TOWARDS A THEORY OF THE APPLICATION OF LEAN PRINCIPLES TO NEW PRODUCT DEVELOPMENT IN A MANUFACTURING FIRM:

FIVE CASE STUDIES

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by

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Supervisor: Dr. Hamieda Parker
This thesis is not confidential. It may be used freely by the Graduate School of Business.

I wish to thank Dr Hamieda Parker for her valuable insight and guidance during the course of this research study.

Thank you to Fibres Inc. for granting me unlimited access to project data and company information, and for the employees for making themselves available for the interviews.

I certify that except as noted above the thesis is my own work and all references used are accurately reported in footnotes.

Signed:

Desigan Govender
TOWARDS A THEORY OF THE APPLICATION OF LEAN PRINCIPLES TO NEW PRODUCT DEVELOPMENT IN A MANUFACTURING FIRM: FIVE CASE STUDIES

ABSTRACT

Five new product development cases at a single manufacturing organisation were studied to develop a better understanding of how lean principles can be applied to the new product development process. Using the Lean Product Development System model (Morgan & Liker, 2006) as a conceptual framework, within-case and between-case analyses were conducted to articulate common themes and practices relating to the application of lean to new product development. Sociotechnical systems theory was used to guide the interpretation of the findings that emerged from the interview and document data.

The findings show that the application of lean principles to new product development can result in a more effective new product (meet customer requirements and fit with organisational competencies), reduce product-to-market delivery time, manage the trade-off between product-to-market delivery time and new product quality, and enable a new product for lean manufacturing. Furthermore, new product developments that proactively embrace the 13 principles of Morgan & Liker’s (2006) Lean Product Development System model were found to achieve a higher degree of success.

The theory developed is represented in a practical framework providing workable advice for managers and organisations.

KEYWORDS: lean, waste, new product development, manufacturing, Toyota, product-to-market delivery time, sociotechnical systems.
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## Glossary of Terms

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<tr>
<td>NPD</td>
<td>New product development.</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and development.</td>
</tr>
<tr>
<td>Lean manufacturing</td>
<td>Process that focuses on eliminating as much waste as possible and aligning value-added activities.</td>
</tr>
<tr>
<td>TPS</td>
<td>Toyota Production System – the benchmark for a lean manufacturing system.</td>
</tr>
<tr>
<td>STS</td>
<td>Sociotechnical systems theory – approach that recognises the interaction between people and technology in meeting workplace objectives.</td>
</tr>
<tr>
<td>Polymer</td>
<td>The major raw material input used in all of Fibres Inc.’s products.</td>
</tr>
<tr>
<td>Spinning machine</td>
<td>Machine that converts the polymer into an intermediate product.</td>
</tr>
<tr>
<td>Drawing machine</td>
<td>Machine that converts the intermediate product from the spinning machine into the end product for the customer.</td>
</tr>
<tr>
<td>Spinneret</td>
<td>Critical spinning machine component that initiates the formation of the products manufactured at Fibres Inc.</td>
</tr>
<tr>
<td>Techno-operations Manager</td>
<td>Plant position that manages technical aspects (e.g. quality) of production.</td>
</tr>
<tr>
<td>Frontloading</td>
<td>The thorough exploration of alternatives at the front-end of the development process to improve decision-making.</td>
</tr>
<tr>
<td>Nemawashi</td>
<td>Decision-making method that incorporates all stakeholders and thoroughly considers all options.</td>
</tr>
<tr>
<td>Kentou</td>
<td>Period of project where the concept is studied and designs are generated.</td>
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1 INTRODUCTION

1.1 Research Area and Problem

New product development and lean thinking are important considerations for manufacturing organisations. In an increasingly global environment, the speed and quality of the development of new products is fast becoming a competitive edge for organisations (Wheelwright & Clark, 1992). Similarly, lean thinking is arguably the biggest contribution to the operations management field in the last 50 years (Jacobs & Chase, 2008). Lean thinking, which originally evolved from just-in-time (JIT) principles pioneered by Toyota, essentially focuses on reducing as much waste as possible from the process, and aligning organisational activities to customer value.

While lean thinking has been successfully applied to the manufacturing environment, examples of its applicability to the new product development process and the rest of the value chain are still in its infancy. This situation exists in part because, with the exception of Morgan & Liker’s (2006) seminal study of Toyota’s application of lean principles to new product development, very little research has been done on the subject.

This research examines the application of lean principles to the new product development process through rigorous case analysis of 5 new product development projects (automotive, aeronautical, polythread, nylthread, airbag) at a single organisation, Fibres Inc.¹.

Fibres Inc. is a medium-sized textile manufacturing organisation located in Cape Town, South Africa. Over the last few decades, Fibres Inc. has developed a strong industry reputation for their successful new product development

¹ Names of products and organisation changed to protect anonymity.
programmes. Additionally, the organisation has evolved into a leading practitioner of lean manufacturing, the principles of which have been built into their new product development process.

The purpose of this study is largely explanatory with elements of descriptive research. Consistent with explanatory research, this study incorporates Morgan & Liker’s (2006) Lean Product Development System model as a conceptual framework to link theory to operational practices (Yin, 2003a, p. 9).

Several authors (McCutcheon & Meredith, 1993; Meredith, 1998; Voss, Tsikritsis, & Frohlich, 2002) have argued for more field-based studies in operations management, specifically case study research to bridge the growing gap between researchers’ findings and practical answers for operations managers. This study therefore has important value for operations managers since it provides practical guidelines on how lean principles can be applied to the new product development process. It also contributes to the academic field by validating and expanding on the Lean Product Development System model developed by Morgan & Liker (2006); adding to the limited research in this field.

1.2 Research Questions and Scope

This study is motivated by 3 questions:

1. How can the application of lean principles to the new product development process improve new product effectiveness (fit with market needs and fit with organisational competencies)?

2. How can the application of lean principles to the new product development process reduce product-to-market delivery time?

3. How can the application of lean principles to new product development enable the lean manufacturing capability of the new product?
This research uses literature, specifically lean principles and case study data to explore the important dimensions of new product development and to identify the impact of lean principles on it. The research findings lead to 8 theoretical propositions describing the effect of lean principles on new product development success.

1.3 Research Assumptions and Ethics

The major assumption relates to the bias of the researcher. Being a former employee of the organisation, and an active participant in several of the cases, there was a possibility that the researcher might influence the outcome of the research findings. This was mitigated by employing semi-structured interviews, respondent validation, and triangulation techniques to ensure that the researcher correctly understood the perspectives and experience of the participants (Bryman & Bell, 2006) and limited his own bias. Where necessary, the researcher contacted the interviewees during the data analysis phase to confirm his understanding of the responses. Documents (e.g. project minutes) and multiple perspectives (e.g. project manager and R&D engineer responses from the same cases) were used together to limit bias when developing arguments (Eisenhardt, 2007, p.28).

