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Proposing a Framework for New Product Development in A Research and Development Manufacturing Environment

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Abstract

New Product Development (NPD) is imperative in the manufacturing sector to exploit the competitive advantage of new products within the South African and global markets. Transnet Research & Development, a State-Owned Enterprise, has been experiencing challenges in commercialising a large portion of NPD products. This study investigated the relationship between NPD best practices and those at Transnet's R&D. The purpose was to distinguish the level of NPD best practices implemented by the company, the specific critical success and failure factors, the process gaps within the NPD process, and to conclusively recommend a suitable NPD model. The significance of the study is to evaluate projects within the Transnet R&D portfolio. The benefits of successfully achieving the research objectives will improve NPD performance at the company's R&D and add to the theory of NPD of physical products, especially in the African market. The benefits are not only academic but, when implemented in the respective company, will yield product success and marginal profits.

Keywords
New product development, Research and Development.

1. Introduction
Manufacturing is seen as a critical success factor in growing South Africa's economy by creating new sustainable developments, leading to a higher production level of manufacturing. The importance of the manufacturing sector to elevate the South African economy is addressed in the government's Industrial Policy Action Plan (IPAP), which

diversifies the growth of various industries and services that contribute to the economy's overall growth. (Barnes and Hons 2018).

NPD is essential in the manufacturing sector to exploit the competitive advantage of new products and technologies. The intense global competition, rapid technology advancements, and diversification in the global market force companies to continuously adapt and invest in NPD to increase profits, remain market-relevant, and survive (Owens and Cooper 2001)**.** Therefore, the development of NPD initiatives and efforts is a critical factor in competitive advantage (Owens and Cooper 2001).

The infant stages of NPD are often initiated within the company's R&D department. R&D projects are diverse, ranging from information technologies, basic research, applied research, operational improvements, and product development with various magnitudes of outcomes (Nagesh and Thomas 2015). The projects destined for new product development should produce a product that meets the customer's needs within a scheduled cost and time frame. Lewis (2007) describes a project as a temporary venture embarked on to produce a unique product, service, or result.

Critical success factors (CSF) and critical failure factors (CFF) are investigated in companies to distinguish the reasons behind the success and failures of projects embarked on, which has yielded a vast number of variables (Chan 2004). Project success factors cannot be implemented in the same manner for every project because each differs in its environment. Thus, the range of different variables should be categorised to classify projects (Dvir 1998). NPD models and best practices were developed, but the implementation into industry-specific environments is still minimal. Kahn et al. (2012) and Murray et al. (2002) reiterate that best practices vary from company to company, evolving periodically and with changes in the marketplace. Hence, there is no rigid procedure for successful new product development, but different routes to the same end goal (Khan et al. 2012).

The research will be structured to answer the following questions:
1. What is the existing NPD framework or model in the R&D department?
2. What are the success and failure factors of new products in the R&D department?
3. What are the process gaps and the required improvements on the different execution levels?

2. Literature Review

Ullman (2009) defines product development as creating products with new or variable characteristics that offer new or additional benefits to the customer. Product development may involve modifying an existing product or designing a completely new product that satisfies a newly defined customer want or market. Smith and Morrow (1999) define product development as the process of converting an idea, market needs, or client requirements into the information from which a product or technical system can be produced. The need to establish a winning recipe for successful NPD has resulted in a vast amount of research published by different researchers who approached the study from strategic, operational, and tactical levels. Research shows various types of NPD models, and recommendations are established for industry and project-specific types. However, many adaptations and tweaks are required to be implemented successfully. No model outperforms another, but the poor implementation of the incorrect model may lead to failure.

NPD is a set of activities companies execute when developing and launching new products (Bhuiyan 2011). A new product (new to the world or modifications to an existing product) that is introduced into the market evolves over a sequence of activities through stages, with the beginning being an idea or concept that is evaluated, developed, tested, and launched into the market (Booz, Allen and Hamilton 1982).

2.1 New Product Development Models

a. Different models

The Stage-Gate Model was developed in the mid-1980s and has been adopted by many manufacturers in both Business-to-Business (B2B) and Business-to-Customer (B2C) industries (Cooper and Sommer 2016). The general process of the Stage-Gate approach involves breaking down the idea-to-launch process into five or six stages from Idea to Product Launch. In addition, the stringent gates allow for proper risk management to be implemented within the product's life cycle. The defining characteristic of the Stage-Gate Model is the Go/No-Go processes for product development. Therefore, assessing the viability of the product moving to the next phase is imperative in ensuring the desired output is achieved. The company employs a Stage-Gate model called the "Project Technical Readiness Assessment" with predetermined criteria to progress to the next phase of the project.

The Agile Model was previously developed and only implemented in the Information Technology (IT) industry. The approach is designed to assist product developers in swiftly creating the correct product by frequently validating the working software with the customers. The Agile approach was introduced to deal with these issues through adaptive planning, evolutionary delivery, a time-boxed iterative approach, and a flexible response to change (Beck 2001). Unlike the Stage-Gate Model, customer engagement is paramount to the success of the Agile Model.

Hybrid models that integrate Stage-Gate and Agile approaches were developed in the interest of companies that produce physical products. The adoption of Agile in the IT industry showed that with appropriate modifications within the Agile model, the hardware R&D department, previously using the Stage-Gate model, incorporated both characteristics to fit their outputs.

