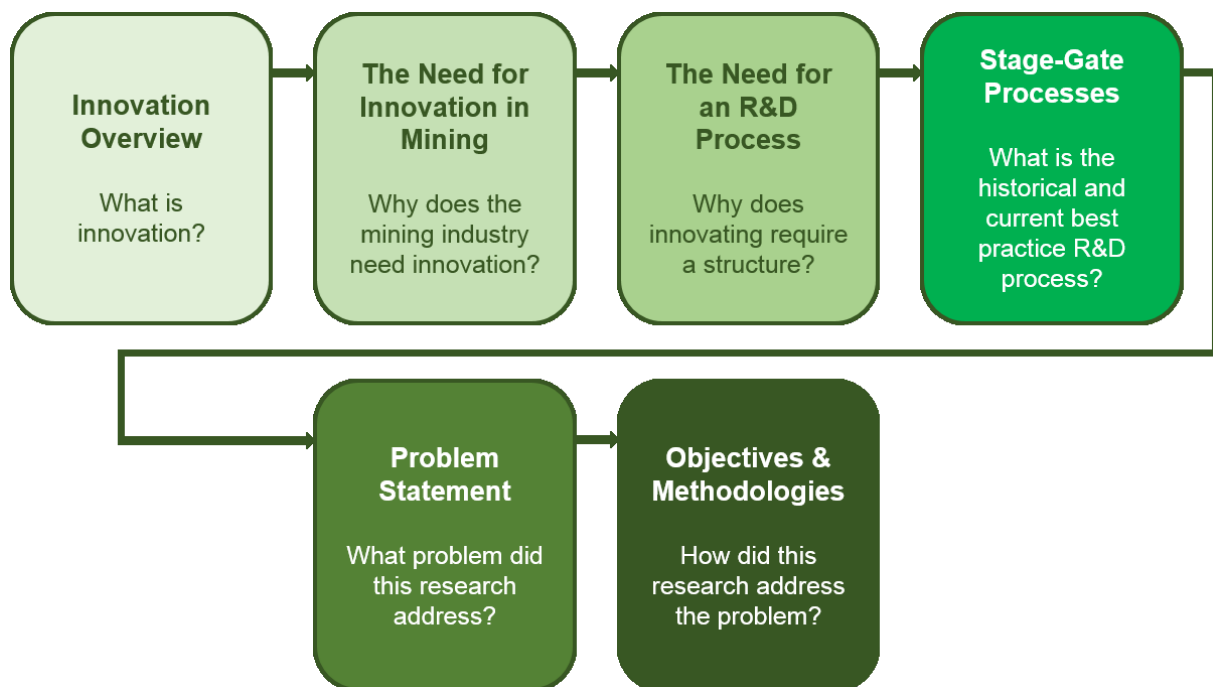


Figure 1: Chapter 1 Overview and Key Questions





## 1.1 INNOVATION: AN OVERVIEW

Innovation is a word that is being used increasingly in the 21<sup>st</sup> century. It has become a word that is used on a daily basis in most industries across the globe. The use of the word in English literature has increased five-fold since the 1940's (Google Books Ngram Viewer, 2016)<sup>1</sup>. Yet innovation is often used interchangeably when referring to an invention, which is not entirely correct. An innovation is not necessarily an invention – and an invention is not necessarily an innovation. Although certain types of inventions can be classified as innovations (and vice versa), inventions have to meet certain 'criteria' to be classified as innovations.

Deloitte (2015)<sup>2</sup> provide a simple definition for the term 'innovation' (verbatim): "*Innovation is the creation of a new, viable business offering*". Countless other definitions for innovation exist, but each different one essentially means the same thing. Innovation is often misinterpreted as referring to a new invention – which, as stated previously, is not necessarily the case. Although a new invention could be an innovation, the application of existing inventions into a new field is also seen as an innovation. Essentially, whether a new invention or not, something can be classified as an innovation if the value it creates in the application field is new.

Expanding on their definition for innovation, Deloitte (2015)<sup>2</sup> provide a more explanatory definition (verbatim): "*Innovation [as separate from invention] is the creation of a new [to our market or the world], viable [creating value for both our customers and ourselves] business offering [ideally going beyond products to platforms, business models and customer experiences]*". The use of the term 'innovation' in this thesis refers to the extended definition provided by Deloitte. However, merely defining innovation is not adequate in terms of fully understanding the concept of innovation.

*"We treat innovation as if it were magical, not subject to guidance or nurturing, much less planning. If we study history, however, we know that's simply untrue. There are times, places, and conditions under which innovation flourish. We can create those conditions."* - Samuel J. Palmisano, IBM (Martikainen, 2016)<sup>3</sup>.

Innovation has traditionally been regarded as something that simply happens. It has been romanticised throughout history as being something that normally stems from a single genial person. In unique cases, this may be true. In most cases, as stated by Palmisano, it is not. DeGraff (2016)<sup>4</sup> believes that everyone has the ability to innovate (verbatim): "*It's something that can occur through a comprehensive innovation process, or through a spontaneous, even serendipitous connection of events*".

Different ambition levels of innovations exist, and these are dependent on the type and magnitude of the value that they create (as well as their intended purpose). Deloitte (2016)<sup>5</sup> distinguish between three different innovation ambition levels: Core, adjacent and transformational.

---

<sup>1</sup> Google Books Ngram Viewer. 2016. *Use of the word "innovation" in English literature*. [Online]. Available: [https://books.google.com/ngrams/graph?content=innovation&year\\_start=1900&year\\_end=2008&corpus=15&something=7&share=&direct\\_url=t1%3B%2Cinnovation%3B%2Cc0](https://books.google.com/ngrams/graph?content=innovation&year_start=1900&year_end=2008&corpus=15&something=7&share=&direct_url=t1%3B%2Cinnovation%3B%2Cc0). [Cited 23 May 2016].

<sup>2</sup> Deloitte. 2015. *Innovation State of Play: Mining Edition 2015*. Deloitte Touche Tohmatsu Limited.

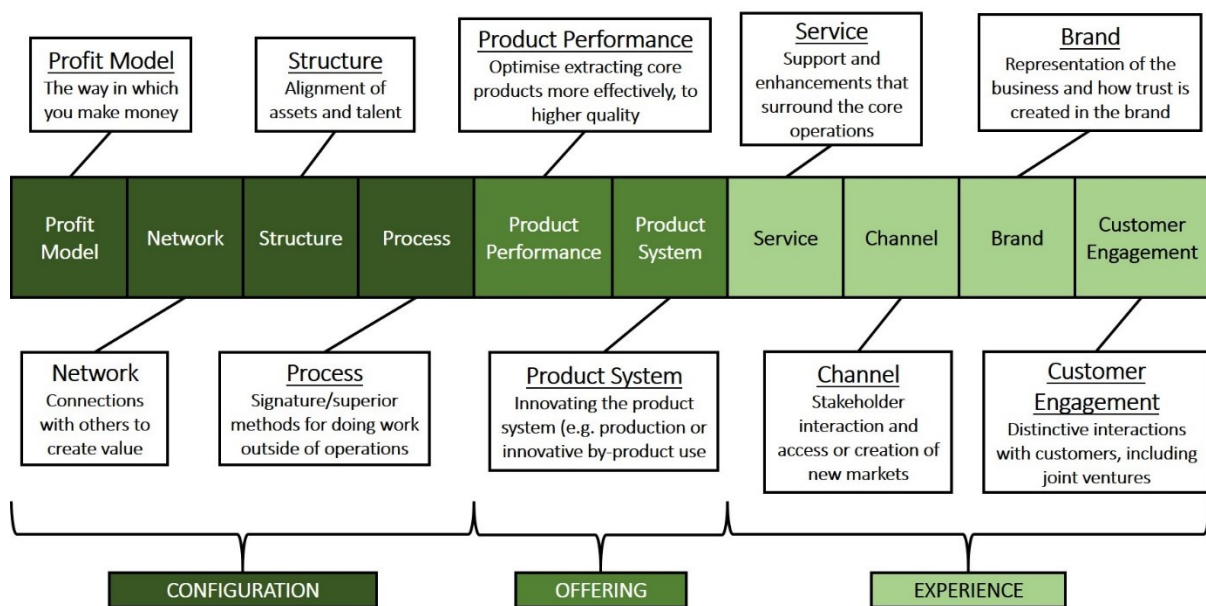
<sup>3</sup> Martikainen, 2016. *What mining industry needs now is revolution - Innovation revolution*. [Online]. Available: <https://www.linkedin.com/pulse/what-mining-industry-needs-now-revolution-mika-martikainen>. [Cited 24 May 2016].

<sup>4</sup> DeGraff, J. 2016. *Jeff DeGraff LinkedIn Profile*.

<sup>5</sup> Deloitte. 2016. *Innovation State of Play: Mining Edition 2016*. Deloitte Touche Tohmatsu Limited.

Core innovations refer to the optimisation of existing products for existing customers, whereas adjacent innovations refer to incremental changes to existing products (with the intention of targeting existing or adjacent markets). Transformational innovations refer to the development of breakthrough new products, where products are invented for markets that don't exist yet. In many cases transformational innovation leads to a paradigm shift in a market, where an existing product is made obsolete by this new invention. Christensen (2011)<sup>6</sup> calls this 'disruptive innovation'.

Apart from the different ambition levels, Doblin (2015)<sup>7</sup> identify ten types of innovation – where more than one type can be present in any given value-offering. Their Ten Types of Innovation® framework is categorised into three main areas of innovation: Configuration, Offering and Experience. The types of innovation that fall within the three categories are all distinctly different, with each type targeting a specific area where a business may benefit from gaining value. The Ten Types of Innovation® framework is shown in Figure 1.1, with brief explanations for each type of innovation.



**Figure 1.1: The Ten Types of Innovations (Redrawn from Doblin, 2015)<sup>5</sup>**

Although the main function of Doblin's framework is to provide terms of reference for companies interested in innovating, the ten types of innovation nevertheless provide a more comprehensive understanding of what innovation really is. Most companies only focus on offering innovations – Doblin (2016)<sup>5</sup> suggest that companies need to consider all types for maximum value gain.

<sup>6</sup> Christensen, C.M. 2011. *The Innovator's Dilemma: The revolutionary book that will change the way you do business*. New York: HarperCollins Publishers.

<sup>7</sup> Doblin. 2015. *Ten Types of Innovation: The building blocks of breakthroughs*. [Online]. Available: [https://www.doblin.com/dist/images/uploads/Doblin\\_TenTypesBrochure\\_Web.pdf](https://www.doblin.com/dist/images/uploads/Doblin_TenTypesBrochure_Web.pdf) [Cited 09 November 2015].



The global Organisation for Economic Co-Operation and Development (OECD) make use of the definition for innovation as stated in the Oslo manual (OECD, 2016)<sup>8</sup>. The Oslo manual provides guidelines for collecting and interpreting innovation data, and rather than explicitly defining innovation, it breaks innovation down into four main types (OECD & Eurostat, 2005)<sup>9</sup>:

- **Product innovation:** the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.
- **Process innovation:** the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
- **Marketing innovation:** the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- **Organisational innovation:** the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

It is important to note that both Doblin's ten types of innovation and Oslo's four types show the diversity of innovation. Innovation can occur (or be achieved) anywhere – the key is just to understand the diversity thereof to not inhibit and limit thinking to new products or inventions.

As stated previously, in terms of this study, Deloitte's extended definition is used when referring to innovation in general. It should however be noted that innovation is a vast and seemingly complex concept, but in actual fact it is more simple than what it seems. Any type of sustainable value-addition is essentially an innovation. The end goal is the creation of sustainable value – anything that enables that goal to be reached is considered an innovation.

## 1.2 THE NEED FOR INNOVATION IN MINING

*"It's interesting times in the mining industry; more interesting than many of us expected. China's economic rebalancing is causing exceptional disruption. Commodity prices are taking much longer to recover than anticipated. To my mind, this makes innovation more imperative. Rather than being optional, being bold may be the prerequisite to survival".* – Glenn Ives, Americas Mining Leader, Deloitte Canada (Deloitte, 2015)<sup>10</sup>.

Considering the current state of the mining industry innovating in a stable environment is already tough, but innovating when the environment is as volatile and uncertain as it is now, is even tougher. This is the situation that the global mining industry is currently facing – near the bottom of a super-cycle downturn, the mining industry is at an innovation inflection point. Looking forward, IBM (2009)<sup>11</sup> believe that mining companies will have to make critical decisions about every aspect of their business – they have to choose to innovate, or inevitably stagnate.

<sup>8</sup> OECD. n.d. *Defining Innovation*. [Online]. Available:

<https://www.oecd.org/site/innovationstrategy/defininginnovation.htm>. [Cited 23 May 2016].

<sup>9</sup> OECD & Eurostat. 2005. *Oslo Manual: Guidelines for collecting and interpreting innovation data*. Paris: OECD Publishing.

<sup>10</sup> Deloitte. 2015. *Tracking the Trends 2016: The Top 10 Issues Mining Companies will face in the Coming Year*. Canada: Deloitte Touche Tohmatsu Limited.

<sup>11</sup> IBM. 2009. *Envisioning the Future of Mining*. [Online]. Available: [https://www.ibm.com/smarterplanet/global/files/ca\\_en\\_us\\_oil\\_smarter\\_natural\\_resources\\_future\\_of\\_mining.pdf](https://www.ibm.com/smarterplanet/global/files/ca_en_us_oil_smarter_natural_resources_future_of_mining.pdf) [Cited 13 January 2016].



In the short-term, declining commodity prices are placing pressure on mining companies' cash flow. In the long-term, many current mines are maturing, which is resulting in lower ore grades; increased hauling distances; declining ore-body replacement rates; and increasing new project development times. In addition to this, worldwide mining operations are approximately 28% less productive now, as compared to a decade ago – and that is after adjusting for declining ore grades (McKinsey, 2015)<sup>12</sup>.

In recent years, innovation in the mining industry has shifted from being a non-essential business activity to an urgent necessity. The future survival of the industry depends on it. The well-known adage “innovate or die” (Matson, 1996)<sup>13</sup> rings true for the industry. If the mining industry does not initiate step changes in how the business of mining is conducted, it will continue on the current downwards slump. Key challenges in the last decade has forced companies to focus on business improvement initiatives – mostly in the form of innovating to gain incremental cost and productivity improvements.

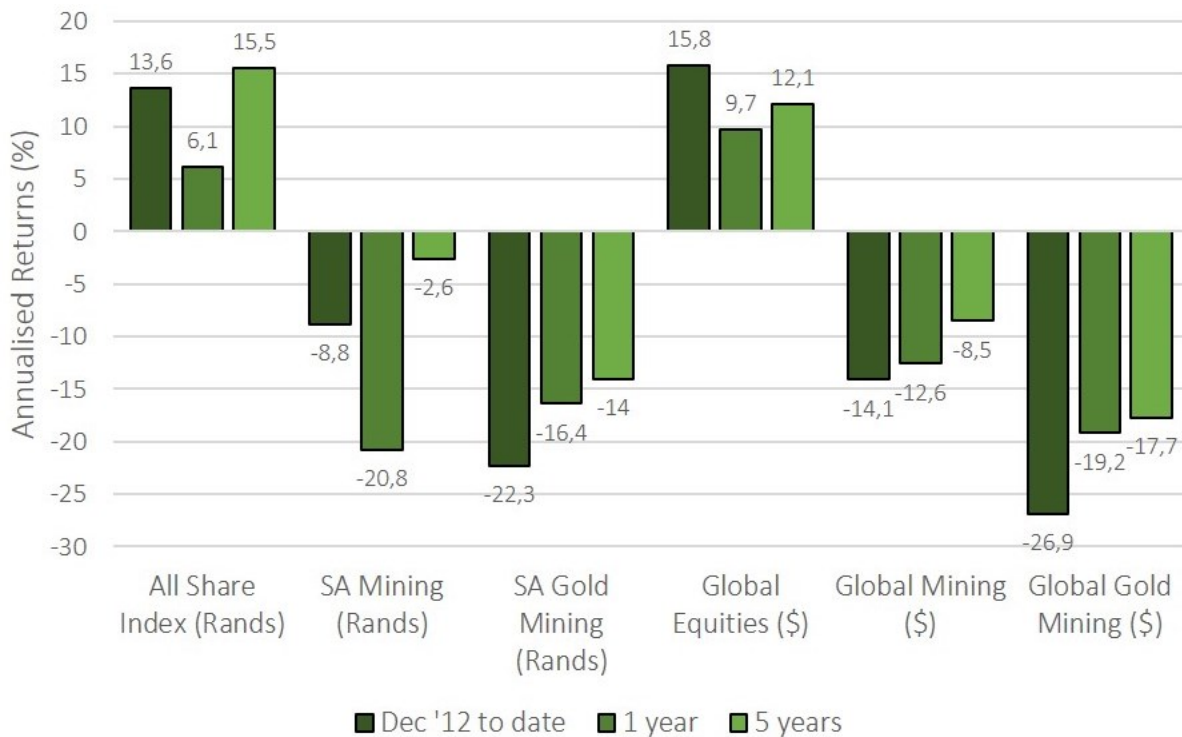
These key challenges have placed the mining industry at a crossroad. The challenges currently facing the industry are substantial, and due to the highly complex nature of these challenges, they cannot be easily solved. Optimisation of traditional practices, technologies and methods have provided some relief in the tough times, but the ability to gain value through incremental improvements has run out. Improving productivity by “sweating” existing assets will only go so far – achieving breakthroughs in productivity performance demands rethinking how mining works (McKinsey, 2015)<sup>10</sup>. Incremental improvements have (to a large extent) run their course in attempting to mitigate these challenges. In order to ultimately solve (and not merely mitigate) these challenges, fundamental step-changes are required.

The impact that these challenges have had on the global mining industry (and the SA mining industry) is evident when looking at the performance of the industry versus the global equities market and the all share index (Figure 1.2a).

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<sup>12</sup> McKinsey & Company. 2015. *How digital innovation can improve mining productivity*. [Online]. Available: [http://www.mckinsey.com/insights/energy\\_resources\\_materials/how\\_digital\\_innovation\\_can\\_improve\\_mining\\_productivity](http://www.mckinsey.com/insights/energy_resources_materials/how_digital_innovation_can_improve_mining_productivity) [Cited 13 January 2016].

<sup>13</sup> Matson, J.V. 1996. *Innovate or Die: A Personal Perspective on the Art of Innovation*. Cambridge: Paradigm Press.



**Figure 1.2a: Global Equity Sector Mining Context - data courtesy of SBG Securities, Bloomberg in July 2015 (Baxter, 2015)<sup>14</sup>**

Figure 1.2a shows that over the last five years the all share index and the global equities market have had annualised returns of 15.5% and 12.1% respectively, whilst the SA and global mining industries have seen returns of -2.6% and -8.5%. When considering the past year, although the all share index and the equities market underperformed at 6.1% and 9.7% annualised returns, the SA and global mining industries recorded annualised returns of -20.8% and -12.6%. These alarming figures highlight the financial impact that these challenges have had on the mining industry.

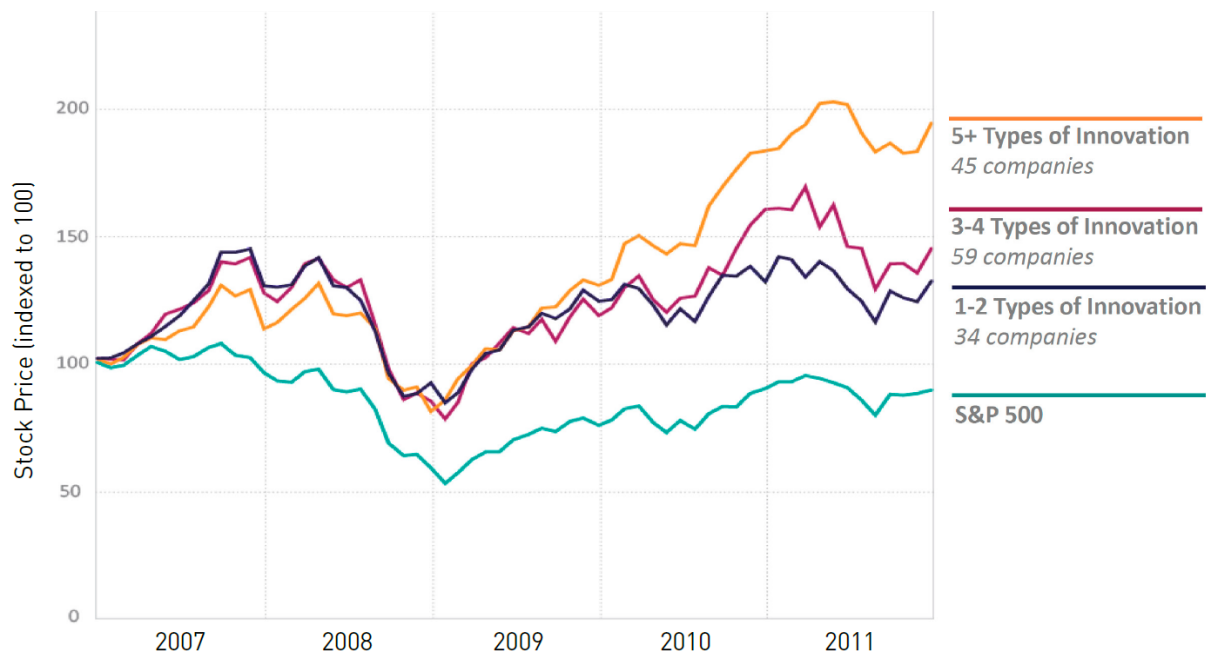
A number of paradigm shifts are required to solve these challenges – and these solutions need to be sustainable. Industry leaders are emphasising the urgency (verbatim): “*The mining industry needs to leap forward 20 years in the next five years*” (Griffith, 2015)<sup>15</sup>. Innovation across the mining value chain has become a necessity – without major changes and interventions the industry will not overcome these challenges. Innovation has the power to not only overcome these challenges, but can also lead to a more sustainable and economically thriving industry.

Research by Deloitte (2015)<sup>2</sup> suggests that companies that actively innovate perform better financially in terms of stock price returns. In comparison to the Standard and Poor (S&P) 500 index (which is essentially the top 500 US companies in terms of market capitalisation), Deloitte’s research showed that top innovating companies outperform the S&P 500 (Figure 1.2b).

<sup>14</sup> Baxter, R. 2015. The Future of the South African Mining Industry.

<sup>15</sup> Griffith, C. 2015. *Modernisation – a vital step in building a sustainable mining industry in South Africa*. Mining Indaba 2015.





**Figure 1.2b: Five-year indexed stock price returns of the top innovators vs. S&P 500 (Deloitte, 2015)<sup>2</sup>**

From Figure 1.2b, it can be seen that the S&P moved from an indexed stock price of 100 at the beginning of 2007, to 85 at the end of 2011, a 15% decrease over 5 years. The companies with five or more types of innovations ended 2011 on an indexed stock price of 190, outperforming the S&P 500 by 124%. Companies with three to four types of innovations (based on the ten types shown previously in Figure 1.1) outperformed the S&P 500 by 71% (ending 2011 on 145), and those with one to two types of innovations outperformed the S&P 500 by 59% (ending 2011 on 135).

In Australia, out of the top 50 companies who spent the most on R&D, 30 of them spent more than four times the national average on R&D per revenue. In turn, these 30 companies' average return on shareholder investment was 17.1%. Australia's top 1000 enterprises returned an average of 7.7% (Gilmore, n.d.)<sup>16</sup>.

What this superior financial performance (in terms of stock price returns) shows, is that innovation in the mining industry could lead to long-term sustainable benefits. Apart from the role it plays in overcoming the current survival challenges, innovation will continue to reward benefits once the challenges have been resolved. The mining industry is currently unfavourable in investor's eyes – innovation has the potential to make it attractive once more. Innovation has numerous benefits. Bhuiyan (2011)<sup>17</sup> states that innovation creates employment, stimulates economic growth, leads to technological progression and can have a significant socio-economic impact.

<sup>16</sup> Gilmore, R. n.d. *Overview of New Product Development*. [Online]. Available: <http://www.aq.org.au/PDF/Gilmore.pdf> [Cited 05 May 2016].

<sup>17</sup> Bhuiyan, N. 2011. *A framework for successful new product development*. *Journal of Industrial Engineering and Management*, vol. 4(4), pp. 74-770.



In comparison to the petroleum sector (which is the most similar to the mining industry), the global mining industry greatly lags behind in terms of innovation and business improvement. On a revenue-to-revenue basis, the global mining industry spends 80% less on technology and innovation than the petroleum sector (Griffith, 2015)<sup>13</sup>. Yet operating costs on mines are increasing three times faster than consumer inflation rates, and are set to double in less than five years (Cutifani, 2015)<sup>18</sup>.

These two facts are in contrast to one another – given the substantial continuous cost increases, it makes logical sense to spend more on innovation and business improvement initiatives (in order to alleviate the cost increases). The Kellogg Innovation Network (KIN) (n.d.)<sup>19</sup> believe that the role of science and technology investments that support new systems in mining cannot be overstressed (verbatim): *“Compared to other industries, mining has invested a fraction of revenues back into R&D efforts”*.

The relatively small amount spent on R&D by the mining industry is not necessarily due to an unwillingness to innovate. The core business of mining is based on a number of uncertainties – and to add to this, the mining industry has numerous constraints. These constraints are both inherent (such as declining ore grades) and imposed (such as political and regulatory issues). In many cases, the want and the need for innovation is there, but the constraints prevent an idea from ever turning into a reality.

As an example, when specifically looking at the South African mining industry (SAMI), one of the key current themes is that of modernisation. Modernisation includes and refers to the mechanisation and automation of mining operations and equipment, whilst considering (and satisfying) the needs and wants of all the other stakeholders in the mining sector. In essence, modernisation refers to the paradigm shift towards next generation mining.

This presents the SAMI’s biggest challenge – the SAMI needs to modernise in order to survive (from a financial point of view) – and needs to keep all stakeholders involved satisfied throughout. The barriers to the successful modernisation of the global mining industry are uniform across the globe. Apart from these uniform challenges, the SAMI has unique barriers to modernisation that may not be present in other countries. Thus, from a global mining perspective, modernisation is already a big challenge. From a SAMI perspective, considering all the stakeholders involved and the unique barriers (political, regulatory, etc.), it is an even bigger challenge

The 2015 Joburg Indaba Index focused on unpacking modernisation of the SA mining industry, in order to determine how ready the SAMI is for modernisation. The index made use of several survey questions – answered by more than 200 key role players in the SAMI (Table 1.2).

<sup>18</sup> Cutifani, M. 2015. *A critical imperative – innovation and a sustainable future*. World Mining Congress 2015.

<sup>19</sup> Kellogg Innovation Network Global, (n.d.). *Reinventing Mining: Creating Sustainable Value - Introducing the Development Partner Framework*. Kellogg School of Management.

**Table 1.2: SA Mining Industry Modernisation Report (Swanepoel, 2015)<sup>20</sup>**

No.	Survey Question	Percentage of Participants
1.	Use of Modern Technology (Overall)	25%
2.	Mining Technologies	55%
3.	Exploration, Modelling and Design	75%
4.	Technical Skills	65%
5.	Leadership Skills	25%
6a.	Communication Skills (Internal)	30%
6b.	Communication Skills (External)	55%
7.	Listening, Engaging, Inspiring Skills	15%
8.	Regulatory Certainty	20%
9.	Ease of Compliance	40%
10.	Investor Friendly Regulations	25%
11.	Correct Balance Between Stakeholders	30%
12.	Providing Jobs/Participation for Communities	60%
13.	Natural Resource Endowment	70%
14a.	Preparedness to Modernise (Top Levels)	70%
14b.	Preparedness to Modernise (Bottom Levels)	20%
<b>Overall Joburg Indaba 2015 Index</b>		<b>42%</b>

One of the questions aimed to determine how SA compared to the rest of the world in terms of using modern technology. The result was not surprising – only 25% of survey participants rated the SAMI as good or world-class (Swanepoel, 2015). This lack of confidence points to a key innovation focus area being the use of modern technology in mining.

The SAMI requires rapid innovation and R&D in order to make modernisation a reality. Care needs to be taken to not waste any time, effort or money on R&D and innovation. Gerald Whittle (2016)<sup>21</sup>, in his Money Mining and Sustainability seminar, also stated that (verbatim): *“Mining companies shouldn’t just innovate for innovation’s sake. They need to innovate for maximum value gain. Not just because everyone else is doing it”*. Whittle’s anecdote speaks to the core definition of innovation. The SAMI needs to innovate – but it has to be meticulous and disciplined with regards to the process followed.

The challenges facing innovation in the mining industry is not so obvious; innovation is traditionally an expensive endeavour, and success rates are generally low. Strategyn (2010)<sup>22</sup> concluded that only 17% of attempts at innovation succeed – and this figure is based on innovation in a stable environment (unlike the highly unstable and volatile mining environment). The main aim would be to seek the maximum return on investment, and in most cases innovative R&D does not yield these returns. The challenge is therefore one where innovation is an expensive investment, and one that is more likely than not to fail.

<sup>20</sup> Swanepoel, B. 2015. *The Joburg Indaba Index 2015*.

<sup>21</sup> Whittle, G. 2016. *Money Mining and Sustainability Seminar*. 07 – 08 April 2016.

<sup>22</sup> Strategyn. 2010. *Innovation Track Record Study*. [Online]. Available: [http://www.strategyn.at/sites/default/files/uploads/TrackRecord\\_07.pdf](http://www.strategyn.at/sites/default/files/uploads/TrackRecord_07.pdf). [Cited 02 May 2016].





Research on new product development (which is essentially innovation) suggests that the overall success rate of new product introductions is relatively low at 60% (across global industries) (Page, 1993)<sup>23</sup>. This figure does not refer to viable products – it merely refers to the success rates of turning ideas into some form of a value-offering. Success rates decline as the cost and risk of developing new products increases – approximately 46% of all resources spent on new product development and commercialisation is essentially wasted. Products are either cancelled somewhere along the R&D process, or they fail to yield adequate returns on investment (Page, 1993).

Considering the innovation challenge in the mining industry, the key to unlocking the potential value of innovation, is to do it at the lowest cost, in the least amount of time, and with the least amount of wasted effort. Success rates of R&D and innovation can be increased dramatically, if an engineering-based approach is followed with regards to the process. An organisational innovation (OECD & Eurostat, 2005)<sup>7</sup> or a process innovation (Doblin, 2015)<sup>5</sup> is required in terms of the approach to R&D and innovation. Thus, one type of innovation (such as a process innovation) is needed first, in order to more successfully achieve other types (such as product innovations).

### 1.3 THE NEED FOR AN INNOVATIVE R&D PROCESS FOR THE MINING INDUSTRY

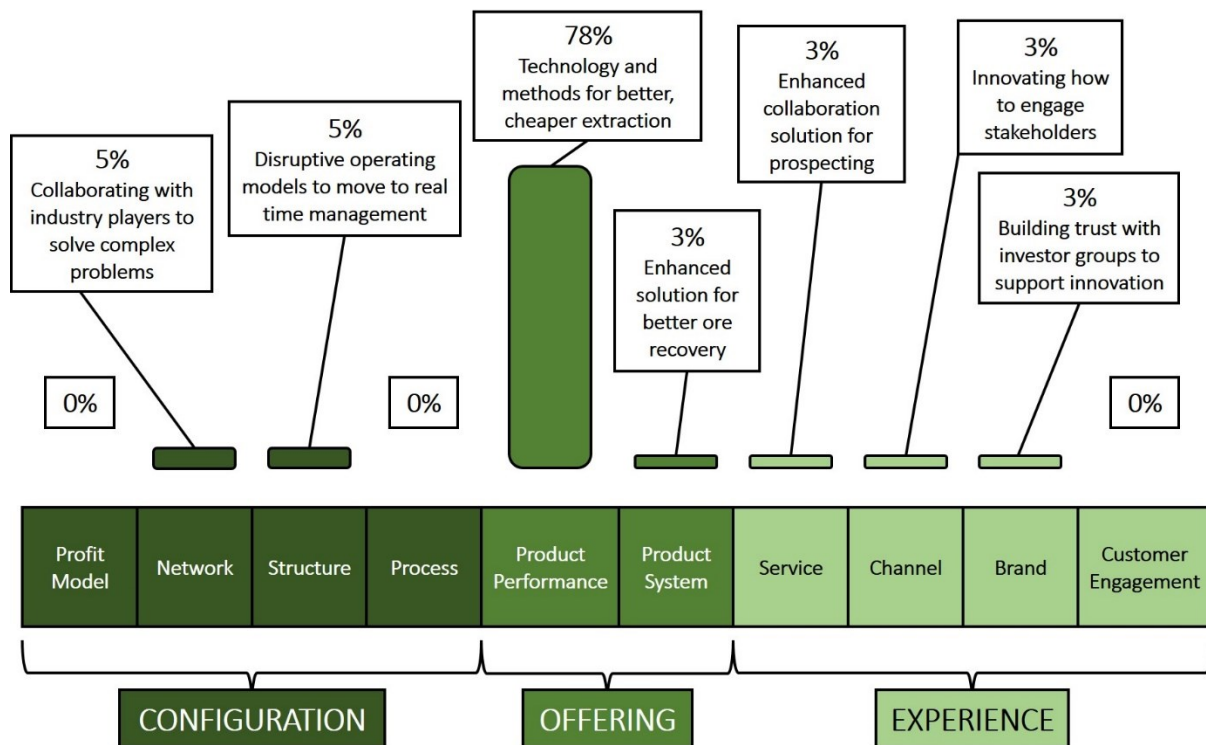
As stated previously, the mining industry, in its current state, requires rapid innovation. A comprehensive innovation process is required to potentially achieve this – serendipitous and spontaneous connections of events will not occur frequently enough to solve all the challenges. In order to foster innovation in the mining industry, a sound innovation foundation is required, and it starts with a comprehensive process. In literature, the most common term for these types of processes is the new product development (NPD) process. New product development can be described as the transformation of a market opportunity into a product available for sale (Krishnan & Ulrich, 2001)<sup>24</sup>.

NPD processes do not necessarily focus only on tangible product development – it is merely due to its origin in the manufacturing industry. An NPD process can refer to the development of any type of value offering, be it a product, process, service, etc. Since its roots in the manufacturing industry, NPD processes have been adopted and adapted by most other industries. Although the mining industry realises the need for innovation, and most companies are actively innovating, the innovation focus does not seem to be on the processes that they follow.

Deloitte (2015)<sup>2</sup> conducted a study on innovation in the mining industry, where one of the outcomes focused on what type of innovations mining companies actively pursue. They made use of Doblin (2015)<sup>5</sup>'s ten types of innovations, and from their cohort of 41 mining companies, they determined where the key innovation focus areas lay (Figure 1.3).

<sup>23</sup> Page, A.L. 1993. *Assessing new product development practices and performance establishing crucial norms*. Journal of Product Innovation Management, vol. 10, pp. 273-290.

<sup>24</sup> Krishnan, V. & Ulrich, K. 2001. *Product development decisions: A review of the literature*. Management Science vol. 47(1), pp. 1–21.



**Figure 1.3: Where mining companies innovate (Redrawn from Deloitte, 2015)<sup>2</sup>**

What is interesting to note from Figure 1.3 is that 0% of the mining companies focus on process innovation. In essence, this points to the need for this type of innovation in mining. Gilmore (n.d.)<sup>14</sup> views process innovation as primarily focusing on improving organisational effectiveness and efficiency. This is what is needed in terms of a NPD process – a more effective and efficient R&D process that creates the conditions needed for innovations to take place.

NPD processes have created clear value gains for those that employ and customise them. Businesses that have a well-articulated NPD strategy fare much better than those lacking in this aspect - they have 32% higher innovation success rates; meet sales objectives 42% more often; and meet profit objectives 39% better (Cooper & Kleinschmidt, 1995)<sup>25</sup>. Firms/companies that are consistently successful in the development of new products and services are likely to be rewarded by higher margins, increased market share and superior financial performance (Tidd, 2000)<sup>26</sup>.

Rio Tinto is one of the mining companies that has realised the value of employing a smart R&D innovation process. Their Mine of the Future™ programme focuses on creating next-generation systems and technologies, and they employ a seven-step innovative process to achieve this (Rio Tinto, 2014)<sup>27</sup>.

<sup>25</sup> Cooper, R. & Kleinschmidt, E. 1995. *Benchmarking the firm's critical success factors in new product development*. Journal of Product Innovation Management, vol. 12, pp. 374-391.

<sup>26</sup> Tidd, J. 2000. *From knowledge management to strategic competence: Measuring technological, market and organisational innovation*. London: Imperial College Press.