Fictitious names have been used to protect the identity of the organisation and participants. At the start of each interview, the researcher highlighted to the participant the option to withdraw to any question they feel is too sensitive. None of the 17 interviewees felt the need to withdraw during the interviews. All interviewees were briefed on two separate occasions prior to the interview regarding the nature and requirements of the study. Although the organisation has unequivocally shared data (documents) with the researcher, this data has been kept in strictest confidence.
2 LITERATURE REVIEW

2.1 Introduction

The available literature on new product development and lean manufacturing as separate entities is extensive, ranging from overviews to detailed case studies and across many industries. A tabulated analysis of the relevant, existing literature is presented in Appendix 1. This literature review serves to place the research questions in context, and highlight the strengths and deficiencies of past, related studies.

Many authors (e.g. Wheelwright & Clark, 1992; Brown & Eisenhardt, 1995; Cohen, Eliashberg, & Ho, 1996) have emphasised the value of strong new product development capability in an organisation. Organisations that get to market faster and more efficiently with products that meet the expectations of the customer create significant competitive advantage (Wheelwright & Clark, 1992).

The Toyota Production System (TPS) is arguably the most extensively researched example of lean manufacturing and formed the basis for much of the lean manufacturing trends that has come to the fore in the last two decades (Liker, 2004). Taiichi Ono (Liker, 2004, p. 7), the founder of the Toyota Production System provides the following simple definition of lean manufacturing:

“All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non-value added wastes”.

Although many organisations have embraced lean principles within the manufacturing context, Morgan & Liker (2006) argue that this should only be the first step. Lean principles can also be applied upstream to the development of new products and processes. While the existing literature on new product development provides several theories and frameworks to build strong organisational new product development capability, there is limited research on
the applicability of lean principles to new product development (Morgan & Liker, 2006; Hines, Francis, & Found, 2005). Furthermore, most of the available literature (e.g. Morgan & Liker, 2006) is focused predominantly on the automobile industry.

While acknowledging overlap, this literature review is developed along 3 broad dimensions identified in the literature; 1) new product effectiveness, 2) product-to-market delivery time and 3) new product lean manufacturing capability.

2.2 New Product Development

In a dynamic environment, organisations need to have a new product development process to be a player in the competitive game. However, doing new product development extremely well can become a source of competitive advantage for an organisation (Brown & Eisenhardt, 1995; Datar, Jordan, Kekre, Rajiv, & Srinivasan, 1997; Schilling & Hill, 1998; Wheelwright & Clark, 1992). Further, Zirger & Maidique (1990) argue that due to fast evolving technology, new product developments are especially vital in manufacturing organisations for growth and prosperity. An effective new product development system can realise the following advantages for an organisation (Wheelwright & Clark, 1992, p. 5): 1) Shorter development cycles, 2) Better targeted products, 3) High development productivity, 4) Creativity combined with total product quality, and 5) Customer integration.

Krishnan & Ulrich (2001, p. 1) define product development as “the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale”. Within this definition, Krishnan & Ulrich (2001) define four perspectives of product development: marketing, organisations, engineering design and operations management.

From an operations management perspective, Krishnan & Ulrich (2001, pg. 3) propose efficiency, total cost, service level, lead time and capacity utilisation as
the typical performance metrics for new product development. Further, the authors identify the critical success factors as supplier and material selection, design of production sequence, and project management. Brown & Eisenhardt (1995), provide a more in-depth identification, and the relationship of the critical success factors for product development. This is replicated in figure 1.

2 Figure 1: Factors affecting the success of product development projects.

2.3 New Product Effectiveness

The effectiveness of a new product is a key determinant of new product development success. Brown & Eisenhardt (1995) and Wheelwright & Clark (1992) both argue that an effective product is one that fits both the market needs, and the firm’s competencies. The fit with market needs is typically established

along dimensions of “cost, quality, clear concept and unique benefits” (Brown & Eisenhardt, 1995, p. 351), while fit with organisational competencies is established along dimensions of “skills and knowledge base, technical systems, managerial systems, and values and norms” (Leonard-Barton, 1992, p. 114).

2.3.1 Fit with Market Needs

The fundamental starting point for any new product development must be the ability to satisfy the customer’s requirements. Brown & Eisenhardt (1995) contend that an effective new product is one that is viewed as superior to competing products, and solves problems that customers face. Wheelwright & Clark (1992) expands on this, arguing that new product developments must not only satisfy current customer requirements, but must also actively anticipate future customers’ needs. The authors contend that this is important as markets or technology may shift unexpectedly, resulting in a misalignment with market needs – hence the need to be able to actively anticipate customer’s future needs. Understanding the voice of the customer is vital to develop products that meet their needs better than that of the competitors (Griffin & Hauser, 1992). Building on this, several researchers (e.g. Bonner, 2004) stress the importance of maintaining customer interaction throughout the development process. Bonner (2004, p. 64) proposes a conceptual framework that links project controls, output and team rewards to customer interactivity. Bonner (2004) argues that too much process control (e.g. stage gate processes, formal procedures and roles) results in too much focus on internal development processes and too little on customer influences, while meaningful output controls (e.g. performance standards) focuses the project on market requirements and financial success. Success against defined performance standards encourages project teams to gain an excellent understanding of customer requirements and meet these needs better than the competition. Linking team rewards to these standards provides strong motivation for teams to continuously interact with customers to ensure product
success (Bonner, 2004). Lean thinking introduces a similar notion, arguing the need to separate “waste activities” from customer-defined value (Morgan & Liker, 2006) – all project activities must be aligned to serve the customer’s needs.

In order to be successful, a new product must present the market with unique benefits, and must consistently meet the quality requirements. If no unique benefits are present, the market may dry up or imitators may rapidly move in destroying market share (Wheelwright & Clark, 1992). To overcome this risk, Wheelwright & Clark (1992, p. 35) propose a development strategy framework that links technology and market assessment, and forecasting with project development goals and objectives, arguing that this creates and defines a set of new product development projects that will provide “superior” products.

Sethi (2000, p. 1) defines new product quality as the “superiority of the product in dimensions such as appearance, performance, workmanship, and life/durability”. However, how can an organisation consistently deliver a product that meets these dimensions? For example, a firm may be able to develop a product that meets or exceeds customer requirements, but fails to meet the internal quality and cost standards once implemented in manufacturing (Kim & Kim, 2009).

The existing literature on new product development is limited in this regard and does not explicitly consider how manufacturing sustainability can be assessed and integrated during the product development phase. Within the broad published literature on new product development, studies by Müller & Fairlie-Clarke (2003), Nihtilä (1993), and Swink & Song (2007) represent the limited attempts to understand manufacturing capability during new product development. All 3 studies focus on cross functional integration as the key driver of new product manufacturing capability, with Swink & Song (2007) highlighting marketing-manufacturing integration and Nihtilä (1993) highlighting R & D-manufacturing integration. No reference to lean manufacturing capability is made.
In addition to cross functional integration, adapting technologies to fit people and processes, specifying work standards, organisational alignment, and continuous improvement are some of the lean principles that have been proposed by Morgan & Liker (2006) that must be considered during the new product development to enable new product manufacturing capability. A key objective of this study is to investigate how these principles can be applied to new product development projects to enable lean manufacturing capability, thus maintaining quality and cost standards post-development.