The Agile-Stage-Gate approach yields three important positive results for manufacturers (Schmidt et al. 2018):

- *Faster development:* The team is focused, dedicated, and has good communication throughout the project's life cycle. Regular feedback sessions within the team and with customers and end users ensure problems are addressed and resolved quickly. In addition, timeboxed iterations result in teams being highly productive, ensuring adherence to the schedule and yielding improved time to market.
- *Right product, correct customer:* Products are validated by the customers regarding functionality, specifications, operations, and ability as the project advances through the various development stages. Changes are made sooner within the development stages to eradicate the costly process later in the project. Customer confidence also increases with each iteration or demo to verify that the product being developed is desired.
- *Team morale:* Team morale improves with each iteration and customer engagement as the development stages advance with greater confidence. The team is managed with structured outputs within stipulated time schedules and quality. The constant team engagements enhance teamwork and improve team morale.

A recent study by **Rehder et al. (2023)** demonstrates that the hybrid approach effectively leverages the structured control of traditional Stage-Gate methodologies with the flexibility and iterative nature of Agile for physical products. The study highlights that the hybrid model facilitates improved internal communication, more efficient planning and resource allocation, enhanced customer feedback loops and the adaptation for hardware/physical products. **Palsodkar et al. (2023)** discuss the hybrid model as a necessity for physical products, as it allows the strict governance and risk management of Stage-Gate models/gates, but the flexibility of Agile to manage product complexity and respond to market demands.

To bridge the gap between user needs and design outcomes in physical product development, **Granato et al. (2022)** propose the Misalignments User-Designers (MUD) method. This novel hybrid approach integrates elements of both Stage-Gate and Agile methodologies, structured around four key stages: establishing designers' perspectives, collecting users' perspectives, identifying (mis)alignments by comparing these viewpoints, and holding a reflection meeting. The MUD method is strategically applied during experimental NPD phases, including concept testing, prototyping, product testing, and design, recognising these as critical junctures for surfacing and addressing user-designer discrepancies.

b. NPD best practices

Researchers and literature cite many success drivers in successfully implementing NPD factors in companies to establish best practices for NPD success (Adams-Bigelow 2005; Barczak et al. 2009, 2012; Cooper et al. 2002, 2004a, 2004b, 2004c). New product development has various facets and has been delineated across multiple dimensions into which numerous characteristics can be classified (Barczak and Khan, 2012).

The framework across the six themes shapes the best practice studies and PDMA certification standards and portrays NPD practice across six categories. The six themes identified for NPD best practices by Barczak and Khan (2012) include:
Strategy: The defining and planning of research and development, product development, and technology management initiatives for the company to focus on NPD. This includes the identification, prioritisation, selection, and resource support for the respective projects.
Market Research: The application of methodologies and techniques to research and understand customers, competitors, and macro-environmental forces in the marketplace.

Commercialisation: The activities related to the marketing, launch, and post-launch management of new products that stimulate customer adoption and market diffusion.
NPD Process: The implementation of an NPD model to transform the idea concept to launch, encompassing the activities and systems that facilitate knowledge management across projects.
Project Climate: The methods, technologies, and resources for accomplishing product development with intracompany integration at the individual and team levels. This underlies portfolio management, which includes leading, motivating, managing, and structuring individual and team human resources for project outcomes.
Company Culture: The company culture (mindset and efforts) to drive the methods and systems to establish NPD thinking and product development collaborations with external partners, suppliers, and customers.
Metrics and Performance: Criteria for measuring and tracking NPD performance and processes.

c. System engineering (SE) for NPD

The projects developed by Transnet R&D are complex and require the investigation of the technical development phases to ascertain if the practices implemented influence project success. For complex projects, a systems engineering approach is most favourable, similar to the practices utilised by NASA. NASA describes systems engineering as the methodical, multidisciplinary approach for the design, realisation, technical management, operations, and retirement of a system (project). A system is referred to as the integration of different elements that are combined to produce a capability for a specific requirement or need. The elements that are integrated within the system function together to produce the capability. These elements range from hardware, software, equipment, personnel, processes, and procedures, which are integrated to create the capability of a product (Kapurch 2010).

d. Critical Success Factors (CSF) and Critical Failure Factors (CFF)

The best practices within the six dimensions are categorised according to Cooper (2013, 2019), as the success drivers for NPD and a model for assessing the company's NPD performance. Figure 1 illustrates the conceptual framework of evaluating the NPD performance and the link between the success drivers and NPD (project) success. The success drivers are categorised to establish the CSF and CFF on three different levels, namely:

- Tactical/Strategic – Capturing the characteristics of the new product, such as execution best practices and the nature of the product itself.
- Business and Operational Level – Organisational and strategic execution includes business innovation strategy, R&D investment decisions, organisation NPD, climate and culture, and leadership.
- Systems and Methods – The systems and methods (models) the company utilises to manage NPD, such as gating systems and ideation methods.