<sup>27</sup> Rio Tinto. 2014. *Mine of the Future: Next-generation mining: People and technology working together*. [Online]. Available: [http://www.riotinto.com/documents/Mine\\_of\\_The\\_Future\\_Brochure.pdf](http://www.riotinto.com/documents/Mine_of_The_Future_Brochure.pdf). [Cited 13 January 2016].



Their smart process is paying off - in October 2015, they announced that they had successfully rolled out fully automated driverless truck fleets at their Yandicoogina and Nammuldi mines. The automated trucks respond to GPS directions to deliver their loads of iron ore 24 hours a day, 365 days a year. They are supervised remotely by operators at a control centre in Perth, more than 1000km away from the mine sites (Financial Times, 2015)<sup>28</sup>.

The value in implementing a systematic approach to innovative R&D is clearly there. Customising the process and effectively executing it is the difficult part. Even among companies that follow a systematic process, many gaps and deficiencies still exist. A number of critically important steps/phases are often omitted (e.g. detailed market research, initial screening and preliminary market assessment). Other key activities, although in the process, are often undertaken superficially by companies (Cooper & Kleinschmidt, 1986)<sup>29</sup>.

Studies undertaken by both academicians and practitioners in the US and across the globe looked at possible causes of why NPD processes do not always work as well as they should. Their findings suggested that a significant dissatisfaction exists amongst companies employing NPD processes – in both the outcomes of the process and the process itself (Heany & Vinson, 1984)<sup>30</sup>. In cases where a systematic product development process has been implemented and the results are unsatisfactory, Wind & Mahajan (1988)<sup>31</sup> suggest that the process should be re-examined (or in cases where no process was followed, one should be constructed).

Considering the urgent need for innovation in mining, the use of an innovative R&D process could lead to significant value gains. The mining industry requires a process innovation of this nature – one that can increase the probability of successfully introducing more sustainable innovations into the industry. A new type of process/approach could lead to more rapid innovation; more cost effective development; and a reduction in the amount of wasted effort and futile attempts at innovation.

A clear need exists for an innovative R&D process, but a key question needs to be answered first. From Wind & Mahajan (1988)<sup>30</sup>'s recommendation on process re-examination, the key question is this: If a superior innovation-fostering R&D process is required for the mining industry, what are the current best-practice processes?

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<sup>28</sup> Financial Times. 2015. *Rio Tinto shifts to driverless trucks in Australia*. [Online]. Available: <http://www.ft.com/cms/s/0/43f7436a-7632-11e5-a95a-27d368e1ddf7.html#axzz46vZbeEH> [Cited 26 April 2016].

<sup>29</sup> Cooper, R.G. & Kleinschmidt, E.J. 1986. *An investigation into the new product development process: Steps, deficiencies and impact*. Journal of Product Innovation Management, Vol. 3(2), pp. 71-85.

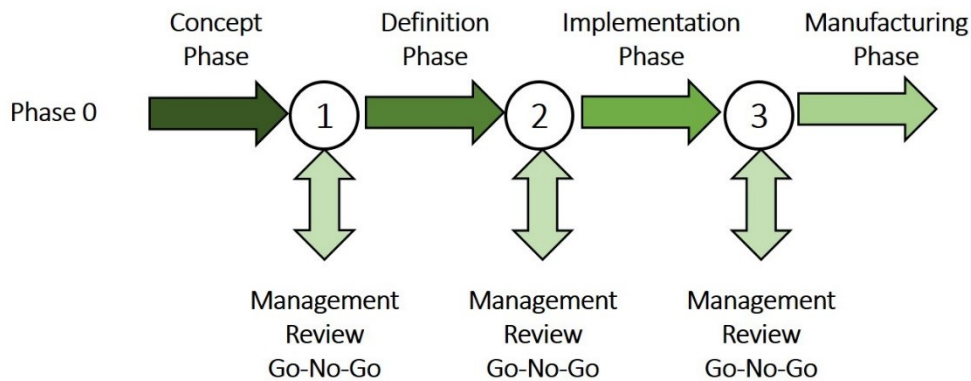
<sup>30</sup> Heany, D.F. & Vinson, W.D. 1984. *A fresh look at new product development*. Journal of Business Strategy, vol. 5(2), pp. 22-31.

<sup>31</sup> Wind, Y. & Mahajan, V. 1988. *New Product Development Process: A Perspective for Re-examination*. Journal of Product Innovation Management, Vol. 5, pp. 304-310.

## 1.4 FIRST, SECOND AND THIRD GENERATION PROCESSES

Cooper (1994)<sup>32</sup> provides a holistic definition for an NPD process (verbatim): “A formal blueprint, roadmap, template or thought process for driving a new product project from the idea stage, through to market launch, and beyond”. Making use of Cooper’s definition, the concept of a structured NPD process only really reached the mainstream in the 80’s and 90’s, where several NPD processes were proposed. However, these were not the first of their kind – the first NPD process originated in the 1960’s, from the National Aeronautics and Space Administration (NASA) in the US (Cooper, 1994)<sup>31</sup>.

NPD processes have been classified into three broad categories: 1<sup>st</sup> generation, 2<sup>nd</sup> generation and 3<sup>rd</sup> generation. NASA’s Phased Project Planning (PPP) process, which is commonly referred to as the Phased Review Process (PRP), was a 1<sup>st</sup> generation process. In essence, it was an elaborate and detailed process for working with contractors and suppliers on projects. The PRP (Figure 1.4a) broke development into discrete phases, with review points at the end of each phase. The process was more of a measurement and control tool than anything else – designed to ensure that a project was proceeding on time and within budget.



**Figure 1.4a: Example 1st Generation; Phase-Review Process**  
(Redrawn from Hughes & Chafin, 1996)<sup>33</sup>

The PRP, as shown in Figure 1.4a, was engineering-driven, focusing on the physical design and development of the project/product. It did not consider anything else outside of this scope. Everything was technically-focused, with little to zero business focus or market considerations.

The PRP received mixed reviews throughout history – it had benefits (e.g. improved discipline; reduction in technical risks; ensured task completion), but also had cumbersome disadvantages. The process was slow and laborious, and an entire project could be put on hold at a review point (either awaiting management review, or the completion of one behind-schedule activity) (Smith & Reinertsen, 1992)<sup>34</sup>.

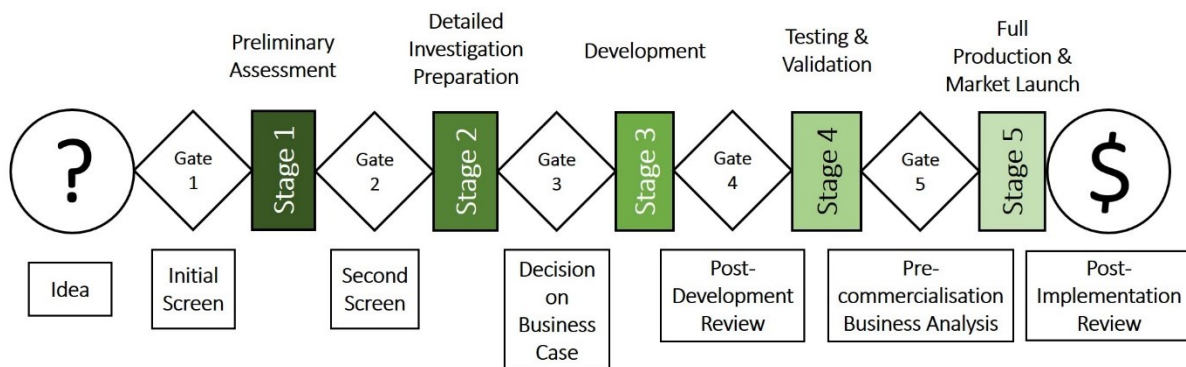
<sup>32</sup> Cooper, R.G. 1994. Third Generation New Product Processes. *Journal of Product Innovation Management*, vol. 11, pp. 3-14.

<sup>33</sup> Hughes, G.D. & Chafin, D.C. 1996. Turning new product development into a continuous learning process. *Journal of Product Innovation Management*, vol. 13, pp. 89-104.

<sup>34</sup> Smith, P.G. & Reinertsen, D.G. 1992. Shortening the product development cycle. *Research and Technology Management*, May-June, pp. 44-49.

The 2<sup>nd</sup> generation processes from the 80's and 90's somewhat resembled the PRP from the 1960's. The Booz-Allen-Hamilton (BAH) process (Booz, Allen & Hamilton Inc., 1982)<sup>35</sup>; Crawford's Process (Crawford, 1987)<sup>36</sup> and Cooper's (1983)<sup>37</sup> stage-gate system were the most prominent 2<sup>nd</sup> generation processes from this era. Bhuiyan (2011)<sup>38</sup> believes that the BAH model underlies most of the processes found in practice today – although this may be true to a certain extent, Cooper's stage-gate process has had the biggest impact on modern-day processes.

Due to this, 2<sup>nd</sup> generation processes were largely referred to as “stage-gate” models, and as with the PRP, consisted of discrete stages followed by review points or “gates”, as can be seen in Figure 1.4b.



**Figure 1.4b: Example 2<sup>nd</sup> Generation: An overview of a Stage-Gate system (Redrawn from Cooper, 1990)<sup>39</sup>**

The similarities between the stage-gate models and the PRP ended there. These 2<sup>nd</sup> generation processes required a lot of market and business research and analysis, along with sound technical assessment, in order to get the development “go-ahead”. The processes improved upon the 1<sup>st</sup> generation PRP through the following (Cooper, 1994)<sup>31</sup>:

- **Review points/gates were now cross-functional:** The PRP review was done either by a single manager, or a group of managers from a single department. The stage-gate review was cross-functional – where various managers from different silos had to make a joint decision on whether a project/product should pass a review point/gate.
- **Stage-gate processes were more holistic:** They captured the entire NPD process from idea conception through to product launch, whereas the PRP only focused on development.
- **Much more emphasis was placed on up-front “homework”:** At least two research phases would be completed in the stage-gate system before actual development started. Market research, competitive analysis, concept testing, manufacturing assessment and financial analysis had to be done to get the go-ahead to start development.

<sup>35</sup> Booz, Allen & Hamilton Inc. 1982. *New Product Management for the 1980's*. New York: Booz, Allen & Hamilton.

<sup>36</sup> Crawford, C. 1987. *New Product management*. 2<sup>nd</sup> Edition. Illinois: Richard D. Irwin.

<sup>37</sup> Cooper, R.G. 1983. A process model for industrial new product development. *Transactions on Engineering Management*, vol. 30, pp. 2-11.

<sup>38</sup> Bhuiyan, N. 2011. A framework for successful new product development. *Journal of Industrial Engineering and Management*, vol. 4(4), pp. 74-770.

<sup>39</sup> Cooper, R.G. 1990. Stage-Gate Systems. A New Tool for Managing New Products. *Business Horizons*, May-June, pp. 44-54.





- **Stage-gate processes had a stronger market orientation:** The customer became an integral part of the NPD process, and the main aim was to focus on pleasing the customer,
- **Products were better defined before development:** All the parties involved had to agree on the product definition, benefits to be delivered, market positioning and product requirements – Crawford (1984)<sup>40</sup> called this the project “protocol”.
- **Parallel/concurrent processing could take place:** The PRP was a sequential process – where the next activity within a phase could not start before the previous one had finished (exactly like a relay race, where a baton is passed from one runner to the next). The stage-gate processes allowed for parallel processing to take place (Uttal, 1987)<sup>41</sup>, where activities within a phase could be done at the same time. This drove down phase completion. Takeuchi & Nonaka (1986)<sup>42</sup>, in contrast to a relay race, made the analogy that concurrent processing is like a team of rugby players – all moving towards the goal line, whilst performing different activities towards a common end goal.
- **Decision points were made more complex:** The PRP essentially only considered schedule and budget as criteria to pass a review point. If the project was on time and within budget, it could pass to the next phase – regardless of the quality of the project. The stage-gate systems featured tougher gates with more rigorous criteria and metrics. These focused on both quantitative measures (e.g. financial & time), and qualitative measures (e.g. business issues, project synergy, market attractiveness).

Although the 2<sup>nd</sup> generation processes improved greatly upon the 1<sup>st</sup> generation PRP, it still had limitations and problems. Some of these problems were inherited from the PRP, and others were unique to the stage-gate models. Cooper (1994)<sup>31</sup> pointed out the six most prominent problems with the 2<sup>nd</sup> generation processes:

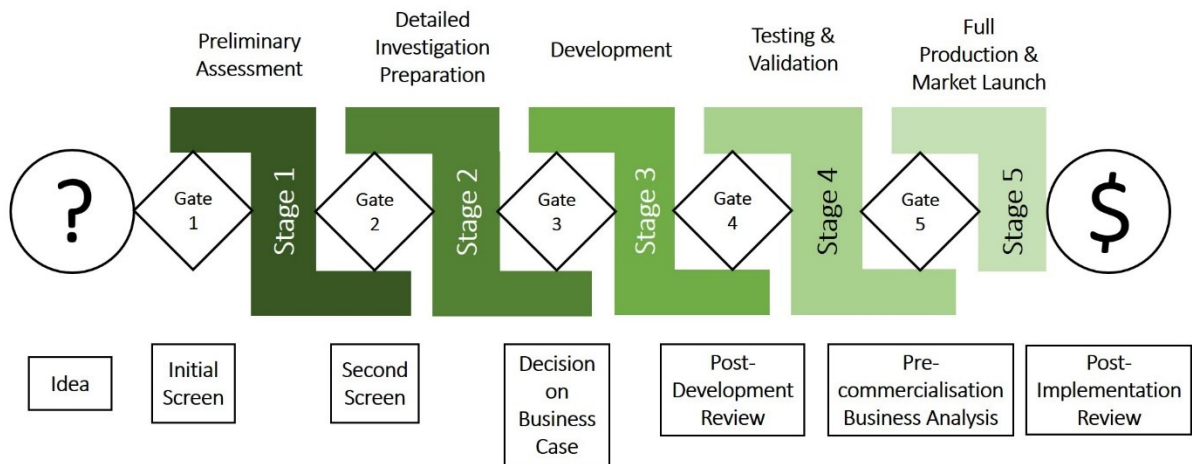
- Projects had to wait at each gate until all tasks had been completed;
- Stages could not overlap;
- Projects had to complete all stages and pass through all gates;
- The system did not lead to project prioritisation and focus;
- Some 2<sup>nd</sup> generation processes were too detailed; and
- Some 2<sup>nd</sup> generation processes tended to be bureaucratic.

As Cooper (1994)<sup>31</sup> pointed out in his list, although the stage-gate models solved several 1<sup>st</sup> generation problems, some of these were inherited, and some new problems were created. This gave rise to the development of the 3<sup>rd</sup> generation stage-gate NPD processes (example shown in Figure 1.4c) – which primarily focused on taking the already *effective* 2<sup>nd</sup> generation processes, and making them more *efficient*.

<sup>40</sup> Crawford, C.M. 1984. Protocol: New tool for product innovation. *Journal of Product Innovation Management*, vol. 2, pp. 85-91.

<sup>41</sup> Uttal, B. 1987. Speeding new ideas to market. *Fortune*, March, pp. 62-66.

<sup>42</sup> Takeuchi, H. & Nonaka, I. 1986. *The new product development game*. *Harvard Business Review*, vol. 64(1), pp. 137-146.



**Figure 1.4c: Example 3<sup>rd</sup> Generation Stage-Gate system (Redrawn from Gilmore, n.d.)<sup>14</sup>**

In order to achieve this, 3<sup>rd</sup> generation processes incorporated four fundamental “F’s” (Cooper, 1994)<sup>31</sup>:

1. **Fluidity:** 3<sup>rd</sup> generation stage-gate processes were made to be more fluid and adaptable, through overlapping stages to ensure greater speed and efficiency.
2. **Fuzzy gates:** These processes featured conditional gates (rather than absolute ones), which are dependent on the unique situation of each project.
3. **Focused:** Prioritisation methods were built in that gave a perspective on the entire portfolio of projects (rather than one at a time), and this allowed for resources to be focused on the most promising projects.
4. **Flexible:** The 3<sup>rd</sup> generation processes were made to not be rigid – which allowed for each unique project to have its own routing through the process.

Since the introduction of the 3<sup>rd</sup> generation processes in the mid 1990’s, adoption of the process has been widespread. A particular example is that of the innovation consulting firm, Stage-Gate® International, founded by Dr Robert Cooper and Dr Scott Edgett (Stage-Gate International, 2016)<sup>43</sup>. By 2015, their range of adaptable Stage-Gate® processes had been adopted (and customised) by approximately 80% of Global 1000 companies (Stage-Gate International, 2015)<sup>44</sup>, and included amongst these are undisclosed mining companies and mining Original Equipment Manufacturers (OEMs) (Booker, 2016)<sup>45</sup>.

2<sup>nd</sup> and 3<sup>rd</sup> generation NPD processes have been shown to yield successful results. This success is however dependent on how these processes are applied – they are not of a “one-size fits all” nature. In order to understand how to apply these processes, consideration needs to be given to the nature of the proposed NPD, and whether it is market-pull driven or technology-push driven. Osterwalder et al (2014)<sup>46</sup> differentiate between the two as technology push indicating that the process starts with a solution, and market-pull indicating that the process starts with a problem.

<sup>43</sup> Stage-Gate International. 2016. Our Founders. [Online]. Available: [http://www.stage-gate.com/aboutus\\_founders.php](http://www.stage-gate.com/aboutus_founders.php). [Cited 03 June 2016].

<sup>44</sup> Stage-Gate International. 2015. Stage-Gate® - Driving Performance for 30+ Years. [Online]. Available: [http://www.stage-gate.com/images/about/30\\_years.pdf](http://www.stage-gate.com/images/about/30_years.pdf). [Cited 03 June 2016].

<sup>45</sup> Booker, M. “Research Enquiry”. Personal Email (03 June 2016).

<sup>46</sup> Osterwalder, A. et al. 2014. Value Proposition Design. New Jersey: John Wiley & Sons.



The mining industry is in a unique situation where both the market-pull and technology-push approaches are relevant. The industry's key challenges drive the need for market-pull R&D being necessary. The holistic driver behind the technology-push R&D being necessary is simple - several new technologies (which could create value for the mining industry) are on the horizon. These technologies could potentially solve key industry challenges, but not without a well-thought out and structured research and development and implementation approach.

## 1.5 PROBLEM STATEMENT

The mining industry is in need of rapid innovation, and a paradigm shift in terms of how the industry will be modernised. This requires a new perspective on the innovation R&D process – a process is required that can effectively and efficiently deliver value to the mining industry. Globally, the stage-gate model has been shown to be the most successful approach to R&D. Applying the concepts found in the stage-gate model to R&D in the mining industry, could prove to be advantageous in terms of successfully modernising the industry.

The study was thus aimed at investigating the stage-gate model in detail; critically analysing the best practices for each stage and gate; and interpreting and applying the model as a R&D implementation process for the mining industry.





## 1.6 OBJECTIVES & METHODOLOGIES

The objectives and methodologies for the study can be seen in Table 1.6.

**Table 1.6: Objectives and Methodologies**

Objective	Methodology
1. Derive a best-practice skeleton Stage-Gate model	A literature review of Stage-Gate models was conducted, with specific focus on the high-level phases in the process. A skeleton framework was constructed from the best practices found in the literature review, which focused the further literature review investigations in (2).
2. Determine key Stage-Gate gate criteria and stage activities	Using the skeleton Stage-Gate model derived in (1), a literature review was conducted on the different stages and gates in the Stage-Gate model. Specific attention was given to gate criteria and stage activities.
3. Determine overall Stage-Gate critical success factors	In parallel with the literature review conducted in (2), high-level critical success factors were identified.
4. Develop a proposed Stage-Gate model for the mining industry	Using the skeleton Stage-Gate model derived in (1); the key gate criteria and activities found in (2); and the high-level critical success factors found in (3), a proposed model was developed.
5. Evaluate the proposed model	The proposed model developed in (4) was evaluated by applying a South African mining R&D case study, in order to briefly illustrate how the proposed model would function.
6. Conclude on findings	Conclusions were made based on the findings in (1), (2), (3), (4) and (5).
7. Make recommendations on findings	Recommendations were made based on the conclusions in (6).
8. Suggest areas for further future research	Suggestion for further future work were made, based on the gaps identified throughout the study, as well as the envisioned continuous improvement of the findings of the study.



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## CHAPTER 2: LITERATURE REVIEW

Chapter 2 firstly aims to provide a holistic understanding of the Stage-Gate model, by considering the broad concepts associated with the model, as well as how the process has evolved over the years. Thereafter, a best-practice skeleton model is derived, in order to shape the remainder of the literature review. From the derived skeleton model, each stage and gate is investigated individually, in terms of key gate criteria and stage activities. Furthermore, the overall critical success factors are investigated through considering individual stages and gates.

After each stage and gate is investigated, the significance of the stated and discussed information is given. This is in order to indicate why the information is relevant, in terms of the aim of the project. An overview of the Chapter 2 sections (as well as key questions for each section) is shown in Figure 2.

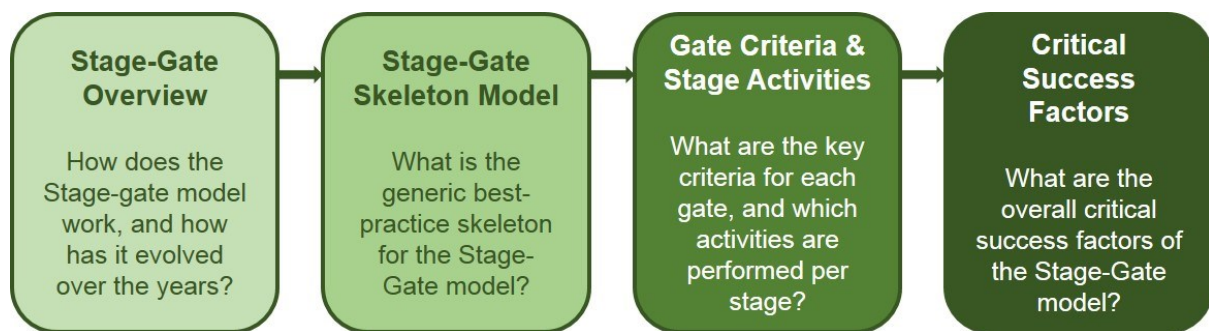


Figure 2: Chapter 2 Overview and Key Questions



## 2.1 STAGE GATE PROCESSES

Stage-gate (or phase-gate) processes, as discussed in Chapter 1, are the norm in terms of new product development (NPD). Many companies started implementing 2<sup>nd</sup> generation processes in the late 1980's, and 3<sup>rd</sup> generation processes (with improved time efficiencies) were widely adopted in the late 1990's (Cooper, 2001)<sup>47</sup>. The term “stage-gate” was coined by Dr Robert Cooper, and in 1988 he trademarked the term. Before this, the first conceptualisation of Cooper's 2<sup>nd</sup> generation process was in 1983, when he proposed a model for industrial NPD (Cooper, 1983)<sup>48</sup>. Since 1983, the 2<sup>nd</sup> generation process was improved upon, and these improvements ultimately led to the conceptualisation of the first 3<sup>rd</sup> generation process in 1994 (Cooper, 1994)<sup>49</sup>.

From the first conceptualisation of the 3<sup>rd</sup> generation stage-gate process, it has been continuously improved and analysed to ensure that the process concept remains relevant. And that is exactly what stage-gate processes are – a concept. Although the process is well-defined, with distinct phases and gates, it is ultimately a worthless tool if the concept is misunderstood and applied incorrectly. Cooper (1988) may have trademarked the Stage-Gate® process, but numerous derivative versions of the concept have been developed and applied by others (usually referring to the process as “phase-gate”).

What is significant about Cooper's Stage-Gate® processes (2<sup>nd</sup> and 3<sup>rd</sup> generation), is that it is these trademarked processes that, as per Chapter 1, have been used by more than 80% of Global 1000 companies (Stage-Gate International, 2015)<sup>50</sup>. Amongst these companies are undisclosed mining companies and mining-specific original equipment manufacturers (OEM)'s (Booker, 2016)<sup>51</sup>. These facts make for a sound argument that Stage-Gate® processes are the norm and “best-practice” in terms of NPD processes. In terms of this study however, stage-gate processes (in terms of broad the layout) will be used as a foundation upon which to adapt and modify towards a fit-for-purpose process for the mining industry.

Cooper (1990) stated (verbatim): “*Individual companies may refer to their systems by different names, and on paper they appear to be unique to that company. In practice, however, there is a surprising parallelism between different stage-gate approaches*”.

This is the purpose of Section 2.1 – to describe 2<sup>nd</sup> and 3<sup>rd</sup> generation stage-gate processes, in order to form a solid foundation/skeleton layout in terms of the different best practice phases and gates. Section 2.1 will thus discuss the following:

- A holistic overview of stages and gates;
- Generic stages and gates; and
- Stage-gate skeleton to be used.

<sup>47</sup> Cooper, R.G. 2001. *Winning at new products: Accelerating the process from idea to launch*. 3<sup>rd</sup> Edition. Reading, Mass: Perseus Books.

<sup>48</sup> Cooper, R.G. 1983. *A process model for industrial new product development*. Transactions on Engineering Management, vol. 30, pp. 2-11.

<sup>49</sup> Cooper, R.G. 1994. Third Generation New Product Processes. *Journal of Product Innovation Management*, vol. 11, pp. 3-14.

<sup>50</sup> Stage-Gate International. 2015. *Stage-Gate® - Driving Performance for 30+ Years*. [Online]. Available: [http://www.stage-gate.com/images/about/30\\_years.pdf](http://www.stage-gate.com/images/about/30_years.pdf). [Cited 03 June 2016].

<sup>51</sup> Booker, M. “Research Enquiry”. Personal Email (03 June 2016).





### 2.1.1 HOLISTIC OVERVIEW OF STAGES AND GATES

A typical stage-gate process is a conceptual and operational framework that is used to guide NPD projects from the initial idea through to the launch of the idea (in the form of a value proposition). Furthermore, a stage-gate process acts as a “blueprint” for managing the NPD process, both effectively and efficiently. Essentially the stage-gate process is a tool that breaks down the innovation process into a predetermined number of set stages, where each stage defines a set of prescribed; cross-functional and parallel activities. In order to manage the process, best practices and critical success factors (CSF) are built into each individual stage.

A typical stage-gate process comprises of either four, five, six or seven (Cooper, 1990)<sup>52</sup> discrete and identifiable stages. Stages consist of a number of activities – focused on gathering information and undertaking tasks needed to progress the project to the next gate/decision point. Cooper (n.d.)<sup>53</sup> highlights some key characteristics with regards to stages in the stage-gate process, they are:

- Each stage is cross-functional. There is no single research and development (R&D) stage or marketing stage – all stages include all the necessary disciplines (e.g. R&D, Marketing, Engineering, etc.).
- Each stage consists of a set of parallel activities, undertaken by persons from the different disciplines within the company. Tasks are done concurrently and in parallel, much like rugby players working together in a game (opposed to a relay running race).
- The activities within a stage are designed to gather critical information, and to reduce the project’s unknown factors and uncertainties. Each stage costs more than the next one – thus risk is effectively managed by reducing uncertainty as the project becomes more cost-intensive.

In order to advance from one stage to the next, a gate has to be passed. Gates serve the purpose of controlling the process; ensuring quality of work; and making a decision on whether the process can advance to the following stage. This is normally done by conducting a meeting, where the project is scrutinised by senior management (based on whether predetermined criteria was adequately met). The project can either be approved and advance to the next stage; it can be completely stopped if management believes that the unmet criteria cannot be met; or it can be “recycled” where management believes that unmet criteria can be met.

The different gates in the process are similar in nature and structure – each consist of required deliverables; criteria against which the project is judged; and defined outputs. These three components are described briefly:

1. **Deliverables:** This refers to the set of results/conclusions/learnings that the project team must bring to the decision gate. These are seen as the inputs in order to make a decision, based on the design criteria.
2. **Criteria:** This refers to the criteria against which the project is assessed. It includes “must-meet” criteria, as well as “should-meet”/desirable criteria.
3. **Defined outputs:** This refers to the action plan for the next stage, based on what the gate decision is.

<sup>52</sup> Cooper, R.G. 1990. *Stage-gate systems: A new tool for managing new products*. Business Horizons, pp. 44–54.

<sup>53</sup> Cooper, R.G. n.d. *Stage-Gate® New Product Development System: A Game Plan from Idea to Launch*.

### 2.1.2 GENERIC STAGES AND GATES

As stated previously the first conceptualisation of Cooper's 2<sup>nd</sup> generation process was in 1983, when he proposed a model for industrial NPD (Cooper, 1983). Cooper (1983) suggested that industrial NPD processes needed to incorporate changes. He proposed an improved process model – based on prior research; previous normative models; and a review of flow charts from 60 different new product project case studies. Cooper's first conceptualisation of the 2<sup>nd</sup> generation process is shown in Figure 2.1.2a.

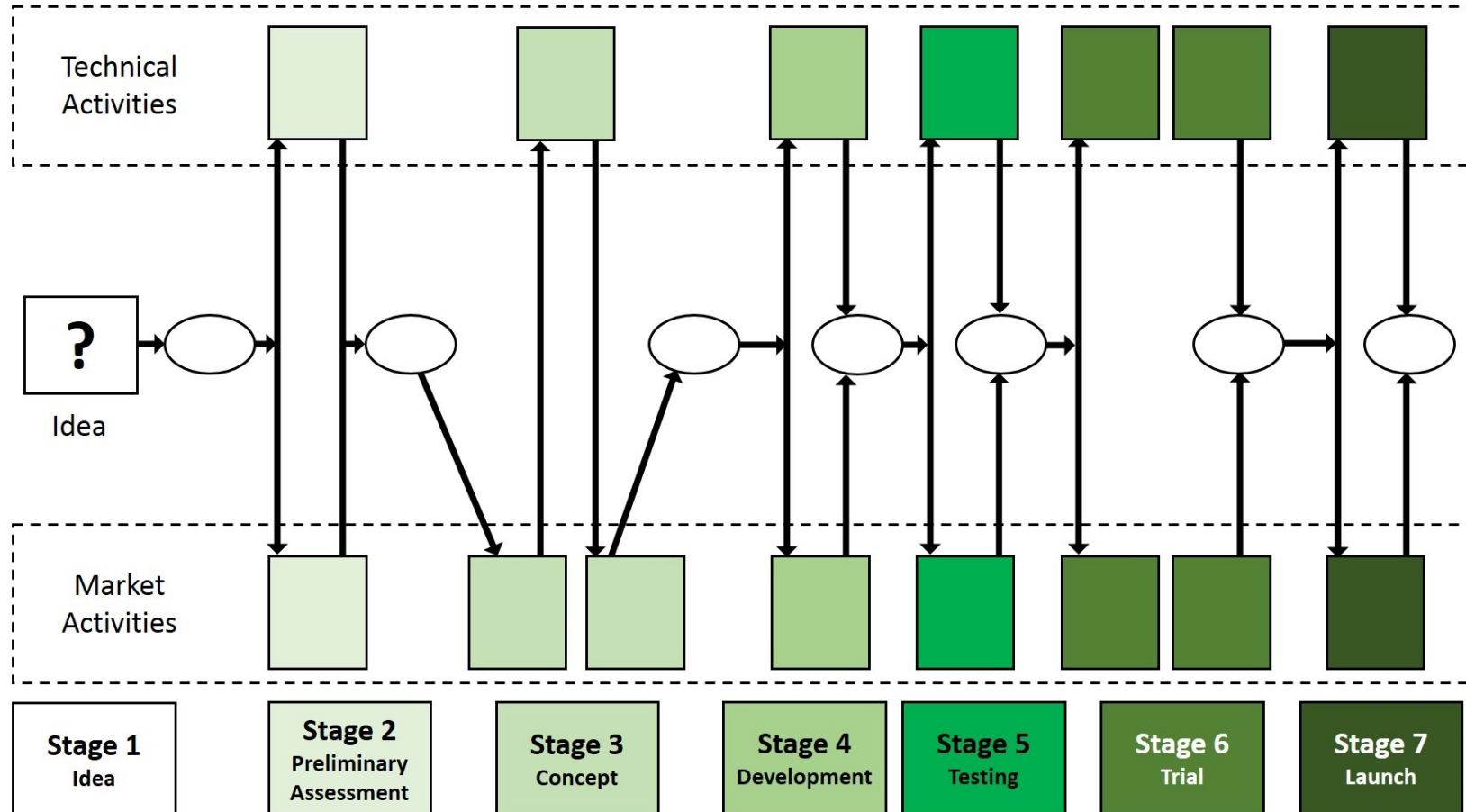
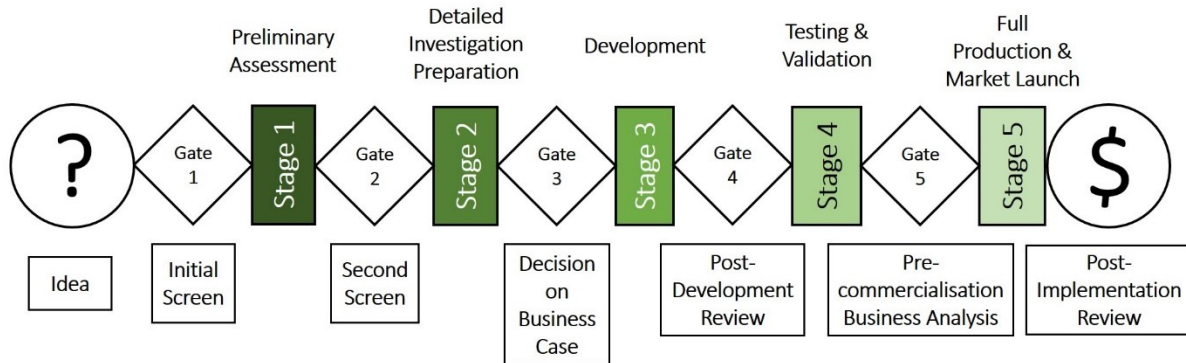


Figure 2.1.2a: A flow diagram of the seven-stage new product process model (Redrawn from Cooper, 1983)



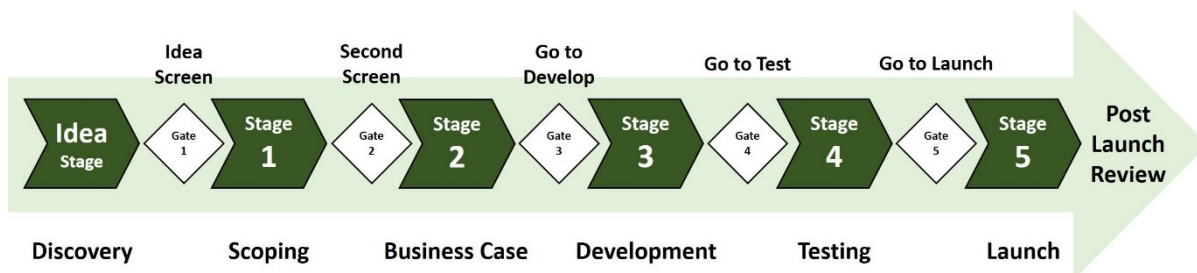
Cooper's first 2<sup>nd</sup> generation model emphasised the need for concurrent market and technical/production activities (Figure 2.1.2a). Each stage comprised of both these types of activities, being performed in parallel, and both contributing to the deliverables required for a gate decision. Whereas Cooper's first conceptualisation comprised of seven stages and six gates, later versions of the process were reduced to five stages and five gates (Figure 2.1.2b).



**Figure 2.1.2b: An overview of a second generation stage-gate system (Redrawn from Cooper, 1990)**

Figure 2.1.2b shows that the fundamentals of the earliest version of the process (Figure 2.1.2a) remained intact, albeit with a few minor changes in the later version. The idea phase was no longer considered to be an explicit stage, but was still the starting point of the process. The biggest difference between the 1983 and 1990 versions of the process was with the testing phase. The 1983 process' fifth and sixth stages were testing and trial – with an evaluation gate after stage five, and a pre-commercial business analysis gate after stage six.

The 1990 process took the fifth and sixth stages and combined them into one – the testing and validation stage. Although the two stages (and their gates) were merged, the activities within this later merged stage remained similar to the earlier split stages. As stated previously, Cooper's conceptualisation of the first 3<sup>rd</sup> generation process was in 1994. In essence, the stages and the gates did not change (as shown in a later 3<sup>rd</sup> generation version (Cooper, 2006)<sup>54</sup> in Figure 2.1.2c). Only the way in which the process was applied changed. These changes will be discussed in detail in this chapter.



**Figure 2.1.2c: An overview of the 3<sup>rd</sup> Generation Stage-Gate (Redrawn from Cooper, 2006)**

<sup>54</sup> Cooper, R.G. 2006. Formula for Success. *Marketing Management*, March/April, pp. 18-24.