2.3.2 Fit with Organisational Competencies

Several studies, notably Leonard-Barton (1992), have emphasised the importance of an organisation’s key competencies with successful new product development. Leonard-Barton (1992, p. 114) describes four dimensions of an organisation’s core capabilities that can both enhance and hinder new product development and innovation: “skills and knowledge base, technical systems, managerial systems, and values and norms”. Leonard-Barton (1992) argues that the closer the alignment of a development project and an organisation’s core capabilities, the more successful is the project. Conversely, if there is no fit with the core capabilities, new product development is often inhibited. Leonard-Barton (1992, p. 118) argues that this often results in inadequate product specifications, problems in manufacture, design issues and poor decision making.

However, according to Leonard-Barton (1992), these “core rigidities” if properly managed by project managers, can redefine an organisation’s core capabilities and / or initiate new capabilities. Similarly, this notion is supported by Wheelwright & Clark (1992) who argue that overcoming these “core rigidities” is important to capture learning from new development projects. They highlight changes to procedures, tools/methods, process, structure and principles as the areas of focus to capture learning and enhance capabilities (Wheelwright &
Clark, 1992, p. 296). In his case study of BMW's product lifecycle reduction efforts, Thomke & Ashok (2001, p. 12) further emphasise the challenge of developing new capabilities, and changing organisational processes to take advantage of the opportunities that new technologies present.

Interestingly, this stance is in contrast to earlier work by Cooper (1979) and Zirger & Maidique (1990), who concluded that a key to successful new product development is for an organisation to avoid products, markets, customers and technologies that are new to the organisation. This stance is surprising as it essentially limits the stimulus for innovation and growth in an organisation. In their study of the application of lean thinking to new product development, Morgan & Liker (2006) support the notion presented by Leonard-Barton (1992), arguing for organisational alignment and continuous learning to develop new capabilities and to overcome change. Using the case study data, this research study investigates these two competing positions on organisational fit and their impact on new product effectiveness.

### 2.4 Product–to–Market Delivery Time

Wheelwright & Clark (1992, p. 16) define product-to-market delivery time as “the time a firm starts a product development project to the time it introduces the product into the market”. They argue that firms that can rapidly develop a high-quality product has a competitive advantage by introducing the product sooner into the market, or by buying time to develop a higher quality product that is better suited to meet customer requirements. Afonso, Nunes, Paisana, & Braga (2008) argue that this is particularly true for global and highly competitive markets, where products have reduced life cycles.

The available literature on new product-to-market delivery times generally focuses on two streams: 1) the trade-off between product-to-market delivery time and product quality, and 2) organisational factors influencing product-to-market
Several studies (Cohen et al., 1996; Lukas & Menon, 2004; Roemer, Ahmadi & Wang, 1999), describe the trade-off implications between time-to-market and quality of the new product. Generally, these studies argue an inverse relationship in that high quality product developments require longer product-to-market delivery times. For example, Cohen et al. (1996, p. 174) take the position that if a new product development takes too long, the firm may miss the window of market opportunity. However, it is also acknowledged that firms that use product performance as the main measurement rather than time-to-market can also achieve success in spite of longer time-to-market. In this case, success is typically achieved by the unique features and innovativeness of the product rather than being the first to market (Cohen et. al., 1996, p. 173).

Several studies (e.g. Afonso et al., 2008; Schilling & Hill, 1993) emphasise reduced time-to-market as the overwhelming success factor in new product development projects, justifying this with shrinking product lifecycles and intensifying global competition. However, the effect of reducing time-to-market delivery on quality is not mentioned, suggesting that the study assumes fixed new product quality / performance targets. This argument is questionable since new product development speed may come at the expense of quality or performance of the product as teams are put under considerable pressure to deliver the product. Sethi (2000) points out that increasing the speed of new product development projects forces the team to take shortcuts, to only consider a narrow range of alternatives and to not explore ways to build innovativeness into the product. There is therefore a need for firms to properly manage the trade-off between time-to-market and new product quality.

Lukas & Menon (2004) propose a model to manage the trade-off between time-to-market and product quality. The findings from their empirical study indicate that “NPD speed, bureaucratic structure and organisational control account for variations in new product quality” (Lukas & Menon, 2004, p. 1262). The authors
conclude that too little or too much new product development speed has a negative impact on new product quality, arguing that slowing down the new product development speed can result in an unfocused effort and lapses in attention. A bureaucratic structure (too many rules, procedures, roles, etc.) and tight organisational control (reduced decision-making) was also found to have a negative impact on new product quality, largely because it limits information sharing within the organisation (Lukas & Menon, 2004).

While the available literature presents empirical evidence arguing the trade-off between time-to-market and new product quality, there is limited evidence of practical guidelines for managers. Thomke & Ashok’s (2001) case study of BMW’s reduction of product development cycle is one of few examples where practical guidelines can be deduced. This identified gap in the literature motivates the second research question: How can the principles of lean (Morgan & Liker, 2006) be applied to reduce new product-to-market delivery time without negatively impacting new product quality?

The key factors impacting product-to-market delivery time have been identified in existing literature as market context (Bhattacharya, Krishnan, & Mahajan, 1998; Lewis, 2001; Thomke & Ashok, 2001), leadership (Aronson, Reilly, & Lynn, 2006; Brown & Eisenhardt, 1995; Swink, 2003; Thomke & Ashok, 2001); internal and external collaboration (Krause, Handfield, & Tyler, 2006; Langerak & Hultink, 2008; Mishra & Shah, 2009; Swink & Song, 2007; Morgan & Liker, 2006), project management (Clark, 1989; Swink, Talluri, & Pandejpong, 2006; Wheelwright & Clark, 1992), organisational structure (Langerak & Hultink, 2008; Lukas, Menon, & Bell, 2002; Swink, 2003; Morgan & Liker, 2006). These factors are also considered integral components of a lean product development system (Morgan & Liker, 2006).

Internal collaboration on new product development projects is aided by high levels of cross functional integration that remove functional barriers impeding communication and information flow, thus ensuring that products and services
are developed rapidly and efficiently (Wheelwright & Clark, 1992; Brown & Eisenhardt, 1995). This stance is supported by Morgan & Liker (2006, p. 139) who argue for a “product-focused” organisational structure rather than the traditional “functional” organisational structure for lean product development. The authors argue that having a “product-focused” structure breaks down barriers between the functions and aligns the whole organisation to a common goal that directly serves the customers. To achieve a “product” organisational structure, Morgan & Liker (2006, p. 140) propose four guidelines:

- Align different functions around common goals that are needed for creating products that satisfy customers.
- Effective communication and coordination to reduce product-to-market delivery time.
- Ability to make well-informed product and process decisions from multiple perspectives.
- Create self-managing teams to be flexible and adaptable to changes in the environment.

The notion of a “product-focused” organisational structure is further supported by Wheelwright & Clark (1992) who argue that effective cross-functional integration for new product developments must be built on shared responsibility for the results, mutual trust, and mutual commitment across functional boundaries. This level of functional interaction must be established by senior management whose role is to establish the sequence, pattern and timing of functional activity throughout the new product development project (Wheelwright & Clark, 1992; Aronson et al., 2006). Furthermore, it is argued that senior management must set the example of communication patterns, respect and trust amongst each other in order to shape the pattern of integration throughout the organisation (Wheelwright & Clark, 1992, p. 185). It is argued that the relationship between senior managers filters through and influences that between their functional
subordinates.