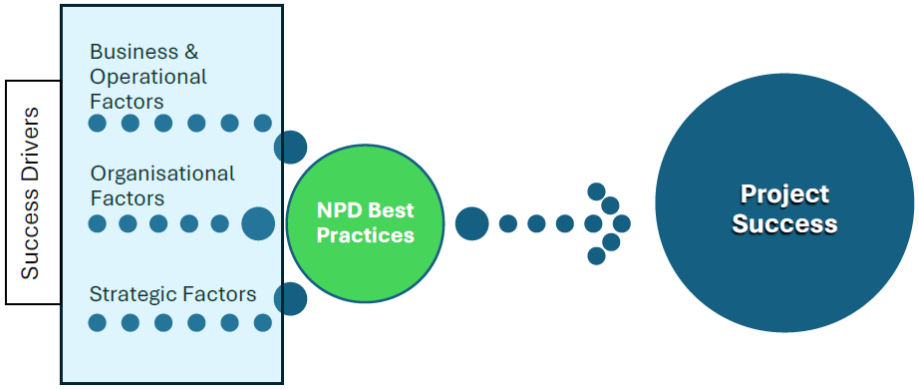

Figure 1. Conceptual Framework - Success Drivers of Project success (Cooper, 2013, 2019)

3. Methods

Following the literature review, the model presented by Cooper (2019) and the themes presented by Barczak and Khan (2012) were established as a suitable base model for the implementation in this research. According to Cooper (2013),

the success drivers include business, organisation, and strategic factors. These factors can further be expanded to the six dimensions for NPD required for overall project success.

a. Success drivers

A system of success drivers enables the effective and efficient creation of NPD. Liberatore and Stylianou (1995) state that most product development ideas fail to become commercialised because of the inappropriate implementation of a structured NPD process. These factors are company-dependent characteristics such as culture, resources, performance metrics, processes, and commercialisation levels (Barczak and Khan 2012). The success drivers are briefly discussed below.

b. Business and Operational Factors

NPD Model

Within this category, the NPD model is defined as the implementation of product development stages and gates for moving products from concept to launch, coupled with those activities and systems that manage of product development process, ownership and adaptability, while poor practices are characterised by the absence of the processes, documentation and management to guide NPD.

Technical Development

The technical development dimension investigates the activities of the technical aspects of the project, including the creation of the user requirements, design and manufacturing, design criteria and standards compliance. This incorporates the integration of SE best practices for NPD success. Transnet R&D develops a wide range of products that integrate different systems for the product to be functional and considered a success. The technical development dimension will look at the key aspects of SE and its impact on the success of the Transnet projects.

Organisational Factors

Company Culture

A positive company climate for innovation is one of the top three success factors that distinguish top-performing businesses in new product development, significantly impacting performance results. Such a culture is found to have many attributes, including Senior management supports innovation in the business, dedicated team efforts recognised by various departments, partnerships and collaborations, risk-taking behaviour is encouraged within the confines of the project (APQC 2003; Cooper 2011, 2013a; Edgett 2011).

Portfolio Management

Most companies suffer from too many projects, often the wrong projects, and insufficient resources to mount an effective or timely effort on each (Cooper 2011, 2013a; Cooper and Edgett 2002, 2006). Therefore, portfolio management is required to identify the preferable product concepts with which to proceed. The Go/No-Go protocol achieves this. This enables companies to filter their product development projects at different gates. As a result, their portfolios do not consist of too many development projects and insufficient resources to focus on and execute the project activities effectively.

Strategic Factors

Project Strategy

Project strategy clearly defines the product innovation goals and objectives and ensures these goals align with the business's overall vision and mission. In addition, strategic arenas are defined to ensure strategic focus is placed on NPD efforts by leadership and management support (Cooper 2011,2017b). The strategic arena aims to ascertain the impacts of resource balancing, leadership and management support and strategic alignment of the project to the company's goals.

Market Strategy

Market planning is an integral part of the development process and a key factor in the project process. Implementing the proper market strategy will enable the research to be incorporated into each developmental stage of the product, from idea generation to product launch. The integration of customer engagement is discussed in the Agile-Stage-Gate model, a development of the Stage-Gate model, indicating the importance of the voice of the customer for project success.

c. NPD Best Practices

Practice, defined by (Argyris 1985) represents implementing a set of ideas to achieve intended consequences, whereas implementation represents the formulation or execution of a policy or framework. NPD practice is referred to as customary performance that implements ideas and policies leading to developing and launching new products and services (Kahn et al. 2012). In the case of NPD best practices, it is those NPD practices that promote greater success in developing and launching new products and services.

d. Project Success

Success denotes different characteristics to different people, and its meaning is very context-dependent. Various literature substantiates the meaning of project success and the evolution of such a meaning coupled with the maturity of project management over the years. Definitions vary between project implementation to project life cycle. The understanding of project success in the 21st century is imperative, coupled with the understanding of key stakeholders in the project. Realising an appropriate understanding enables the stakeholders to drive the objectives and milestones understood by the meaning of project success. The differences are susceptible at the different levels within the organisations; however, the overall objective is an improvement of the company's bottom line.

e. Detailed Conceptual Model

The detailed conceptual model is illustrated in Figure 2 with the six success drivers required for project success.

Figure 2. Detailed Conceptual Model

The model details the dimensions which will be used for the study to ascertain the correlation of NPD best practices to Transnet R&D. The model expands on the project success area to include project commercialisation as the company aims to commercialise (produce and sell to customers) their product and improve the bottom line of the company. A modification of the model by Barczak and Khan (2012) includes SE in the model to cover the technical driver (technical development) of NPD and project success.

f. Research design

A qualitative multiple case study research was selected to investigate this research problem. The multiple case study approach enabled the researcher to explore the differences and similarities between the cases and draw conclusions about the theory (Baxter and Jack. 2008).