Combining the three different versions of the stage-gate process (shown in Figure 2.1.2a, Figure 2.1.2b and Figure 2.1.2c), Table 2.1.2 was constructed to derive a generic classification of phases and gates. The gates are displayed in italic font, with a box border around each gate. Two more processes were added to Table 2.1.2 (from Tzokas et al. 2003<sup>55</sup> and Booz, Allen & Hamilton Inc., 1982<sup>56</sup>), the relevance of which will be discussed.

Table 2.1.2 shows that the only fundamental difference between the different Cooper versions lies in Stage 4, and as was discussed previously, the difference is merely cosmetic (and does not change or omit any key activities). Apart from some minor differences in the naming of the stages and gates, the entire process (and flow thereof) has remained the same.

As stated previously, the stage-gate process has been successfully adopted in several industries. Although these adaptations may seem different, the fundamentals behind the process remains the same. This can be illustrated by comparing the process used by Tzokas et al. (2003) to the three Stage Gate versions. Once again, the only differences are in slightly different labelling of the stages and gates. When considering the Booz, Allen & Hamilton (1982) model (BAH) (as compared to the four SG processes), it is concluded that this model underlies most NPD processes (and confirmed in Table 2.1.2).

The relevance of the comparison in Table 2.1.2 is simple – the fundamentals behind stage-gate processes (regardless of where and by whom they have been applied), are the same. This means that a skeleton stage-gate process can be constructed from Table 2.1.2 and shown in Figure 2.1.3. This is done so as to initiate a literature search relating to the best practices at the different stages and gates.

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<sup>55</sup> Tzokas, N. et al. 2003. *Navigating the new product development process*. Industrial Marketing Management, vol. 33, pp. 619-626.

<sup>56</sup> Booz, Allen & Hamilton Inc. 1982. *New Product Management for the 1980's*. New York: Booz, Allen & Hamilton.

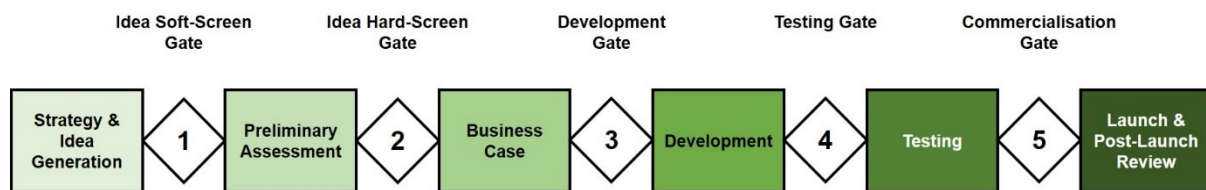
**Table 2.1.2: Comparison of different versions of the stage-gate process, along with an adapted SG process and the BAH model**

	Stage 0	Stage 1			Stage 2		Stage 3		Stage 4				Stage 5			
First 2nd generation stage-gate conceptualisation (Cooper, 1983)	Idea	Initial Screening gate	Preliminary Assessment	Preliminary evaluation gate	Concept	Concept evaluation gate	Development	Evaluation Gate	Testing	Evaluation Gate	Trial	Pre-commercial business analysis gate	Launch	Post-launch evaluation and control		
2nd generation stage-gate process (Cooper, 1990)	Idea	Initial Screen gate	Preliminary Assessment	Second Screen gate	Detailed Investigation Preparation	Decision on business case gate	Development	Post-development review gate	Testing and Validation		Pre-commercialisation business analysis gate		Full production and market launch	Post-implementation review		
3rd generation Stage-Gate® process (Cooper, 2006)	Discovery & Idea	Idea Screen	Scoping	Second Screen	Business Case	Go to development gate	Development	Go to test gate	Testing		Go to launch gate		Launch	Post-launch review		
Process used by Tzokas et al, 2003	Idea Generation	Idea screening gate	Concept Development	Concept testing gate	Build Business Case	Business Analysis Gate	Product Development	Product Testing Gate	Market Testing		Market Test Results gate		Market launch	Post-launch evaluation short-term and long-		
Booz, Allen & Hamilton 7-step (1982)	New Product Strategy Development	Idea generation			Screening and evaluation		Business Analysis		Development		Testing				Commercialisation	

### 2.1.3 STAGE-GATE SKELETON

The literature review component of this thesis revolves around understanding the different stages and gates in the NPD process, in order to derive a best practice from them for innovations in the mining industry. In order to provide structure to the literature review process, it was necessary to define a “skeleton” layout of the entire process. This skeleton layout merely serves as a starting point for research on all the different activities and best practices at the different stages and gates.

Figure 2.1.3 shows that the skeleton layout to be used in the literature review comprises of six stages and five gates. It must be noted that the Strategy & Idea Generation stage will be labelled as ‘Stage 0’, as the activities performed in the stage are generally seen as pre-process work.

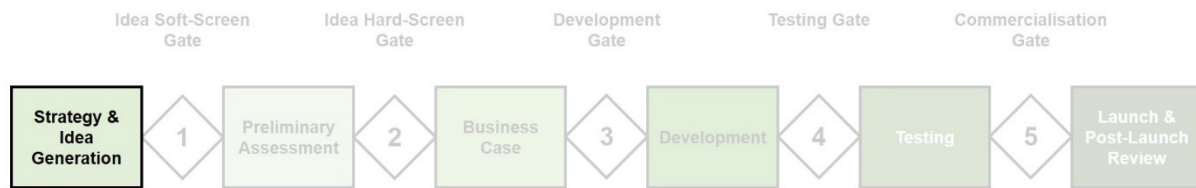


**Figure 2.1.3: Stage-Gate Skeleton Structure**

The remainder of the literature review is therefore based on the six stages and five gates as shown in Figure 2.1.3. Each of these stages/gates are discussed under their own headings after which the relevance of the related information is discussed.



## STAGE 0: STRATEGY & IDEA GENERATION



### 2.2 STAGE 0: STRATEGY AND IDEA GENERATION

The first stage of the NPD process is not explicitly defined as a stage (hence the 'Stage 0' naming convention). It is seen as the preparation necessary to start off the process. This being the most important part of the process, as all the following stages and gates in the NPD process depend on Stage 0.

The stage focuses on:

- Formulating a NPD strategy (Booz, Allen & Hamilton Inc., 1982; Bhuyain, 2011<sup>57</sup>);
- Identifying and analysing opportunities (Koen et al., 2001<sup>58</sup>; Khurana & Rosenthal, 1997<sup>59</sup>; Schwankl, 2002<sup>60</sup>); and
- Ultimately generating new product ideas (Herstatt & Verworn, 2007<sup>61</sup>; Koen et al., 2001; Cooper, 1997<sup>62</sup>; Booz, Allen & Hamilton Inc., 1982; Bhuyain, 2011; Page, 1993<sup>63</sup>; Tidd & Bodley, 2000<sup>64</sup>; Moen, 2001<sup>65</sup>; Cooper, 1990; Tzokas et al., 2003).

#### 2.2.1 STRATEGY

The first step in Stage 0 is to formulate a strategy for the new product development process. NPD literature refers to this strategy as the new product strategy (NPS) (Bhuyain, 2011). The NPS clarifies the strategic requirements for new products, and provides the first point of reference for the following stages in the process (Booz, Allen & Hamilton Inc., 1982). Apart from the NPS providing direction for the NPD process, Crawford (1972) notes that a NPS also helps companies identify areas that they should not pursue.

<sup>57</sup> Bhuyain, N. 2011. *A framework for successful new product development*. Journal of Industrial Engineering and Management, vol. 4(4), pp. 74-770.

<sup>58</sup> Koen, P., et al. 2001. Providing clarity and a common language to the "fuzzy front end". *Research Technology Management*, pp. 46-55.

<sup>59</sup> Khurana, A. & Rosenthal, S.R. 1997. Integrating the fuzzy front end of new product development. *Sloan Management Review*, 1997.

<sup>60</sup> Schwankl, L. 2002. *Analyse und Dokumentation in den frühen Phasen der Produktentwicklung*. Dr. Hut, München.

<sup>61</sup> Herstatt, C. & Verworn, B. 2007. *Management der frühen Innovationsphasen*. Gabler Verlag, Wiesbaden.

<sup>62</sup> Cooper, R.G. 1997. Fixing the fuzzy front end of the new end process: Building the business case. *CMA Magazine*, vol. 8, pp. 21-23.

<sup>63</sup> Page, A.L. 1993. *Assessing new product development practices and performance establishing crucial norms*. Journal of Product Innovation Management, vol. 10, pp. 273-290.

<sup>64</sup> Tidd, J. & Bodley, K. 2000. *The Effects of Project Novelty on the New Product Development Process*. Science and Technology Policy Research, University of Sussex.

<sup>65</sup> Moen, R. 2001. *A Review of the IDEO process*. [Online]. Available: <http://rand.gatech.edu/wp-content/uploads/2010/11/The-IDEO-Process.pdf>. [Cited 05 May 2016].



Different strategy types exist, and these are generally characterised by how rapidly a company alters its products and markets in response to change (Agrawal, 2003)<sup>66</sup>. According to both Griffin & Page (1996)<sup>67</sup> and Miles & Snow (1999)<sup>68</sup>, four strategy types exist:

- **Prospective:** Companies with prospective strategies are industry innovators – they value most being the first to develop or adopt new technologies.
- **Analytical:** Companies with analytical strategies are “fast followers” of prospective companies. They achieve this by monitoring the actions taken by major competitors. By acting swiftly, they may often be able to bring superior products to the market (e.g. more cost efficient products, products with better features/benefits).
- **Defensive:** Companies with defensive strategies attempt to maintain a secure position in a relatively stable or niche market. They achieve this by offering high quality products, superior service or better prices than competitors.
- **Reactive:** Companies with reactive strategies are not as aggressive as defensive companies (in terms of maintaining position). They respond only when forced to by strong external forces.

Irrespective of which strategy a given company follows, the formulation of a successful NPS has to consider several generic key aspects. It must be noted that the different aspects are interdependent in nature, and they should not be considered in isolation.

### **2.2.1.1 NPS ALIGNMENT WITH COMPANY STRATEGY**

Wind (1982)<sup>69</sup> recommends that, prior to commencing a new project, companies must set objectives and devise a clear NPS to meet them. This strategy needs to align with strategic business requirements of the company. Booz, Allen & Hamilton Inc. (1982) state that this can be achieved by reviewing the company mission and objectives, and determining how new products may play a role in satisfying these directives and objectives.

The NPS is also where company success factors need to be identified - Daniel (1961)<sup>70</sup> and Rockart (1979)<sup>71</sup> proposed that organisations need to identify factors that are critical to the organisation’s success. They believed that the failure to achieve goals associated with these factors would result in organisational failure.

The process of NPD needs to fit in with the organisational culture, and the NPD efforts need to receive organisational support. A poor fit with organisational culture and a lack of organisational support are typical causes of NPD failure (Jain, 2001)<sup>72</sup>. To prevent these failures, the NPS needs to be formulated such that these potential threats are mitigated.

<sup>66</sup> Agrawal, A. 2003. Critical Success Factors and Metrics for New Product Development Success. National Library of Canada.

<sup>67</sup> Griffin, A. & Page, A. 1996. PDMA success measurement project: Recommended measures for product development success and failures. *Journal of Product Innovation Management*, vol. 14, pp. 478-495.

<sup>68</sup> Miles, R. & Snow, C. 1999. *Organisational Strategy: Structure and Process*. New York: McGraw-Hill.

<sup>69</sup> Wind, Y. 1982. *Product policy: Concepts, methods, and strategy*. Reading, Mass: Addison-Wesley.

<sup>70</sup> Daniel, R. 1961. *Management data crisis*. *Harvard Business Review*, Sept-Oct, pp. 111-112.

<sup>71</sup> Rockart, J. 1979. *Chief executives define their own data needs*. *Harvard Business Review*, vol. 57(2), pp. 238-241.

<sup>72</sup> Jain, D. 2001. *Managing new product development for strategic competitive advantage*. Kellogg on marketing, pp. 130-150. New York: John Wiley and Sons.





### **2.2.1.2 INTENDED CUSTOMER SEGMENTS**

The intended customer segments shape the scope of the NPD process. In the NPS, the intended customer segments need to be defined on a high level basis. A study by Tidd & Bodley (2000) showed that customer segmentation was a key technique used by 89% of companies conducting NPD. However, their study classified segmentation as an idea generation technique. This is not incorrect, but segmentation can also be used to make strategic decisions.

### **2.2.1.3 TYPE OF PRODUCTS**

The NPS should define what types of products are desired. Products can range from simple improvements to existing products, to brand-new radically innovative products. Products are categorised into six types (Booz, Allen & Hamilton Inc., 1982):

- Improvements to existing products;
- New-product lines;
- Additions to existing product lines;
- New-to-the-world products;
- Cost reductions - process development; and
- Repositioning - product augmentation development.

Clark and Wheelwright (1992)<sup>73</sup> differentiate between four types of products: research or advanced development products; breakthrough development products; platform/generational products; and derivative/incremental products. Their four types are similar to the six aforementioned types, although differently phrased. Regardless of what the different types of products are called, it is important to define what types of products a company will actively pursue in the NPS.

### **2.2.1.4 USE OF METRICS**

The critical success factors of NPD are controlled and measured through the use of metrics. Metrics are defined as a set of figures or statistics that measure results (Oxford Dictionaries, 2016)<sup>74</sup>. A lack of useful metrics has been proven to be one of the reasons why NPD success rates have not improved appreciably over the last 40 years (Crawford, 1979<sup>75</sup>; Crawford, 1992<sup>76</sup>). It must be noted that purely having useful metrics in place will not lead to NPD success. These metrics need to be used as tools to make decisions.

Metrics are used throughout the stage-gate process. Each stage is followed by a gate, and an idea/product passes through the gate based on the ability to meet benchmark metrics. Metrics for each gate are similar. The difference comes in with the levels of detail for each gate, where detail increase as the process moves forward. A key activity in formulating the NPS is thus to decide on which metrics will be used throughout the entire process, and what the performance benchmarks are.

<sup>73</sup> Clark, K.B. & Wheelwright, S.C. 1992. *Managing New Product & Process Development: Test & Cases*. Free Press, New York.

<sup>74</sup> Oxford Dictionaries. 2016. *Definition of the word 'metric'*. [Online]. Available: <http://www.oxforddictionaries.com/definition/english/metric>. [Cited 31 May 2016].

<sup>75</sup> Crawford, C. 1979. *New product failure rate: Facts and Fallacies*. Journal of Research Management, pp. 9-13.

<sup>76</sup> Crawford, C. 1992. *The hidden costs of accelerated product development*. Journal of Product Innovation Management, vol. 9(3), pp. 188-199.





### **2.2.1.5 MANAGEMENT APPROACH TO THE NPD PROCESS**

The NPS needs to define the management style and approach required for the NPD process. This is of critical importance in terms of NPD success – one of the root causes of recurring NPD failure can be attributed to the general management level. This is due to improper new product strategies, and unsuited management approaches (Crawford, 1987)<sup>77</sup>. The NPS thus needs to describe, amongst others, how decisions will be made; how effective communication will be ensured; and how progress will be assessed. Decision-making occurs at the various gates during the process – and it is these decisions that determine whether an idea/product can proceed to the following stage.

Globe et al. (1973)<sup>78</sup> state that the importance of well executed decisions should not be underestimated. Poor decisions can lead to a considerable amount of wasted resources. Bessant & Francis (1997)<sup>79</sup> believe that a new product executive team needs to be established to make these critical decisions. This elevates NPD to a senior level within the company, where decisions are made in support of the strategy of the entire company, and resources are not wasted.

Communication has been shown to be a critical success factor in NPD. A study by Roberts & Burke (1976)<sup>80</sup> revealed that successful innovations had one factor in common. Communication was excellent between departments. In support of this, many of the research studies analysed by Cooper (1983), showed that communication at an internal level was of critical importance. Cooper (1983) recommends that the focus should be on instilling effective cross-departmental and inter-disciplinary communication.

Ensuring (and maintaining) excellent communication is thus a key component of the NPS. This motivates the need for a well-defined communication plan. This communication plan must be implemented at the offset, during the NPS. A shared understanding of the company's competitive strengths and strategic focus (from all the project members) has been shown to be critical to successful NPD efforts (Bhuyain, 2011, Bessant & Francis, 1997).

Apart from effective decision-making and communication, management of the process needs to be effective as well. Cooper (2008)<sup>81</sup> makes a critical observation in terms of managing the process. He notes that NPD is not a bureaucratic system. The objective is for the process to be systematic and streamlined, and should not be hampered by imposing unnecessary paperwork, meetings or committees. Cooper (2008) recommends that if any procedure, meeting, committee or activity does not add value, it should be removed from the process.

<sup>77</sup> Crawford, C. 1987. *New Product Management*. 2<sup>nd</sup> Edition. Illinois: Richard D. Irwin.

<sup>78</sup> Globe, S. et al. 1973. *Key factors and events in the innovation process*. *Research Management*, July, pp. 8-15

<sup>79</sup> Bessant, J. & Francis, D. 1997. Implementing the new product development process. *Technovation*, vol. 17(4), pp. 189-197.

<sup>80</sup> Roberts, R.W. & Burke, J.E. 1976. *Six new products – What made them successful?* *Research Management*, vol. 19(4).

<sup>81</sup> Cooper, R.G. 2008. The Stage-Gate Idea-to-Launch Process Update: What's new and NextGen Systems. *Journal of Product Innovation Management*, vol. 25(3), pp. 213-232.

### 2.2.2 IDEA GENERATION

During idea generation, ideas are generated (or searched for) that are compatible with the strategic requirements of the process. The surrounding environment is investigated in an attempt to identify potential growth opportunities. Ideas do not only have to originate from project members – ideas can originate from any source. Companies that are successful at idea generation are those that focus on several different sources of ideas, and not only the first source (Crawford, 1997)<sup>82</sup>. These sources can be both internal and external, but should not be limited.

The primary goal of the idea generation stage is to produce a mass of ideas, which should all be initially considered as feasible. Booz, Allen & Hamilton Inc. (1982)'s study determined that a company has to generate at least seven ideas for each successful one (14.3% success rate). A similar study by Griffin (1997)<sup>83</sup> showed that an average of 100 ideas will yield 15.2 successes (15.2% success rate). These studies show that a critical success factor of the idea generation phase lies with the volume of ideas generated.

It must be noted that volume is not the only factor. The quality of ideas are also critically important. Quality directly correlates with the amount of different idea sources (Crawford, 1997). Thus the main aim of the idea generation phase should be to generate a large amount of high quality ideas, from several different sources. Gilmore (n.d.)<sup>84</sup> provides a diagrammatical overview of potential idea sources (Figure 2.2.2).

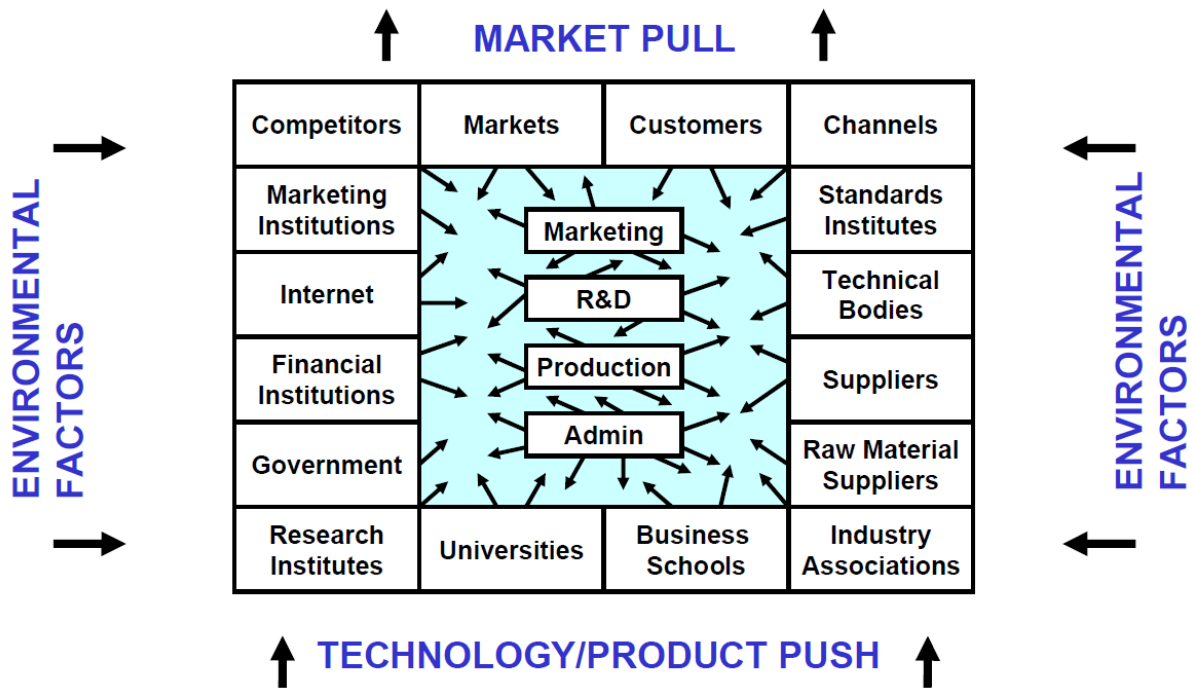


Figure 2.2.2: Sources of Product Opportunities (Gilmore, n.d.)

<sup>82</sup> Crawford, C. 1997. *New product management*. 5th Edition. Illinois: Richard D. Irwin.

<sup>83</sup> Griffin, A. 1997. *PDMA research on new product development practices: Updating trends and benchmarking best practices*. Journal of Product Innovation Management, vol. 14(6), pp. 429-458.

<sup>84</sup> Gilmore, R. n.d. *Overview of New Product Development*. [Online]. Available: <http://www.aq.org.au/PDF/Gilmore.pdf> [Cited 05 May 2016].



Figure 2.2.2 shows that potential idea sources are numerous, and that they are dependent on whether the opportunity is of a market-pull or technology-push nature. A well-established debate in NPD literature exists, with regards to the relative merits of market-pull versus technology-push approaches (Tidd & Bodley, 2000). The best approach is to consider both.

The correct identification of an existing market demand is critically important (Myers & Marquis, 1969; Roberts & Burke, 1976), but identification of technological opportunities is equally important. Opportunities (shown in Figure 2.2.2) can be both market-pull and technology push in nature. A study by Globe et al. (1973) on ten radical innovations showed that recognising technical opportunities, as well as market needs, was critical to success.

The identification of technical opportunities still require a market need. Roberts & Burke (1976)'s study on six successful innovations showed that if an identified technical success did not have a specific market need, the technical success was consequently adapted to suit the identified need. This shows the need for a parallel identification of market and technical opportunities. The results from these parallel research activities should then undergo an analysis (Schwankl, 2002; Koen et al., 2001), where technological opportunities are matched to the market needs they may potentially satisfy.

Identifying sources for ideas is the relatively straightforward part of the idea generation phase. Eliciting ideas from these sources is the hard part. Several "best practice" techniques exist that aid the idea elicitation process, and these are discussed in the following section. It must be noted though that the techniques appear to be of a market-pull nature. It should be remembered that technology push ideas still require a market – the techniques are still relevant, albeit with a more narrowed scope.

Numerous approaches to idea generation exist. A study by Page (1993) showed that 90% of companies use specific approaches, such as brainstorming and other creativity-stimulating techniques. These approaches differ, based on the type of products and the proposed market. Several studies reveal that the 'key theme' for idea generation is customer-focus and understanding customer needs (Cooper & Kleinschmidt, 1993)<sup>85</sup>.

Studies show that a proper understanding of the customer is vital to new product success (Cooper, 1993). Bhuyain (2011) agrees – she believes that a strong customer involvement is necessary from the start, in order to increase the probability of success. Idea generation techniques found throughout NPD literature confirm the importance of customer involvement. Cooper & Edgett (2008)<sup>86</sup> refer to these techniques as "voice of the customer" (VoC) approaches. These customer-focused idea generation techniques, along with others, are explained as follows.

### **2.2.2.1 ETHNOGRAPHY**

Ethnography is an effective customer-focused idea generation approach (Bhuyain, 2011). An ethnographic approach is a descriptive and qualitative market research methodology, which focuses on studying the customer in the context of their specific environment. The approach is performed by spending time in the field, in order to observe customers in their environment. Ethnographic approaches have been proven to be effective in generating significant new product ideas in business-to-business (B2B) environments (Cooper & Edgett, 2008).

<sup>85</sup> Cooper, R.G. & Kleinschmidt, E.J. (1993) 'Screening New Products for Potential Winners', *Long Range Planning*, 26(6), pp. 74-81.

<sup>86</sup> Cooper, R., & Edgett, S. 2008. *Maximizing Productivity in Product Innovation*. Research Technology Management, vol. 51(2), pp. 47-58.

The aim of ethnography is to observe how customers use, abuse and misuse products as they go about their daily routines (Cooper & Edgett, 2008). This provides a better understanding of customer's lifestyles and cultures, which leads to an enhanced understanding of their needs and problems. It is important to note that ethnographic approaches should be non-intrusive. The team conducting the ethnographic research should be merely observing, and not interacting.

### **2.2.2.2 INTERVIEWS**

Cooper & Edgett (2008) recommend detailed interviews with customers as a good technique for idea solicitation. The project team must visit the potential customer in their working environment, and conduct face-to-face, in-depth interviews with them. Cooper & Edgett (2008) further note that in the case of B2B customers, the visiting team should be cross-disciplinary (e.g. marketing, technical and sales), and that the customer is often represented by a corresponding group. A study by Souder (1987)<sup>87</sup> showed that the highest rate of success for new product ideas stemmed from marketing personnel and customers, which emphasises the importance of incorporating a cross-disciplinary approach.

### **2.2.2.3 LATENT-NEEDS ANALYSIS**

Latent needs analysis is an abstract form of gaining insights into customer needs and requirements. The analyses are designed to uncover the unarticulated requirements of customers, by means of their responses to symbols, concepts and forms (Dimancescu and Dwenger, 1995)<sup>88</sup>. Latent-needs analysis does not have to be abstract. Moen (2001) notes that it can also refer to discovering customers' latent needs, by observing them and identifying needs not addressed by current products and services (needs that they are unaware of).

### **2.2.2.4 LEAD-USER ANALYSIS**

In certain cases, new products are partly or completely developed by a customer (Murphy and Kumar, 1997)<sup>89</sup>. These customers are referred to as lead-users, which can be broadly defined as the "visionaries" of a certain technology or product (or the early adopters). The ultimate goal of lead-user analysis is to identify the most innovative customers in the target market (Cooper & Edgett (2008), and then to develop a relationship with these lead users (Cooper, 1999)<sup>90</sup>.

This is because they are a good representative of the needs of the market. Lead-users represent the future needs of the rest of the market, and are one of the most important sources of market knowledge for product improvements (von Hippel, 1982)<sup>91</sup>. Lead-users allow for future market trends to be extrapolated or predicted (Tidd & Bodley, 2000).

Lead-user analysis essentially focuses on collecting information about both the needs and solutions from the lead-users of the target market. It must be noted that information collection should consider other markets as well, such as markets facing similar problems in a more extreme form (Bhuyain, 2011). Lilien et al (2002)<sup>92</sup> believes that the rich body of information collected in this process remains useful throughout the remainder of the NPD process.

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<sup>87</sup> Souder, W. 1987. *Managing new products innovations*. Massachusetts: D.C. Health and Company.

<sup>88</sup> Dimancescu, D. and Dwenger, K. (1995) *World Class New Product Development*. American Management Association, New York.

<sup>89</sup> Murphy, S. & Kumar, V. (1997) 'The front end of a new product development', *R&D Management*, 27(1), pp. 5-15.

<sup>90</sup> Cooper, R. 1999. *From experience: The invisible success factors in product innovation*. Journal of Product Innovation Management, vol.16, pp. 115-133.

<sup>91</sup> von Hippel, E. 1982. Get new products from customers. *Harvard Business Review*, March-April, pp. 117-122.

<sup>92</sup> Lilien, G., et al. 2002. *Performance assessment of the lead user idea generation process for NPD*. Management Science, vol. 8(8), pp. 1042-1059.



### **2.2.2.5 SITE VISITS**

Cooper (1999) recommends that site visits, especially by technical staff, can lead to ideas being generated from observing the technicalities of a customer's environment.

### **2.2.2.6 PROBLEM FOCUS GROUPS AND BRAINSTORMING SESSIONS**

Focus sessions with customers are a good way of developing innovative ideas (Cooper & Edgett, 2008). However, the aim is not to get feedback from customers on new ideas, but rather to find out what their problems and challenges are. Understanding customer problems and challenges is often the starting point for developing a breakthrough solution. Mahajan & Wind 1992<sup>93</sup> believe that focus groups and brainstorming sessions allow developers to get idea feedback more effectively.

In some cases, design engineers observe the customer focus groups on closed-circuit TV (CCTV), and once a concrete problem has been identified, the engineers quickly brainstorm and come up with proposed solutions (Cooper & Edgett, 2008). These solutions are then immediately tested on the focus group in order to get feedback.

A similar result can be obtained by making use of surveys to identify problems/challenges in the target market (Tidd & Bodley, 2000). The participants can then also be surveyed again once a proposed solution has been developed, in order to get feedback on the new idea.

### **2.2.2.7 OPEN INNOVATION**

Docherty (2006)<sup>94</sup> notes that during idea generation, companies should also look beyond the customer for unmet needs or unsolved problems. If an open innovation approach is followed, companies should look externally to inventors, start-ups, small entrepreneurial firms, partners, and other sources of available technologies.

### **2.2.2.8 COMPETITIVE ANALYSIS**

Competitive analysis involves the investigation of existing products, in order to generate ideas for either new products or improved products. This can be achieved by either reverse engineering competing products, or benchmarking their features (Watson, 1993)<sup>95</sup>.

### **2.2.2.9 INDUSTRY EXPERTS/CONSULTANTS**

Tidd & Bodley (2000) recommend that industry experts or consultants should be used in order to generate ideas. These experts/consultants should have a wide range of experience of different user needs. It must be noted that a certain 'danger' exists in using these experts, as they may have become too immersed in the user's world to have the vision required to assess and evaluate the potential of an innovation (Leonard-Barton, 1995)<sup>96</sup>. To overcome this problem, 'proxy experts' can be used. They have knowledge both in the product category, and the usage context (Ort & Schoormans, 1993)<sup>97</sup>.

<sup>93</sup> Mahajan, V. & Wind, J. 1992. New Product Models: Practice, Shortcomings and Desired Improvements. *Journal of Product Innovation Management*, vol. 9, pp. 128-139.

<sup>94</sup> Docherty, M. 2006. Primer on 'Open Innovation': Principles and Practice. *Visions*, vol. 2, pp. 13-15.

<sup>95</sup> Watson, G.H. 1993. *Strategic Benchmarking*. Wiley, New York.

<sup>96</sup> Leonard-Barton, D. 1995. *Wellsprings of Knowledge*. Harvard Business School Press.

<sup>97</sup> Ort, R.J. & Schoormans, J.P.L. 1993. Consumer research in the development process of a major innovation. *Journal of the Market Research Society*, vol. 35(4), pp. 375-388.



### 2.2.3 SIGNIFICANCE OF AVAILABLE INFORMATION

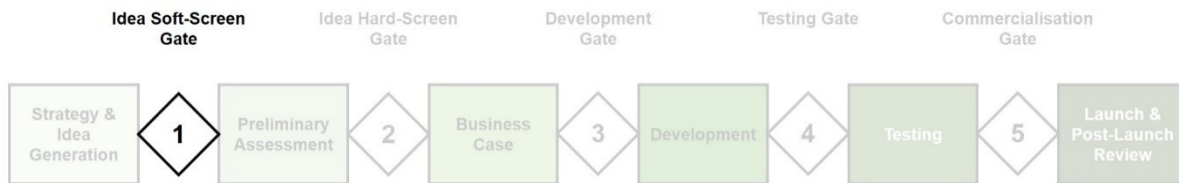
Table 2.2.3 shows the significance of the information discussed under Heading 2.2, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

**Table 2.2.3: Key Learnings: Stage 0: Strategy & Idea Generation**

Description	Activities (Stage 0)	Critical Success Factors
1. Develop R&D strategy (New Value Strategy) for the development of new value propositions. 2. Identify and analyse opportunities. 3. Generate new (or apply existing) ideas for new value propositions (in alignment with the strategy)	<ul style="list-style-type: none"> <li>▪ <b>Formulate new value strategy (NVS)</b> <ul style="list-style-type: none"> <li>▪ <i>Align R&amp;D collaborative companies strategy</i></li> <li>▪ <i>Select strategy type</i></li> <li>▪ <i>Identify customer segments</i></li> <li>▪ <i>Identify types of value propositions to pursue</i></li> <li>▪ <i>Develop success metrics/performance benchmarks</i></li> <li>▪ <i>Develop management approach</i></li> <li>▪ <i>Develop gate criteria for each gate in the model</i></li> </ul> </li> <li>▪ <b>Idea generation</b> <ul style="list-style-type: none"> <li>▪ <i>Identify opportunities (market pull and technology push)</i></li> <li>▪ <i>Analyse opportunities (market pull and technology push)</i></li> <li>▪ <i>Identify idea sources</i></li> <li>▪ <i>Generate ideas, both internally and externally, through the use of several idea generation techniques</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Alignment of NVS with collaborators' strategies (objectives, vision, mission, etc.)</li> <li>▪ Selecting the correct type of NVS</li> <li>▪ Identification of company "success" factors and associated metrics (e.g. IRR, NPV)</li> <li>▪ Fit with organisational culture</li> <li>▪ Applying the correct management approach (for activities and decision-making)</li> <li>▪ Effective communication</li> <li>▪ Shared understanding of NVS</li> <li>▪ Removing unnecessary bureaucracy</li> <li>▪ Number of idea sources</li> <li>▪ Volume of ideas generated</li> <li>▪ Quality of ideas generated</li> <li>▪ Use of market-pull and technology push approaches</li> <li>▪ Customer involvement</li> <li>▪ Sound understanding of potential customers</li> <li>▪ Use of several idea generation techniques</li> </ul>



## GATE 1: IDEA SOFT SCREEN



### 2.3 GATE 1: IDEA SOFT SCREEN

Once ideas have been generated in the previous stage, they need to be evaluated (Tzokas et al., 2003) in order to select the best ideas (Koen et al., 2001). The first gate in the NPD process performs this function. The volume of new product ideas decrease, as they are narrowed down and screened out (where only those ideas that offer the greatest potential are left) (Booz, Allen & Hamilton Inc., 1982). The ideas with the most potential proceed to the next stage as “tentative positive” projects (Cooper, 1983; Cooper, 1990), and the others are either eliminated or recycled/iterated.

Cooper (1990) refers to Gate 1 as a “gentle” screen, which subjects ideas to a handful of key “must meet” and “should meet” criteria (excluding financial criteria). 76% of companies screen ideas through scoring and ranking them according to a set of criteria (Page, 1993). A checklist for the “must meet” criteria and a scoring model (weighted rating scales) for the “should meet” criteria are used to help focus the discussion, and rank projects in the first screen (Cooper 1990). The final result from the screening stage is a ranking of NPD proposals, which represents the first decision to allocate resources to the most promising ideas (Crawford, 1997; Cooper, 1983).

The idea screening criteria can be categorised into four main groups: strategic criteria; resource criteria; technical criteria; and commercial criteria. Strategic criteria consider whether an idea suits the company, its strategy, as well as its objectives. Resource criteria consider whether the company has adequate resources (or access to the correct resources) in order to turn an idea into a reality. Technical criteria focus on whether an idea is technically feasible, whereas commercial criteria focus on whether the product could be commercially feasible.

#### 2.3.1 STRATEGIC CRITERIA

In the first stage, the new product strategy is devised and developed in order to fit in best with the overall company strategy, mission and objectives. Product ideas need to comply with the NPS, in order to work towards a common goal of meeting the objectives and goals of the company (Clark and Fujimoto, 1991<sup>98</sup>; Clark and Wheelwright, 1992). A key gate criteria is thus whether ideas align with the NPS and the company strategy (Cooper, 1983; Cooper, 1990; Bhuyain, 2011; Page, 1993).

New products can fail due to a poor fit with the organisational culture (Jain, 2001). Thus, in addition to assessing ideas based on strategy, ideas also need to be assessed in terms of how they fit in with company culture.

<sup>98</sup> Clark, K.B. & Fujimoto. 1991. *Product Development Performance*. Boston: Harvard University Press.