External collaboration refers to the quality of the interaction with customers and suppliers (Morgan & Liker, 2006; Wheelwright & Clark, 1992; Bonner, 2004; Griffin & Hauser, 1992). Consistent with the need to satisfy customer requirements articulated earlier (Bonner, 2004, Griffin & Hauser, 1992), effectively integrating the customer during the new product development phase can reduce product-to-market delivery time. A better articulation of the customer’s requirements allows project teams to separate “waste activities” from customer-defined value, effectively reducing the development time of the new product (Morgan & Liker, 2006). Similarly, integrating key suppliers into the new product development project has been shown by several studies to result in lower development costs and increased speed of product development (Langerak & Hultink, 2008; Morgan & Liker, 2006; Brown & Eisenhardt, 1995). This is achieved primarily by leveraging the technical expertise and knowledge of suppliers into the product development process (Langerak & Hultink, 2008, p. 160). In the context of reduced product-to-market delivery time, Morgan & Liker (2006) argue that building strong relationships and integrating suppliers into the new product development project from the start, sets clear expectations on requirements and quality, thus preventing delays later in the project.

2.5 Lean Manufacturing Capability

Within the lean definition, the Toyota Production System (TPS) advocates 7 types of waste that can be eliminated from the supply chain: “waste from overproduction, waste from waiting time, transportation waste, inventory waste, processing waste, waste of motion, and waste from product defects” Jacobs & Chase (2008, p. 226). Essentially lean manufacturing refers to the elimination of as much waste as possible and increased focus on the value-adding activities.

Spear & Bowen (1999, p. 98) proposes 4 rules that can help organisations
decode and apply the Toyota Production System:

**Rule 1:** All work shall be highly specified.

**Rule 2:** Every customer-supplier connection must be direct, no ambiguity.

**Rule 3:** The pathway for every product and service must be simple and direct.

**Rule 4:** Any improvement must be made in accordance with the scientific method.

The authors argue that it is these rules and not the specific practices and tools used at Toyota that form the basis of the Toyota Production System. It is the rigidity and specification incorporated in these rules that drives flexibility and creativity (Spear & Bowen, 1999). Standard activities and processes are constantly being challenged and pushed to a higher level of performance, enabling Toyota to continually innovate and improve. A fundamental tenet of this system is the shared understanding and motivation of employees who strive for improvements that exceeds the current needs of their customers (Spear & Bowen, 1999). Employee buy-in is facilitated by respect for employees, where management treats workers as assets and not human machines (Jacobs & Chase, 2008, p. 233).

In a study spanning 20 years, Liker (2004) developed the 4P (philosophy, process, people and partners, problem solving) model to understand the Toyota Production System. Consistent with the assertions by Spear & Bowen (1999) and Jacobs & Chase (2008), Liker (2004) argues that while techniques like “just-in-time”, “kaizen”, “jidoka” and “heijunka” helped initiate the lean manufacturing revolution at Toyota; sustainability is achieved from Toyota’s deep business philosophy and its understanding of people and human motivation. Lean success at Toyota is ultimately based on its ability “to cultivate leadership, teams, culture, to devise strategy, to build supplier relationships, and to maintain a learning organisation” (Liker, 2004, p. 6).
Figure 2: 4P model of the Toyota way.

The notion of continuous improvement and learning at the apex of the 4P model are important considerations that link to Leonard-Barton’s (1992) study of an organisation’s core competencies and core rigidities. Consistent with Leonard-Barton’s (1992) argument for organisations to embrace learning to overcome organisational rigidities and develop new capabilities, continuous improvement and learning is defined to be a basic characteristic inherent in a true lean learning organisation (Morgan & Liker, 2006, p. 203). The ability to lean and continuously improve has important implications for new product developments that are not compatible with an organisation’s current core competencies (Leonard-Barton, 1992).

In the context of production plants, continuous improvement tools include know-how databases, learning from focused problem solving, reflection, checklists and quality matrices, and review meetings (Morgan & Liker, 2006, p. 206). In line

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with the third research question, how can these tools enable the lean manufacturing capability of new products?

As articulated in the next section, a number of lean practices that constitute the 4P model can be applied to the new product development process.

2.6 Application of Lean Principles to New Product Development

While several frameworks for organising and managing new product development projects are available in the literature, the application of lean principles to new product development is a relatively under-developed research area. The major work thus far has been Morgan & Liker’s (2006) development of the Lean Product Development Systems model based on their study of Toyota. Using sociotechnical systems theory, the model is built on three primary subsystems: 1) process, 2) people, and 3) tools and technology (Morgan & Liker, 2006, p. 16). The authors argue that these 3 subsystems are interrelated and interdependent and have a key impact on lean new product development. Within these 3 subsystems, 13 principles are defined that comprise the Lean Product Development System model (Morgan & Liker, 2006, p. 19-24).

The process subsystem includes all the tasks and sequence of tasks required to bring a product from concept to start of production. Morgan & Liker (2006) argue that the strength of this subsystem is that it emphasises actual day-to-day activities over the typical documented new product development processes used by most organisations. By focusing on the day-to-day activities, emphasis is placed on the flow of information, evolving product designs, product testing, building prototypes, and the final product (Morgan & Liker, 2006, p. 17).
<table>
<thead>
<tr>
<th>Subsystem</th>
<th>No.</th>
<th>Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>1</td>
<td>Establish Customer-Defined Value to Separate Value-Added Activity from Waste.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Front-Load the Product Development Process While There is Maximum Design Space to Explore Alternative Solutions Thoroughly.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Create a Leveled Product Development Process Flow.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Utilize Rigorous Standardization to Reduce Variation, and Create Flexibility and Predictable Outcomes.</td>
</tr>
<tr>
<td>People</td>
<td>5</td>
<td>Develop a Chief Engineer System to Integrate Development from Start to Finish.</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Organize to Balance Functional Expertise and Cross-functional Integration.</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Develop Towering Technical Competence In All Engineers.</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Fully Integrate Suppliers into the Product Development System.</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Build in Learning and Continuous Improvement.</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Build a Culture to Support Excellence and Relentless Improvement.</td>
</tr>
<tr>
<td>Tools &amp; Technology</td>
<td>11</td>
<td>Adapt Technology to Fit Your People and Processes.</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Align your Organization through Simple, Visual Communication.</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Use Powerful Tools for Standardization and Organizational Learning.</td>
</tr>
</tbody>
</table>

*Table 1: Lean Product Development System model*

The people subsystem focuses on training, leadership, organisational structure, and learning patterns – essentially encompassing the importance of an organisation’s culture. The third subsystem (tools and technology) incorporates...

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machine technology and the use of tools that complements people’s efforts in the development projects. These tools reinforce the important lean thinking tenets of problem solving, learning and standardising best practices (Morgan & Liker, 2006, p. 23).

The 3 subsystems of this model suggest that the basis for lean product development is similar to that of lean manufacturing: people, processes, tools and technology must be appropriately integrated to add value to the customer and society (Liker, 2004; Morgan & Liker, 2006).