The study selected six dimensions of NPD success from Cooper (2014, 2016, 2019), Barczak, and Khan (2012) and Kapurch (2010) and benchmarked the study around these NPD dimensions. The research incorporated semi-structured interviews for the different case studies to address similar and contrasting themes within the selected dimensions. The case study approach enabled the researcher to gather the information and data within the specific themes and within the constraints of time.

g. Sampling

The target population for the investigation were projects within the Transnet R&D portfolio, responsible for NPD in the company. The targeted sampling were projects deemed the flagship projects of the portfolio and have passed onto the final stages of development or design iteration in the past five years. A purposive non-probability sampling approach was used for this study.

h. Interview questions and data collection

Interview questions were compiled based on the literature studied, focusing on NPD best practices within the six dimensions, using semi-structured interviews. The interview structure is illustrated in Figure 3. Secondary data was also used to gain in-depth knowledge of the NPD processes, project characteristics, and project teams. Three level of employees were selected, namely, Principal Engineers (Department head or Senior Management), Project Lead (Lead Engineer driving the technical aspects of the project) and the Project Manager (Management of the Project's deliverables). The interviewee selection aimed to cover the three main success driver dimensions in Figure 1.

i. Data Analysis

The acquisition of the data through the interviews was recorded via Microsoft Teams and documented accordingly. A thematic approach was used to cut and arrange the data into meaningful interpretation units by inductively looking for key phrases, terms, and practices. This allowed themes to emerge from the data that could be matched to existing themes from the literature and any new themes arising.

j. Validity

External validity was established by comparing the research results with relevant literature. The multiple case study also allowed the researcher to compare the results with a cross-case analysis method and secondary data.

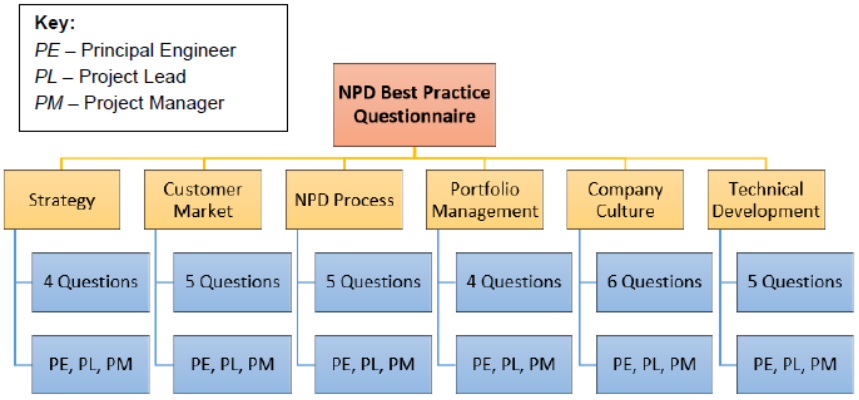

Figure 3. Interview structure

k. Ethical Considerations

The researcher followed the governing principles of research ethics, as stipulated by the research institute and the organisation to protect the participants' rights. All approval letters and documents were signed before commencing the data collection.

4. Results and Discussion

a. Project Success

Within the strategy dimension, the perception of success was established by asking the respondents of each case study. Various literature substantiates the meaning of project success and the evolution of the understanding, coupled with the maturity of project management. Understanding success enables the stakeholders to drive the objectives and milestones understood by the meaning of project success. Table 1 describes the high-level outputs and understanding of project success described by the interviewees.

Table 1. Respondent's definition of Project Success

Project Category	Project A	Project B	Project C	Project D
Completing project milestones outlined in the project.	□	□	□	□
Achieve company Vision and Goals.	□	□	□	□
Develop a customer-demanded product.	□	□	□	□
Launching a product at the right time.	□	□	□	□
Develop a product within budget and time.	□	□	□	□

b. NPD Best Practices versus Transnet Practices

The researcher used the best practices by Barczak and Khan (2012) as the benchmark for the comparison. Table 2 is a brief description to quickly identify the level of best practices implemented by the portfolio of projects used as the case studies. The weighting structure was summarised to illustrate the level of NPD best practices compared to each other and Barczak and Khan (2012) elements. The overall weighing indicates the maximum score for total elements within each of the dimensions. A summary of the findings is discussed within each dimension.

Table 2. NPD Practices vs TE R&D

Dimension	Project A	Project B	Project C	Project D	Overall Dimension Weighing
Strategy	15	13	13	13	**15**
Customer Research	12	6	6	12	**12**
NPD Model	8	8	8	8	**21**
Portfolio Management	8	8	8	8	**9**
Company Culture	9	7	6	8	**9**

c. Results: Theme/Dimensions Summary

Strategy

All respondents were well-versed with Transnet Engineering's strategy and objectives of becoming an original equipment manufacturer for port and rail equipment. As a result, all projects were structured to meet the strategic requirements and milestones envisioned by leadership with sufficient resource balancing, prioritisation, and leadership support to meet scheduled timelines. All respondents highlighted the benefits of having leadership alignment as intervention by the leadership assisted in progressing the Projects' milestones, especially during the requesting of additional budget phases.