### 2.3.2 RESOURCE CRITERIA

A study conducted by Tidd & Bodley (2000) revealed that 95% of companies make use of core competency as a criteria. Although core competency in this context refers to the available internal resources of the company, access to external resources should also be considered. Cooper (1983) recommends that, if a company has inadequate resources for a specific project idea, it should be investigated whether the resources can be readily acquired elsewhere. Thus, regardless of whether the needed resources are internal or external, if they are available, the idea passes the criteria (Cooper, 1990; Bhuyain, 2011).

### 2.3.3 TECHNICAL CRITERIA

One of the first screening criteria to consider is whether the project/product is technically feasible (Cooper, 1983; Cooper, 1990). Tzokas et al (2003)'s study showed that 70% of companies use technical feasibility as a key criteria. It must be noted that some of the companies in the study did not make use of an idea screening gate. In cases where companies employ this gate, Tidd & Bodley (2000)'s study showed that 100% of the companies use the relative probability of technical success as a key screening criteria.

### 2.3.4 COMMERCIAL CRITERIA

As with the technical criteria, Tidd & Bodley (2000)'s study emphasised the importance of ideas' probability of being commercially successful as a key criteria. 100% of the companies within the sample made use of this criteria at the idea screening gate. This probability for success is heavily reliant on the market attractiveness and differential advantage (Cooper, 1990); the acceptance of the idea by the potential customer (Tzokas et al, 2003); competitors (Bhuyain, 2011) and the uniqueness of the proposed product (Page, 1993; Tzokas et al., 2003).

Using the aforementioned factors, a subjective estimation of the probability of success can be determined. In order to correctly assess the ideas, potential magnitudes need to be determined as well. Cooper (1990) refers to this as the magnitude of the opportunity, and it refers to how much value could be gained if a product were successful.

Several other factors are involved in determining whether a product might be commercially successful. Amongst these are market potential. Tzokas et al. (2003)'s study revealed that 59% of companies use market potential as a criteria at the first gate. Booz, Allen & Hamilton Inc. (1982) share this sentiment. They recommend that each idea should be envisioned as a product in the market, so that it can be evaluated on its potential value contribution to the market.

In the absence of financial data, other methods of comparing attractiveness of different projects need to be used (Cooper, 1983). In terms of the commercial criteria broad group, the best method is the use of a relative weighting system. Magnitudes of success for each idea should be subjectively ranked (e.g. 1 – 10, with 1 being very low and 10 being very high), and then multiplied with their associated probabilities of success. This leads to the relative weighting of ideas for comparative purposes.

An interesting finding in terms of the screening gate criteria is that of the use of intuition (Tzokas et al., 2003). Their study showed that 56% of companies make use of intuition at the first gate. This finding shows the mind-set required at the first screening gate. Assessment and evaluation is subjective and intuition-based, and it should be treated as such.



The following stage focuses on conducting preliminary assessments on the ideas that pass through the first gate, and the ideas are once again screened at the second gate. In essence, the double-screening of ideas is what allows for the relatively relaxed attitude towards idea screening in this gate. Assessments can be subjective and intuition based, and if this leads to a “no-go” idea passing this screen, the second screen will discard the idea.

### 2.3.5 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.3.5a shows the significance of the information discussed under Heading 2.3, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3). Table 2.3.5b shows a summary of the key criteria to take into consideration at Gate 1.

**Table 2.3.5a: Key Learnings: Gate 1: Idea Soft Screen**

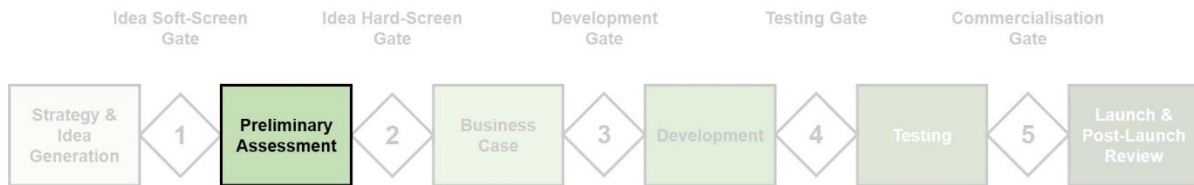
Description	Activities (Gate 1)	Critical Success Factors
First assessment of ideas generated in Stage 0, through subjecting ideas to a range of pre-determined criteria	<ul style="list-style-type: none"> <li>▪ Assessment of ideas through scoring model, focusing on technical, strategic and market criteria</li> <li>▪ Ranking of ideas based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Allowing for subjectivity and intuition in decision-making</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> </ul>

**Table 2.3.5b: Summary of Typical Gate Criteria at Gate 1**

Criteria Group	Criteria
Strategic	Fit with company/ies strategy and NPS
	Fit with organisational culture
	Leverage of company/ies core competencies (internal and external)
Market	Size (Market attractiveness)
	Expected Growth (Market attractiveness)
	Differential advantage
	Potential value contribution to market
	Acceptance of idea by customers
Technical	Uniqueness
	Potential competitors
	Feasibility (Relative probability of technical success)



## STAGE 1: PRELIMINARY ASSESSMENT



### 2.4 STAGE 1: PRELIMINARY ASSESSMENT

The first official stage of the process is referred to as the preliminary assessment stage, or the preliminary investigation stage (Cooper, 1997). In this stage, the question concerning what the product will be (with respect to initial applications), begins to be addressed in earnest (Veryzer, 1998)<sup>99</sup>.

The preliminary assessment stage is the first stage where mentionable resources are spent to gather information, with regards to the feasibility and attractiveness of ideas (Cooper, 1983). The assessments should be deliberately limited in terms of time spent, and should be kept as inexpensive as possible (Cooper, 1983; Cooper, 1990). In essence, the preliminary assessment stage has the objective of determining technical and marketplace merits (Cooper, 1990).

Determining these merits involves several types of activities, with the main focus of the activities being on the technical and market assessments of the ideas. As stated previously, these assessments need to be short and inexpensive, but should contain enough detailed information to be properly assessed at Gate 2.

#### 2.4.1 MARKET ASSESSMENT

The preliminary market assessment involves a quick and inexpensive market study. The desired information should give an overview of the market through the following:

- Identification of possible segments (Cooper, 1983; Cooper & Edgett, 2008);
- Investigation of potential market size (Cooper, 1983; Cooper, 1990; Cooper & Edgett, 2008);
- Investigation of market potential, need, attractiveness and acceptance of the new product (Cooper, 1983; Cooper & Edgett, 2008; Cooper, 1990; Page, 1993);

The information can be obtained through several different methods and sources. The use of in-house available information; secondary sources of data (e.g. library search for publications); and accessing outside sources of data (e.g. industry experts or potential customers) should all be considered (Cooper, 1983; Cooper, 1990).

<sup>99</sup> Veryzer, R.W. 1998. Discontinuous Innovation and the New Product Development Process. Journal of Product Innovation Management, vol. 15, pp. 304-321.



Customer involvement in the preliminary market assessment is of critical importance (Cooper & Edgett, 2008; Bhuyain, 2011; Cooper, 1990). Customer needs, wants, requirements and value definitions should be investigated in order to gain initial insights. This is done by means of conducting a concept test of the idea. Investigation methods are similar to those given for idea generation in Section 2.2. Furthermore, Bhuyain (2011) and Cooper & Edgett (2008) note that a competitive analysis should also be conducted as part of the market assessment.

#### 2.4.2 TECHNICAL ASSESSMENT

The preliminary technical assessment encompasses the in-house technical appraisal of the idea (Cooper, 1983; Cooper, 1990). The key questions concern the technical feasibility of the idea (Bhuyain, 2011). This firstly requires the identification of the probable technical solution on paper, as well as the possible technical challenges/risks (Cooper & Edgett, 2008). Secondly, the proposed feasible development route in terms of time and costs should be considered (Cooper, 1990; Cooper & Edgett, 2008). Lastly, a broad indication of the resources required is needed (including the potential need for resource alliances) (Cooper, 1983; Cooper, 1990; Tzokas et al. 2003).

According to Cooper & Edgett (2008)'s best practice study, the preliminary technical assessment is the best-executed activity in the first stage. Almost half of companies were seen as executing this activity well, and amongst high-productivity businesses, 64% were assigned this rating. The preliminary technical assessment should also include an assessment of manufacturing/operations feasibility (Cooper, 1990; Bhuyain, 2011). It is important to note that an idea may be technically feasible, but may not be scalable.

Another key aspect of the preliminary assessment is to focus on defining the entire value offering of the product idea. Successful NPD should not only focus on providing value through product features. It should focus on the entire value offering (Wind & Mahajan, 1988)<sup>100</sup>. The aim should be to meet the market needs, and bring the desired benefits/solutions to market. This should be applied to the entire product value chain, namely purchase, transportation, usage, storage and disposal of the products/services.

From a management/strategic perspective, a key consideration is the identification of an internal product champion. Studies concur that the actions of people in NPD projects determined the success or failure of the project (Cooper, 1983). Despite consistent findings on the importance of internal project champions, most NPD efforts fail to identify, appoint and effectively reward a champion (Wind & Mahajan, 1988). This highlights the need for an internal individual that takes ownership and responsibility for the project.

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<sup>100</sup> Wind, Y. & Mahajan, V. 1988. *New Product Development Process: A Perspective for Re-examination*. Journal of Product Innovation Management, Vol. 5, pp. 304-310.



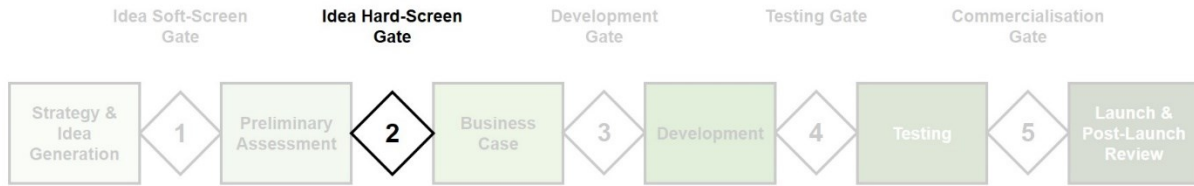
### 2.4.3 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.4.3 shows the significance of the information discussed under Heading 2.4, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

**Table 2.4.3: Key Learnings: Stage 1: Preliminary Assessment**

Description	Activities (Stage 1)	Critical Success Factors
Preliminary assessment of new value propositions, based on holistic technical, market and financial assessments	<ul style="list-style-type: none"> <li>▪ Defining the entire value-offering of the new value proposition</li> <li>▪ <b>Market Assessment</b></li> <li>▪ <i>Investigation into broad customer segments and potential market size</i></li> <li>▪ <i>Investigation into market potential, need, wants and acceptance</i></li> <li>▪ <i>Investigation into potential competitors</i></li> <li>▪ <b>Technical Assessment</b></li> <li>▪ <i>Development/Identification of probable technical solution</i></li> <li>▪ <i>Identification of possible technical challenges/risks</i></li> <li>▪ <i>Development of preliminary timeline and budget</i></li> <li>▪ <i>Broad indication of resources required</i></li> <li>▪ <b>Financial Assessment</b></li> <li>▪ <i>High-level indication of financial viability</i></li> </ul>	<ul style="list-style-type: none"> <li>▪ Speed</li> <li>▪ Low cost</li> <li>▪ Correct level of detail of information</li> <li>▪ Customer involvement</li> <li>▪ Sound information (internal and external)</li> <li>▪ Sound technical expertise</li> <li>▪ Use of internal champion (person who takes ownership)</li> </ul>

## GATE 2: IDEA HARD SCREEN



### 2.5 GATE 2: IDEA HARD SCREEN

Following Stage 1, ideas need to be screened once again. The second gate is essentially a repeat of the first gate. Ideas are re-evaluated, in light of new information obtained in Stage 1 (Cooper, 1990). Ideas are subjected to the same “must-meet” and “should-meet” criteria as at Gate 1, with additional “should-meet” criteria (focusing on sales force and customer reaction to the proposed product) (Cooper, 1990). A preliminary financial analysis may be possible at this point in the process, but it is more likely that qualitative information will influence the outcome of the gate decision (Cooper, 1983).

Cooper (1990) recommends that financial return should be assessed at the second gate, but that it should be a quick and simple financial calculation (e.g. payback period). Tzokas et al. (2003)’s study showed that only 10% of companies used financial-based criteria at the second gate. This shows that financial assessment should be conducted from a high-level perspective, with more detailed focus on qualitative metrics. Cooper (1990) provides recommended inputs for Gate 2 (Table 2.5a).

**Table 2.5a: Gate 2 Required Inputs (Cooper, 1990)**

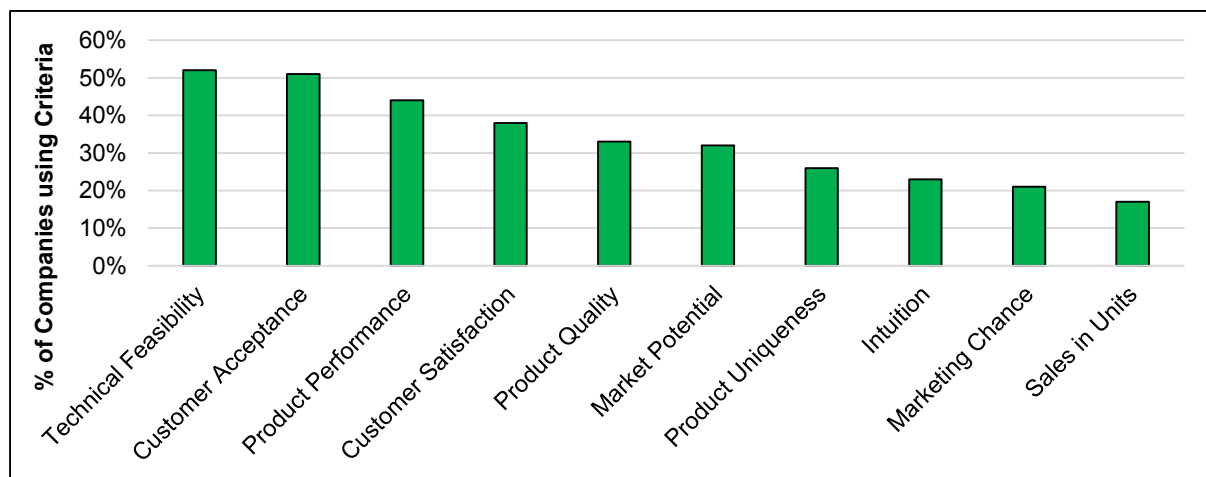
Group	Metrics
Market Analysis	<ul style="list-style-type: none"> <li>▪ Size</li> <li>▪ Growth</li> <li>▪ Segmentation</li> <li>▪ Trends</li> </ul>
Competitive Analysis	<ul style="list-style-type: none"> <li>▪ Players</li> <li>▪ Market Shares</li> <li>▪ Strategies</li> </ul>
Customer Reaction	<ul style="list-style-type: none"> <li>▪ Reaction to concept</li> <li>▪ Price sensitivities</li> </ul>
Development & Production Appraisal	<ul style="list-style-type: none"> <li>▪ Feasibility</li> <li>▪ Route</li> <li>▪ Times and cost</li> </ul>

Table 2.5a shows that Cooper’s recommended inputs are all essentially metric-based. His recommendations focus on the factors that need to be measured, and excludes Gate 1 items such as strategic alignment and resource availability. This does not exclude these criteria from Gate 2. As stated previously, Gate 2 is essentially a repeat of Gate 1, and should include all criteria from it. Rosenau et al. (1996)<sup>101</sup> provide a list of criteria for Gate 2 (Table 2.5b), which is similar to that given in Table 2.5a, with some minor differences.

**Table 2.5b: Sample Screening Criteria (Rosenau et al., 1996)**

Screen	Criteria
Strategic	<ul style="list-style-type: none"> <li>Fit with company mission and strategy</li> <li>Familiarity to company</li> <li>Market Competitiveness</li> <li>Market size and expected growth</li> </ul>
Consumer	<ul style="list-style-type: none"> <li>Importance of consumer needs addressed</li> <li>Consumer benefit delivered</li> <li>Product Superiority</li> <li>Perceived value for money</li> </ul>
Product Development	<ul style="list-style-type: none"> <li>Fit with company technical capabilities</li> <li>Degree of benefit delivered</li> <li>Time to market</li> <li>Competitor’s ability to follows</li> <li>Estimated development costs</li> </ul>
Regulatory and Legal	<ul style="list-style-type: none"> <li>Ability to protect from quick competitor reaction</li> <li>Estimated timing for regulatory approval</li> </ul>

Table 2.5b shows that as with the required inputs in Table 2.5a, Rosenau et al. do not include financial criteria (apart from the estimated development costs). Tzokas et al. (2003)’s study revealed the criteria most used by companies at Gate 2 (Figure 2.5a).



**Figure 2.5a: Top 10 Criteria used by Companies at Second Screening Gate (Tzokas et al., 2003)**

<sup>101</sup> Rosenau, M., et al. 1996. The PDMA Handbook of New Product Development. New York: John Wiley & Sons Inc.



Figure 2.5a shows that Tzokas et al.'s results broadly match the criteria focus areas given by Cooper in Table 2.5a and Rosenau et al. in Table 2.5b. Tzokas et al. do however include a financial criteria, not included in the other recommendations (potential sales in units). This relates to Cooper (1990)'s recommendation of calculating a very basic financial return, such as the payback period (which would require the estimated development cost, market size/expected growth, and expected sales in units). It can be concluded that Gate 2 is essentially a repeat of Gate 1, and should primarily consider the same main criteria groups as at Gate 1: Strategic, Resource, Technical and Commercial.

It must be noted that although the criteria is similar to Gate 1, ideas at Gate 2 should be subjected to the criteria more rigorously than at Gate 1. The inputs into the gate should be more detailed, and have higher levels of certainty.

Care should be given in terms of screening ideas at this gate. Two types of errors can occur when screening ideas: Potentially successful ideas can be eliminated, or inevitable failures can be allowed to pass (Crawford, 2003)<sup>102</sup>. A matrix of these two types of errors is shown in Figure 2.5b.

	<b>A: Abort the new project</b>	<b>B: Continue to next stage</b>
<b>A: Product would fail</b>	<b>AA</b>	<b>BA</b>
<b>B: Product would succeed</b>	<b>AB</b>	<b>BB</b>

**Figure 2.5b: Matrix of Risk/Payoff (Redrawn from Crawford, 2003)**

Figure 2.5b shows that the desired and correct decisions are AA and BB, and the undesired and erroneous decisions are AB and BA. BA decisions end up wasting precious resources, whereas AB decisions lead to a loss of potential opportunity. These two errors should be avoided by incorporating well-thought out screening criteria.

<sup>102</sup> Crawford, C. 2003. *New Product management*. 8<sup>th</sup> Edition. Illinois: Richard D. Irwin.

### 2.5.1 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.5.1a shows the significance of the information discussed under Heading 2.5, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3). Table 2.5.1b shows a summary of the key criteria to take into consideration at Gate 2.

**Table 2.5.1a: Key Learnings: Gate 2: Idea Hard Screen**

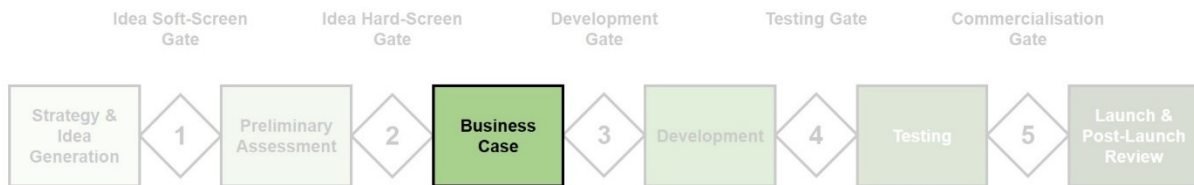
Description	Activities (Gate 2)	Critical Success Factors
Second round of assessment of value propositions that have undergone preliminary assessment, through subjecting these value propositions to a range of pre-determined criteria	<ul style="list-style-type: none"> <li>▪ Assessment of ideas through scoring model, focusing on key criteria (Table 2.5.1b)</li> <li>▪ Ranking of ideas based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> <li>▪ Emphasis on qualitative rather than quantitative assessment</li> </ul>

**Table 2.5.1b: Summary of Typical Gate Criteria at Gate 2**

Criteria Group	Criteria
Strategic	Fit with company/ies strategy
	Familiarity to company
	Leverage of company/ies core competencies
	Estimated timing for regulatory and legal approval
Market	Size
	Expected Growth
	Segmentation & Trends
	Importance of customer needs addressed
	Benefit delivered
	Value proposition superiority
	Perceived value/reaction to proposed value proposition
	Potential competitors
	Competitor's ability to replicate
	Competitor's market share
Competitor's strategies	
Technical	Ability to protect from quick competitor reaction
	Feasibility
	Degree of benefit delivered
	Development plan
	Estimated time to market
	Estimated cost



## STAGE 2: BUSINESS CASE



### 2.6 STAGE 2: BUSINESS CASE

The business analysis stage is a more detailed repeat of the preliminary assessment stage. Investigations are similar in nature, but just more detailed (Cooper, 1997). However, whereas the preliminary assessment stage did not involve financial analysis, the business analysis stage places focus on financial aspects. Page (1993) refers to the stage as an evaluation of the product idea in financial terms, in order to determine its attractiveness as a business proposition. Although the stage places emphasis on financial aspects, close attention should still be paid to thorough market and technical analysis (Tzokas et al., 2003).

The business analysis stage is the final stage prior to actual product development. It is thus the stage that must verify project attractiveness and feasibility (Schwankl, 2002; Cooper, 1990; Khurana & Rosenthal, 1997) before considerable financial resources are allocated to the project. Enough information should be available at this stage to clearly define the new product concept (Schwankl, 2002; Cooper, 1990; Khurana & Rosenthal; Koen et al., 2001; Herstatt & Verworn, 2007) and to properly plan the project for the following stages (Herstatt & Verworn, 2007; Khurana & Rosenthal, 1997).

The activities performed in the business analysis stage provide the necessary inputs for the development of a hypothetical business plan (or business case) for the product idea. These activities include, amongst others (Booz, Allen & Hamilton Inc., 1982):

- Market Assessment
- Technical Assessment
- Business Assessment

It must be noted that the three activities are mostly concurrent, and that they are not performed in isolation.

#### 2.6.1 MARKET ASSESSMENT

The market assessment firstly focuses on conducting a detailed market investigation, in order to identify a segment of customers who either have a problem; customers who are dissatisfied with the current solution; underperforming competitor products; or a niche where a new technology or design can lead to a competitive advantage (Cooper, 1983). The purpose of the market assessment is to determine, amongst others (Booz, Allen & Hamilton Inc., 1982):

- Current and potential competitors;
- Target markets; and
- Market growth predictions.



A study by Cooper (1975)<sup>103</sup> on new industrial product failure showed that the main reasons for failure was primarily market-related. The study determined that 36% of new products failed due to underestimating competitive strength and/or competitive position in the market. Furthermore, 21% of new products failed due to an overestimated number of potential customers. This shows is that it is critically important to ensure that the market assessment and analysis is conducted effectively (as this is the final stage before financial spending increases considerably).

Apart from focusing on the potential customer segments and competitors, a further market study should be conducted that details the identified customer segments. The purpose of the further market study is to determine customer wants, needs, preferences, and their “must have” and “would like to have” features in a product (Cooper, 1990). This information is what leads to the design specifications of what constitutes a good product (in the eyes of the potential customers) (Cooper, 1983).

Understanding customer needs, and satisfying those needs has been proven to be critical success factors for new products. An innovative product which is either unique or totally new, is not sufficient. The product must be unique in the eyes of the customer, and not just the opinion of the NPD team (Cooper, 1983). Several studies on new product success have emphasised this fact. Underlying factors responsible for separating product successes from failures included market need satisfaction (Author unknown, 1974)<sup>104</sup> and the understanding of customer needs (Rothwell, 1972<sup>105</sup>; Rothwell et al, 1974<sup>106</sup>; Jain, 2001).

Once the results of the market study have been translated into a “winning new product” (Cooper, 1990), a concept test needs to be performed. The concept test is essentially a test of whether the marketplace will accept the new product concept. Interest, preference and intent to purchase are established (Cooper, 1983; Cooper, 1990; Cooper & Edgett, 2008). The concept test should have something tangible to show the marketplace, in order to obtain feedback (e.g. sketches, diagrams, models, or descriptions of the proposed product) (Cooper & Edgett, 2008; Cooper, 1983).

Additional benefits of the concept test feedback include potential suggested modifications (or if the concept is rejected, reasons why it was rejected). Thus the concept test, if not accepted, provides information for the concept to be recycled/iterated. Cooper (1983) notes that the market assessment activities in this stage do not only perform their primary functions (as outlined above). They also begin the marketing planning process, as they identify the target market. Thus prior to actual product development, the marketing planning process is already initiated.

In some cases, a lopsided reliance on customer inputs may exist in the NPD process (Wind & Mahajan, 1988). Effective NPD should not only focus on customer inputs, but should also consider the needs and requirements of all other relevant stakeholders (e.g. salespeople, distributors, government agencies, suppliers).

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<sup>103</sup> Cooper, R.G. 1975. *Why new industrial products fail*. Industrial Marketing Management, vol. 4, pp. 315-326.

<sup>104</sup> Author unknown. 1974. *The Hungarian SAPPHO: Some comments and comparison*. Res. Policy 3, pp. 30-38.

<sup>105</sup> Rothwell, R. 1972. *Factors for success in industrial innovations*. Project SAPPHO – A comparative study of success and failure in industrial innovation.

<sup>106</sup> Rothwell, R. et al. 1974. *SAPPHO updated project: SAPPHO phase 2*. Res. Policy 3, pp. 258-291.



## 2.6.2 TECHNICAL ASSESSMENT

Cooper (1983) suggests that the new product process must integrate the technical side with the needs of the marketplace. This ensures that the product does indeed deliver unique benefits to the customer. This is achieved through conducting a technical appraisal on the product, which determines whether customer requirements (found through the concept test) can be translated into a technically feasible product. This type of appraisal may include some preliminary design/laboratory work, but development should be kept to an absolute minimum.

In essence, the technical appraisal should determine the most probable technical solution of the product. This includes the likelihood of completion, costs and times to develop the solution, potential “killer” variables (Cooper, 1990) and the product attributes (Booz, Allen & Hamilton Inc., 1982).

A detailed and thorough technical appraisal has been shown to be a critical success factor in NPD efforts. Cooper (1975)’s study showed that 21% of new products fail due to technical difficulties/deficiencies with the product. In support of this, poor product design and products not working as were identified as key causes of NPD failure (Jain, 2001). As with the market assessment in this stage, the technical assessment has to be detailed and conducted properly. This ensures that a gate decision is not made on “false” or misinformed information, which may lead to finances being wasted on a non-technically feasible product.

## 2.6.3 BUSINESS ASSESSMENT

The business assessment aspect of Stage 2 comprises of several aspects. These aspects are listed and explained.

### 2.6.3.1 PRODUCT DEFINITION

The product definition requires the entire NPD team to integrate the information acquired in the stage, in order to form a product definition (Cooper, 1990). The definition should specify the following (Cooper & Edgett, 2008):

- Project scope;
- Target market;
- Product concept;
- Benefits and value proposition;
- Target price and positioning;
- Features and requirements; and
- High-level technical specifications.

### 2.6.3.2 SOURCE OF SUPPLY ASSESSMENT

The source of supply assessment is an initial appraisal of where the required resources for the envisioned product will come from. This includes operating requirements, probable material and equipment needs, potential outsourcing needs, potential suppliers and partners/alliances (Cooper & Edgett, 2008). This type of assessment has been found to be very weak amongst companies performing NPD, where only one in five were deemed to have performed it adequately (Cooper & Edgett, 2008).

Cooper (1990) believes that this assessment should also include any manufacturability issues and the potential costs of manufacturing.



### **2.6.3.3 VALUE-OFFERING ASSESSMENT**

Cooper & Edgett (2008) refer to this as a value-to-the-customer assessment (or a value-in-use analysis). The proposed product's potential value to the customer is defined and quantified. The assessment considers the potential economic impact on a customer's operation, versus the current solution they have in place. Essentially the assessment determines how much value the proposed product can deliver to customers, and is a good determinant of how the product should be priced.

Cooper (1975)'s study determined that one of the main reasons for new industrial product failure was that the product price was too high (18% of NPD failures). The value-offering assessment is thus critical in ensuring that a product is not overpriced. The value of performing this assessment is greatly underestimated. Only one in six businesses are deemed to perform the assessment adequately (Cooper & Edgett, 2008).

### **2.6.3.4 FINANCIAL ANALYSIS**

The financial analysis involves the integration of all the information, data and projections of the NPD process up until this point. This allows for a full financial analysis of the proposed new product (Booz, Allen & Hamilton Inc., 1982). The financial analysis typically involves a discounted cash flow approach, where the Net Present Value (NPV), Internal Rate of Return (IRR) and payback period are calculated. Additionally, a sensitivity analysis on various influencing factors is also performed (Cooper & Edgett, 2008; Cooper, 1990).

Diligence and quality of inputs are critical in terms of performing the financial analysis. One of the main causes of new product failure can be attributed to a low Return on Investment (ROI) (Jain, 2001). It is thus important to perform a "true" financial analysis, so that a product that may not provide the best returns can be identified at this stage in the process (where financial risks associated with failure are still low).

### **2.6.3.5 MANAGEMENT AND COMMUNICATION**

Bessant & Francis (1997) believe that the identification of clear roles and responsibilities within the process (especially hand-over from product managers to project managers) is critical to success. A Hungarian study in the electronics industry showed that the role of key individuals in the NPD process was closely linked to product success (Author unknown, 1974).

The business case should thus include the roles and responsibilities of individuals, and should also state what the ideal characteristics of NPD project managers should be. Rothwell (1972)'s and Rothwell et al. (1974)'s studies showed that the characteristics of managers in the NPD process were key discriminators between product success and failure.

Apart from the management aspects and the roles of individuals in the process, effective external and internal communication has shown to be closely linked to success (Author unknown, 1974; Rothwell, 1972; Rothwell et al., 1974). The business case should include a communication plan and communication "best practice", to ensure that this aspect is handled successfully.





### **2.6.3.6 COMPETITOR ANALYSIS**

As stated previously in the market assessment, a critically important aspect of Stage 2 is a comprehensive competitor analysis (Cooper, 1990). Wind & Mahajan (1988) suggest that the likely offensive and defensive competitive and trade activities should be considered, and how these can impact on the success of the new proposed product. This may also lead to the identification of possible barriers to entry in to the market (Booz, Allen & Hamilton Inc., 1982).

### **2.6.3.7 LEGAL**

The business analysis stage should include an investigation (through the legal department) into the copyright/legal/patent status of the proposed product (Cooper, 1990). Furthermore, the investigation should also include contingency plans that address any potential problems with regards to new legal issues arising.

### **2.6.3.8 MARKETING/PROMOTIONAL PLANS**

The business assessment should also include the plans for marketing the product in the future, and should specify which methods will be used to promote the product (Booz, Allen & Hamilton Inc., 1982). Rothwell (1972)'s and Rothwell et al. (1974)'s studies showed that a key discriminatory variable between product successes and failures lay with the magnitude of marketing efforts. It is thus essential to include a marketing plan-of-action in the business case, to ensure that the proposed product does not fail due to this reason.

### **2.6.3.9 TIMING**

Jain (2001) identified poor timing of a new product as one of the key reasons for new product failure. Entering a market too late, as well as too early, can lead to new product failure. It is thus important to, in the business case, properly define the required timing of the product. If it reaches the market too late, a different strategy could be adopted. If it reaches the market too early, the project may could be deliberately placed on hold.





### 2.6.4 SIGNIFICANCE OF AVAILABLE INFORMATION

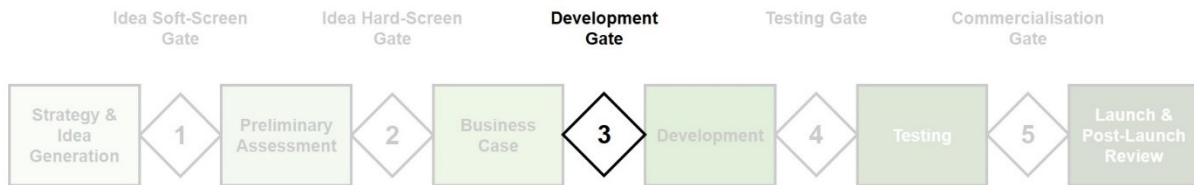
Table 2.6.4 shows the significance of the information discussed under Heading 2.6, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

**Table 2.6.4: Key Learnings: Stage 2: Business Case**

Description	Activities (Stage 2)	Critical Success Factors
<p>More detailed repeat of Stage 1, with specific emphasis on financial analysis</p>	<ul style="list-style-type: none"> <li>▪ <b>Concept testing</b></li> <li>▪ <i>Determine acceptance of new value proposition</i></li> <li>▪ <i>Determine intent to purchase</i></li> <li>▪ <b>Financial analysis, including sensitivity analysis</b></li> <li>▪ <b>Technical Assessment</b></li> <li>▪ <i>Clear definition of new value proposition concept</i></li> <li>▪ <i>Determine likelihood of completion</i></li> <li>▪ <i>Determine costs</i></li> <li>▪ <i>Determine time to develop</i></li> <li>▪ <i>Determine potential “killer” variables</i></li> <li>▪ <b>Market Assessment</b></li> <li>▪ <i>Detailed investigation of target markets</i></li> <li>▪ <i>Identification of current and potential competitors and their strength</i></li> <li>▪ <i>Potential market growth analysis</i></li> <li>▪ <b>Development of marketing plan</b></li> <li>▪ <b>Source of supply assessment</b></li> <li>▪ <b>Determine value-add to potential customer/s</b></li> <li>▪ <b>Competitor analysis</b></li> <li>▪ <b>Legal analysis</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ Understanding customer needs</li> <li>▪ Value proposition uniqueness</li> <li>▪ Consideration of needs of all stakeholders, not only potential customers</li> <li>▪ Quality of assessments</li> <li>▪ Quality and confidence of financial inputs</li> <li>▪ Management of activities</li> <li>▪ Parallelism of activities</li> <li>▪ Effectiveness of internal communication</li> </ul>



## GATE 3: GO TO DEVELOPMENT



### 2.7 GATE 3: GO TO DEVELOPMENT

The third gate represents the decision on the business case developed in the previous stage. If the decision is positive, it allows the project to go into the development stage (where the first mentionable financial resources will be allocated) (Cooper, 1990). The decision is made based primarily on the outcomes of the concept testing. Intent to purchase data, gained through the concept testing, permits estimates of market acceptance and expected sales (Cooper, 1983). Along with the development cost estimates, reasonable financial analysis metrics can be used as criteria to make the gate decision (Cooper, 1990).

The project should once again be subjected to all the “must meet” and “should meet” criteria used at Gate 2 (Cooper, 1990). A qualitative review of the activities in Stage 2 should also be performed, in order to decide whether the quality of execution was sound (and therefore whether the metrics put forward can be used to make a decision). The objective of the decision is to determine whether the product is technically feasible; whether it has market potential; and whether it will make a sound financial contribution to the company (Tzokas et al., 2003).

The most prominent method used by businesses for assessment at this gate is a financial approach, followed by strategic approaches and scoring models (Cooper et al., 2000)<sup>107</sup>. Cooper (2008) provides a best-practice Gate 3 approach that incorporates financial, strategic and other criteria into one scoring model. He recommends that the project should be assessed at this gate in terms of six key factors, which should all be incorporated into the scoring model:

- Strategic Fit and Importance;
- Product and Competitive Advantage;
- Market Attractiveness;
- Core Competencies Leverage;
- Technical Feasibility; and
- Financial Reward versus Risk.

New product projects should be scored based on these six factors, where a score of 0 – 10 is assigned to each factor. The scores are added together, and leads to what Cooper (2008) refers to as the “Project Attractiveness Score”. A score of 60% or higher is usually required to pass the gate and move on to development.

<sup>107</sup> Cooper, R., et al. 2000. New problems, new solutions: Making portfolio management more effective. *Research Technology Management*, vol. 43(2), pp. 18-33.

### 2.7.1 STRATEGIC FIT AND IMPORTANCE

As with previous gates, the alignment of the product with the company strategy is a key gate criteria. Apart from verifying this alignment, the importance of the new product to the company needs to be stated and verified (Cooper, 2008). In relation to this, the impact that the new product may have on the business as a whole needs to be confirmed.