Morgan & Liker (2006) argue that although the Lean Product Development System model is not as well known as the Toyota Production System (TPS), it can be a very powerful tool and can possibly have a bigger impact on an organisation than lean manufacturing. This is based on the premise that the ability to impact customer-defined value is defined early in the development phase and decreases progressively as the product moves into production. Furthermore, many organisations have already embraced and implemented the concept of lean thinking in manufacturing, resulting in a narrowing of the performance gap in manufacturing capability. Thus the biggest opportunity for competitive advantage now resides in effective lean new product development (Morgan & Liker, 2006).

Despite the model’s roots in lean systems, there is currently limited evidence of it’s applicability to manufacturing industries outside the automobile industry. As discussed earlier, this model forms the basic conceptual framework of this study, investigating how lean principles can be applied to new product development in a textile manufacturing organisation.

2.7 Research Approach, Strategy and Design

A review of the past research in new product development (Appendix 1) suggests a predominantly quantitative research strategy focusing on testing various
hypotheses. Examples of these studies include Cohen et al. (1996), Datar et al. (1997), Mishra & Shah (2007), Roemer et al. (1999), Swink et al. (2004) and Zirger & Maidique (1990). These quantitative approaches are largely deductive in nature featuring survey and longitudinal designs, spanning a number of new product developments across industries and countries. While these studies are useful in synthesising existing literature into frameworks and testing them, they lack the richness of detail and context that is often useful to practitioners.

Several authors (e.g. McCutcheon & Meredith, 1993; Meredith, 1998; Voss et al., 2002; Yin, 2003a) argue for more field-based research, specifically case study research in operations management to 1) bridge the gap between researcher’s findings and practical answers for operations managers, and 2) cope with rapidly changing technology and management methods. The literature synthesis (Appendix 1) supports this argument, citing a limited number of qualitative, case based studies. Examples of the limited qualitative case study research in new product development include Griffin & Hauser (1992), Hines et al. (2005), Krishnan & Ulrich (2001), Leonard-Barton (1992), Morgan & Liker(2006) and Thomke & Ashok (2001). These studies have focused on both single and multiple case studies, offering workable answers to practitioners.

This study therefore supports the call by operations management academia for more case based studies to bridge the growing gap between academia and operations managers.

2.8 Conclusion

In reviewing current literature on new product development, it was found useful to synthesise the available work into two metrics: “new product effectiveness” and “product-to-market delivery time”. A third metric, “new product manufacturing capability” is relatively less developed in the literature, but is argued to be a critical measure of new product success.
The literature review has also highlighted that with the exception of Morgan & Liker's (2006) Lean Product Development System model, research on new product development and lean principles largely exist as separate entities. Several new product development frameworks are presented in the literature and while these often incorporate elements of lean thinking, the “how to” part is not clear.

This study aims to bridge the literature gap between lean principles and new product development by investigating how applying lean principles (specifically Morgan & Liker’s (2006) Lean Product Development System model) to new product development can 1) improve the effectiveness of new products, 2) reduce product-to-market delivery times and 3) enable lean manufacturing capability of the new product. This forms the motivation for the proposed research questions presented earlier. A framework linking the areas of research for this study is graphically illustrated in Figure 3.

![Figure 3: Framework for the research study.](image)

The review of the existing literature indicates past focus on new product development to be predominantly deductive in approach and quantitative in
nature (Appendix 1). Additionally, most of these studies (Lukas & Menon, 2004; Sethi, 2000; Swink et al., 2004) have been developed on data collected mainly from senior management respondents, ignoring the possibly rich input from other members of the new product development project team. The survey research design often favoured by these studies relies on self completion questionnaires as the primary research instrument – this structured approach limits the ability to extract rich, insightful, learning from the interviewees.

In line with the growing calls for more field-based studies in operations management (e.g. McCutcheon & Meredith, 1993; Yin, 2003a; Voss et al., 2002), a qualitative approach with a case study research design is used to answer the research questions motivated by this study; providing practical, workable advice for managers. Voss et al. (2002), highlight the power of case research by citing that many of the breakthrough theories in operations management such as lean production and manufacturing strategy have been developed using this research design. To achieve this objective, semi-structured interviews, emphasising open-ended questions (Appendix 2), were used as the primary data collection method, allowing for new and creative insights (Voss et al., 2002, p. 195). Interviewees included a wide cross-section of project team members, including project managers, project leaders, process engineers, plant managers, plant engineers, and customer service representatives, allowing for diverse perspectives to be drawn.

3 RESEARCH APPROACH AND STRATEGY

This research was developed on a sociotechnical framework (people, process and technology) and is largely inductive in approach, and qualitative in nature. The focus was to develop theory on the application of lean principles to new product development using the case study data (Bryman & Bell, 2007; Eisenhardt, 1989). Despite this inductive approach, the research was underpinned by the use of Morgan & Liker’s (2006) Lean Product Development
System model. This model served as a conceptual framework to guide the study, and allow a prior view of variables, constructs and their relationships (Miles & Huberman, 1994; Voss et al., 2002).

The deductive component of this research used the case study data to validate Morgan & Liker’s (2006) Lean Product Development System model. Bryman & Bell (2007, p. 29) confirm this as an acceptable approach and describe research examples where qualitative research has been successfully employed to both test and generate theory. The applicability of using qualitative research to test theory, particularly case studies, is further confirmed by Eisenhardt (1989) and McCutcheon & Meredith (1993).

Quantitative research typically does not cause a change in practice since researchers often define the problem in their own terms (Bolster, 1983). In contrast, qualitative researchers aim to understand the meaning of action to the participants, understand the particular context, identify unanticipated phenomena and offer improved arguments for practice; making the research very useful for practitioners (Maxwell, 2005). A qualitative research strategy is therefore best suited to meet the study goal of developing new product development propositions that organisations and management can practically consider.

3.1 Epistemological and Ontological Considerations

Consistent with the research focus on understanding rather than explaining human behaviour, an epistemological position of interpretivism is taken for this study (Bryman & Bell, 2007; Meredith, 1998). This research paradigm is justified for case studies as it is process orientated, which helps the researcher understand why certain effects occur (Meredith, 1998). This position is further developed under “Qualitative Approach Assumptions”.

An ontological position of constructionism is assumed for this research study since the phenomena studied in the 5 cases are produced through the social
interaction of employees, and are in a constant state of evolution (Bryman & Bell, 2007, p. 23).

3.2 Qualitative Approach Assumptions

According to Bryman & Bell (2007, p. 416-420) the major preoccupations with qualitative research are “1) Focus on seeing through the eyes of the people being studied, 2) description and emphasis on context, 3) emphasis on process, 4) flexibility and limited structure and 5) concepts and theory grounded in data”.

The first and fourth preoccupations were satisfied by using a semi-structured interview guide which covered the specific research topics, but also allowed the interviewees “a great deal of leeway to respond” (Bryman & Bell, 2007, p. 474). In instances, questions not in the guide were asked to explore interesting responses from the interviewees. During the data analysis phase, follow-up contact was made with 4 interviewees to clarify their initial interview responses.