Customer Market

A significant divergence in customer market engagement was observed across projects. Projects A and D consistently demonstrated strong customer relationships and frequent engagement throughout their product development. This proactive approach enabled continuous concept testing and iterative feedback loops, ensuring alignment with customer requirements. Conversely, Projects B and C, despite identifying potential global users, largely neglected active relationship management. Consequently, their concept testing was delayed until the completion of a full prototype (e.g., Project B at an exhibition) or was entirely absent, precluding crucial customer feedback. This weak customer validation proved a key factor limiting the success of Projects B and C. The absence of front-end marketing techniques, inadequate cross-department collaboration for customer insights, and a failure to leverage networking opportunities collectively compromised these projects' alignment with market demands and undermined their commercial viability.

NPD Process

Secondary data analysis indicated that Transnet R&D's existing Stage-Gate model was conceptually robust, with defined criteria used for all projects and faced significant implementation challenges. Respondents noted the model was relatively new, introduced only at the end of project design phases, and not applied adequately or regularly. Furthermore, there was an absence of a dedicated NPD Champion, with management delegated to a sub-department, hindering effective implementation. This aligns with literature emphasising the need for NPD model adaptation and a trained gatekeeper. Respondent dissatisfaction stemming from the model's inconsistent application also negatively impacted team morale and project execution.

Shortfalls of the R&D Model:
Go/Kill – Gatekeepers struggled to implement definitive Go/Kill decisions, allowing projects (particularly B and C) to progress without meeting desired outcomes or adequate customer validation. This procedural lapse indicated a predominant "Go/No-Go" culture, favouring progression over decisive termination. The reluctance to terminate non-viable projects was attributed to a consensus-driven culture lacking clear "kill" criteria, exacerbated by systemic concerns about re-allocating large project teams post-termination, thus continuing investment in unvalidated initiatives.
Customer engagement – The model's development stages lacked provisions for actual customer engagements, relationship management, or iterative customer feedback. Consequently, critical concept testing criteria for assessing market conditions were absent within the defined phases.
Periodic review – The review process was set annually, prior to the financial year-end, without verified dates. This limited, timely market assessment indicated insufficient consideration for time-to-market.

Portfolio Management

While core R&D team members remained constant, the availability of supporting external disciplines emerged as a significant challenge. Although these disciplines generally integrated well with R&D, their engagement in other concurrent projects often led to delays, as their urgency and motivation for R&D tasks appeared isolated to the core R&D team. This directly impacted project timelines, contributing to longer time-to-market for procurement and overall project completion. Project financing and funding were generally available upon approval of a viable business case. However, Projects A, B, and C all ran over budget. These deviations were attributed to the Project Leaders' minimal prior NPD experience, which impacted initial cost forecasting. Additionally, PFMA regulations (concerning local content quality, supplier BBBEE status, and local cost inaccuracies) and design deviations further contributed to budget overruns.

Company Culture
Transnet R&D projects, balanced between innovative and customer-demand products, received strong Senior Management support. However, projects consistently exhibited poor risk management, primarily attributed to Project Leaders' limited NPD experience and the responsible department's insufficient involvement. This led to reactive, rather than planned, responses to risks.

Poor procurement collaboration also significantly impacted project timelines and budgets. Respondents universally stressed delays arising from supplier management and procurement issues. The insufficient engagement and communication between project teams and the procurement department frequently resulted in protracted lead times for critical components, cost escalation due to limited competitive sourcing, and occasional compromises on quality due to restricted supplier options, notably contributing to cost overruns in Projects A, B, and C.

Furthermore, a lack of formal collaborations or partnerships across all projects meant minimal technology transfer occurred, largely limited to functional and technical specifications during procurement. Respondents emphasised that leveraging external expertise through partnerships is crucial for minimising learning curves for complex products and streamlining design and integration, suggesting a balanced approach between in-house development and strategic purchasing is essential for project progression.

Technical Development
Technical development consistently proved to be an exceptionally strong foundation throughout the project lifecycle, driven by the application of an effective Systems Engineering approach. Secondary data confirmed robust technical development systems, evidencing comprehensive design concept evaluations, diligent product specification compilations, and streamlined engineering change request processes that effectively linked manufacturing to design. Moreover, the early involvement of manufacturing teams during the design phase significantly contributed to this efficacy.
A key differentiator was customer involvement in technical specifications: Project A and D respondents highlighted that their product specifications were thoroughly reviewed and accepted by customers, enhancing project confidence and ensuring compliance with requirements. Conversely, Projects B and C did not engage customers for technical specification reviews; Project B, for instance, relied on desktop research, which proved insufficient due to intellectual property restrictions among other OEMs.

Successful Projects
The results indicated that two projects (Projects A and D) indicated the best level of NPD practices when compared to Barczak and Khan (2012). These two projects showed characteristics of best practices when compared to Projects B and C. The success can be attributed to many factors, but the key practice was involving the customer/end-user throughout the development of the project. Project A is on the second iteration, preparing for production, and Project D is commercialised and ready for order. Projects B and C are still in their testing phases, but with no customer possibility.

d. Critical Success and Failure Factors
The semi-structured interviews yielded emerging success factors and failure factors for the case studies. The success factors identified are case-specific to the portfolio of projects investigated within the dimensions for NPD success. The factors that emerged are the common factors identified by many researchers (Adams-Bigelow 2005; Barczak et al. 2009, 2012; Cooper et al. 2002, 2004a, 2004b, 2004c), with additional factors relating to Transnet and the R&D department. The metric factors were coded to be incorporated in the recommended model for easy illustration and understanding. The success and failure factors are illustrated in Table 3 to showcase the case comparison and the projects that contributed the most CSF towards NPD success.