### 2.7.2 PRODUCT AND COMPETITIVE ADVANTAGE

The product and its potential competitive advantage needs to be assessed as part of the gate criteria. The product development plan, as well as the preliminary operations plan, should be part of the inputs into the gate (Cooper, 1990). These plans should be assessed in terms of probability of success, both in the short-term and the long-term. Furthermore, the following aspects play key roles:

- Product uniqueness and delineation of the unique customer benefits it delivers (Cooper, 1990; Cooper, 2008; Tzokas et al., 2003);
- Product performance in terms of how compelling the value proposition is (value for money) (Cooper, 2008; Tzokas et al., 2003);
- Customer acceptance of the product (e.g. from positive customer feedback on the concept test) (Cooper, 2008; Tzokas et al., 2003);
- Agreement on essential and desired product features, attributes and specifications (Cooper, 1990); and
- Estimated time to market (Tzokas et al., 2003; Cooper & Edgett, 2008).

### 2.7.3 MARKET ATTRACTIVENESS

Market attractiveness is one of the most important factors in terms of new product success. When assessing the market attractiveness of a new product at this gate, the target market should be clearly defined, and should be accompanied by a marketing plan (Cooper, 1990). The marketing plan is assessed in terms of the probability that it will be successful. The target market definition and marketing plan should include:

- Current market size (Cooper, 2008);
- Market growth and future potential (Tzokas et al., 2003; Cooper, 2008); and
- Competitiveness, in terms of the potential market share (Tzokas et al., 2003);
- The margins currently earned by competitors in the market (Cooper, 2008); and
- The product positioning strategy (Cooper, 1990).

### 2.7.4 CORE COMPETENCIES LEVERAGE

A key “passing” criteria is company resource utilisation. The new product concept should be evaluated in terms of how it leverages company resources and strengths in terms of (Cooper, 2008):

- Technology;
- Production or operations;
- Marketing (image, brand, communications); and
- Distribution and sales force.



### 2.7.5 TECHNICAL FEASIBILITY

The technical feasibility of the proposed product should once again be assessed at this point in the process. 29% of companies assess technical feasibility at this gate, and 20% assess product quality (Tzokas et al., 2003). Although these numbers are relatively low, it must be noted that Tzokas et al.'s study showed that these numbers were much higher at the previous gate. However, this does not entail that technical feasibility and quality is less important at this gate.

Cooper (2008) elaborates on the technical feasibility criteria, and recommends that the following aspects should form part of the technical feasibility criteria:

- Size of technical gap;
- Technical complexity (few barriers, solution envisioned);
- Familiarity of technology to the company;
- Business track record on similar projects; and
- Technical results to date (proof of concept).

### 2.7.6 FINANCIAL REWARD VERSUS RISK

Many NPD efforts focus on forecasting and determining market acceptability, and not necessarily economic performance (Wind & Mahajan, 1988). It is of critical importance to determine potential economic performance, and this is especially true at the pre-development gate. Literature suggests a number of financial metrics in order to assess economic performance (or the size of the financial opportunity), such as:

- **NPV** (Cooper, 2008; Cooper & Edgett, 2008; Bhuyain, 2011)

Net present value (NPV) is the difference between the present value of the future cash flows from an investment, and the amount of investment. Present value of the expected cash flows is computed by discounting them at the required rate of return (Business Dictionary, 2016)<sup>108</sup>.

- **IRR** (Cooper, 2008; Tzokas et al., 2003; Bhuyain, 2011)

Internal rate of return (IRR) is a metric used to measure the profitability of potential investments. It is the discount rate that makes the NPV of all cash flows from a particular project equal to zero (Investopedia, 2016)<sup>109</sup>.

- **ECV** (Cooper, 2008; Bhuyain, 2011)

Expected commercial value (ECV) is an amalgamation of the probabilities of success into a more standard NPV calculation. The formula for ECV is as follows (AccountingTools, 2016)<sup>110</sup>:

$$ECV = (((a * b) - c) * d) - e$$

Where:

<b>a</b>	=	<b>Project NPV</b>
<b>b</b>	=	<b>Probability of commercial success</b>
<b>c</b>	=	<b>Commercialisation cost</b>
<b>d</b>	=	<b>Probability of technical success</b>
<b>e</b>	=	<b>Product development cost</b>

<sup>108</sup> Business Dictionary. 2016. *Net present value*. [Online]. Available: <http://www.businessdictionary.com/definition/net-present-value-NPV.html>. [Cited 31 May 2016].

<sup>109</sup> Investopedia. 2016. *Definition of "internal rate of return"*. [Online]. Available: <http://www.investopedia.com/terms/i/irr.asp>. [Cited 31 May 2016].

<sup>110</sup> AccountingTools. 2016. *R&D Funding Decisions*. [Online]. Available: <http://www.accountingtools.com/research-funding-decisions>. [Cited 31 May 2016].



- **ROI/PI** (Tzokas et al., 2003; Cooper, 2008; Bhuyain, 2011)

Return on investment (ROI) or Profitability index (PI) is an investment appraisal technique calculated by dividing the present value of future cash flows of a project, by the initial investment required for the project (AccountingExplained, 2016)<sup>111</sup>.

- **EVA** (Cooper & Edgett, 2008)

Investopedia (2016)<sup>112</sup> define Economic value added (EVA) as a measure of a company's financial performance. It is based on the residual wealth calculated by deducting the company's cost of capital from its operating profit (adjusted for taxes on a cash basis).

- **Break-even time/Payback period** (Tzokas et al., 2003)

Break-even time refers to the amount of time it will take for the initial capital investment to be paid back.

- **Margin** (Tzokas et al., 2003)

Margin refers to the profit margin of the new product (how much revenue is generated versus profit made from that revenue).

The aforementioned metrics are calculated through, amongst others, projections of yearly sales and growth (Cooper & Edgett, 2008; Tzokas et al., 2003). The metrics are then compared to the sales and profit objectives determined in the NPS (Tzokas et al., 2003). A key consideration in making decisions based on the financial metrics, is to incorporate the certainty of the financial estimates (Cooper, 2008). This can be done through the use of a sensitivity analysis, which highlights the potential impact on the metrics if certain variables fluctuate. This brings to the fore the level of risk that the company may experience if the variables fluctuate from the predictions. Cooper (2008) recommends that plans on addressing these risks should also form part of the gate decision.

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<sup>111</sup> AccountingExplained. 2016. *Profitability Index*. [Online]. Available: <http://accountingexplained.com/managerial/capital-budgeting/profitability-index>. [Cited 31 May 2016].

<sup>112</sup> Investopedia. 2016. Economic Value Added. [Online]. Available: <http://www.investopedia.com/terms/e/eva.asp>. [Cited 19 June 2016].

### 2.7.7 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.7.7a shows the significance of the information discussed under Heading 2.7, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3). Table 2.7.7b shows a summary of the key criteria to take into consideration at Gate 3.

**Table 2.7.7a: Key Learnings: Gate 3: Go to Development**

Description	Activities (Gate 3)	Critical Success Factors
Third round of assessment of value propositions that have undergone business case assessment, through subjecting these value propositions to a range of pre-determined criteria	<ul style="list-style-type: none"> <li>▪ Assessment of value proposition concepts through scoring model, focusing on key criteria (Table 2.7.7b)</li> <li>▪ Ranking of concepts based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> </ul>

**Table 2.7.7b: Summary of Typical Gate Criteria at Gate 3**

Criteria Group	Criteria
Strategic	Impact of value proposition on company/ies
	Familiarity of technology/value proposition to company/ies
	Track record of company/ies on similar projects
	Fit with company/ies strategy
	Importance of new value proposition to the company/ies
	Leverage of company/ies core competencies <ul style="list-style-type: none"> <li>▪ Technology</li> <li>▪ Production/operations</li> <li>▪ Marketing (image, brand, communications)</li> <li>▪ Distribution and sales force</li> </ul>
Market	Market Size
	Expected Growth and future potential (market)
	Value proposition positioning strategy
	Customer acceptance
	Value Proposition uniqueness and benefit delivered
	Value proposition “value for money”
	Clarity on essential and desired value proposition features
	Margins currently earned by competitors
Potential competitor’s market share	
Technical	Feasibility <ul style="list-style-type: none"> <li>▪ Size of technical gap</li> <li>▪ Technical complexity (few barriers, solution envisioned)</li> <li>▪ Technical results to date (proof of concept)</li> </ul>
	Operations plan
	Development plan
	Estimated time to market
	Quality



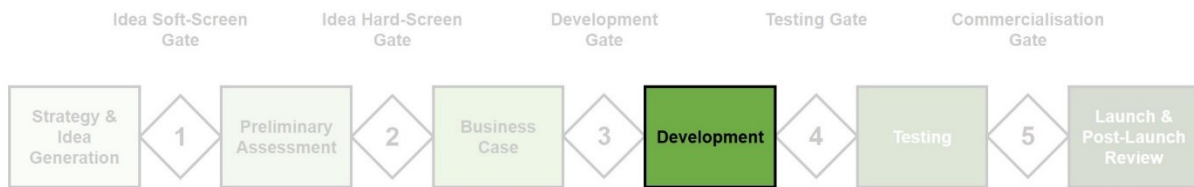


**Table 2.7.7b (continued): Summary of Typical Gate Criteria at Gate 3**

Criteria Group	Criteria
Financial	Net Present Value (NPV)
	Internal Rate of Return (IRR)
	Expected Commercial Value (ECV)
	Return on Investment (ROI)
	Economic Value Added (EVA)
	Payback Period
	Margin



## STAGE 3: DEVELOPMENT



### 2.8 STAGE 3: DEVELOPMENT

Once the results of the business case of a new product conforms to company objectives and criteria, the product can move on to the development stage. The focus is no longer on buying or selling the concept, but rather on developing the actual product (Cooper, 1983; Booz, Allen & Hamilton Inc., 1982). The development stage focuses on all the activities that are necessary to turn the concept into a commercial product (Tidd & Bodley, 2000; Page, 1993). These activities do not only include technical development. Detailed marketing, testing, operations and business plans are developed in parallel to the technical development (Cooper, 1990; Cooper, 1983).

In terms of the technical product development, the outcome of the stage is usually one prototype/product sample, or a range of several different prototypes of the product (Cooper, 1983; Tzokas et al., 2003). Booz, Allen & Hamilton Inc. (1982) note the difference between products and service in the development stage. For tangible products, development involves the physical building/assembly of the product. For services, development involves the assembly of all the components required for the services to be offered (e.g. office space, equipment, operating permits, personnel).

In terms of the marketing plan, supporting elements are required, such as pricing, distribution, advertising, salesforce strategy and service. These elements may require another market study on buyer behaviour (e.g. how customers buy the product; who the influencers are; sources of product information), in order to design an effective marketing plan (Cooper, 1983). In addition to the marketing plan being developed further, the entire business case plans need to be converted into concrete variables (Bhuyain, 2011).

Product development may take a considerable amount of time (often years), and unexpected events can occur during this time. Markets may change; customer requirements may shift; or competitors may introduce similar products into the market. These factors lead to the initial product definition and assumptions no longer being entirely valid. A critical success factor for the development stage is thus one of speed. The external influencing factors can be mitigated by reducing development time. In short, the goal is to shorten the development time so as to minimise the probability that the initial development target changes (Bhuyain, 2011).

Studies conducted by Rothwell (1972) and Rothwell et al. (1974) on the differences between product successes and failures, showed that efficiency of development was a key discriminatory variable. New product successes were all shown to have been developed efficiently. Apart from being efficient, development has to be effective as well. Products need to be developed quickly and accurately (in terms of continued relevance to the target market and customer requirements). The most prominent approach to achieve this, is to follow a non-linear approach (or as Cooper & Edgett (2008) call it, a “spiral” development approach).



### 2.8.1 ITERATIVE DEVELOPMENT

During the development stage, products/services may undergo many alterations. This is a common occurrence in translating ideas into physical products/services (Booz, Allen & Hamilton Inc., 1982). Whenever a gap appears between the current design and the requirement, the development team must take action in order to close the gap. How these gaps are closed determines the speed and effectiveness of the development stage. In many cases, this involves iterative design-test-build cycles (Tidd & Bodley, 2000).

This is commonly referred to as iterative development. To fully understand what iterative development entails, it is necessary to firstly understand what the traditional linear development approach entails. During traditional linear development, the project team starts off with the product definition (stated in the previous stage). The product definition may have been correct at the time that it was defined, and could have been based on solid customer inputs and sound pre-development homework. Cooper & Edgett (2008) state that the project team then spends months on designing and developing the product, consistent with the product definition. However, things can then invariably go wrong (Cooper & Edgett, 2008):

- The customer may have not known exactly what they wanted at the time;
- The customer may have changed their mind as time went by;
- The project team may have misinterpreted the customer inputs;
- The market may have shifted; or
- A competitive product may have been introduced.

Thus, when the development stage reaches field trials or beta tests, the project team realises that although the product conforms to the original definition, the original definition is in actual fact no longer correct. The team realises that the product may not be what the market and customer wants anymore, and this resets the development stage (and essentially means that the months of development work was a waste). The original customer inputs are not enough. Continuous feedback is required to ensure that every prototype version of the product still meets the requirements of the customer.

In contrast to linear development, “smart” development teams practice iterative/spiral development (Cooper & Edgett, 2008). The team starts off with a very basic first prototype of the product, and instantly seek feedback from the customer. This ensures that the product still conforms to what the customer wants. The team then uses the feedback obtained to produce the next and more complete iterative version of the prototype. This second prototype is once again subjected to immediate feedback, and the same iterative process is repeated thereafter.

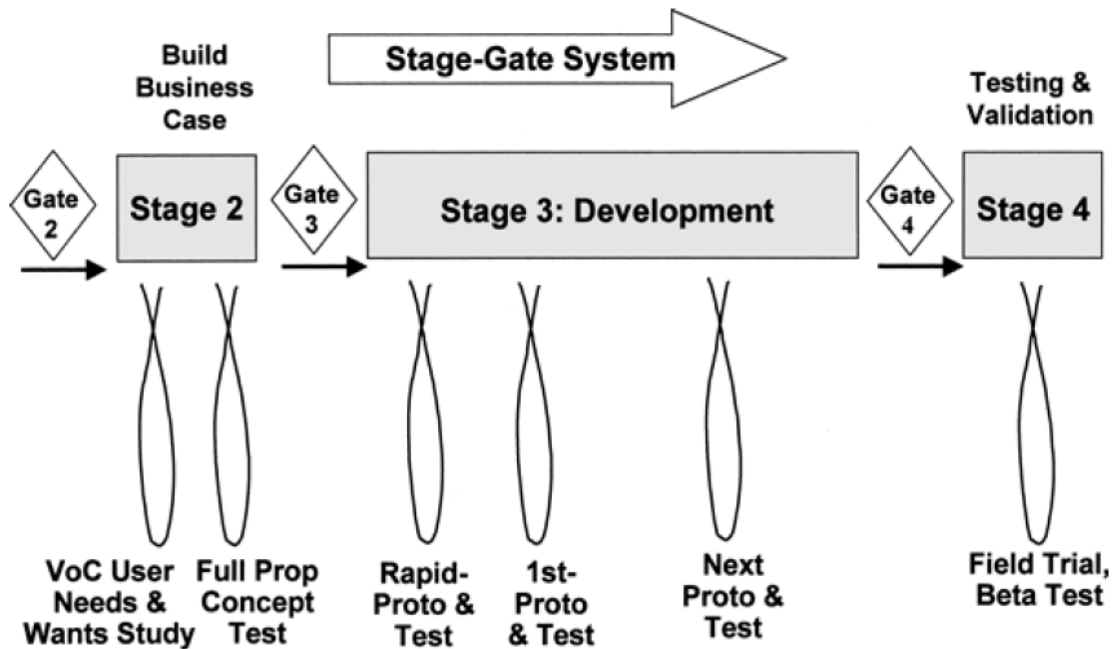
These development iterations (or “build-test-feedback-revise” loops) remove unnecessary work, and ensures that the product continuously conforms to the customer requirements (Cooper & Edgett, 2008). Iterative development greatly reduces development time as well, which ensures that no development efforts are wasted on building products that the customer does not want (Cooper, 1999).

Apart from continuously seeking customer feedback, continuous assessment should also be done for each iteration in terms of the market, positioning, product value and technology (Urban & Hauser, 1993)<sup>113</sup>. These continuous assessments assist in increasing the probability of delivering a successful final product to the market.

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<sup>113</sup> Urban, C., & Hauser, J. 1993. *Design and marketing of new products*. New Jersey: Prentice-Hall.

Spiral development in the NPD process should not only be implemented in the development stage, but should be an integral part of the entire process (Cooper & Edgett, 2008). Most notably, spiral/iterative loops should be incorporated into the 2<sup>nd</sup> stage (business case); the 3<sup>rd</sup> stage (development) and the 4<sup>th</sup> stage (testing) (Figure 2.8).



**Figure 2.8: Spiral development in the Stage-Gate® system (Cooper & Edgett, 2008)**

The iterative loops during each different stage should involve considerable planning in terms of how the customers will be interacted with in order to gain feedback (Cooper & Edgett, 2008). In essence, iterative development is a waste-reduction approach, and can involve several different design and development techniques.

## 2.8.2 TOOLS AND TECHNIQUES

As stated previously, several techniques exist to assist in the development process. Some of the most prominent techniques are discussed in the following section. It must be noted that these techniques mostly focus on tangible products, but is nevertheless relevant.

### 2.8.2.1 QUALITY FUNCTION DEPLOYMENT (QFD)

Quality function deployment (or “House of Quality”) is a structured approach to defining customer needs/requirements, and translating these into specific plans to produce products to meet those needs (NPD Solutions, 2016)<sup>114</sup>. QFD creates a link between customer needs and product design parameters, and it focuses and coordinates the resources and skills within a company in order to design, manufacture and market the product (Hauser and Clausing, 1988)<sup>115</sup>.

The main aim of QFD is to answer three primary questions (Cohen, 1995)<sup>116</sup>:

- What are the critical attributes for customers?
- What design parameters drive these attributes?
- What should the design parameter targets be for the new design?

<sup>114</sup> NPD Solutions. 2016. Customer-Focused Development with QFD. [Online]. Available: <http://www.npd-solutions.com/qfd.html>. [Cited 20 June 2016].

<sup>115</sup> Hauser, J.R. & Clausing, D. 1988. The House of Quality. *Harvard Business Review*, May-June, pp. 63-73.

<sup>116</sup> Cohen, L. 1995. *Quality Function Deployment*. Addison Wesley, New York.



### **2.8.2.2 DESIGN FOR MANUFACTURE (DFM)**

Tidd & Bodley (2000) believe that a potential tool/technique to use in the development stage is the DFM technique. Ettlíe (1990)<sup>117</sup> defines DFM as the full range of policies, techniques, practices and attitudes that are responsible for a product being designed at the optimum manufacturing cost. In addition to the cost, it involves the optimum achievement of manufactured quality, and the optimum achievement of life-cycle support (e.g. serviceability, reliability and maintainability). DFM includes sub-techniques such as Design for Assembly (DFA), Design for Producibility (DFP) and several other approaches (Tidd & Bodley, 2000).

### **2.8.2.3 RAPID PROTOTYPING**

Rapid prototyping is the core element of iterative development, and it can increase the amount of learning that occurs with each iteration (Tidd & Bodley, 2000). The first prototype is far from what the final product is envisioned to be, and as more iterations are performed, more is learnt about the real problem at hand (and potential alternative solutions to the problem). The number of rapid prototype iterations depends on the time and cost constraints of the specific project (Tidd & Bodley, 2000).

A study conducted by Bacon et al. (1994)<sup>118</sup> found that frequent prototyping proved to be very useful for internal team communication; for obtaining customer feedback; and for developing the future manufacturing process. A tangible and visual prototype has been shown to lead to more reliable assessments of both customer and team member preferences and suggestions (Srinivasan et al., 1997)<sup>119</sup>.

### **2.8.2.4 COMPUTER AIDED TECHNIQUES (CAD/CAM)**

Potential benefits of computer-aided techniques include (Tidd & Bodley, 2000):

- Reduction in development lead times;
- Economies in design; and
- Ability to design products which may be too complex to visualise using manual techniques.

CAD can be combined with Computer Aided Manufacture (CAM) techniques, in order to achieve several benefits due to this integration (Senker, 1996)<sup>120</sup>. However, these benefits may not always be realised if there are inherent shortcomings within the development team (Tidd, 1991<sup>121</sup>; Tidd, 1994<sup>122</sup>).

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<sup>117</sup> Ettlíe, J.E. 1990. *Managing the Design-Manufacturing Process*. McGraw-Hill, London.

<sup>118</sup> Bacon, G. et al. 1994. Managing product definition in high-technology industries. *California Management Review*, vol. 36(3), pp.32-56.

<sup>119</sup> Srinivasan, V. et al. 1997. Integrating Product Design for Marketability and Manufacturing. *Journal of Marketing Research*, vol. 34, pp. 154-163.

<sup>120</sup> Senker, P. 1996. Computer Aided Design. In Rhodes, E. & Wield, D. (eds.) *Implementing New Technologies: Innovation and the Management of Technology*. Blackwell, London.

<sup>121</sup> Tidd, J. 1991. *Flexible Manufacturing Technologies and International Competitiveness*. Pinter, London.

<sup>122</sup> Tidd, J. 1994. The link between manufacturing strategy, organization and technology. In J. Storey (ed.). *New Wave Manufacturing Strategies*. Paul Chapman, London.



### 2.8.3 DEVELOPMENT CRITICAL SUCCESS FACTORS

Apart from the design and development techniques, a substantial agreement exists in NPD literature on the need for effective integration of all stakeholders involved in the development process (Tidd & Bodley, 2000). In order to maximise the probability of success in the development stage, several critical success factors need to be considered:

- Cross-functionality of teams;
- Level of team member commitment;
- Parallel nature of activities;
- Relationships with external organisations; and
- Development efficiency.

#### 2.8.3.1 CROSS-FUNCTIONAL TEAMS

Bhuyain (2011) believes that a critical success factor for the development stage is the degree of functional integration. This refers to how well multi-disciplinary teams are working together towards the same goal (e.g. solving specific issues, making decisions). True cross-functional integration occurs at the working level between groups, between individuals and different departments (Tidd & Bodley, 2000; Bhuyain, 2011). How these groups work together determines the extent and effectiveness of integration in the development of the product (Wheelwright & Clark, 1992)<sup>123</sup>.

In a study of product development amongst engineering firms, it was found that the most popular methods were based on the use of teams (Barclay & Benson, 1990)<sup>124</sup>. Another similar study found that more than 76% of firms use multidisciplinary teams during the development phase (Barclay, 1992)<sup>125</sup>. It is thus critically important that the development stage should also involve all the different disciplines that have been involved throughout the NPD process. The actual development (or building) of the product is in actual fact a small component of the development stage. The work that goes into the development decision-making process is what is most important (and this is where the multidisciplinary teams add significant value).

#### 2.8.3.2 LEVEL OF TEAM MEMBER COMMITMENT

A critical success factor for the development stage is the level of team member commitment (Bhuyain, 2011). If members on a development team can not commit all their time to the project (and have focuses elsewhere), development time will most likely increase and cross-functional integration will be weaker. It is thus important to ensure that a development team comprises of dedicated team members, and most importantly, a dedicated project leader. The degree of team cohesiveness gauges the growth of the team as a working group, which is a function of the length of time a team has worked together in a past or present project (Balakrishnan, 1998)<sup>126</sup>.

<sup>123</sup> Wheelwright, S., & Clark, S. 1992. *Revolutionizing product development*. New York: The Free Press.

<sup>124</sup> Barclay, I. & Benson, M. 1990. New product development: organisation and current practice. *Leadership and Organisation Development Journal*, vol. 11(6), pp. 13-24.

<sup>125</sup> Barclay, I. 1992. The new product development process: past evidence and future practical application Part 1. *R&D Management*, vol. 22(3), pp. 255-264.

<sup>126</sup> Balakrishnan, A. 1998. *Concurrent engineering: Models and metrics*. Master dissertation, McGill University, Canada.





### **2.8.3.3 PARALLEL ACTIVITIES**

Concurrency of activities is another metric to measure the relative success of the development stage. It entails more activities being undertaken in a certain amount of time, at a faster rate than if the same amount of activities had to be performed sequentially. Parallel processing/overlapping activities can lead to a greatly reduced development stage time, due to the following reasons (Bhuyain, 2011):

- Activities that are not dependent on the outcomes of one another can run in parallel;
- Better and more timely identification of design problems; and
- Improved communication earlier and throughout the team.

Generally, a high number of overlapping activities indicates a higher degree of concurrency, whilst a low number of overlapping activities indicates the opposite.

### **2.8.3.4 RELATIONSHIPS WITH EXTERNAL ORGANISATIONS**

Both the efficiency and effectiveness of development will be influenced by the relationships that a company has with external organisations. Relationships include, amongst others, those with suppliers, customers and external sources of innovation (Tidd & Bodley, 2000). Working closely with key suppliers can increase the effectiveness of development, and reduce the cost and time of development (Nishiguchi, 1994)<sup>127</sup>. Utilising other external sources of technology and market knowledge, allows a company to focus on its own core competencies (Tidd and Brocklehurst, 1993<sup>128</sup>; Tidd and Trehwella, 1997<sup>129</sup>).

The integrity of these relationships influence (and may enhance) the dynamic capabilities of the company. The reason for this is due to the exploitation of the existing technology and marketing capabilities, in response to the changing market and technological environment (Wang, 1997)<sup>130</sup>.

### **2.8.3.5 EFFICIENT DEVELOPMENT**

Efficient development is essentially a product of the aforementioned critical success factors. It serves as the main critical success factor of the development stage, and relates to how effectively development iterations can be performed (and progress made). Studies in Britain and Hungary have both highlighted the importance of efficient development in the NPD process. These studies showed that one of the major underlying factors that distinguishes product successes from failures, was how efficiently the team was able to develop the product from a concept into a commercially-viable product offering (Author unknown, 1974; Rothwell, 1972; Rothwell et al, 1974).

<sup>127</sup> Nishiguchi, T. 1994. *Strategic Industrial Sourcing*. Oxford University Press, Oxford.

<sup>128</sup> Tidd, J. & Brocklehurst, M. 1993. Innovation & Collaboration: Towards a New Strategy for European Business. *European Business Journal*, vol. 3(4).

<sup>129</sup> Tidd, J. & Trehwella, M. 1997. Organisational and technological antecedents for knowledge acquisition and learning. *R&D Management*.

<sup>130</sup> Wang, Q. 1997. R&D/Marketing Interface in a Firm's Capability-Building Process: Evidence from Pharmaceutical Firms. *International Journal of Innovation Management*, vol. 1(1), pp. 23-52.



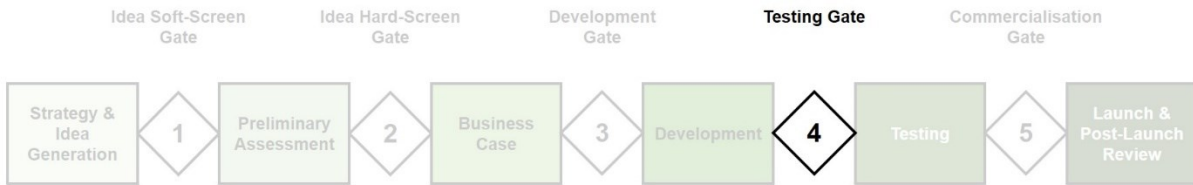
### 2.8.4 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.8.4 shows the significance of the information discussed under Heading 2.8, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

**Table 2.8.4: Key Learnings: Stage 3: Development**

Description	Activities (Stage 3)	Critical Success Factors
Iterative/spiral development of actual value proposition, integrated with testing stage. Development of business-related plans in parallel to development and testing activities	<ul style="list-style-type: none"> <li>▪ Technical development of new value proposition (prototype – pilot)</li> <li>▪ Development of Marketing plan</li> <li>▪ Development of Testing plan</li> <li>▪ Development of Operations plan</li> <li>▪ Development of Business plan</li> </ul>	<ul style="list-style-type: none"> <li>▪ Quality of development work</li> <li>▪ Cross-functionality of teams;</li> <li>▪ Level of team member commitment;</li> <li>▪ Parallel nature of activities;</li> <li>▪ Relationships with external organisations; and</li> <li>▪ Development efficiency (speed)</li> <li>▪ Iterative development</li> <li>▪ Iterative integration with Testing stage</li> <li>▪ Customer feedback</li> </ul>

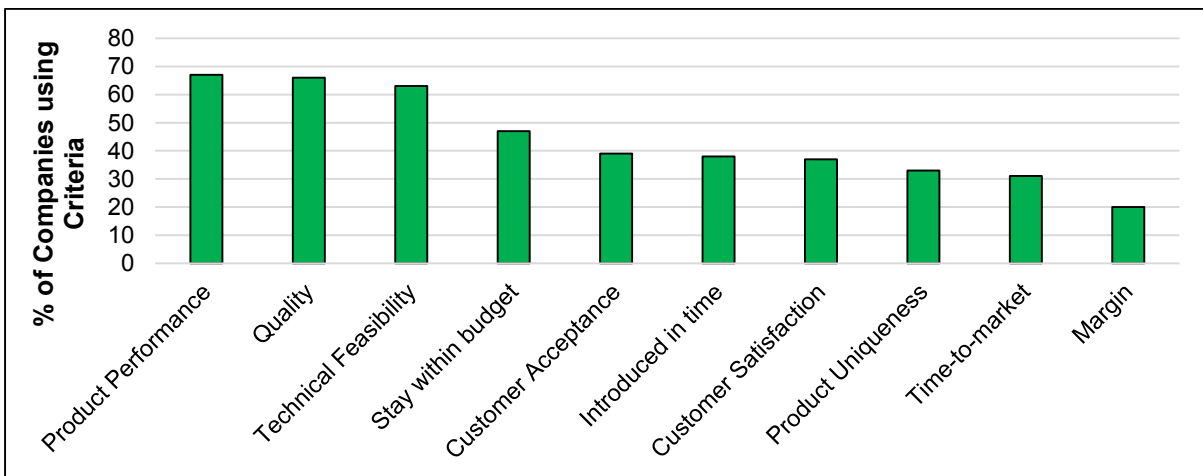
## GATE 4: GO TO TESTING



### 2.9 GATE 4: GO TO TESTING

The post-development review gate (or “go to testing” gate) acts as a check on the progress and continued market attractiveness of the product. At this gate, it is verified whether the developed prototype meets internal technical and manufacturing requirements (Tzokas et al., 2003). The development work conducted in the previous stage is reviewed in order to ensure that it has been completed at an acceptable level of quality (Cooper, 1990). Apart from the technical and manufacturing requirements, the gate once again considers market, business and financial criteria (as at the previous gate).

A revised financial analysis (based on newer and more accurate data) is performed; the test/validation plans for the next stage are approved; and the detailed marketing and operations plans are reviewed for probable future implementation (Cooper, 1990). Tzokas et al. (2003)’s study revealed the top 10 criteria used by companies at Gate 4 (Figure 2.9).



**Figure 2.9: Top 10 Criteria used by Companies at Product Testing Gate (Tzokas et al., 2003)**

Figure 2.9 shows that the companies included in Tzokas et al.’s study primarily make use of product-based criteria. An almost equal split between product performance (67% using); product quality (66% using); and technical feasibility (63% using) exists. The results also show that companies consider staying within the development budget and being on time as important, with 47% of companies using the former and 38% using the latter.



As stated previously, continued customer acceptance of the product is also critically important. Although Tzokas et al.'s study showed that customer acceptance and satisfaction was seen as less important than product-based criteria, it is in actual fact equally important. If a technically sound product that is of a high quality (and performs well) is not satisfying a customer need, it will inevitably be a failure.

It must be noted that although the recommendations from the literature on this specific gate is sparse, all the criteria from Gate 3 should be considered at this gate again (at an even more intense level of detail).



### 2.9.1 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.9.1 shows the significance of the information discussed under Heading 2.9, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

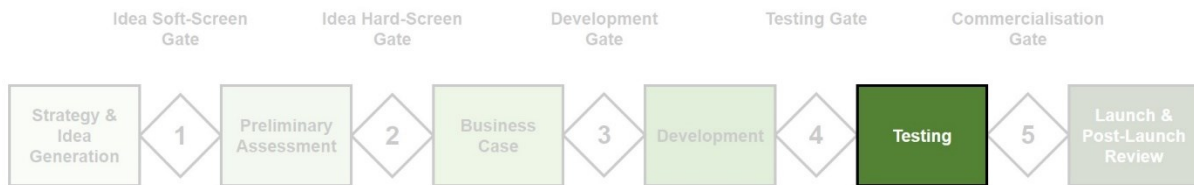
**Table 2.9.1: Key Learnings: Gate 4: Go to Testing**

Description	Activities (Gate 4)	Critical Success Factors
Fourth round of assessment of value propositions that have undergone development, through subjecting these value propositions to a range of pre-determined criteria	<ul style="list-style-type: none"> <li>▪ Assessment of developed value propositions through scoring model, focusing on key criteria</li> <li>▪ Ranking of value propositions based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> <li>▪ Customer feedback</li> </ul>

It must be noted that the criteria to consider at Gate 4 comprises of all the criteria identified at the previous gates. The only difference comes in with an increased level of confidence in meeting the criteria at Gate 4.



## STAGE 4: TESTING



### 2.10 STAGE 4: TESTING

The purpose of the testing stage is to validate the viability of the new product (Booz, Allen & Hamilton Inc., 1982; Cooper, 1983). The validation does not only focus on the product and its features. It also focuses on the entire project viability (Cooper, 1990; Cooper & Kleinschmidt, 1987<sup>131</sup>). This includes the validation of the product itself; the production process; customer acceptance; marketing plan; and the financial viability (Cooper, 1990; Cooper & Kleinschmidt, 1987; Tzokas et al., 2003).

The testing phase is critically important, as it may decrease the chances of a product failing in the launch process (as it has the ability to reveal flaws that could cause market failure (Urban & Hauser, 1993). This importance is emphasised by the amount of companies that conduct testing. Page (1993)'s study showed that 87% of companies perform formal testing. This formal testing comprises of a number of different phases (Cooper, 1988)<sup>132</sup>. Cooper (1990) suggests that there should be four different phases of testing during the stage: In-house; In-field; Trial; and Test market.

#### 2.10.1 IN-HOUSE TESTING

Product prototypes are tested within the company ("in the laboratory") to determine whether any flaws exist (Cooper, 1983). A critical success factor for this testing is product functionality, which essentially refers to whether the product can deliver what it claims (Bhuyain, 2011). In addition to the product functionality, product quality and performance should be verified (Cooper, 1990).

In parallel to the in-house testing, the customer field-testing needs to already commence. This assists in verifying the functionality, performance and quality of the products (Cooper, 1983).

#### 2.10.2 IN-FIELD TESTING

The main purpose of the in-field testing is to verify that the product functions in the actual usage environment, and also to gauge potential customers' reaction to the product (Cooper, 1990). A critical success factor is customer acceptance of the product. A product must not only work in the laboratory or development department, but needs to work right in the customer's hands. The aim is not only for acceptance. Ideally the customer must be delighted by the product and truly like it. In essence, the customer must like it enough to be willing to pay for it (Bhuiyan, 2011).

<sup>131</sup> Cooper, R.G., & Kleinschmidt, E.J. 1987. *New products: What separates winners from losers?* Journal of Product Innovation Management, vol. 4(3), pp. 169-184.

<sup>132</sup> Cooper, R. 1998. *Product leadership: Creativity and launching superior new products*. Massachusetts: Perseus Books.





### 2.10.3 TRIAL/PILOT TESTING

The trial stage represents a “dry-run” of all commercial aspects of the project: production, product design, and marketing. Before starting the trials, both the product design and marketing plan need to be finalised. The testing from the previous stage provides the inputs required to finalise the product design. A trial/pilot production run tests the production method that will eventually be used for full scale production of the product. This uncovers flaws in the production facilities/methods, and also provides more accurate estimates of production time, throughput, and costs. (Cooper, 1983; Cooper, 1990).

### 2.10.4 SCALE TEST MARKET

Page (1993) and Cooper (1983) refer to the test market phase as selling the product to a limited number of customers. This not only tests the product, but all the elements of the marketing mix together. The test market sub-stage also identifies the required adjustments to the marketing and launch plans, as well as providing final estimates of the market share and the expected sales/revenues (Cooper, 1983; Cooper, 1990). This allows for a revised financial analysis, which confirms the continued economic viability of the project, based on new and more accurate revenue and cost data (Cooper, 1990). Testing should however not be restricted to this stage. It should be conducted in its many shapes and forms throughout the NPD process (Ulrich & Eppinger, 2011)<sup>133</sup>. Cooper & Kleinschmidt (1987) agree – development and testing are overlapping activities, and testing should start in earnest throughout the development stage (where test results are used to guide the development activities).

Based on the critical success factors, the metrics for the testing stage are product performance and customer-perceived value of the product. Validation and user-testing techniques are used to gather data on product performance, which generates quantitative data. At this stage in the NPD process, the results of these tests are necessary to make final critical decisions, and to reduce the risk of possible failed launches (Bhuiyan, 2011).