The second and fifth preoccupations were inherently satisfied by the selection of a case study design, which allowed for a rich description and intensive examination of new product developments at Fibres Inc. (Bryman & Bell, 2007), thus satisfying the preoccupation of description and context. The multiple case study design selected for this study is well suited to theory development as it allowed the researcher to theoretically reflect what is unique and common across the 5 new product development cases (Bryman & Bell, 2007; Voss et al., 2002), thus satisfying the preoccupation with theory development from the data.

3.3 Limitations of the Qualitative Approach

The difficulty of replication and generalisation are the two main criticisms of qualitative research (Bryman & Bell, 2006, p. 423; Meredith, 1998).

The difficulty of replication arises from the absence of standard procedures to be followed in qualitative research (Bryman & Bell, 2007). However, Meredith
(1998, p. 449) proposes that the issue of replicability in qualitative case research can be satisfied by “applying the resulting theory to a somewhat different set of conditions”. Researchers will therefore be able to replicate the theory that will be developed in this study by testing it in other new product development contexts. The propositions and practical model (Figure 9) developed from the research findings will aid the replication.

Since the selected case studies and the people interviewed are not representative of a larger population, this study does not seek to generalise the findings to a larger population but rather focuses on deep contextual understanding, and generalising to theory (Bryman & Bell, 2007; Meredith, 1998). The focus is therefore on the quality of the theoretical inferences drawn from the 5 new product development cases.

4 RESEARCH DESIGN

4.1 Considerations

A multiple-case study design was selected over the cross-sectional and comparative research design alternatives.

Bryman & Bell (2007, p. 65) argue that if the focus is on the unique features of the cases, a multiple-case study research design should be employed. Conversely, the authors argue that if the focus is on producing general findings with little regard for the case features, a cross-sectional research design should be employed. For this study, the researcher was specifically interested in the unique features of the five new product development cases which justified the selection of the multiple-case study rather than the cross-sectional research design.

A comparative research design entails the comparison of two or more contrasting cases to gain a greater understanding of specific phenomena (Bryman & Bell,
While there may be a degree of contrast between the 5 new product development cases selected, the cases were not specifically selected primarily for meaningful contrasting features. Several of the propositions are constructed from common themes across the 5 cases.

There are increasing calls for increased case study research in the operations management field (McCutcheon & Meredith, 1993; Meredith, 1998; Voss et al., 2002). The authors argue that the gap between researchers’ findings and practical applications in the workplace is growing, requiring researchers to gather more “real world” information on operations systems in order to develop more complete theories in the field. McCutcheon & Meredith (1993, p. 239) conclude that a case study research design can address this gap and be used to develop well-grounded theories through empirical field-based research.

Consistent with the methodology selected for this 5-case study, Meredith (1998, p. 451) concludes that multiple-case study research is typically used for units of analysis ranging from 2 to 8 in past operations management studies.

![Methodological applicability relative to number of units (cases).](image)

\[^5\text{Figure 4: Methodological applicability relative to number of units (cases).}\]

\[^5\text{Source: Meredith (1998).}\]
4.2 Case Study Design

The multiple case study design employed in this study is an extension of the single case study described by Bryman & Bell (2007, p. 62) as the “detailed and intensive analysis of a single case, where the case is defined as a single organisation, location, person or event”. The multiple case study design therefore focuses on what is unique and what is common across cases, thus promoting theoretical reflections on the findings (Bryman & Bell, 2007, p. 64).

The framework for the research design was guided by the 5 case study components specified by Yin (2003a, p. 21). These components and its application to this study are tabulated in Table 2 overleaf.
<table>
<thead>
<tr>
<th><strong>Case Study Component (Yin, 2003a)</strong></th>
<th><strong>Application to Study</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The study’s questions.</td>
<td>The “how” form of the three research questions presented earlier fits a case study design since it focuses on contemporary events and does not require control of events (Yin, 2003a).</td>
</tr>
<tr>
<td>Propositions.</td>
<td>Initial propositions from literature were used to guide data collection and gather an initial view of variables, constructs and their relationships (Miles &amp; Huberman, 1994; Voss et al., 2002). Final propositions emerged from analysis of case study data.</td>
</tr>
<tr>
<td>Unit(s) of analysis.</td>
<td>Each new product development case was defined as a unit of analysis and served as contrasts, replications and extensions to the emergent theory (Eisenhardt, 2007).</td>
</tr>
<tr>
<td>The logic linking the data to the propositions.</td>
<td>Cross-case patterns, themes, contrasts and comparisons were analysed (Miles &amp; Huberman, 1994).</td>
</tr>
<tr>
<td>The criteria for interpreting the findings.</td>
<td>Sociotechnical systems theory (people, processes, technology) was used to guide the interpretation of the findings (Cherns, 1987).</td>
</tr>
</tbody>
</table>

**Table 2: Research design framework.**
5 DATA COLLECTION

Consistent with case study research, interviews were the primary source of data, and were complemented by documentation and to a lesser degree, archival records (Yin, 2003b, p. 85). This data collected for the analysis was predominantly qualitative, supplemented by a degree of quantitative data that aided cross-case analysis (Eisenhardt, 2007).

Care was taken to ensure that information was collected from at least 3 sources of data to corroborate the same fact - triangulation (Yin, 2003b, p. 99; Bryman & Bell, 2007, p. 412). Different data sources were also used to improve the validity and reliability of the study (McCutcheon & Meredith, 1993, p. 239). For example, the same facts were corroborated between different members on the same project, and to the documented data.

5.1 Documentation

Documentation included company policies and procedures, meeting minutes, decision logs, project scope documents and project closure reports.

5.2 Interviews

Interviews were conducted with the various new product development project team members including business managers, project managers, R&D engineers, production managers and production engineers. Consistent with the guidelines for case study research specified by Yin (2003b, p. 89), the interview approach was “guided conversations” rather than “structured queries”. Open-ended questions were followed by more focused questions which allowed the interviewees to express themselves more freely, offering new insights while at the same time, ensured that the data collected was relevant to the focus of the research (Voss et al., 2002, p. 205).
Interview questions were formulated along the three broad new product development dimensions of new product effectiveness, product-to-market delivery time, and lean manufacturing capability of new products developed in the literature review. To aid the cross case analysis, the researcher attempted to maintain a consistent line of questioning across interviewees (Bryman & Bell, 2007). However, minor deviations arose due to the different functional and organisational levels of the interviewees, and the use of follow-up and probing questions to explore rich responses.

All interviews were conducted face-to-face and were recorded for data analysis. The interview guide used is presented in Appendix 2.

6 SAMPLING

6.1 Cases

In order to replicate and extend the emergent theory, the 5 new product development cases were theoretically, rather than randomly sampled (Eisenhardt, 1989, p. 537). The cases were selected to highlight significant characteristics related to the study (Eisenhardt, 1989; Yin, 2003a).