Critical Success Factors (CSF)
PM3 - Motivated and dedicated resources
Resources are the driving force of executing the activities to complete a project. The need for motivated and dedicated resources is vital to ensure the activities are completed timeously along with the required quality. Dedicated resources can range from the external departments solely responsible for supporting the projects within the R&D department. Investing resources into the department will improve team morale, efficiency, and effort towards tasks within the project activities.

R1 - Customer/User Focus

Market research needs to be implemented effectively with an effective market strategy to enable the developers to produce a product for the correct market and customer. Customer research must be done throughout the project's life cycle, with the degree of uncertainty decreasing as the project is developed (Table 3).

Table 3. Critical Success Factors and Critical Failure Factors

Description	**Interview Metric**	**Project**			
Critical Success Factors (CSF)		**A**	**B**	**C**	**D**
Motivated and dedicated resources	PM3	Y	Y	Y	Y
Customer/User Focus	R1	Y	N	N	Y
User/Customer Relationship Management	R2/ R3	Y	N	N	Y
Concept Testing	R5	Y	N	N	Y
Flexible NPD Model	P3	N	N	N	N
Continuous Market Review	R2/R3	Y	N	N	Y
NPD Champion	P5	N	N	N	N
Constant Team members	PM1	Y	Y	Y	Y
NPD Experience of Leader	PM2	N	N	N	Y
Leader and Team capability	CUL3	Y	Y	Y	Y
Constant Leadership Vision	ST2	Y	Y	N	Y
Customer reviewed product specifications	TD2	Y	N	N	Y
Concurrent Engineering techniques	TD3	Y	N	Y	Y
Manufacturing involvement	TD4/TD5	Y	Y	N	Y
Adaptation of PFMA regulations for R&D	CUL5	N	N	N	N
Critical Failure Factors (CFF)					
Poor Quality Management	CUL5/ PM4	Y	Y	Y	N
Poor Customer identification	R1-R5	N	Y	Y	N
Poor Review periods	P2/P4	N	Y	Y	N
Poor financial forecasting	R4/ PM4/ CUL5	Y	Y	Y	N
Poor Risk Management	CUL4	Y	Y	Y	Y
Lack of Partnerships and collaborations	CUL6	Y	Y	Y	Y
Lack of technology transfer	CUL3	N	Y	Y	N

R2/R3 - Relationship Management

Implementing an effective market strategy and nurturing relationships with all stakeholders, from customers to suppliers, will allow the developers to advance confidently. Relationship management includes regular reviews and meetings with stakeholders, maintaining good communication, ensuring the customers' needs are considered for the development, implementing concept testing initiatives and ensuring the contracts are set up to benefit all stakeholders involved.

R5 - Concept Testing

Concept testing needs to be implemented as a review process with the possible customers and end-users and done throughout the project with specified milestones. The concept testing must be implemented to mitigate risks before moving further into the development phases to improve project milestones, customer confidence, and cost reduction.

P3 - Flexible NPD Model
A developer whose portfolio ranges into different markets (rail, port, etc.) requires a flexible NPD model to achieve project success. The flexibility of the model must incorporate the inputs of one or more customers throughout the project lifecycle. The Go/Kill decision is imperative to be incorporated with the customer's inputs to eliminate wastage of resources. The model also needs to be adapted to cater for the different types of projects (innovation versus engineer-to-order).

R2/R3 - Continuous Market Review
Complementary to implementing good relationship management, it is vital for the developers to continuously analyse and review the market environment, the customer requirements, and the economic status of the economy. A continuous review process of the market enables developers to create a product that meets the market needs at its latest stage of the customer and market requirements.

P5 - NPD Champion
Supporting the NPD model success factor is having an NPD Champion to ensure the NPD model is appropriately implemented. The NPD Champion is also responsible for regularly reviewing the model and adapting where required to ensure flexibility and aid in the project's success.

PM2 - NPD Experience of Leader
NPD experience is crucial for a Project Lead to possess when undertaking a complex project. The NPD experience of the leader can be used in previous experiences to effectively lead, manage, and execute the project's milestones to drive project success. The previous experience of the Project Lead also instils confidence in all stakeholders and greatly improves the project environment to ensure the project milestones and risks are adequately within the project scope.
TD2 – Customer reviewed product specifications
Obtaining reviews of the product specification from end-users or customers is imperative, and forms part of the customer focus CSF, as it entails the review of the customers' requirements. Front-end planning is vital in complex projects to determine the correct specifications are included in the product. The review will also ensure that the developers are aligned with industry standards and customers. Furthermore, the intensified front-end planning with customer reviews will ensure that few changes are made during the latter, expensive stages of development.