Customer-perceived value is measured to determine whether the customer is willing to purchase the product. This requires user and field-testing. Important metrics for measuring perceived value are: perceived relative performance; customer satisfaction; and the preference score to determine the nature of the competitive situation (Bhuiyan, 2011). Although this type of data is qualitative, they are nonetheless important to fully understand the market before the product launch.

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<sup>133</sup> Ulrich, K.T. & Eppinger, S.D. 2011. *Product Design and Development*. McGraw-Hill.



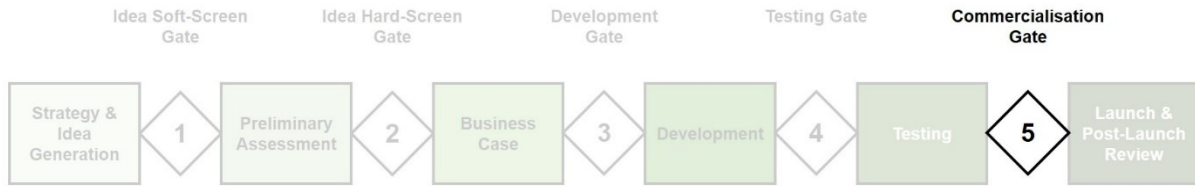
### 2.10.5 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.10.5 shows the significance of the information discussed under Heading 2.10, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

**Table 2.10.5: Key Learnings: Stage 4: Testing**

Description	Activities (Stage 4)	Critical Success Factors
Testing of iterations of value propositions developed in Stage 3	<ul style="list-style-type: none"> <li>▪ In-house-testing</li> <li>▪ In-field testing</li> <li>▪ Pilot/trial testing</li> <li>▪ Scale market test</li> <li>▪ Development of Marketing plan</li> <li>▪ Development of Testing plan</li> <li>▪ Development of Operations plan</li> <li>▪ Development of Business plan</li> </ul>	<ul style="list-style-type: none"> <li>▪ Well-designed tests</li> <li>▪ Customer involvement</li> <li>▪ Objectivity in assessing test results</li> </ul>

## GATE 5: GO TO COMMERCIALISATION



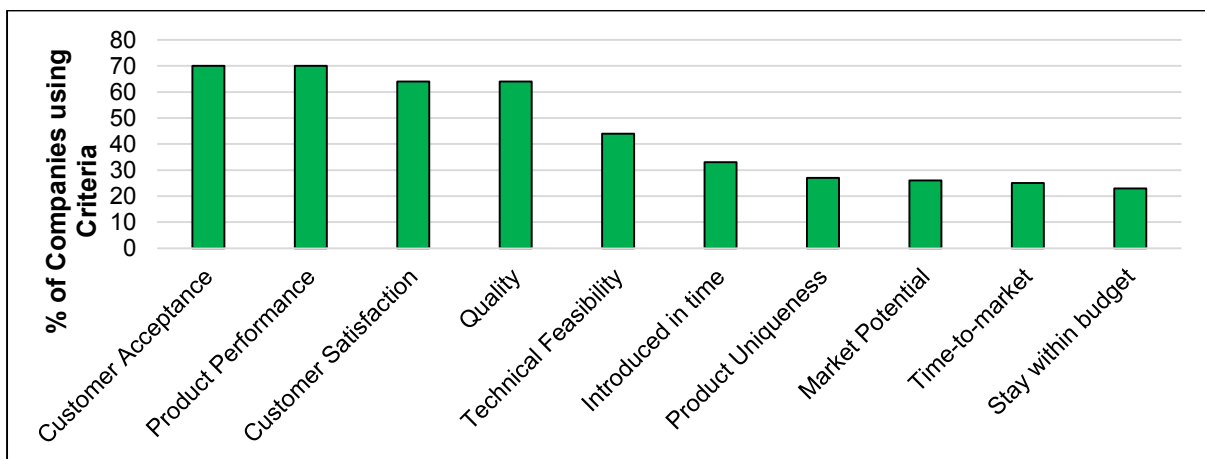
### 2.11 GATE 5: GO TO COMMERCIALISATION

This is the final gate before the commercialisation/launch of the product into the full market. The gate primarily focuses on the quality of the activities conducted during the testing stage, as well as their results (Cooper, 1990). After the trial testing stage, a final pre-commercialisation business analysis evaluation is made, based on concrete financial data from the stage (Cooper, 1983). Financial projections play a key role in the decision to move ahead (Cooper, 1990).

The financial analysis, coupled with a market plan and operations plan, are the deciding factors of whether the product can proceed to the final commercialisation stage (Cooper, 1983; Cooper, 1990; Tzokas et al. 2003). The analysis and the plans are reviewed, and if it is deemed that these are satisfactory, the product moves to the next stage.

Common themes in Cooper (1983)'s research in terms of successful product launch were a strong marketing effort; a well-targeted selling approach; effective aftersales service; and sound marketing communications. In essence, this shows that a well-conceived launch plan is vital to success.

Although the final gate in the process should consider all the gate criteria from previous gates, Tzokas et al. (2003)'s study on the most used criteria shows where the main focus lies (Figure 2.11).



**Figure 2.11: Top 10 Criteria used by Companies at Commercialisation Gate (Tzokas et al., 2003)**



### 2.11.1 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.11.1 shows the significance of the information discussed under Heading 2.11, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

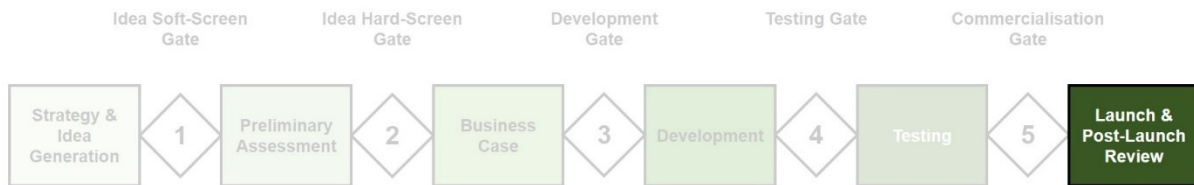
**Table 2.11.1: Key Learnings: Gate 5: Go to Commercialisation**

Description	Activities (Gate 5)	Critical Success Factors
Fifth round of assessment of value propositions that have undergone testing, through subjecting these value propositions to a range of pre-determined criteria	<ul style="list-style-type: none"> <li>▪ Assessment of final value propositions through scoring model, focusing on key criteria</li> <li>▪ Ranking of value propositions based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> <li>▪ Customer feedback</li> </ul>

It must be noted that the criteria to consider at Gate 5 comprises of all the criteria identified at the previous gates. The only difference comes in with an increased level of confidence in meeting the criteria at Gate 5 (100% level of confidence).



## STAGE 6: LAUNCH & POST-LAUNCH REVIEW



### 2.12 STAGE 6: LAUNCH & POST-LAUNCH REVIEW

The final launch stage involves the full-scale market introduction and full production of the newly developed product (Cooper, 1983; Booz, Allen & Hamilton Inc., 1982; Tzokas et al., 2003, Page, 1993). It involves the implementation of both the marketing plan and the operations plan (Cooper, 1990), in the full customer segment (Cooper, 1983).

In many cases, the product development stage ‘blurs’ into the commercialisation stage (Tidd & Bodley, 2000). This is due to the parallel nature of the process. Cooper (1983) believes that if the testing in the previous stages was conducted properly, the launch should be a simple matter of executing a well-designed plan of action.

The post-launch review of the NPD process focuses on the overall performance of the product after being launched. It is not an explicit gate. Post-launch control points at pre-designated times after the launch provide benchmarks to assess whether the product is on target (Cooper, 1983). Tzokas et al (2003) recommend that the post-launch review should be divided into two control points: short term and long term. The short term review should be done after the product has been in the market for 25% of its projected lifetime, and the long-term review after 75% of the life cycle has elapsed. Bull (2007)<sup>134</sup> recommends that the first review should be done after a time period of three months, and that the product should be monitored for the first two years of the life of the product.

The recommendations in terms of timing of the control points represent a challenge. Tzokas et al. (2003)’s recommendation considers the life-cycle of the product in order to ‘time’ control points. Calculating the life-cycle of a product is highly subjective, especially when considering the nature of digital technologies. Bull (2007)’s recommendation considers concrete points in time after launch, which is more applicable to this specific study. Thus, in terms of this study, the post-launch evaluations should be scheduled in terms of elapsed time (months), and not according to product life-cycle.

Evaluating the product after launch is essential, in order to control the product and to signal the implementation of corrective measures if the product is veering off course (Cooper, 1983). The post-launch review is the final stage of accountability for the project team. Results achieved are compared to the projections (or original success criteria). When variances are identified in the comparisons, the root causes must be identified and corrective measures should be designed and put in place (Cooper & Edgett, 2008). Booz, Allen & Hamilton Inc. (1982) agree that product monitoring is critically important to uncover any problems, and that they should be rectified as soon as possible.

<sup>134</sup> Bull, S. 2007. *Innovating for Success: How EXFO’s NPDS Delivers Winning New Products*. Proceedings, First International Stage-Gate Conference, St. Petersburg Beach.



What this shows is that post-launch monitoring and evaluation is done for a primary purpose, which is not to purely gauge performance. NPD is a process of continuous improvement, even after the product has been developed. The evaluation and comparison of actual performance vs. projected performance allows for deviations to be highlighted. These deviations then need to be fixed through corrective measures. Thus, for the purposes of this study, post-launch evaluation and performance comparisons should be seen as tools for continuous improvement (where any deviations need to be accompanied by corrective action plans).

Monitoring of the product once it has entered the market requires the use of certain metrics. These metrics can be broadly classified into three main groups: Market-based; Financial-based and Product-based.

The market-based metrics focus on customers and sales, whereas the financial-based metrics focus mostly on profitability of the product. Product-based metrics focus on whether the product is performing as was planned, or whether the quality of the product is meeting standards acceptable to the company. Each one of these three categories have a main objective that it aims to achieve through the use of different metrics. The main categories are explained in terms of the metrics each one requires; the activities that need to be performed; and the desired objective.

### **2.12.1 MARKET-BASED**

The main objectives of the market-based evaluation are to determine sales performance; customer satisfaction and market share.

#### ***2.12.1.1 SALES PERFORMANCE***

Studies conducted by Tidd & Bodley (2000) showed that 95% of companies measured sales performance after launch. However, in order to measure the performance of the sales of the product, it is firstly necessary to determine what the sales volume/number of units sold (Cooper, 1983) was over the elapsed time period. A study on metric-usage by Tzokas et al. (2003) showed that 62% of companies measure unit sales in the short-term, and 55% measure it in the long-term. Once this has been measured, the data can be used to determine sales performance/growth (Bull, 2007; Tzokas et al., 2003).

However, performance can only be measured against a benchmark. The benchmark in terms of sales performance is what the projected sales figures and growth was at the time of the launch. Tzokas et al. (2003) recommend that the initial sales objectives should be compared to the actual performance, in order to measure sales performance.

#### ***2.12.1.2 MARKET PERFORMANCE***

Measuring market performance has the main objectives of determining the market share, competitive responses and the future market potential. Cooper (1983) and Tidd & Bodley (2000) recommend that market share should be determined during the post-launch review. It makes more sense to perform this evaluation in the long-term after the launch – Tzokas et al (2003)'s study showed that, on average, companies preferred to assess market-share in the long-term (as opposed to the short-term). The calculation of market share requires not only the product sales volumes, but also the sales figures of competitors.

This analysis, if done correctly, will effectively determine the size of the current market (and which share the company as well as its competitors have). The analysis also enables the measurement of two other metrics – the market potential and the competitive response to the product. Tzokas et al. (2003) recommend that the market potential should be measured in order to ensure that the product is not being over-marketed or under-marketed. Determining market potential further provides the basis for new sales objectives to be set.



Booz, Allen & Hamilton Inc. (1982) believe that competitor reactions to the new product entry should be carefully monitored, so that necessary steps can be taken to counteract competitor responses. Jain (2001) identifies a lack of monitoring of competitive response as a possible cause of product failure, and also recommends that it needs to be monitored to ensure that the product maintains a competitive edge.

### **2.12.1.3 CUSTOMER SATISFACTION**

As the product enters the market, ongoing customer feedback should be sought to ensure that they meet (and, ideally, exceed) customer expectations (Booz, Allen & Hamilton Inc., 1982). Cooper & Edgett (2008) state that 65% of the most successful companies practicing NPD determine customer satisfaction after launch. This may include (but is not limited to) a variety of tools, such as results from satisfaction surveys, warranty claims, returns and complaints tracking. In Tzokas et al. (2003)'s study, it was found that the single most important post-launch metric was customer satisfaction. In the short-term, 62% of companies made use of this metric. In the long-term, 56% made use of customer satisfaction as a key evaluation metric.

### **2.12.2 FINANCIAL-BASED**

The main objective of the financial-based evaluation is to determine financial performance. This is, in essence, determined by performing calculations and financial analysis based on a range of inputs. The inputs, amongst others, comprise of the number of unit sales (measured under the market-based category); the production cost per unit (Cooper, 1983; Cooper, 1990); and any other fixed expenses (Cooper, 1990). From these inputs revenue can be determined – 75% of businesses that measure performance compare forecasted revenue to actual revenue (Cooper & Edgett, 2008).

This is followed by an assessment of profit (Cooper 1990), through profitability calculations, which come in several shapes and forms. Measuring profitability post-launch can be done through the use of various financial tools: Operating profit (Cooper & Edgett, 2008); NPV/IRR (Tidd & Bodley, 2000; Tzokas et al., 2003; Cooper & Edgett, 2008); ROI (Tidd & Bodley, 2000; Bull, 2007); and Margin (Tzokas et al., 2003). Once current actual profitability has been measured, the financial performance can be determined. This is done by comparing current profitability with previously determined profit objectives (Tzokas et al., 2003), in order to determine whether objectives have been met.

Finally, using the profitability calculations, an updated projection of the payback period (Tidd & Bodley, 2000; Tzokas et al., 2003) should be calculated. As a final financial performance measure, this should be compared to the payback period that was calculated at the time of product launch.

### **2.12.3 PRODUCT-BASED**

The main objective of the product-based evaluation is to determine whether the product is performing as it was designed to perform. Once again, this is to ensure that the product does what it was intended to do. Tzokas et al (2003)'s study showed that 45% of companies measure product performance in the short-term, whilst 36% measure performance in the long-term. Furthermore, their study showed that 42% of companies measure product quality in the short-term, and 34% in the long-term.



Another key activity during the post-launch review, as pointed out by Cooper (1990), is that of performing a post-assessment of the entire NPD process. This is also the point where the NPD project team is disbanded, and the NPD project is terminated. The post-assessment is a critical assessment of the project’s strengths, weaknesses and learnings (in retrospect), and what can be done to improve the next project. Cooper & Edgett (2008) state that learning and continuous improvement is an integral part of the NPD process – and this reflection on the process is what leads to (verbatim): “*Every project being executed better than the one before*”.

#### 2.12.4 SIGNIFICANCE OF AVAILABLE INFORMATION

Table 2.12.4 shows the significance of the information discussed under Heading 2.12, in the form of displaying the key learnings obtained and carried forward into the results section (Chapter 3).

**Table 2.12.4: Key Learnings: Stage 6: Launch & Post-launch Review**

Description	Activities (Stage 6)	Critical Success Factors
Final Launch/commercialisation of new, viable value proposition. Post-launch assessment of commercial performance	<ul style="list-style-type: none"> <li>▪ Executing Launch plan</li> <li>▪ Measure market performance</li> <li>▪ Measure technical performance</li> <li>▪ Measure financial performance</li> <li>▪ Modify value proposition if necessary</li> </ul>	<ul style="list-style-type: none"> <li>▪ Post-launch review to confirm performance</li> <li>▪ Customer feedback</li> <li>▪ Continuous performance monitoring</li> </ul>

## 2.13 SUMMARY OF RELEVANCE OF LITERATURE

The main aim of the literature review was to:

- Understand each stage and gate;
- Determine the key activities performed at each stage and gate;
- Determine the criteria used at the various gates throughout the process; and
- Determine the overall critical success factors of the Stage-Gate model.

This section thus provides a summary of all of the abovementioned aims. Table 2.13a provides a summary of the brief descriptions for each stage and gate in the model.

**Table 2.13a: Summary of brief descriptions of stages and gates**

Stage/Gate	Description
<i>Stage 0</i>	<ol style="list-style-type: none"> <li>4. Develop R&amp;D strategy (New Value Strategy) for the development of new value propositions.</li> <li>5. Identify and analyse opportunities.</li> <li>6. Generate new (or apply existing) ideas for new value propositions (in alignment with the strategy)</li> </ol>
<i>Gate 1</i>	First assessment of ideas generated in Stage 0, through subjecting ideas to a range of pre-determined criteria
<i>Stage 1</i>	Preliminary assessment of new value propositions, based on holistic technical, market and financial assessments
<i>Gate 2</i>	Second round of assessment of value propositions that have undergone preliminary assessment, through subjecting these value propositions to a range of pre-determined criteria
<i>Stage 2</i>	More detailed repeat of Stage 1, with specific emphasis on financial analysis
<i>Gate 3</i>	Third round of assessment of value propositions that have undergone business case assessment, through subjecting these value propositions to a range of pre-determined criteria
<i>Stage 3</i>	<ol style="list-style-type: none"> <li>1. Iterative/spiral development of actual value proposition, integrated with testing stage.</li> <li>2. Development of business-related plans in parallel to development and testing activities</li> </ol>
<i>Gate 4</i>	Fourth round of assessment of value propositions that have undergone development, through subjecting these value propositions to a range of pre-determined criteria
<i>Stage 4</i>	Testing of iterations of value propositions developed in Stage 3
<i>Gate 5</i>	Fifth round of assessment of value propositions that have undergone testing, through subjecting these value propositions to a range of pre-determined criteria
<i>Stage 5</i>	<ul style="list-style-type: none"> <li>▪ Final Launch/commercialisation of new, viable value proposition</li> <li>▪ Post-launch assessment of commercial performance</li> </ul>

The descriptions given Table 2.13a provided a sound understanding of the various stages and gates in the Stage-Gate model, and were used as background information in the development of the proposed model in Chapter 3.

Table 2.13b provides a summary of all the activities performed at the various stages and gates throughout the model.

**Table 2.13b: Summary of activities at stages and gates**

Stage/Gate	Activities
Stage 0	<ul style="list-style-type: none"> <li>▪ <b>Formulate new value strategy (NVS)</b> <ul style="list-style-type: none"> <li>▪ <i>Align R&amp;D collaborative companies strategy</i></li> <li>▪ <i>Select strategy type</i></li> <li>▪ <i>Identify customer segments</i></li> <li>▪ <i>Identify types of value propositions to pursue</i></li> <li>▪ <i>Develop success metrics/performance benchmarks</i></li> <li>▪ <i>Develop management approach</i></li> <li>▪ <i>Develop gate criteria for each gate in the model</i></li> </ul> </li> <li>▪ <b>Idea generation</b> <ul style="list-style-type: none"> <li>▪ <i>Identify opportunities (market pull and technology push)</i></li> <li>▪ <i>Analyse opportunities (market pull and technology push)</i></li> <li>▪ <i>Identify idea sources</i></li> <li>▪ <i>Generate ideas, both internally and externally, through the use of several idea generation techniques</i></li> </ul> </li> </ul>
Gate 1	<ul style="list-style-type: none"> <li>▪ Assessment of ideas through scoring model, focusing on technical, strategic and market criteria</li> <li>▪ Ranking of ideas based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>
Stage 1	<ul style="list-style-type: none"> <li>▪ Defining the entire value-offering of the new value proposition</li> <li>▪ <b>Market Assessment</b> <ul style="list-style-type: none"> <li>▪ <i>Investigation into broad customer segments and potential market size</i></li> <li>▪ <i>Investigation into market potential, need, wants and acceptance</i></li> <li>▪ <i>Investigation into potential competitors</i></li> </ul> </li> <li>▪ <b>Technical Assessment</b> <ul style="list-style-type: none"> <li>▪ <i>Development/Identification of probable technical solution</i></li> <li>▪ <i>Identification of possible technical challenges/risks</i></li> <li>▪ <i>Development of preliminary timeline and budget</i></li> <li>▪ <i>Broad indication of resources required</i></li> </ul> </li> <li>▪ <b>Financial Assessment</b> <ul style="list-style-type: none"> <li>▪ <i>High-level indication of financial viability</i></li> </ul> </li> </ul>
Gate 2	<ul style="list-style-type: none"> <li>▪ Assessment of ideas through scoring model, focusing on key criteria</li> <li>▪ Ranking of ideas based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>
Stage 2	<ul style="list-style-type: none"> <li>▪ <b>Concept testing</b> <ul style="list-style-type: none"> <li>▪ <i>Determine acceptance of new value proposition</i></li> <li>▪ <i>Determine intent to purchase</i></li> </ul> </li> <li>▪ <b>Financial analysis, including sensitivity analysis</b></li> <li>▪ <b>Technical Assessment</b> <ul style="list-style-type: none"> <li>▪ <i>Clear definition of new value proposition concept</i></li> <li>▪ <i>Determine likelihood of completion</i></li> <li>▪ <i>Determine costs</i></li> <li>▪ <i>Determine time to develop</i></li> <li>▪ <i>Determine potential “killer” variables</i></li> </ul> </li> <li>▪ <b>Market Assessment</b> <ul style="list-style-type: none"> <li>▪ <i>Detailed investigation of target markets</i></li> <li>▪ <i>Identification of current and potential competitors and their strength</i></li> <li>▪ <i>Potential market growth analysis</i></li> </ul> </li> <li>▪ <b>Development of marketing plan</b></li> <li>▪ <b>Source of supply assessment</b></li> <li>▪ <b>Determine value-add to potential customer/s</b></li> <li>▪ <b>Competitor analysis</b></li> <li>▪ <b>Legal analysis</b></li> </ul>

**Table 2.13b (continued): Summary of activities at stages and gates**

Stage/Gate	Activities
<i>Gate 3</i>	<ul style="list-style-type: none"> <li>▪ Assessment of value proposition concepts through scoring model, focusing on key criteria</li> <li>▪ Ranking of concepts based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>
<i>Stage 3</i>	<ul style="list-style-type: none"> <li>▪ Technical development of new value proposition (prototype – pilot)</li> <li>▪ Development of Marketing plan</li> <li>▪ Development of Testing plan</li> <li>▪ Development of Operations plan</li> <li>▪ Development of Business plan</li> </ul>
<i>Gate 4</i>	<ul style="list-style-type: none"> <li>▪ Assessment of developed value propositions through scoring model, focusing on key criteria</li> <li>▪ Ranking of value propositions based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>
<i>Stage 4</i>	<ul style="list-style-type: none"> <li>▪ In-house-testing</li> <li>▪ In-field testing</li> <li>▪ Pilot/trial testing</li> <li>▪ Scale market test</li> <li>▪ Development of Marketing plan</li> <li>▪ Development of Testing plan</li> <li>▪ Development of Operations plan</li> <li>▪ Development of Business plan</li> </ul>
<i>Gate 5</i>	<ul style="list-style-type: none"> <li>▪ Assessment of final value propositions through scoring model, focusing on key criteria</li> <li>▪ Ranking of value propositions based on scores</li> <li>▪ Decision: Yes; No; Revise</li> </ul>
<i>Stage 5</i>	<ul style="list-style-type: none"> <li>▪ Executing Launch plan</li> <li>▪ Measure market performance</li> <li>▪ Measure technical performance</li> <li>▪ Measure financial performance</li> <li>▪ Modify value proposition if necessary</li> </ul>

The activities described in Table 2.13b were used (along with key gate criteria) to determine the generic best-practice activities and criteria in Chapter 3. It was found that the stage activities and gate criteria in the Stage-Gate model are inter-related. This means that all activities performed result in certain deliverables – and it is these deliverables that lead to either meeting (or not meeting) the various gate criteria.

It was further found that in order to successfully apply the Stage-Gate model (and determine which activities will be performed throughout the different stages), the starting point should be the gate criteria at the subsequent gates. Thus, in Chapter 3, in order to determine which activities need to be performed, the focus was on the gate criteria, rather than the stage activities.

Table 2.13c provides a summary of all the critical success factors found throughout the model.

**Table 2.13c: Summary of critical success factors**

Stage/Gate	Critical Success Factors
<i>Stage 0</i>	<ul style="list-style-type: none"> <li>▪ Alignment of NVS with collaborators' strategies (objectives, vision, mission, etc.)</li> <li>▪ Selecting the correct type of NVS</li> <li>▪ Identification of company "success" factors and associated metrics (e.g. IRR, NPV)</li> <li>▪ Fit with organisational culture</li> <li>▪ Applying the correct management approach (for activities and decision-making)</li> <li>▪ Effective communication</li> <li>▪ Shared understanding of NVS</li> <li>▪ Removing unnecessary bureaucracy</li> <li>▪ Number of idea sources</li> <li>▪ Volume of ideas generated</li> <li>▪ Quality of ideas generated</li> <li>▪ Use of market-pull and technology push approaches</li> <li>▪ Customer involvement</li> <li>▪ Sound understanding of potential customers</li> <li>▪ Use of several idea generation techniques</li> </ul>
<i>Gate 1</i>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Allowing for subjectivity and intuition in decision-making</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> </ul>
<i>Stage 1</i>	<ul style="list-style-type: none"> <li>▪ Speed</li> <li>▪ Low cost</li> <li>▪ Correct level of detail of information</li> <li>▪ Customer involvement</li> <li>▪ Sound information (internal and external)</li> <li>▪ Sound technical expertise</li> <li>▪ Use of internal champion (person who takes ownership)</li> </ul>
<i>Gate 2</i>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> <li>▪ Emphasis on qualitative rather than quantitative assessment</li> </ul>
<i>Stage 2</i>	<ul style="list-style-type: none"> <li>▪ Understanding customer needs</li> <li>▪ Value proposition uniqueness</li> <li>▪ Consideration of needs of all stakeholders, not only potential customers</li> <li>▪ Quality of assessments</li> <li>▪ Quality and confidence of financial inputs</li> <li>▪ Management of activities</li> <li>▪ Parallelism of activities</li> <li>▪ Effectiveness of internal communication</li> </ul>
<i>Gate 3</i>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> </ul>





**Table 2.13c (continued): Summary of critical success factors**

Stage/Gate	Critical Success Factors
<i>Stage 3</i>	<ul style="list-style-type: none"> <li>▪ Quality of development work</li> <li>▪ Cross-functionality of teams;</li> <li>▪ Level of team member commitment;</li> <li>▪ Parallel nature of activities;</li> <li>▪ Relationships with external organisations; and</li> <li>▪ Development efficiency (speed)</li> <li>▪ Iterative development</li> <li>▪ Iterative integration with Testing stage</li> <li>▪ Customer feedback</li> </ul>
<i>Gate 4</i>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> <li>▪ Customer feedback</li> </ul>
<i>Stage 4</i>	<ul style="list-style-type: none"> <li>▪ Well-designed tests</li> <li>▪ Customer involvement</li> <li>▪ Objectivity in assessing test results</li> </ul>
<i>Gate 5</i>	<ul style="list-style-type: none"> <li>▪ Quality and relevance of assessment team</li> <li>▪ Quality of assessment</li> <li>▪ Sound scoring model</li> <li>▪ Assignment of correct weightings to criteria in the scoring model</li> <li>▪ Customer feedback</li> </ul>
<i>Stage 5</i>	<ul style="list-style-type: none"> <li>▪ Post-launch review to confirm performance</li> <li>▪ Customer feedback</li> <li>▪ Continuous performance monitoring</li> </ul>

The critical success factors given in Table 2.13c were used to derive overall critical success factors for the Stage-Gate model. Although the factors in Table 2.13c were categorised according to different stages and gates, the information was processed in order to derive overall critical success factors. Where factors were isolated to single stages/gates, these factors were nevertheless included.

Table 2.13d provides a summary of all the gate criteria found at the various gates throughout the model.

**Table 2.13d: Summary of gate criteria for all gates in the Stage-Gate model**

Gate	Strategic Criteria	Market Criteria	Technical Criteria
<i>Gate 1</i>	<ul style="list-style-type: none"> <li>Fit with company/ies strategy and NPS</li> <li>Fit with organisational culture</li> <li>Leverage of company/ies core competencies (internal and external)</li> </ul>	<ul style="list-style-type: none"> <li>Size (Market attractiveness)</li> <li>Expected Growth (Market attractiveness)</li> <li>Differential advantage</li> <li>Potential value contribution to market</li> <li>Acceptance of idea by customers</li> <li>Uniqueness</li> <li>Potential competitors</li> </ul>	<ul style="list-style-type: none"> <li>Feasibility of technical success (Relative probability of technical success)</li> </ul>
<i>Gate 2</i>	<ul style="list-style-type: none"> <li>Fit with company/ies strategy</li> <li>Familiarity to company</li> <li>Leverage of company/ies core competencies</li> <li>Estimated timing for regulatory and legal approval</li> </ul>	<ul style="list-style-type: none"> <li>Size</li> <li>Expected Growth</li> <li>Segmentation &amp; Trends</li> <li>Importance of customer needs addressed</li> <li>Benefit delivered</li> <li>Value proposition superiority</li> <li>Perceived value/reaction to proposed value proposition</li> <li>Potential competitors</li> <li>Competitor's ability to replicate</li> <li>Competitor's market share</li> <li>Competitor's strategies</li> <li>Ability to protect from quick competitor reaction</li> </ul>	<ul style="list-style-type: none"> <li>Feasibility of benefit delivered (Degree of benefit delivered)</li> <li>Development plan</li> <li>Estimated time to market</li> <li>Estimated cost</li> </ul>

**Table 2.13d (continued): Summary of gate criteria for all gates in the Stage-Gate model**

Gate	Strategic Criteria	Market Criteria	Technical Criteria	Financial Criteria
<i>Gate 3</i>	<ul style="list-style-type: none"> <li>▪ Impact of value proposition on company/ies</li> <li>▪ Familiarity of technology/value proposition to company/ies</li> <li>▪ Track record of company/ies on similar projects</li> <li>▪ Fit with company/ies strategy</li> <li>▪ Importance of new value proposition to the company/ies</li> <li>▪ Leverage of company/ies core competencies</li> </ul> <i>Technology</i> <i>Production/operations</i> <i>Marketing (image, brand, communications)</i> <i>Distribution and sales force</i>	<ul style="list-style-type: none"> <li>▪ Market Size</li> <li>▪ Expected Growth and future potential (market)</li> <li>▪ Value proposition positioning strategy</li> <li>▪ Customer acceptance</li> <li>▪ Value Proposition uniqueness and benefit delivered</li> <li>▪ Value proposition “value for money”</li> <li>▪ Clarity on essential and desired value proposition features</li> <li>▪ Margins currently earned by competitors</li> <li>▪ Potential competitor’s market share</li> </ul>	<ul style="list-style-type: none"> <li>▪ Feasibility</li> </ul> <i>Size of technical gap</i> <i>Technical complexity (few barriers, solution envisioned)</i> <i>Technical results to date (proof of concept)</i> <ul style="list-style-type: none"> <li>▪ Operations plan</li> <li>▪ Development plan</li> <li>▪ Estimated time to market</li> <li>▪ Quality</li> </ul>	<ul style="list-style-type: none"> <li>▪ Net Present Value (NPV)</li> <li>▪ Internal Rate of Return (IRR)</li> <li>▪ Expected Commercial Value (ECV)</li> <li>▪ Return on Investment (ROI)</li> <li>▪ Economic Value Added (EVA)</li> <li>▪ Payback Period</li> <li>▪ Margin</li> </ul>
<i>Gate 4</i>	All criteria used in Gates 1, 2 and 3	All criteria used in Gates 1, 2 and 3	All criteria used in Gates 1, 2 and 3	All criteria used in Gates 1, 2 and 3
<i>Gate 5</i>	All criteria used in Gates 1, 2, 3 and 4	All criteria used in Gates 1, 2, 3 and 4	All criteria used in Gates 1, 2, 3 and 4	All criteria used in Gates 1, 2, 3 and 4

The criteria given in Table 2.13d were used to derive the key criteria to consider throughout the Stage-Gate model. It was found that, in essence, each gate needs to consider the same main groups of criteria, apart from financial criteria in Gate 1 and 2. Although the gates generally consider the same criteria, the difference comes in with the level of confidence in meeting the criteria. It was found that the level of confidence increases chronologically throughout the model.

Thus, the criteria shown in Table 2.13d was used to firstly derive the key criteria throughout the model, and secondly assign levels of confidence to each criteria for each gate in the model (Chapter 3). This in turn was used to illustrate the inter-related nature of the gate criteria and stage activities. It was found that the gate criteria used determines the preceding stage activities.



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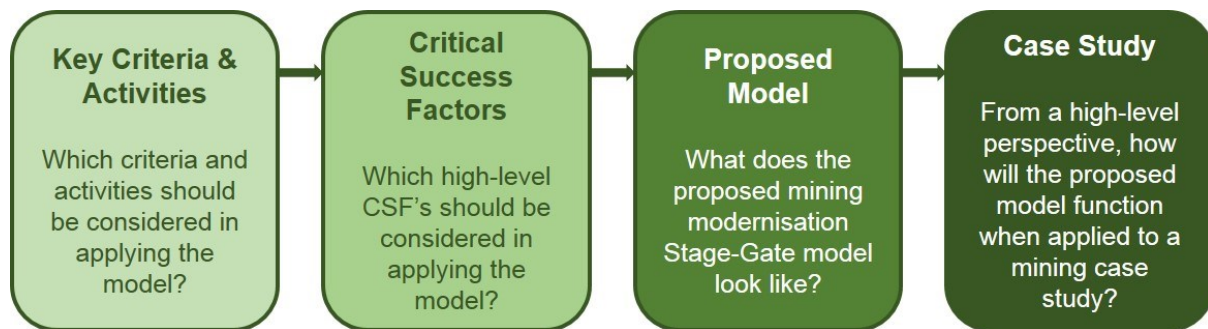
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## CHAPTER 3: RESULTS AND ANALYSIS OF RESULTS

The main aim of the study is to investigate the Stage-Gate model and concepts, in an attempt to apply it as a research and development (R&D) process in modernising the mining industry. In Chapter 2, a comprehensive literature review was conducted on the Stage-Gate model skeleton, key gate criteria, stage activities and critical success factors. This was done for the model as a whole, as well as the individual stages and gates.

Chapter 3 thus discusses the key gate criteria of the Stage-Gate model, and discusses the inter-relation between gate criteria and stage activities. A generalised approach in terms of determining stage activities (based on subsequent gate criteria) is proposed as a way of designing a fit-for-purpose Stage-Gate model. The high-level critical success factors for the Stage-Gate model are discussed, and these factors (along with the criteria and activities) are used to develop a proposed/applied model.

Lastly, the proposed model is evaluated at the hand of a real-world mining case study, in order to illustrate how the model would be applied to the mining industry. Figure 3 displays an overview of Chapter 3, along with key questions for each section.



**Figure 3: Chapter 3 Overview and Key Questions**



### 3.1 KEY STAGE-GATE CRITERIA & ACTIVITIES

From the literature review conducted in Chapter 2, key stage activities and gate criteria were identified. It was found that the activities performed in each stage are inter-related to the decision-making criteria at the subsequent gate. Furthermore, it was found that the gate criteria used at the various gates in the model are generally the same. Although the criteria is the same for each gate, the level of confidence in meeting the criteria at each gate was found to be different. The level of confidence in meeting the criteria was found to increase chronologically. Thus, the same criteria (e.g. technical feasibility) may be present at each gate in the model, with an increase in the level of confidence as the model progresses.

The gate criteria identified at the various gates in the Stage-Gate model were found to comprise of four main groups of criteria, namely: Strategic criteria; Market criteria; Technical criteria; and financial criteria. The four main groups of criteria further comprise of several sub-criteria per main group. Table 3.1a shows the main criteria groups, the sub-criteria for each main group, and the required levels of confidence across all the gates in the Stage-Gate model.