The nylthread and airbag cases provided examples of new product developments that were highly successful while the polythread case was an example of an unsuccessful new product development. The aeronautical and automotive cases were deemed “moderately” successful by Fibres Inc. Success of the cases was measured by the product’s ability to satisfy customer requirements, the product-to-market delivery time and the internal manufacturing performance of the new product. The theoretical sampling tactic allowed the researcher to study specific management practices related to the outcome of each case, thus satisfying the objective of extending the emergent theory of lean application to new product development.
6.2 Interviewees

A key differentiator of this study from past studies in the literature was to incorporate a cross sectional view from the project team rather than focusing only on the views expressed by senior management (Voss et al., 2002).

Consistent with qualitative multiple case studies, interviewees were sampled on a non-probability sampling basis. The selection was dictated by 1) convenience – all key project team members, 2) stratified – all positional levels of the project (e.g. R&D, production, business, engineering), and 3) relevance to this study’s propositions (Voss et al., 2002).

A tabulation of the number interviews for each case is presented in Table 3.

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of Interviews Conducted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>3</td>
</tr>
<tr>
<td>Aeronautical</td>
<td>4</td>
</tr>
<tr>
<td>Polythread</td>
<td>3</td>
</tr>
<tr>
<td>Nylthread</td>
<td>3</td>
</tr>
<tr>
<td>Airbag</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total Interviews</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

Table 3: Interviews conducted.

In accordance with the high response rate required to capture contextual insights in case study research, an interviewee availability rate of 89% was achieved. Although 2 interviewees became unavailable during the data collection phase, the impact of this was minimised due to the relevant information becoming available from other members on the same new product development projects, and the extensive documentation data.
7 RESEARCH CRITERIA

The quality of this study was evaluated using the criteria of “construct validity, internal validity, external validity and reliability” specified by (Yin, 2003b, p. 34) for qualitative case study research. These criteria parallel the criteria of credibility, transferability, dependability and confirmability proposed by Bryman and Bell (2007, p. 411) to measure the quality of qualitative studies.

Construct validity was strengthened during data collection by using multiple sources of evidence including multiple respondents on the same cases and documented case data to develop the propositions. This tactic confirmed that the measurements reflected the same phenomena they were supposed to and prevented the subjective collection of data by the researcher (Yin, 2003b). In accordance with Stuart, McCutcheon, Handfield, McLachlin & Samson (2002, p. 430), construct validity was further strengthened by having two of the project managers and one of the production managers interviewed, review the analysis and discussion sections of this report and confirm the researcher’s understanding and correct use of the measurements.

Internal validity was strengthened during the analysis phase by using cross-case pattern matching techniques, and addressing alternative explanations to prove causality and make broader inferences (Yin, 2003b, p. 36). Specific practices across the cases were used to develop a chain of evidence to link the data with the propositions. The triangulation of data sources (multiple respondents and document data) further strengthened internal validity (Tellis, 1997).

While the generalisation of this study has been improved by selecting a multiple case design over a single case design, this study cannot be generalised out of the particular context of Fibres Inc. (Meredith, 1998). External validity was therefore met by using the case study data to generalise to Morgan & Liker’s (2006) Lean Product Development Systems model, and by developing a theory that researchers can replicate in other new product development contexts.
The reliability of the study was strengthened by the use a case study protocol and by the establishment of a database during the data collection phase (Yin, 2003b, p. 37). A case study protocol was developed using guidelines from leading exponents, including Yin (2003a), Eisenhardt (1989, 2007), Voss et al. (2002), Meredith (1998) and McCutcheon & Meredith (1993), in the case study and operations management research field. These are highly authoritative studies that were collectively published in the highly credible research journals *The Academy of Management Review* and the *Journal of Operations Management*.

A database including all the project documentation and interview recordings are available for alternate researchers to repeat the analytical procedures and test the research findings of this study.

### 8 DATA ANALYSIS METHODS

Content analysis, analytic induction and grounded theory methods were considered as possible frameworks for the data analysis (Bryman & Bell, 2007).

While content analysis is commonly used to analyse documents and texts by rigorously quantifying them into predetermined categories, a potential pitfall is that this method, which has its roots in quantitative analysis, can easily result in the research focusing more on what is measurable rather than what is theoretically significant (Bryman & Bell, 2007). Using content analysis by itself could thus impede the study objective of theory development by diverting attention from the rich insights present in the case data (Eisenhardt, 2007).

Analytical induction was found to have limited applicability to this multiple case study approach as it does not provide guidelines of how many cases need to be investigated; it specifies the conditions that are sufficient but not necessary for the phenomena occurring, and it is far too rigorous since encountering a single case that does not meet the hypothesis necessitates further data collection.
(Bryman & Bell, 2007, p. 584). Although grounded theory is arguably the most popular framework for analysing qualitative data, its applicability to this study was limited due the fact that it does not encourage the development of initial propositions, and the view that it tends to result in the generation of concepts rather than theory (Bryman & Bell, 2007). Nevertheless, several tools of grounded theory (e.g. coding) were incorporated into the analysis method.

The data for this study was analysed along the guidelines proposed by Eisenhardt (1989) and using tools specified by Miles & Huberman (1994). The guidelines are an adaptation of content analysis for case study research, in that it promotes the categorisation of matching themes between cases, but reduces the risk of the analysis becoming too measurement focused (Eisenhardt, 1989, p. 540). To aid this, the method is developed on two iterative steps, a within-case analysis followed by a cross-case analysis. A summary of the data analysis steps followed by the researcher is presented in Table 4.

<table>
<thead>
<tr>
<th>Step</th>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Partially ordered</td>
<td>Single case descriptive analysis: data-formatting, data-standardising,</td>
</tr>
<tr>
<td></td>
<td>meta-matrix</td>
<td>data-reducing.</td>
</tr>
<tr>
<td>2</td>
<td>Case-ordered descriptive</td>
<td>Cross-case analysis: identifying contrasts and comparisons, counting,</td>
</tr>
<tr>
<td></td>
<td>meta-matrix</td>
<td>pattern and theme detection.</td>
</tr>
<tr>
<td>3</td>
<td>Variable-by-variable</td>
<td>Cross-case analysis: Identify key variables, their inter-relationships,</td>
</tr>
<tr>
<td></td>
<td>matrix</td>
<td>and their effect on specific phenomena.</td>
</tr>
<tr>
<td>4</td>
<td>Causal Networks</td>
<td>Cross-case analysis: Draw inferences and develop causal explanations.</td>
</tr>
</tbody>
</table>

Table 4: Overall data analysis framework.

Source: Miles & Huberman (1994).
9 RESEARCH FINDINGS AND ANALYSIS

Consistent with the rigorous guidelines proposed by Eisenhardt (1989) and Miles & Huberman (1994), the analysis focused on finding patterns within and between cases. The data structure is developed in this section.

9.1 Within-Case Analysis

The objective of the within-case analysis was to develop a detailed description of each new product development case. This allowed the researcher to become thoroughly familiar with each case, making it easier for unique patterns to emerge (Eisenhardt, 1989). A “partially ordered meta-matrix” (Appendix 3) was developed to condense and display all the relevant case data (Miles & Huberman, 1994, p. 177). Consistent with the suggestion of Eisenhardt (1989) to limit the complexity of coding, the data was categorised into the 3 emerging dimensions of “New product effectiveness”, “Product-to-market delivery time”, and “Lean manufacturing capability” that became apparent from the literature review and linked to the research questions. The interview responses were generally coded in order of the questions asked, which facilitated the detection of common themes across the cases (Appendix 3).