TD3 – Concurrent Engineering techniques
An essential technique to ensure productivity within manufacturing is to implement concurrent engineering techniques during the manufacturing phase of the development. This ensures the design and manufacturing activities are linked to produce the iterations of a customer-required product. A technique that involves all stakeholders to be abreast with the development of the product, such that technical or operational activities are included in the product's specification and design. This method impressively improves the development schedule, allowing a shorter time to market.

TD4/TD5 - Manufacturing involvement
Complementary to concurrent engineering techniques, it is imperative that manufacturing teams are involved throughout the development stages, as their operational knowledge is vastly different from that of the design engineers. In addition, manufacturing teams offer vital knowledge of the extent and limitations of the business operations.

Critical Failure Factors (CFF)
Cul5/PM4 – Poor Quality Management
Good quality management is required in different spheres for NPD, ranging from design, manufacturing, product quality, and overall work ethic. Conversely, poor quality management hinders the advancement of products and may find its way to the final product if not managed adequately.

R1 to R5 - Poor Customer identification
Identifying and distinguishing a customer or end-user is a core process for NPD, with the identification of a specific customer or a customer group and their fundamental requirements (cost, quality, reliability, etc.). Developers from new Original Equipment Manufacturers must consider the existing global competitors within the market and the assessment of penetrating the market to obtain market share.

P2/P4 - Poor Review periods
With technology and economic advancement in global markets, developers are required to review the market and its competitors regularly. Therefore, review periods should be arranged on the completion of development stages instead of only specific periods.

R4/PM4/CUL5 - Poor financial forecasting
Sufficient front-end planning and forecasting are required to determine all factors relating to financial aspects affecting the project milestones and development stages. Accurate forecasting is achieved with inputs from all stakeholders involved throughout the project's life cycle (marketing, manufacturing, testing, etc.), enabling each development stage to be costed.

CUL4 - Poor Risk Management
Risk management coupled with a risk register improves risk mitigation procedures to address issues effectively and efficiently. Continuous risk register review is required to verify if risk mitigations are still valid, identify the upcoming risks, and update or evaluate the risks encountered for project success.

CUL 6 - Lack of Partnerships and Collaborations
The company needs to leverage the external expertise through partnerships and collaborations, as the expertise required is not always available within the company. Partnerships and collaborations also ensure the development of products commercialised faster and with greater success, as external expertise is essential for complex products.

CUL3 - Lack of technology transfer
Complementary to having partnerships and collaborations in place, technology transfer is required to enhance the knowledge and capabilities of the internal team members. The technology transfer is attainable through contracts or on-the-job training from external sources to improve the capabilities of team members for future NPD projects.

Proposed Framework for NPD in Transnet

The integration of characteristics from the Stage-Gate Models and the highly adaptive Agile Model approach, gives rise to the Agile-Stage Gate Hybrid Model, which is the proposed framework to be utilised for TE R&D. The Hybrid Model integrates the Stage-Gate and Agile approaches, which defines each stage of the NPD process, with iterative processes, and ensuring the feedback loop incorporates customer feedback or criteria. This ensures customer satisfaction and ensures the product is in a favourable position in the market when launched. Project A and D results indicated that customer engagement is paramount for overall project success. The typical Agile Model in the software industry recommends 'sprints' over 2-4 weeks long; however, in the manufacturing industry, 1–2-month sprints are more realistic due to the complex nature and length of the projects. The study showcased that the hybrid model is required for the development of physical products.

The proposed Agile-Stage Gate framework encompasses the different activities required for NPD success on the different execution levels, namely, strategic, commercial, operational, NPD model and project management. This was derived from the dimensions researched in literature and adapted for TE R&D. The CSFs are included in the model, as seen in Figure 4, to highlight the magnitude and phases that the CSFs are attributed to. The framework includes feedback loops from customers or end-users during the life cycle of the project, as it was evident from the case studies investigated that customer engagements are required from initiation to commercialisation.

The CFF elements are not included in the framework but instead used as developmental categories throughout the project's lifecycle and managed accordingly. CFF will undergo continuous reviews and, upon succession, will be included in the framework.

The efficacy of any project management strategy is based on the success criteria. The following success criteria are standard Stage-Gate practices but also applicable to Agile- Stage-Gate models.

1. More than 50 % of the skilled personnel within the team are dedicated to the project.
2. Good customer access - this is paramount to establishing customer feedback loops.
3. Project Management and Process coach - to help project leaders to execute the project sprints effectively to drive the product success factors.

4. Collaboration Systems - to collaborate effectively with external stakeholders to efficiently yield the desired result/systems and ensure customer/ end users' satisfaction.

Limitations of the Model in South Africa
As Transnet is an SOE, the PFMA regulations are strictly implemented to follow the outlines from National Treasury. To counter the effects of state capture and any corrupt activities, SOE's are heavily forced to comply; however, the lengthy processes make it difficult for the R&D development to advance quickly.

The development teams discussed the following as difficulties in the SA environment:
Local content: Many of the sub-systems required encountered problems with complying with local content and obtaining suppliers locally who stocked the system. This resulted in extended timelines to receive items, alternate quality, and, in some cases, a total change of design.

Partnership and collaborations: The processes involved in attaining the partnerships and collaborations were discussed as lengthy processes with more resources and heavy front-end planning. The foresight of these actions needs at least 12 – 18 months before development to the project's initiation, which consumes the time to market milestone.