**Table 3.1a: Key Stage-Gate Criteria**

		Required levels of confidence				
		20%	40%	70%	90%	100%
		Gate 1	Gate 2	Gate 3	Gate 4	Gate 5
<b>Strategic</b>	Alignment with R&D Collaboration New Value Strategy					
	Leverage of R&D Collaboration core competencies/resources					
	Familiarity/track record of type of Value Proposition to R&D Colab					
	Impact & importance of Value Proposition to R&D Collaboration					
	Regulatory & Legal Approval of Value Proposition					
	Value Proposition positioning strategy					
<b>Market</b>	<b>Market Attractiveness</b>					
	Size					
	Expected Growth & Future Potential					
	Segmentation and Trends					
	Potential Market Share					
	Customer Acceptance					
	Uniqueness					
	Differential Advantage					
	Perceived/Potential Value					
	Benefit delivered					
	Importance of customer needs addressed					
	Customer Satisfaction					
	Value Proposition superiority					
	Value Proposition "value for money"					
	<b>Competitive Analysis</b>					
Competitors Market Share						
Competitors Strategy						
Competitors ability to replicate						
Margins earned by competitors						
<b>Technical</b>	<b>Feasibility</b>					
	Value Proposition Development Plan					
	Cost					
	Time					
	Size of technical gap					
	Technical complexity					
	Value Proposition Operations & Production Plan					
	Value Proposition Quality and Performance					
Alignment of Value Proposition with operations ability						
<b>Financial</b>	<b>Financial Feasibility</b>					
	Net Present Value (NPV)					
	Internal Rate of Return (IRR)					
	Expected Commercial Value (ECV)					
	Return on Investment (ROI)					
	Economic Value Added (EVA)					
	Payback Period					
Margin						

From Table 3.1, the following general observations with regards to gate criteria can be made:

- A strong emphasis is placed on alignment with the New Value Strategy (NVS). At each gate, alignment has to be 100%. The reason for this is intuitive – if a proposed new value proposition does not align with the objectives of the R&D being conducted, further pursuit of the new value proposition will be counter-productive.
- For gates 1 and 2, only three of the four main criteria groups are applicable. The financial criteria main group is excluded from the first two gates. The reason for this is due to the exploratory nature of the stages preceding the first two gates. The stages focus on further developing ideas for new value propositions, and thus the question of what exactly the new value proposition will be is unanswered.
- At Gate 5 (Go to Launch), all criteria require a level of confidence of 100%. This is to ensure that as soon as a new value proposition has undergone final testing, it can immediately be launched/commercialised without any further delays in the process.

As discussed previously, the activities performed in each stage in the Stage-Gate model are inter-related to the criteria of subsequent gates. From the literature review conducted in Chapter 2, it was found that several sources of literature described and prescribed “best-practice” activities for each stage in the model. However, bearing in mind the inter-relatedness of the stages and gates, a simpler (and more complete) manner of assigning activities to each stage was found.

In order to decide whether any given criteria at any given gate has been met (or has not been met), an activity (or group of activities) needs to be performed in the preceding stage. Thus, in order to determine which activities need to be performed in the stages, the criteria at the subsequent gates should be used. In order to illustrate this, consider the Technical main group of criteria as an example (Table 3.1b).

**Table 3.1b: Example of activities (Technical main group of criteria)**

Main Group	Criteria	Stage 0	Gate 1	Stage 1	Gate 2	Stage 2	Gate 3	Stage 3	Gate 4	Stage 4	Gate 5
Technical	Feasibility	Subjective/intuitive indication of technical feasibility, based on expert opinion (without any further investigations)	20%	Brief technical desktop study	40%	Technical conceptual study/business case	70%	Technical pre-feasibility study	90%	Technical feasibility study	100%

The example given in Table 3.1b, albeit basic, provides an indication of how stage activities should be determined based on subsequent gate criteria (and levels of confidence required). It must be noted that the Stage-Gate approach to R&D is not a plug-and-play process. Wherever the Stage-Gate model is applied, it needs to be designed to be fit-for-purpose (based on the new values strategy (NVS) of the proposed R&D effort). Using the NVS as a starting point, key relevant gate criteria can be determined, and subsequently stage activities can be determined (leading to the basic design of a fit-for-purpose Stage-Gate model).



### 3.2 HIGH-LEVEL CRITICAL SUCCESS FACTORS

From the literature review conducted in Chapter 2, it was found that several high-level critical success factors (CSF) were applicable to the Stage-Gate model as a whole. In applying the Stage-Gate model for R&D purposes in the mining industry, it is imperative that these CSF's be incorporated in the proposed model. The high-level CSF's are listed and explained in Table 3.2.

**Table 3.2: High-level critical success factors**

CSF	Description	Where?
1 <i>Sound understanding of the Stage-Gate model and associated concepts</i>	In order to successfully apply the Stage-Gate model to the mining industry, a sound and comprehensive understanding is required of the model and the associated concepts. Of critical importance is to view the model and concepts as broad guidelines, and nothing more. The model is not of a “plug-and-play” nature – it is rather an exercise involving skill, knowledge and meticulous interpretation, modification and application. Companies wishing to apply the model to their R&D programmes (without thoroughly educating themselves first), will inevitably experience counter-productive R&D outputs.	Overall
2 <i>Careful consideration in the formulation of a New Value Strategy (NVS)</i>	<p>The most critical factor to the success of using the model, lies with the formulation of the NVS. How the remainder of the model will be approached and applied is dependent on decisions made in the NVS. Essentially, the formulation of the NVS is where the model is designed to be fit-for-purpose, and care should be taken by companies to consider any relevant aspects and build them in to the NVS. Special attention should be given to the following aspects:</p> <ul style="list-style-type: none"> <li>▪ Select the correct type of strategy (e.g. analytical, prospective, etc.)</li> <li>▪ Ensure that all R&amp;D collaborators' individual strategies align with the NVS</li> <li>▪ Leverage resources, partners, current customer segments, value propositions and channels.</li> <li>▪ Identify a co-creator/champion mine (or mining group), and involve them in the formulation of the NVS.</li> <li>▪ Identify an individual (champion) who will take ownership and responsibility for the R&amp;D effort.</li> <li>▪ Identify key value drivers and associated metrics, and build these into the gates contained in the model.</li> <li>▪ Carefully scrutinise and assess the macro-environmental factors of the mining industry, and ensure that relevant factors are considered in the NVS and model.</li> <li>▪ Consider the tripartite stakeholders in the mining industry, and plan to engage all stakeholders (labour, employers and government) where required.</li> <li>▪ Remove any unnecessary bureaucracy from the model and R&amp;D programme. Bureaucracy hinders innovation and development of new value propositions, and paperwork, meetings and reporting should be kept to an absolute minimum.</li> <li>▪ Develop a sound management approach.</li> <li>▪ Ensure that NVS aligns/fits in with the organisational culture of the R&amp;D collaborators (and the management approach), and that a shared comprehensive understanding of the NVS is present amongst all stakeholders.</li> </ul>	Stage 0

**Table 3.2 (continued): High-level critical success factors**

CSF	Description	Where?
<b>3</b> <i>A high degree of parallelism of activities</i>	<p>Parallelism throughout the Stage-Gate model is critical to the success of the model. Activities within stages should be performed in parallel, and stages should also be performed in parallel (where applicable). Multi-disciplinary teams should be used to perform this parallel processing. Speed is essential in the Stage-Gate model, and a high degree of parallelism ensures that each stage (and the model as a whole) is completed as efficiently and effectively as possible. A high degree of parallelism also allows for costs to be kept to an absolute minimum.</p>	Stage 1, 2, 3, 4 and 5
<b>4</b> <i>Generating a large volume of high-quality ideas</i>	<p>In terms of idea generation, the volume and quality of ideas for new value propositions is of critical importance. This can be achieved by searching for as many sources of ideas as possible, be it internally or externally. Both market-pull and technology-push approaches should be considered during the idea generation stage, and several different idea generation techniques should be considered.</p> <p>Customer-focused idea generation ensures that new ideas solve actual needs, and that ideas are relevant and contextual. Ideas should be generated with the customer in mind at all times. In the mining industry, both technology-push ideation and market-pull ideation should be incorporated. This is due to the abundance of new technologies entering the mining industry and adjacent industries. Modernisation of the industry has started, and technology adoption and “pushing” will be critically important in speeding this up. Furthermore, idea generation should take the following key aspects into consideration:</p> <ul style="list-style-type: none"> <li>▪ The entire mining value chain should be understood, so that the upstream and downstream impacts of a new value proposition can be defined.</li> <li>▪ Theory of constraints thinking should be applied to new value propositions. They should be assessed in terms of whether the potential value they could unlock targets the bottleneck in any given system. If they do not, then the customer will not realise any real value.</li> <li>▪ Current and future developments in the industry should be taken into consideration. Ideas for new value propositions should be targeted at solving problems that are not already being solved (unless they could solve the problem more effectively and efficiently). E.g. a value proposition that improves truck-driver productivity should not be pursued if the truck driver will be replaced by driverless truck technology in the near future.</li> <li>▪ The unique mining environment and its associated operational constraints should be taken into account.</li> <li>▪ The current state of technology of the intended implementation environment should be used to define the scope for new value propositions.</li> <li>▪ The aim of generating ideas for new value propositions should be on long-term, sustainable solutions, and should take into account what the future mining industry will look like.</li> </ul>	Stage 0
<b>5</b> <i>Effective communication</i>	<p>In order to ensure successful parallelism of activities (and decision-making), effective communication is highly important. All the stakeholders involved in the R&amp;D process should be willing and able to communicate effectively. Failure to do so will decrease the efficiency of the model, and will ultimately greatly decrease the probability of achieving a successful end result. Both internal and external communication needs to be effective.</p>	Overall

**Table 3.2 (continued): High-level critical success factors**

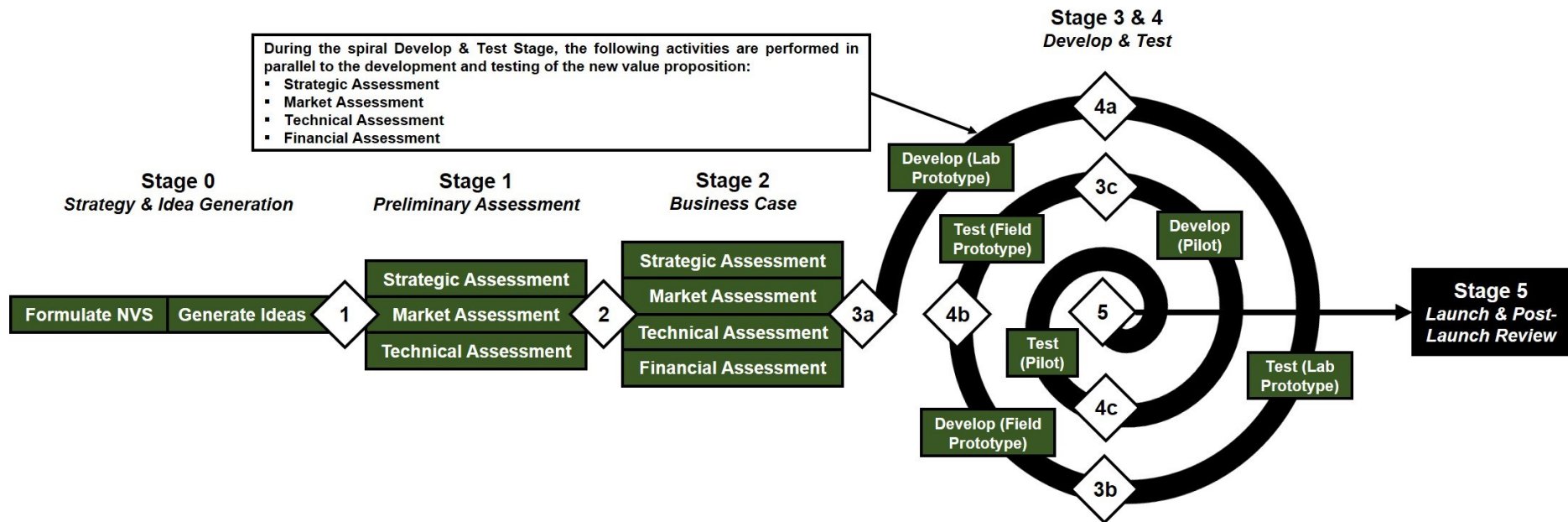
CSF	Description	Where?
6 <i>Sound decision-making at gates</i>	<p>Decision-making at all the gates throughout the Stage-Gate model is critical to success. Poor/incorrect decisions can lead to wasted resources and preventable failures. In formulating the NVS, the persons who will be responsible for decision-making should be carefully considered. In addition to this, the selection and establishment of gate criteria (and required levels of confidence in the criteria) should also be carefully considered. Lastly, the tools that will be used for decision-making purposes (e.g. scoring/ranking/weighting models) should be designed such that they are not counter-productive in terms of the NVS.</p> <p>In reaching decisions, it must be noted that the needs of all stakeholders in the process should be considered, and not only those of customers. Decision-making should generally be objective in nature, apart from decisions made at gates 1 and 2 (where subjectivity and intuition is desired, as objectivity is not yet 100% possible).</p>	Gates 1, 2, 3, 4 and 5
7 <i>Involving potential customers throughout the process</i>	Potential customers should be involved throughout the entire Stage-Gate model, in order to obtain continuous feedback and insights. In addition to this, a sound understanding (or profile) of customers is necessary.	Stages 0, 1, 2, 3, 4 and 5
8 <i>Quality of activities performed</i>	<p>In terms of the activities performed throughout the various stages in the model, the following critical success factors apply:</p> <ul style="list-style-type: none"> <li>▪ Activities should be performed to produce deliverables with the correct level of detail (relevant to the succeeding gate requirements)</li> <li>▪ Information used to perform activities should be sound and factual in nature</li> <li>▪ The correct and relevant expertise should be used in performing the activities</li> </ul>	Stage 0, 1, 2, 3, 4 and 5
9 <i>Iterative development and testing</i>	Of critical importance to successfully apply the Stage-Gate model, is the incorporation of iterative development and testing. These two stages, as well as the “Go to Testing” gate should not be viewed in isolation. They should be applied as an iterative “develop-test-learn” spiral.	Stages 3 and 4
10 <i>Use of multi-disciplinary, cross-functional teams</i>	In performing stage activities and reaching gate decisions, a multi-disciplinary and cross-functional team approach should be used. This allows for a high-degree of parallelism to exist, and also increase the probability of reaching success. In addition to this, the level of team member commitment is of critical importance – team members should not have divided attention.	Overall

**Table 3.2 (continued): High-level critical success factors**

CSF	Description	Where?
11 <i>Embracing failure as a result</i>	In order to successfully apply the Stage-Gate model and concepts, a mindset change is required. Traditionally, successes are celebrated and rewarded, and failure is punished and undesired. The iterative nature of the Stage-Gate model is designed to induce failure. Failure should be embraced and even celebrate in the R&D process – failure leads to new learnings, and the more a company fails early on in the process, the higher the probability of eventually achieving success.	Overall
12 <i>Disprove value rather than proving value</i>	In line with the embracing failure, the main aim throughout the Stage-Gate model should be to disprove hypotheses and potential value. Traditionally, ideas are developed into value propositions through a process of trying to prove value. However, in using the Stage-Gate model, the approach should be the opposite. Potential value propositions should be subjected to extreme scrutiny, and tests should be designed to attempt to prove value hypotheses wrong. This may seem counter-intuitive, but research has shown that trying to disprove value in the development of new value propositions yields better results than trying to prove value.	Overall
13 <i>Post-launch monitoring</i>	Once a new value proposition has been commercialised (or launched), it is imperative to perform continuous monitoring on the performance of the value proposition. Based on the performance assessment, modifications should be made to the value proposition, in order to ensure that it reaches full commercial potential. Post-launch monitoring should not be taken lightly – lack thereof could lead to a new value proposition failing (where it could have been successful).	Stage 5

### 3.3 PROPOSED STAGE-GATE MODEL

From the results obtained in 3.1 and 3.2, as well as the general knowledge gathered through conducting the study, a proposed Stage-Gate model was developed for application in the mining industry. The main aim of the proposed model was to provide an enhanced understanding of the general Stage-Gate model and approach, such that it could be applied more easily for purposes of R&D in the mining industry. Specific emphasis was placed on highlighting the need for a high degree of parallelism throughout the model, as well as iterative development and testing (as described in 3.2). It must be noted that although the visualisation of the proposed model (Figure 3.3) is different to the general model visualisation, the nature of the model remains the same.



**Figure 3.3: Proposed Stage-Gate Model indicating parallel stage activities and spiral development and testing**

As is the case with the general Stage-Gate model, the proposed model also comprises of six main stages (Stage 0 – Stage 5) and five general gates (Gate 1 – Gate 5). The main difference lies with the development and testing stages and gates. The two stages were integrated into one spiral development and testing stage, and Gates 3 and 4 were split into three sub-gates each.

The basic chronological flow of the proposed model is explained (Table 3.3), with specific reference to the general gate criteria (as per Table 3.1a) and the critical success factors (as per Table 3.2).

**Table 3.3: Proposed model chronological flow**

Stage/Gate	Brief Flow Description	Applicable CSF's (as per Table 3.2)
<i>Stage 0</i>	Formulation of the NVS	1, 2, 5, 7, 8, 10, 11, 12
<i>Stage 0</i>	Generation of ideas for new value propositions, taking into consideration the NVS and the gate criteria (and corresponding required levels of confidence) at Gate 1.	1, 4, 5, 7, 8, 10, 11, 12
<i>Gate 1</i>	Assessment of ideas generated in Stage 0, by making use of the Gate 1 criteria and required levels of confidence (as per Table 3.1a)	1, 5, 6, 10, 11, 12
<i>Stage 1</i>	Preliminary assessment of ideas that passed through Gate 1, through performing the activities required to produce the correct deliverables/inputs for Gate 2.	1, 3, 5, 7, 8, 10, 11, 12
<i>Gate 2</i>	Assessment of ideas generated in Stage 1, by making use of the Gate 2 criteria and required levels of confidence (as per Table 3.1a)	1, 5, 6, 10, 11, 12
<i>Stage 2</i>	Detailed assessment of value proposition concepts that passed through Gate 2, through performing the activities required to produce the correct deliverables/inputs for Gate 3a (including concept testing).	1, 3, 5, 7, 8, 10, 11, 12
<i>Gate 3a</i>	Assessment of value proposition concepts further investigated in Stage 2, by making use of the Gate 3 criteria and required levels of confidence (as per Table 3.1a)	1, 5, 6, 10, 11, 12
<i>Stage 3a</i>	Development of the first tangible in-house/laboratory prototype, in parallel with the performance of the activities required to produce the correct deliverables/inputs for Gate 4.	1, 3, 5, 7, 8, 9, 10, 11, 12
<i>Gate 4a</i>	Assessment of the prototype developed (and the activities performed) in Stage 3a, by making use of the Gate 4 criteria and required levels of confidence (as per Table 3.1a)	1, 5, 6, 10, 11, 12
<i>Stage 4a</i>	Testing of the prototype developed in Stage 3a. Based on the test results, the same parallel activities performed in Stage 3a are performed again (if the test resulted in new applicable information being gained)	1, 3, 5, 7, 8, 9, 10, 11, 12
<i>Gate 3b</i>	Assessment of prototype test results found in Stage 4a, by making use of the Gate 3 criteria and required levels of confidence (as per Table 3.1a) (Did the test results and outcomes of the parallel activities prove that further, more detailed in-field development should be performed?)	1, 5, 6, 10, 11, 12
<i>Stage 3b</i>	Development of an in-field prototype of the value proposition, in parallel with the performance of the activities required to produce the correct deliverables/inputs for Gate 4.	1, 3, 5, 7, 8, 9, 10, 11, 12
<i>Gate 4b</i>	Assessment of the in-field prototype developed (and the activities performed) in Stage 3b, by making use of the Gate 4 criteria and required levels of confidence (as per Table 3.1a)	1, 5, 6, 10, 11, 12



**Table 3.3 (continued): Proposed model chronological flow**

Stage/Gate	Brief Flow Description	Applicable CSF's (as per Table 3.2)
<i>Stage 4b</i>	Testing of the in-field prototype developed in Stage 3b. Based on the test results, the same parallel activities performed in Stage 3b are performed again (if the test resulted in new applicable information being gained)	1, 3, 5, 7, 8, 9, 10, 11, 12
<i>Gate 3c</i>	Assessment of in-field prototype test results found in Stage 4b, by making use of the Gate 3 criteria and required levels of confidence (as per Table 3.1a) (Did the test results and outcomes of the parallel activities prove that further, more detailed pilot development should be performed?)	1, 5, 6, 10, 11, 12
<i>Stage 3c</i>	Development of a pilot value proposition, in parallel with the performance of the activities required to produce the correct deliverables/inputs for Gate 4.	1, 3, 5, 7, 8, 9, 10, 11, 12
<i>Gate 4c</i>	Assessment of the pilot value proposition developed (and the activities performed) in Stage 3c, by making use of the Gate 4 criteria and required levels of confidence (as per Table 3.1a)	1, 5, 6, 10, 11, 12
<i>Stage 4c</i>	Testing of the pilot value proposition developed in Stage 3c. Based on the test results, the same parallel activities performed in Stage 3c are performed again (if the test resulted in new applicable information being gained)	1, 3, 5, 7, 8, 9, 10, 11, 12
<i>Gate 5</i>	Assessment of pilot test results found in Stage 4c, by making use of the Gate 5 criteria and required levels of confidence (as per Table 3.1a) (Did the test results and outcomes of the parallel activities prove that the value proposition is commercially viable, and should be launched?)	1, 5, 6, 10, 11, 12
<i>Stage 5</i>	Full-scale launch of new value proposition, with continuous post launch monitoring (based on Gate 5 criteria, as per Table 3.1a).	1, 3, 5, 7, 8, 10, 11, 12, 13



### 3.4 MINING RESEARCH & DEVELOPMENT CASE STUDY

The mining case study used to evaluate the proposed model (and illustrate the application thereof) is a project titled “*Missing Person Locator System (MPLS)*”. The project is currently being conducted by the University of Pretoria’s Mining Engineering Department, through the Mining Resilience Research Centre (MRRC). The 24-month project was awarded to the University of Pretoria by the South African Mine Health and Safety Council (MHSC) in March of 2016, as part of their Centre of Excellence (CoE) group of projects.

The main objective of the project is to develop the user specifications for a system that can effectively and efficiently locate missing persons in underground mining environments. The main value-driver behind this objective (as per the project Terms of Reference (TOR) – *Appendix A*) is to achieve zero occurrences of fatalities as a result of employees becoming lost underground.

Several MPLS’s currently exist and are available to mines. However, none of these systems are currently completely fit-for-purpose. The MHSC envisions that the expected outcomes of the project should be used to either develop an entirely new MPLS, or to modify existing MPLS’s (based on the user specifications). The final expected outcome/milestone of the project is as follows (verbatim, from TOR in *Appendix A*):

*“Month 24: Research and development programme proposals to close the outstanding gaps between user requirements and technologies available by that time.”*

Taking into consideration the literal definition of R&D, the scope of the MPLS project focuses on the necessary research component, which precedes the development component. The MPLS project was thus deemed to be an applicable case study to evaluate and illustrate how the project would be conducted, if the proposed Stage-Gate model was applied (as it has the future potential to lead into a development project).

The approach followed in the case study evaluation of the proposed Stage-Gate model was to illustrate how the project would be conducted, if the proposed model were applied. This was done in four parts:

1. Discussing several factors that would have to be considered in formulating a new value strategy (NVS) for the MPLS project;
2. Illustrating how the research component of the MPLS project would be conducted (Stage 0 – Gate 3a in the proposed Stage-Gate model);
3. Illustrating how the eventual development and testing component of the MPLS project would be conducted (Stage 3a – Stage 5 in the proposed Stage-Gate model); and
4. Illustrating how both the R&D components of the MPLS would be conducted if the traditional 1<sup>st</sup> Generation Phase-Review process were used (in order to compare the proposed Stage-Gate model to the traditional R&D model).

### 3.4.1 FORMULATING THE NEW VALUE STRATEGY (NVS)

In order to demonstrate how a NVS would be formulated for the MPLS project, several key NVS considerations are discussed in this section. The considerations are as follows:

- Alignment of R&D collaborators’ strategies;
- Intended customer segments;
- Strategy type;
- Desired value proposition;
- Key stakeholders;
- Metrics and gate criteria; and
- Management approach.

#### 3.4.1.1 ALIGNMENT OF R&D COLLABORATORS’ STRATEGIES

As mentioned previously, the MPLS project was awarded to the University of Pretoria’s MRRC, by the MHSC. Thus, before the new value strategy (NVS) can be formulated, these two organisations’ strategies need to align. Table 3.4.1.1 provides the missions and visions of both organisations.

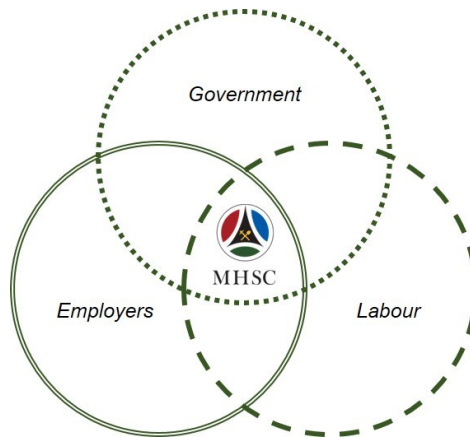
**Table 3.4.1.1: Mission & Vision of the MHSC and MRRC (MHSC, 2016<sup>135</sup>; University of Pretoria, 2016<sup>136</sup>)**

	MHSC	MRRC
Mission	<i>“To promote the culture of Occupational Health and Safety (OHS) in the mining industry, by striving towards zero harm, on all health and safety issues and legislation.”</i>	<i>“The MRRC will increase the resilience of the mining industry by contributing towards practical implementable solutions, through rigorous integrated scientific research.”</i>
Vision	<i>“The MHSC has a vision to be the trusted advisor to the Minister of Minerals Resources and to stakeholders for the South African Mining Sector, as knowledge leader in occupational health and safety issues, towards the achievement of zero harm to mine workers, communities and the environment.”</i>	<i>The vision of the MRRC is to establish the Centre at the University of Pretoria as a leading international contributor to solutions for complex mining industry problems.”</i>

Table 3.4.1.1 shows that a high degree of alignment exists between the strategies of the MHSC and MRRC. The relationship is of such a nature that the MRRC (from a strategic perspective) serves as a “vehicle” for the MHSC to achieve its mission and vision. What is important to note in terms of conducting the project, is the tripartite structure of the MHSC (Figure 3.4.1.1). The MHSC comprises of three key stakeholders, namely: Government, Employers and Labour. Thus, all three stakeholders need to be involved both internally and externally, in order to ensure strategic alignment of the project to their individual needs.

<sup>135</sup> Mine Health & Safety Council. 2016. *About the MHSC*. [Online]. Available: <http://www.mhsc.org.za/about-mhsc/vision-mission-and-values>. [Cited 23 November 2016].

<sup>136</sup> University of Pretoria. 2016. *Mining Resilience Research Centre*. [Online]. Available: <http://www.universityofpretoria.co.za/en/mining-engineering/article/2164003/mining-resilience-research-institute-mrri>. [Cited 23 November 2016].

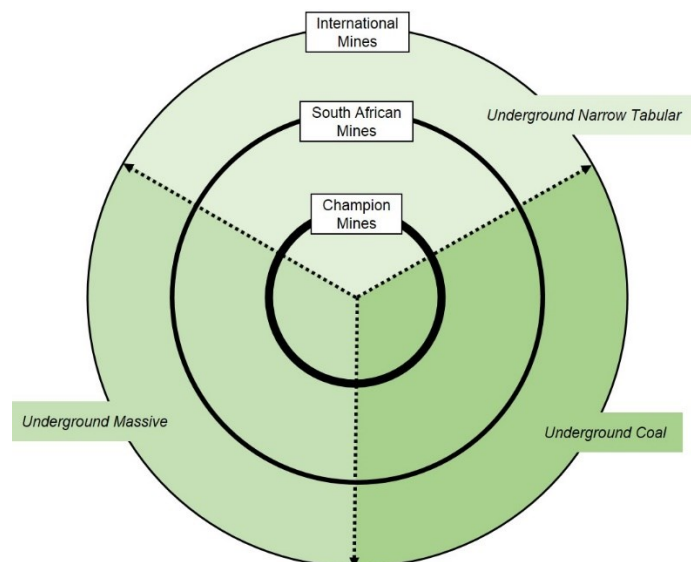


**Figure 3.4.1.1: Mine Health and Safety Council Tripartite Structure**

### **3.4.1.2 INTENDED CUSTOMER SEGMENTS**

The holistic intended “customer” for the MPLS is underground mines in South Africa. This can be broadly segmented into underground coal mines, underground narrow-tabular mines and underground massive mines. However, it must be noted that although the scope of the project is limited to underground mines in South Africa, international mines should not be excluded. They should be considered as potential future customers, dependent on the eventual outcomes of the project.

Of critical importance to the success of the MPLS project is to identify mine “champions” for underground coal, narrow-tabular and massive mines in South Africa. The mine champions, in the context of the MPLS project, will serve as industry collaborators. Figure 3.4.1.2 shows the holistic intended customer segments for the project, indicating an inwards-outwards prioritisation of the different customer segments.



**Figure 3.4.1.2: Holistic Intended Customer Segments for MPLS**

It must be noted that Figure 3.4.1.2 merely represents the holistic customer segments. As the project commences, further detailed segmentation needs to be performed. This segmentation will take into factors such as mining layouts; existing “backbone” infrastructure and existing technologies on the mines.



### **3.4.1.3 STRATEGY TYPE**

The MPLS project needs to consider two strategy types, namely: Analytical and Prospective (as per Griffin & Page (1996) and Miles & Snow (1999)'s four general strategy types discussed in the literature review in Chapter 2). The analytical strategy will place emphasis on assessing the existing MPLS's (and potentially modifying them), whilst the prospective strategy will cater for the potential new and innovative MPLS's.

### **3.4.1.4 DESIRED VALUE PROPOSITION**

A system that is able to locate missing persons in underground mining environments, in order to ultimately achieve a zero occurrence of fatalities due to employees going missing.

### **3.4.1.5 KEY STAKEHOLDERS**

The key stakeholders that will either be involved in the project (or need to be considered) are as follows (apart from the MHSC and the MRRC):

- Underground coal, narrow tabular and massive mine champions
- Underground coal, narrow tabular and massive mines South Africa
- Labour unions
- Government
- Current MPLS manufacturers

The mine champions will be involved in the project on an internal level, whereas the rest of the underground coal, narrow tabular and massive mines in South Africa will be involved externally. Labour unions' involvement will be critical in determining what the implementation challenges will be (from an employee perspective), and how these challenges could be overcome. Government will play a key role in terms of advising on any regulatory or legal constraints.

### **3.4.1.6 METRICS AND GATE CRITERIA**

Whereas the Stage-Gate model generally considers commercial viability as a key metric (with associated performance benchmarks), this is not the case with the MPLS project. The aim is not to gain direct financial value from a future fit-for-purpose MPLS. The aim is rather to gain value in the form of preventing fatalities in underground mines in South Africa. Thus, the main key metric (and associated performance benchmarks) should revolve around how effectively the MPLS can prevent fatalities. Based on this main metric, the gate criteria of the MPLS project should revolve around both technical feasibility and strategic alignment, and should exclude financial and commercial criteria.

### **3.4.1.7 MANAGEMENT APPROACH**

The project management of the MPLS project will be the shared responsibility of both the MHSC and MRRC. The MRRC will manage the project from a technical research and activities perspective, whereas the MHSC will manage the project from a governance perspective. In terms of the management approach with regards to making gate decisions, a review board of sorts should be formed, comprising of key relevant stakeholders (Figure 3.4.1.7).

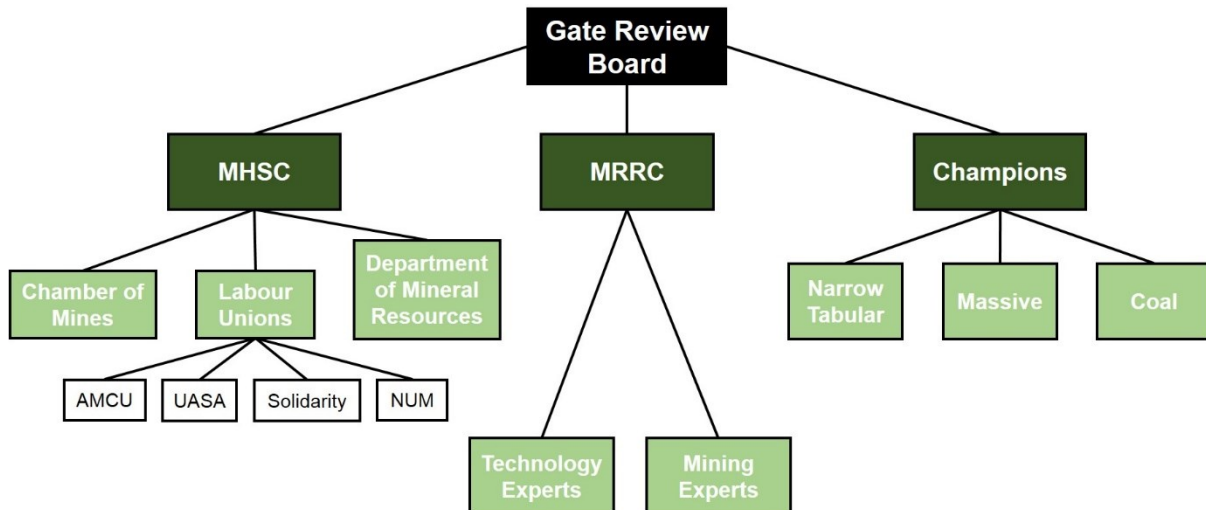


Figure 3.4.1.7: MPLS Gate Review Board Structure

### 3.4.2 PROPOSED STAGE-GATE MODEL (STAGE 0 – GATE 3A) APPLIED TO CASE STUDY

As mentioned previously, the scope of the current MPLS project is limited to the research component of R&D. For purposes of illustrating how the current project scope would be conducted if the proposed Stage-Gate model was used, the milestones of the MPLS project (as per the terms of reference – *Appendix A*) were used as a basis for this illustration. This illustration was limited to the first part of the proposed Stage-Gate model (Stage 0 – Gate 3a).

Table 3.4.2a illustrates how the first part (Stage 0 – Gate 3a) of the proposed Stage-Gate model would be applied to the MPLS project. Table 3.4.2b provides a breakdown of the MPLS milestone activities (as they appeared in the original MRRC tender proposal submission to the MHSC). It must be noted that Table 3.4.2a and Table 3.4.2b should be viewed in conjunction with one another, as Table 3.4.2b describes the milestone activities visualised in Table 3.4.2a.





**Table 3.4.2b: Missing Person Locator System Milestone Activities Breakdown**

Milestone	Milestone Activities
1. Project Initiation	1.1 Determine collaborator alignment ( <i>not from original MRRC tender proposal for MPLS project</i> )
	1.2 Formulate new value strategy (NVS) and prepare proposal ( <i>not from original MRRC tender proposal for MPLS project</i> )
2. Conduct a Literature Review of missing person locator systems used in the mining industry locally and internationally	2.1 Conduct Literature Review of missing person locator systems used/in development in the South African Mining Industry.
	2.2 Conduct Literature Review of missing person locator systems used/in development in the International Mining Industry.
	2.3 Conduct Literature Review of missing person locator systems used in other relevant industries.
	2.4 Conduct Literature Review on relevant technological developments in terms of missing person locator system components.
3. Develop a comprehensive set of scenarios where personnel location systems will be critical	3.1 Conduct Interviews with SA mines and manufacturers to determine why they implemented/want to implement the system.
	3.2 Conduct Literature Review on DMR accident statistics and local case studies, identifying root causes of why personnel went missing.
	3.3 Conduct Literature Review on international accident statistics and case studies, identifying root causes of why personnel went missing.
	3.4 Develop scenarios where a personnel location system will be critical.
	3.5 Categorise scenarios according to mining method and commodity.
4. Generic requirement list for a missing person locator system	4.1 Develop a generic requirement list for the ideal missing personnel locator system.
	4.2 Perform What-If analysis on requirements.
	4.3 Determine possible effects of not adhering to individual requirements.
	4.4 Assign weightings to each requirement, and rank from highest to lowest.
	4.5 Conduct a labour union workshop to obtain feedback on requirements developed
	4.6 Conduct an industry workshop to obtain feedback on requirements developed
	4.7 Modify requirements
5. Evaluate the effectiveness of current personnel location systems against the generic requirements	5.1 Evaluation of currently available systems against generic requirements for the ideal system.
	5.2 Conduct gap analysis of the actual systems vs. ideal system.
	5.3 Rank systems performance against actual from highest weighted score to lowest weighted score.
	5.4 Categorise according to mining method and commodity.
	5.5 Conduct an industry and manufacturer workshop to obtain feedback on evaluation
	5.6 Modify evaluation
6. Recommendations on technology that could be commercially available and fit for purpose	6.1 Refine a means of accurately locating (to a certain degree) personnel without any major infrastructure upgrades.
	6.2 Recommend on what infrastructure should be upgraded first.
	6.3 Make recommendations on technology and systems which could be commercially available and fit for purpose.
	6.4 Conduct industry, labour union and manufacturer workshop to obtain feedback on recommendations
	6.5 Modify recommendations

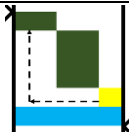
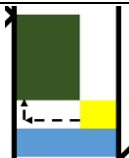
**Table 3.4.2b (continued): Missing Person Locator System Milestone Activities Breakdown**

Milestone	Milestone Activities
<i>7. Research and development programme proposals to close the outstanding gaps between generic requirements and current systems</i>	7.1 Compile list of broad gaps between the current systems/technologies and the ideal system.
	7.2 Identify key focus areas for future research and development.
	7.3 Conduct workshop on key focus areas in order to isolate the most critical areas.
	7.4 Modify key focus areas
	7.5 Write research and development programme proposals on the critical focus areas.

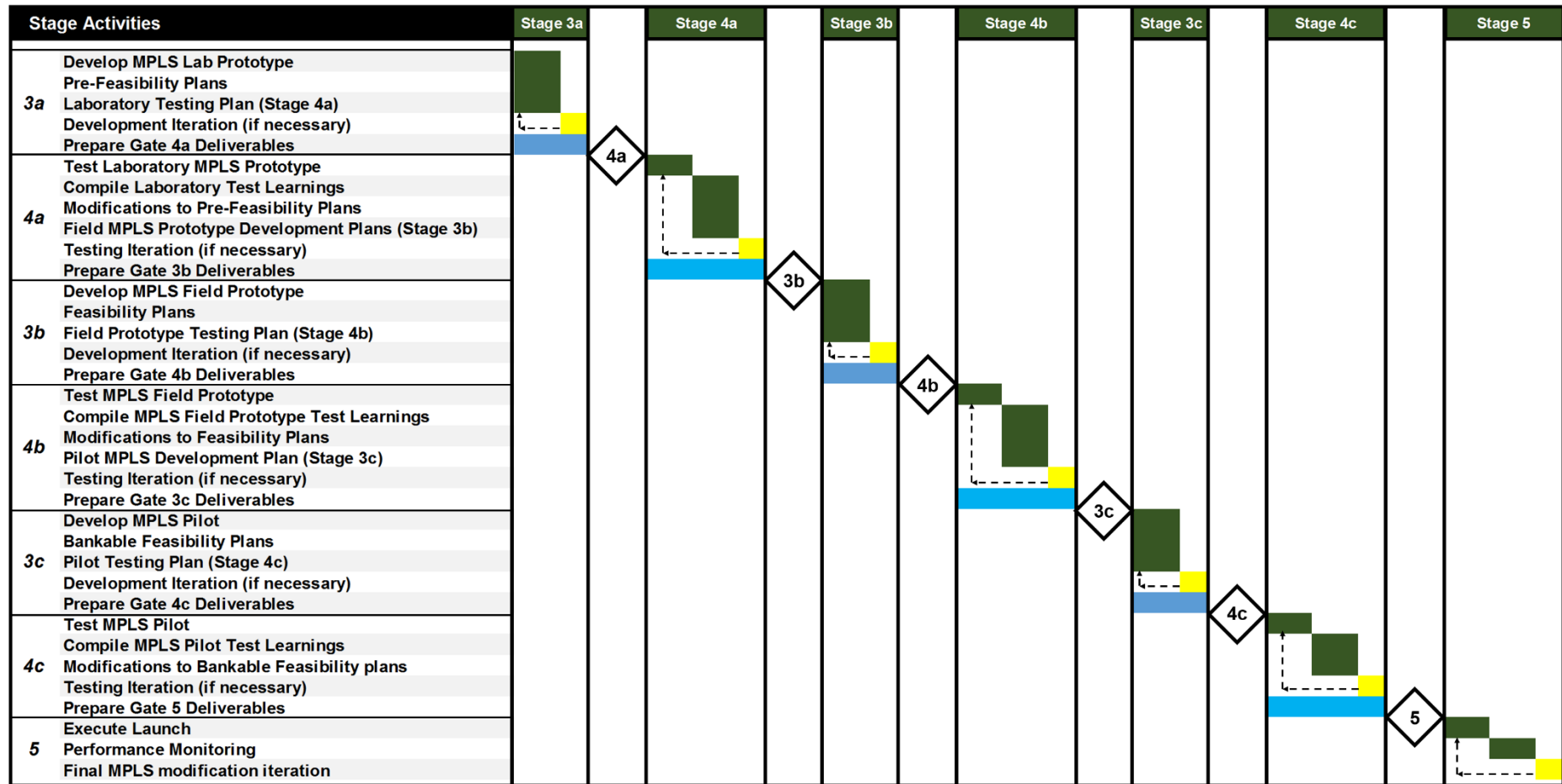
**3.4.3 PROPOSED STAGE-GATE MODEL (STAGE 3A – STAGE 5) APPLIED TO CASE STUDY**

In terms of the second part of the proposed Stage-Gate model (Stage 3a – Stage 5), a more general approach was taken in order to illustrate how the model would be applied to the eventual development and testing of a MPLS. Table 3.4.3a provides descriptions for selected terms used in this illustration, which should be used to enhance understanding of the case-study illustration of the in Table 3.4.3b.

**Table 3.4.3a: Description of selected Terms used in Table 3.4.3b**

Term Used	Description
<i>Pre-Feasibility Plans</i>	<ul style="list-style-type: none"> <li>Technical Pre-Feasibility (will the MPLS function?)</li> <li>Operational Pre-Feasibility (will the MPLS function in the implementation environment?)</li> <li>Implementation Pre-Feasibility (will the MPLS be implementable?)</li> </ul>
<i>Feasibility Plans</i>	<ul style="list-style-type: none"> <li>Technical Feasibility</li> <li>Operational Feasibility</li> <li>Implementation Feasibility</li> </ul>
<i>Bankable Feasibility Plans</i>	<ul style="list-style-type: none"> <li>Bankable Technical Feasibility</li> <li>Bankable Operational Feasibility</li> <li>Bankable Implementation Feasibility</li> </ul>
<i>Prepare Gate Deliverable</i>	Refers to documenting the required gate deliverables throughout a stage, such that succeeding gate decisions are not delayed
<i>Development Iteration</i>	 <p>Development iteration blocks (in yellow) serve the purpose of illustrating the ability to perform spiral/iterative development within a development stage. This is in the case of an unsatisfactory development attempt, where the development may require iteration</p>
<i>Testing Iteration</i>	 <p>Testing iteration blocks (in yellow) serve the purpose of illustrating the ability to perform spiral/iterative testing within a testing stage. This is in the case of inconclusive test results, where the design of the test may require iteration</p>

**Table 3.4.3b: Proposed Stage-Gate Model (Stage 3a – Stage 5) MPLS Case Study Illustration**



### 3.4.4 1<sup>ST</sup> GENERATION PHASE-REVIEW PROCESS APPLIED TO CASE STUDY

In order to comparatively demonstrate the potential value of the proposed Stage-Gate model, the traditional 1<sup>st</sup> Generation Phase-Review Process (as discussed in Chapter 1, Figure 1.4a) was also used to illustrate how the MPLS project would be conducted. The research component of the MPLS project (Milestones 1 – 7, as per the TOR), as well as the potential future MPLS development, are illustrated through the 4-step Phase-Review Process (Table 3.4.4).

**Table 3.4.4: 1st Generation Phase Review Process: MPLS Case Study Illustration**

Activities	Concept Phase		Definition		Implementation		Manufacturing
1 Milestone 1	█						
2 Milestone 2	█						
3 Milestone 3	█						
4 Milestone 4	█						
5 Milestone 5	█						
6 Milestone 6	█						
7 Milestone 7	█	Go / No-Go					
8 Technical Pre-Feasibility			█				
9 Technical Feasibility			█				
10 Bankable Technical Feasibility			█				
11 Operational/Implementation Pre-Feasibility					█		
12 Operational/Implementation Feasibility					█		
13 Bankable Operational/Implementation Feasibility					█		
14 Manufacturing Pre-Feasibility						█	
15 Manufacturing Feasibility						█	
16 Bankable Manufacturing Feasibility							█



### LIST OF REFERENCES: CHAPTER 3

Mine Health & Safety Council. 2016. *About the MHSC*. [Online]. Available: <http://www.mhsc.org.za/about-mhsc/vision-mission-and-values>. [Cited 23 November 2016].

University of Pretoria. 2016. *Mining Resilience Research Centre*. [Online]. Available: <http://www.universityofpretoria.co.za/en/mining-engineering/article/2164003/mining-resilience-research-institute-mrri>. [Cited 23 November 2016].

## CHAPTER 4: CONCLUSIONS

From the results obtained in Chapter 3, and the objectives stated in Chapter 1, Chapter 4 concludes on the findings of the study. Figure 4 displays an overview of the conclusions made in Chapter 4.

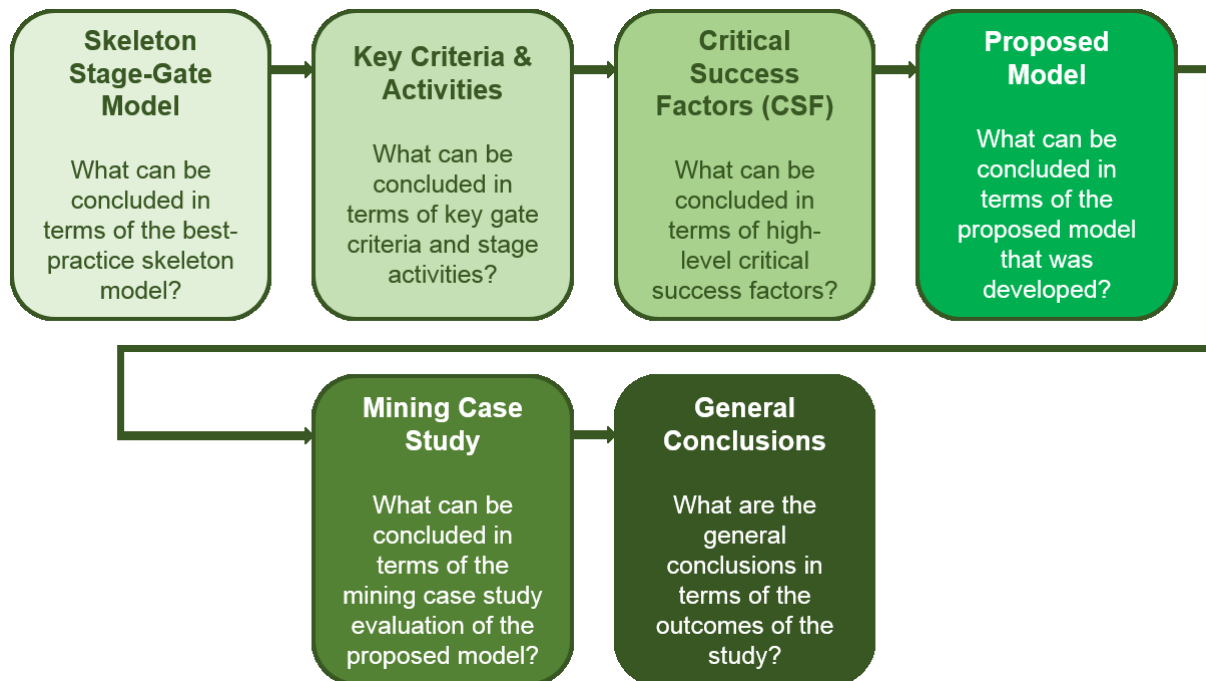


Figure 4: Chapter 4 Overview



## 4.1 STAGE-GATE MODEL SKELETON

It can be concluded that the best-practice Stage-Gate model skeleton comprises of six distinct stages and five gates. Although naming conventions for the different stages and gates differ between different literature sources, in essence, their purposes are the same. The skeleton model was derived in order to focus further literature research into the individual stages and gates. This approach proved to be successful, and provided the necessary structure for the further literature review into key gate criteria, stage activities and critical success factors.

## 4.2 KEY STAGE-GATE CRITERIA & ACTIVITIES

In terms of the key Stage-Gate gate criteria and stage activities, the following conclusions can be made:

- The gate criteria typically used throughout the Stage-Gate model comprises of four main criteria groups, namely: Strategic criteria, Market criteria, Technical criteria and financial criteria. These groups further comprise of numerous sub-criteria, which differ depending on the nature of the R&D being conducted.
- In essence, the different gates in the Stage-Gate model make use of the same set of criteria throughout. However, each gate is different in terms of the level of confidence of gate deliverables/inputs required to meet (or not meet) the criteria. The level of confidence of gate deliverables/inputs increases chronologically, and thus it becomes more difficult to meet the criteria at later gates in the model.
- The stage activities performed in the Stage-Gate model are inter-related to the gate criteria. Each activity performed produces certain deliverables, and these deliverables serve as the required inputs in order to assess gate criteria.

## 4.3 HIGH-LEVEL CRITICAL SUCCESS FACTORS (CSF)

It can be concluded that the CSF's of the Stage-Gate model are essential in the overall success of applying the model for R&D purposes in the mining industry:

- The formulation of a sound new value strategy (NVS) is particularly important in the mining context. The NVS shapes the rest of the Stage-Gate model, and it is in the formulation of the NVS where all the unique mining considerations will be incorporated.
- To ensure efficiency when applying the Stage-Gate model, stage activities should be performed in parallel (where possible) by multi-disciplinary and cross-functional teams. The outcomes of these activities should be subjected to sound decision-making at succeeding gates, based on gate criteria (and corresponding levels of confidence) defined in the NVS.
- Involving potential customers throughout the R&D effort is critically important. Potential customers provide insights and feedback on the work being conducted, which ensures that any proposed value propositions align with customer needs and wants throughout.
- Performing iterative/spiral development and testing is essential in terms of the effectiveness and efficiency of the Stage-Gate model. If performed correctly, the iterative/spiral development and testing of new value propositions will reduce resource waste, and ultimately will increase the probability of developing a successful new value proposition.





- Embracing failure as a result requires a mind-set change. This correlates with “disproving value rather than proving value”. In order to obtain the most successful (and un-biased) results during testing (or feedback sessions), tests/feedback sessions should be designed such that they attempt to disprove value hypotheses. The earlier value hypotheses could be disproved, the faster a new solution can be sought.
- Post-launch monitoring of new value propositions in the market should not be underestimated. Continuous improvement should be performed on value propositions released into the market, to ensure that they are performing as expected. If this is not the case, post-launch monitoring allows for modifications to be made to these value propositions.

#### 4.4 PROPOSED MODEL

It can be concluded that the proposed Stage-Gate model developed provides a sound basis for conducting R&D in the mining industry. The proposed model is based on best-practice Stage-Gate model stages and gates, as well as overall Stage-Gate CSF's. The proposed model visually illustrates the parallelism of the broad activity groups for each stage, and depicts the spiral/iterative nature of the development and testing stages.

#### 4.5 PROPOSED MODEL: CASE STUDY EVALUATION

In terms of the Missing Person Locator System (MPLS) case study evaluation of the proposed Stage-Gate model, the following can be concluded:

- Before formulating the NVS, strategic alignment between the Mine Health and Safety Council (MHSC) and the Mining Resilience Research Centre (MRRC) was confirmed. This showed that, in principle, the MPLS project aligned with both R&D collaborators' strategies, and that the two collaborators should commence towards formulating the NVS.
- The formulation of the NVS for the MPLS project illustrated that the NVS is of critical importance in terms of planning how the project will be conducted. The NVS formed the scope of the project, through:
  - Identifying the intended customer segments (as well as their respective priority levels), in alignment with the project terms of reference (TOR);
  - Identifying the strategy types as prospective (searching for new, innovative value propositions) and analytical (assessing existing value propositions in bid for incremental improvements), in alignment with the project TOR ;
  - Defining the desired value proposition as “A system that is able to locate missing persons in underground mining environments, in order to ultimately achieve a zero occurrence of fatalities due to employees going missing”; in alignment with the overall objective of the project (as per the TOR);
  - Identifying the key stakeholders to be involved in the project (internal and external);
  - Defining the key performance metric (not financially-driven, but rather value-driven in terms of increased safety) and gate criteria groups (excluding financial and market/commercial criteria); and
  - Defining the proposed management approach to be used in conducting the project.

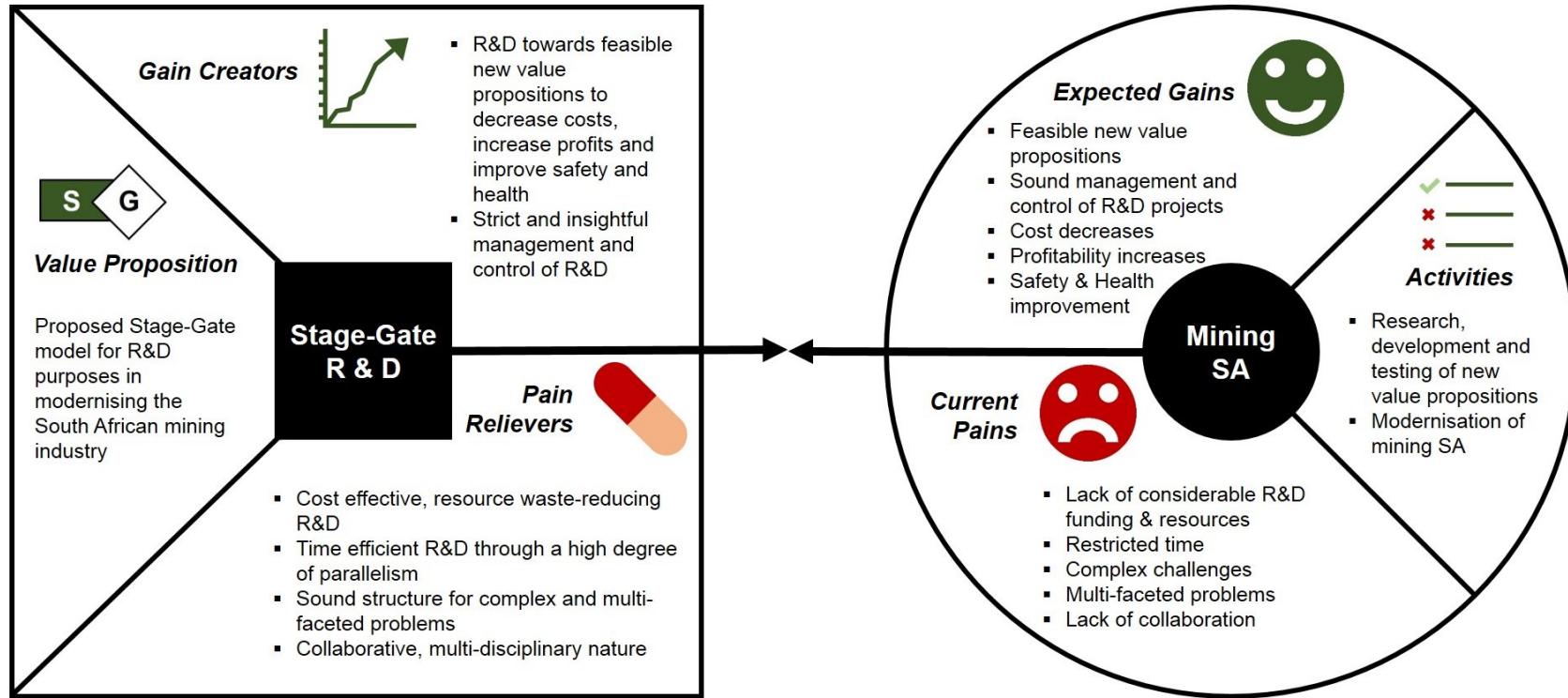


- Although the NVS for the MPLS project was formulated on a high-level basis, it provided enough information such that the remainder of the proposed Stage-Gate model could be illustrated at hand of the MPLS case study.
- In order to illustrate how the expected milestones of the MPLS project (as per the TOR) would be achieved if the proposed Stage-Gate model were applied, the first part of the proposed model (Stage 0 – Gate 3a) was used. Expected milestones (and their respective sub-activities) were chronologically mapped onto the first part of the proposed Stage-Gate model, which demonstrated how the project would be conducted if the proposed model were applied.
- As per the MPLS TOR, the final expected outcome of the project is to develop R&D programme proposals for the development of a fit-for-purpose MPLS for the SA mining industry. In order to illustrate how any given MPLS R&D programme would be conducted if the proposed Stage-Gate model were applied, the second part of the proposed model (Stage 3a – Stage 5) was used. From this, the following can be concluded:
  - The proposed Stage-Gate model provides the necessary structure for a somewhat ill-structured set of activities.
  - The eventual development and testing of new/modified MPLS's will need to be iterative (and sometimes, repetitive) in nature, in order to ensure that the most effective and efficient system is developed. The use of the proposed Stage-Gate model in this regard will add value, in the sense that it will prevent any unnecessary wastage of resources. The various gates in the development and testing spiral in the proposed model serve to control resource allocation, through only allocating further resources if sound justification (and factual evidence) exists.
  - In parallel with the actual development and testing activities, the proposed Stage-Gate model illustrated which additional activities needed to be performed in order to meet gate criteria. These activities included technical feasibility, operational feasibility and implementation feasibility of the MPLS, at increasing levels of confidence (pre-feasibility, feasibility and bankable feasibility).
  - In the mining context, these additional activities will be critical in the successful roll-out of a fit-for-purpose MPLS for underground mines in South Africa. Arguably, the operational and implementation feasibilities of a MPLS will be more important than the technical feasibility. A MPLS may be technically sound, but if it is not developed with implementation and day-to-day operation in mind, it will pose the risk of not yielding the desired results. The proposed Stage-Gate model ensures that these activities are considered continuously, and thus (if used correctly) will mitigate this risk.

## 4.6 GENERAL CONCLUSIONS

In general, it can be concluded that the general Stage-Gate model approach, and the proposed mining Stage-Gate model could add value in terms of R&D in the mining industry. This potential value is illustrated (Figure 4.6) by making use of the Value Proposition Canvas (Osterwalder et al., 2014)<sup>137</sup>, with the broad value proposition (Stage-Gate R&D) on the left, and the broad customer segment (Mining South Africa) on the right.

<sup>137</sup> Osterwalder, A. et al. 2014. *Value Proposition Design*. New Jersey: John Wiley & Sons.



**Figure 4.6: General Conclusions: Value Proposition Canvas Mapping**

Figure 4.6 shows that the application of the proposed Stage-Gate model for R&D purposes in the South African mining industry (SAMI) has several potential benefits. The model and associated concepts has the potential to create the SAMI's expected gains; it has the potential to relieve the current SAMI pains; and it serves as an insightful and well-designed process to conduct the required SAMI R&D activities.

In support of this, consider a comparison between the MPLS case study for both the traditional/phase review process, and the proposed Staged Gate model. The comparison (Table 4.6) assess the use of both, at the hand of the SA Mining "Pains" shown in Figure 4.6.

**Table 4.6: Traditional Phase Review Process vs. Proposed Stage Gate Model: Mining R&D Pains**

Pains	Traditional (e.g. Phase-Review Process)		Proposed Stage-Gate Model	
	<i>General</i>	<i>MPLS Case Study</i>	<i>General</i>	<i>MPLS Case Study</i>
Lack of considerable R&D funding and resources	<ul style="list-style-type: none"> <li>Potential for wasteful resource spending due to extended intervals between spending decisions, especially during capital intensive development.</li> <li>“Pre-phase funding”</li> </ul>	<ul style="list-style-type: none"> <li>Higher probability of resource wastage</li> <li>Spending decisions (MPLS case study, Milestones 1 – 7):</li> <li>Start-up and Milestone 7.</li> </ul>	<ul style="list-style-type: none"> <li>Model provides sound platform for resource risk management and mitigation.</li> <li>Resource spending is directly correlated to value proposition certainty.</li> <li>Thus, wasteful resource spending is reduced, especially during capital intensive development</li> <li>“Funding-on-the-go”</li> </ul>	<ul style="list-style-type: none"> <li>Lower probability of resource wastage</li> <li>Spending decisions (MPLS case study, Milestones 1 – 7):</li> <li>Start-up, Milestones 2, 4 and 7.</li> </ul>
Restricted time	<ul style="list-style-type: none"> <li>Low degree of parallelism of activities and phases</li> <li>Thus not as time efficient as possible</li> </ul>	Likely to be completed slower than Stage-Gate model	<ul style="list-style-type: none"> <li>High degree of parallelism of activities and stages</li> <li>Thus, could be more time efficient than traditional process.</li> </ul>	Potential to be completed faster than phase-review process
Complex, multi-faceted challenges	<ul style="list-style-type: none"> <li>Activities and phases are performed using a “silo” approach</li> <li>Involvement of potential customers during testing phase</li> </ul>	Lower probability of achieving satisfactory expected outcomes (Milestones 1 – 7), within time and budget	<ul style="list-style-type: none"> <li>Parallel activities with multi-disciplinary collaborative team approach</li> <li>Involvement of potential customers from the start</li> <li>Involvement of key stakeholders from the start</li> </ul>	Higher probability of achieving satisfactory expected outcomes (Milestones 1 – 7), within time and budget
Lack of collaboration	Collaboration is possible, but process is not designed to accommodate a high degree of collaboration	Less opportunity for collaboration to take place	Model provides sound platform for a high degree of collaboration (internal and external) to take place.	More opportunity for collaboration to take place

Table 4.6 shows that, in terms of the Mining SA “Pains”, the proposed Stage-Gate model has the potential to relieve the pains better than the traditional/phase-review process would. The proposed model (and general Stage-Gate concepts and approach) thus has the potential to reduce resource wastage; deliver new value propositions faster; solve complex and multi-faceted problems more effectively; and provides a better platform for collaboration to take place (in comparison to the traditional/phase-review process).



## LIST OF REFERENCES: CHAPTER 4

Osterwalder, A. et al. 2014. *Value Proposition Design*. New Jersey: John Wiley & Sons.

## CHAPTER 5: RECOMMENDATIONS

From the results obtained in Chapter 3, the objectives stated in Chapter 1 and the conclusions made in Chapter 4, Chapter 5 makes recommendations in terms of the findings of the study. Figure 5 displays an overview of the recommendations made in Chapter 5.

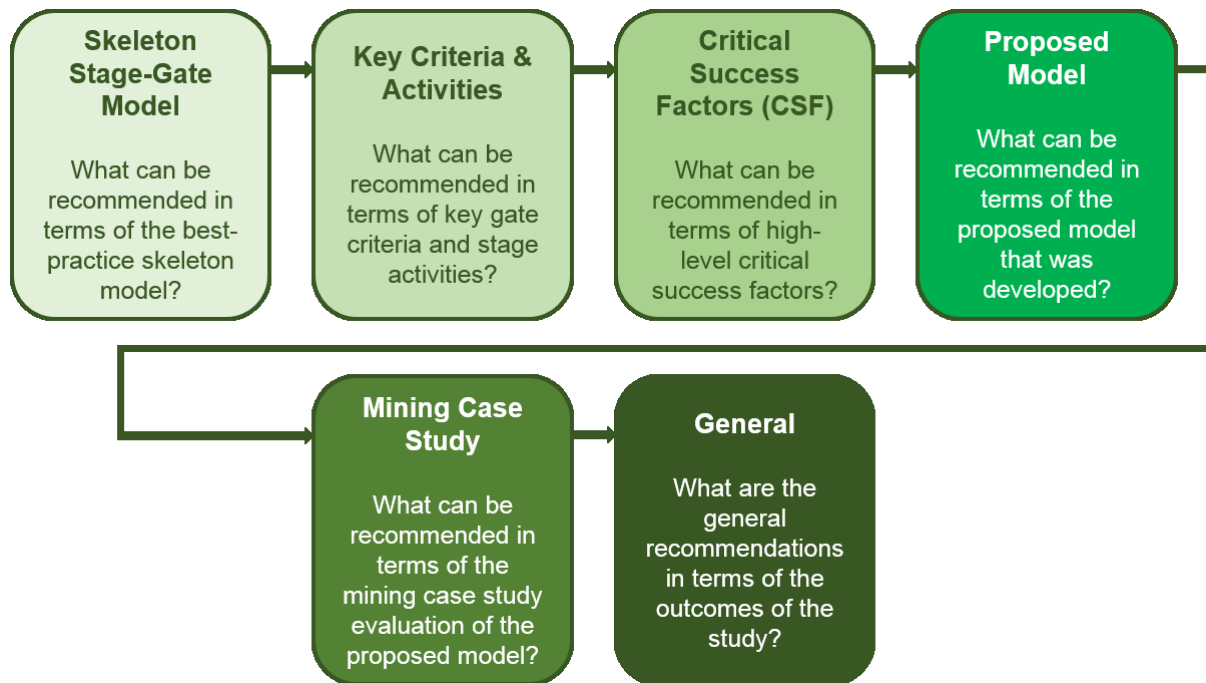


Figure 5: Chapter 5: Overview



## 5.1 STAGE-GATE MODEL SKELETON

It is recommended that the basic Stage-Gate model and skeleton be understood and used as a sound knowledge basis, in the application of the model and concepts for R&D purposes in the SAMI.

## 5.2 KEY STAGE-GATE CRITERIA & ACTIVITIES

It is recommended that the key gate criteria main groups (and associated sub-criteria) be used to formulate fit-for-purpose criteria for R&D efforts in the mining industry. It is further recommended that required levels of confidence be assigned to criteria at the various gates, and that stage activities should be designed such that they produce the correct deliverables for corresponding gates.

## 5.3 HIGH-LEVEL CRITICAL SUCCESS FACTORS (CSF)

It is recommended that all the CSF's discussed should be considered when applying the Stage-Gate model for R&D purposes in the SAMI.

## 5.4 PROPOSED MODEL

It is recommended that the proposed Stage-Gate model be used as a starting point in applying the Stage-Gate model and concepts to R&D in SAMI. The proposed model is based on best-practices and simplifies some of the more abstract Stage-Gate concepts, and should thus be seen (and used) as a sound basis for SAMI R&D.

## 5.5 PROPOSED MODEL: CASE STUDY EVALUATION

It is recommended that the latter part of the proposed Stage-Gate model (Stage 3a – Stage 5) be used for the eventual development and testing of an effective and efficient MPLS for the SAMI.

## 5.6 GENERAL RECOMMENDATIONS

In general, it is recommended that the outcomes of this study be considered for R&D in the SAMI, in order to more effectively and efficiently conduct R&D in the SAMI (and ultimately modernise the SAMI).





## CHAPTER 6: SUGGESTIONS FOR FURTHER WORK

The suggestions for further work (aimed at improving the outcomes of the study), are as follows:

- Stage 0 and Gate 1 need to be refined. This could be achieved through conducting a number of workshops to generate new ideas, based on hypothetical new value strategies (including Gate 1 criteria). The subsequent assessment of the ideas at Gate 1 could produce key learnings, necessary for the refinement. It is thus suggested that the workshops be conducted, in order to test Stage 0 and Gate 1.
- The first portion of the proposed Stage-Gate model (Stage 0 – Stage 3a) needs to be refined. This will be possible through experiential learning. It is thus suggested that the proposed model be applied to a research project in the SAMI, in order to test the model (and iteratively refine the model itself).
- The second portion of the proposed Stage-Gate model (Stage 3a – Stage 5) needs to be refined. This will be possible through experiential learning. It is thus suggested that the first and second portions of the proposed model be applied to a R&D project in the SAMI, in order to test the model (and iteratively refine the model itself).



## APPENDICES

### APPENDIX A: MISSING PERSON LOCATOR SYSTEM PROJECT TERMS OF REFERENCE (TOR)

#### Terms of Reference to Undertake Research

##### REQUEST FOR A PROPOSAL TO UNDERTAKE RESEARCH PROJECT CoE 1507: "MISSING PERSON LOCATOR SYSTEM"

#### 1. BACKGROUND

In underground mining environments, it is possible for an employee to become incapacitated or disoriented due to seismic events, gas accumulation, underground fires, exhaustion, inexperience or a combination thereof. It is important that rescue services are able to ascertain the employee's location as soon as possible, in order to recover the employee in the best possible condition.

The purpose of this project would be to search for and understand the different technologies available to enable person location. In conjunction with this a roadmap needs to be developed that differentiates different shaft communications infrastructure capabilities to determine operational readiness relative to the identified technologies. The idea would be to be able to determine what a given operation can do to enable a degree of ability to locate people and then also to understand what needs to be altered from an infrastructure perspective to upgrade that ability. It is likely that during the process that areas of technology development may be identified which too could form part of the project scope. Interacting with mining companies and manufacturers that have already worked towards solutions will be of importance as a reasonable degree of technical understanding already exists in this field and would prevent unnecessary delays.

A specific example is the system that Sibanye Gold, in conjunction with Enterprise Intelligence, is in the process of developing as a standalone, RFID based, personnel locating system, which is independent of any additional infrastructure (see picture above). The system consists of active RFID tags, retrofitted to existing cap lamp battery packs as well as a handheld scanning device that is capable of isolating a single tag number and directing search and rescue personnel to the location of that tag. When searching for a specific tag, all surrounding tags function as signal repeaters extending the effective search range of the system

The following stakeholders and documents may be consulted:

- a) Sibanye Gold
- b) Enterprise Intelligence
- c) Other mining companies and suppliers developing and testing personnel tracking devices.

#### 2. OBJECTIVES OF THE TOPIC

To achieve zero occurrences of fatalities as a result of employees becoming lost underground.

#### 3. SCOPE OF WORK

1. Conduct a literature review of missing persons locator systems used in the mining industry locally and internationally.
2. Develop a comprehensive set of scenarios where personnel location systems will be critical.

TF



## APPENDIX A: MISSING PERSON LOCATOR SYSTEM PROJECT TERMS OF REFERENCE (TOR) (continued)

### Terms of Reference to Undertake Research

3. Using the scenarios and risk based methods determine the generic requirements for personnel location systems including employee involvement after consultation with suppliers and mines testing such systems.
4. Evaluate the effectiveness of current personnel location systems against the generic requirements.
5. In parallel with the above, refine a means, independent of additional network infrastructure, of accurately locating lost or incapacitated personnel underground.
6. Identify broad gaps between the requirements and current technologies and prepare a research and development programme proposals to close these gaps.

### 4. OUTPUTS

NB This project will be over 24 months as per the following:

- a) Month 3 – Report literature review of missing persons locator systems used in the mining industry locally and internationally.
- b) Month 3 - Broadly representative set of scenarios for South African mines that requires Personnel Location Systems.
- c) Month 6 – Generic requirement list for Personnel Location Systems based upon the scenarios, a risk based approach and any concerns from stakeholders
- d) Month 12 – Evaluation of Personnel Location Systems against user requirements based on different commodities and mining methods.
- e) Month 18 – Recommend technology that could be commercially available and fit for purpose.
- f) Month 24 – Research and development programme proposals to close the outstanding gaps between user requirements and technologies available by that time.

### 5. MINIMUM REQUIREMENTS

In carrying out this work the service provider must be able to demonstrate how they are going to promote:

1. Research capacity building (in terms of including smaller and previously disadvantaged institutions).
2. Skills transfer to historically disadvantaged institutions.
3. Skills transfer to historically disadvantaged individuals.
4. Skills transfer to women.

### 6. APPLICABILITY

All South African underground mines.

### 7. PROJECT MANAGEMENT



## APPENDIX A: MISSING PERSON LOCATOR SYSTEM PROJECT TERMS OF REFERENCE (TOR) (continued)

### Terms of Reference to Undertake Research

The winning bidder will be expected to report as and when required by to MHSC on the progress of the project.

#### 8. EVALUATION CRITERIA

Evaluation will be done in line with the PPPFA and its Regulation 2011. The bid is based on a 90/10 principle

##### 8.1. FUNCTIONAL EVALUATION CRITERIA

No.	CRITERIA	WEIGHT
1.	Examples of relevant projects undertaken. Evidence of work done must be supplied for evaluation purpose. Two or more projects =5 One project =3 No projects =1	20
2.	Demonstrate how you will promote:  1. Research capacity building (in terms of including smaller and previously disadvantaged institutions). 2. Skills transfer to historically disadvantaged institutions. 3. Skills transfer to historically disadvantaged individuals. 4. Skills transfer to women.  Fully addressed all requirements listed above= 5 Partially addressed some of the requirements listed above = 3 None = 1	30
3.	Does the proposal provide a defined methodology with clear timelines and milestones? Yes=5 Partially=3 No=1	11
4.	Will the proposed methodology deliver on the outcomes? Yes=5 Partially=3 No=1	11
5.	Has the researcher substantiated the timelines? Yes=5 Partially=3 No=1	11
6.	Has the researcher addressed the expected outcomes of the project? Yes=5 Partially=3 No=1	11
7.	Has the proposal template that was provided by the MHSC been correctly completed? Yes=5 Partially=3 No=1	6

Bidders must meet a minimum of 70% threshold in order to qualify for further evaluation on price.