Market environment Government: The South African market for rail and port products is limited—products that are destined for the global market encounter various competitors with vast experience and branding. The products destined for South Africa and the African market require government intervention to assist an SOE, such as Transnet, to gain traction in product development initiatives to become a household brand in SA for port and rail. The government's partnerships with subsidiaries and other African countries are imperative to power Transnet and the African continent in evolving its NPD capabilities and branding.

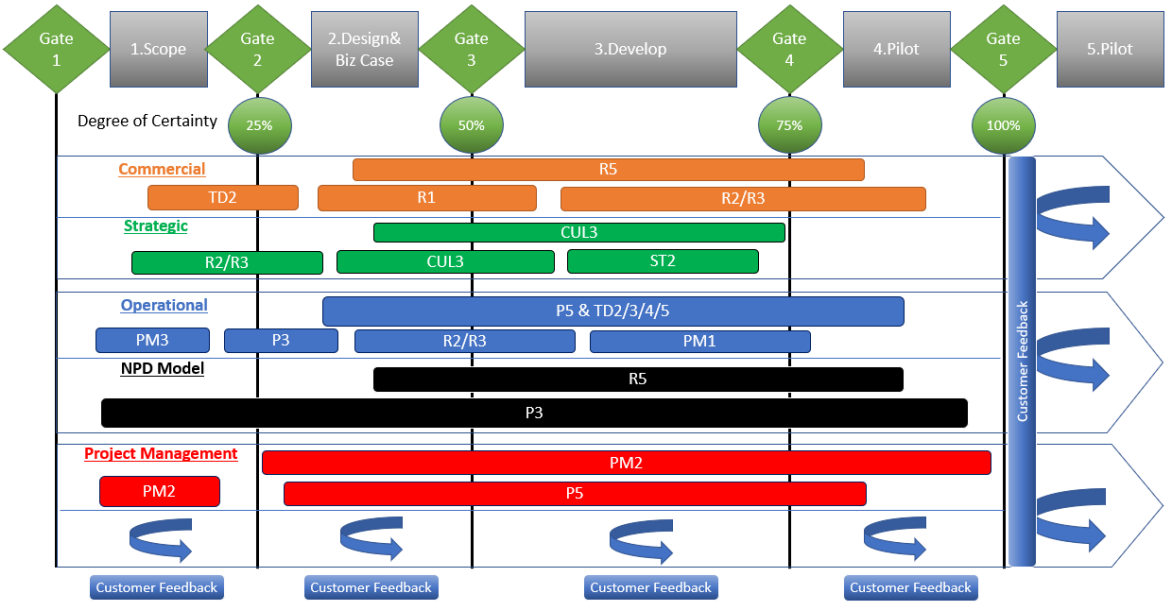

Figure 4. Hybrid Model with TE CFF

5. Conclusion

Successful New Product development is imperative for organisations to stay competitive in an era that is advancing at a great pace. Commercialising NPD products is the livelihood of the Transnet R&D department and Transnet Engineering, but it is a difficult and complex task that many organisations and departments are challenged with. The study aimed to investigate the relationship between New Product Development best practices in industry and those at Transnet's R&D, by using a multiple case study approach. The six dimensions of NPD best practices, by Barczak and Khan (2012), were selected as a benchmark to investigate the NPD practices at the company. The dimensions: strategy, customer market, NPD model, company culture, portfolio management, and technical development were categories

deemed to be best practices for NPD success. A qualitative study approach was used to determine the level of best practices in the six dimensions. Semi-structured interviews were used to obtain in-depth data of the practices and secondary data to analyse the data that could not be obtained during the interviews.

A thematic analysis approach was to correlate best practices with the literature and to ascertain the R&D department's strengths and weaknesses with the South African environment. The list of CSFs and CFFs were established to Propose a framework for R&D in a manufacturing environment. The factors were subsequently included in the model on the different strategic, managerial, and operational levels.

The proposed framework was developed with CSF and continuous improvement of critical failure factors by evaluating the process gaps and the successful projects. Based on the literature framework by Cooper (2019), a hybrid Agile-Stage-Gate model was proposed with the core fundamentals of the NPD model being customer engagements and scums. The investigation showed that Transnet's R&D departments' strengths lie in the technical development phase using techniques from Systems Engineering; however, NPD management and frameworks need to be implemented for overall project success. Additionally, it was indicated that government entities, such as Transnet, are regulated by PFMA, which has a direct impact on NPD performance.

5.1 Research Limitations

This study investigated a very small sample of projects and only projects within the Transnet R&D portfolio. As a result, the data and findings obtained were limited to a single R&D manufacturing environment. Additionally, the data was gathered from a State-Owned Enterprise, which encompasses its own set of regulations and policies, different from the private sector. The proposed model was not implemented to validate the framework, however, it is aligned with the literature along its major dimensions. The research only covered physical products within the mechanical department. A similar study within the same organisation for the development of software & electronic products will provide more in-depth insight into an R&D public organisation.

5.2 Recommendation for Future Research

As the study was conducted within a single environment within the organisation, the first recommendation is to follow several case studies of NPD projects within Transnet. This will provide a larger population of data to develop a more generalised theory for the specific organisation. Additionally, the research is recommended to investigate case studies from other South African manufacturing companies to establish the theory of NPD in the South African environment. The research can incorporate the findings from public and private sector organisations.

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