9.2 Cross-Case Analysis

The second step involved an in-depth analysis of the partially ordered matrix, searching for cross case patterns, themes, comparisons and contrasts (Miles & Huberman, 1994). The output of this analysis was the case-ordered descriptive meta-matrix (Table 5) and the variable-by-variable matrix (Table 6) (Miles & Huberman, 1994, p. 184)

The case-ordered descriptive meta-matrix and the variable-by-variable matrix allowed the researcher to observe key differences and similarities across cases. Further, the variable-by-variable matrix helped to identify key variables,
understand inter-relationships between the key variables, and their effect on specific lean new product development practices (Miles & Huberman, 1994). Inferences were drawn by understanding the stream of variables leading to particular outcomes and interpreting those that were both similar and consistently different across the five new product development cases. This analysis formed the basis for the 8 propositions developed in this study.

Finally, the 5 new product development cases were quantitatively analysed using Morgan & Liker’s (2006) Lean Product Development System Model to understand the relationship between the degree of engagement of the lean principles and the success of the five new product developments (Table 8). Using the case data, each new product development case was ranked according to the degree of engagement with each of the 13 Lean Product Development System principles: 1) absent, 2) resistant, 3) partial, 4) embraced, and 5) proactive.
Table 5: Case-ordered descriptive meta-matrix.

<table>
<thead>
<tr>
<th>Dimension/Theme</th>
<th>Representative Quotations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>automotive</td>
</tr>
<tr>
<td><strong>Dimension 1: New Product Effectiveness</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Theme 1: Integration of customer and new product development project team.</strong></td>
<td>“…excellent open, working relationship with customer’s technical manager…unlimited access to customer’s production plant…”</td>
</tr>
<tr>
<td><strong>Theme 2: New product compatibility with organisational core competencies.</strong></td>
<td>“…brought knowledge of polymer science and downstream property requirements…would have taken us years to develop…”</td>
</tr>
<tr>
<td>Dimension 2: Product-to-Market Delivery Time</td>
<td>Theme 1: Hierarchal and silo organisational structures.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>&quot;Decision making took too long and the importance of this new product development was not well understood outside the business and R&amp;D functions.&quot;</td>
<td>&quot;…company structure had too many silos which had a negative impact on project delivery… slowed down the development since there was conflict between marketing, sales and R&amp;D.&quot;</td>
</tr>
<tr>
<td>&quot;…very rigid and defined roles in the company… engineering has always been very isolated and became more so once machine failures were experienced.&quot;</td>
<td>&quot;…very hierarchal company structure but product-to-market time was reduced due to techno-ops manager driving the project…bridged the gap between R&amp;D and production.&quot;</td>
</tr>
<tr>
<td>&quot;…not aware of frontloading&quot;. (After explanation): &quot;…we did not consider alternatives….under tight deadlines from the customer…&quot;</td>
<td>&quot;…we did a lot of technical work on an existing product while we waited for the new polymer. We were confident that the results could be extrapolated to the new product development.&quot;</td>
</tr>
</tbody>
</table>
### Dimension 3: Lean Manufacturing Capability of New Products

<table>
<thead>
<tr>
<th>Theme 1: Functional leadership of new product development project teams.</th>
<th>“Project Leader was too high level and focused on pure R&amp;D...no understanding of plant capabilities and was not willing to listen.”</th>
<th>“…we needed more commitment from the production management team.”</th>
<th>“Production initially worked close with us (R&amp;D), but distanced themselves when problems became apparent.”</th>
<th>“Plant was aware of existing product line flaws and was able to build improvements into the new product development.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theme 2: Compatibility of new products with existing production plant systems.</td>
<td>“...very resource intensive product takes our eye off the rest of the plant.”</td>
<td>“…we had to constantly use a dedicated rapid action team to run the product...very frustrating for the plant...organisation unfairly blamed operators.”</td>
<td>“…suffered from a white coat effect...ran well with constant babysitting by R&amp;D, but efficiencies fell when R&amp;D stepped back.”</td>
<td>“Plant personnel were not preparing the drawing machine properly before each cycle. Project team developed a work instruction detailing proper preparation procedure.”</td>
</tr>
<tr>
<td>Theme 3: Manufacturing input to new product manufacturing specifications.</td>
<td>“Manufacturing specification was agreed with the Production Manager who was part of the stage gate process”</td>
<td>“I warned them about the time it would take to change the rolls on the machine...”</td>
<td>“...with this level of capital investment, you will achieve conversion efficiencies greater than 90%...”</td>
<td>“Techno-ops and production manager did a joint study of process capability to develop tentative conversion efficiency target...agreed to adjust this based on initial process performance.”</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>“Techno-operations manager had extensive day-to-day experience and knowledge of the particular machines.”</td>
<td>“Greater ownership of product development by plant which ensured appropriate work instructions was updated.”</td>
<td>“...internal specification was developed on known capability of machines...agreed upfront with production manager and techno-ops manager.”</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>
Table 6: Variable-by-variable matrix.

<table>
<thead>
<tr>
<th>New product development case</th>
<th>automotive</th>
<th>aeronautical</th>
<th>polythread</th>
<th>nylthread</th>
<th>airbag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project duration (months)</td>
<td>9</td>
<td>3.5</td>
<td>5</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Customer location</td>
<td>South Africa</td>
<td>South Africa</td>
<td>China</td>
<td>China + Europe</td>
<td>China</td>
</tr>
<tr>
<td>Level of customer involvement</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Level of project management adherence</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Core project team size</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Supplier involvement</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>% Prime Manufacturing Conversion Efficiency Target</td>
<td>75</td>
<td>75</td>
<td>90</td>
<td>75</td>
<td>85</td>
</tr>
<tr>
<td>% Prime Manufacturing Conversion Efficiency Actual</td>
<td>80</td>
<td>60</td>
<td>75</td>
<td>83</td>
<td>94</td>
</tr>
<tr>
<td>% Prime Manufacturing Conversion Efficiency Differential</td>
<td>6.7</td>
<td>-20.0</td>
<td>-16.7</td>
<td>10.7</td>
<td>10.6</td>
</tr>
<tr>
<td>Level of customer satisfaction</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Level of internal plant satisfaction</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Level of cross functionality of team</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Level of plant Integration</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Dedication of team members</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Degree of product complexity</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Project leader experience</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>Platform</td>
<td>Current</td>
<td>Current</td>
<td>New</td>
<td>Current</td>
<td>New</td>
</tr>
<tr>
<td>Level of learning generated</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Project deadlines met</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Days over (+) / under deadline (-)</td>
<td>40</td>
<td>25</td>
<td>54</td>
<td>-20</td>
<td>-16</td>
</tr>
<tr>
<td>Within budget</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Level of frontloading of development process</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Number of sample product iterations at the customer</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

H = high, M = medium, L = low.
10 RESEARCH DISCUSSION

10.1 Sociotechnical Systems Theory Application to New Product Development

The initial analysis of the case data suggested that successful new product development at Fibres Inc. is highly dependant on both technical and social factors. New product developments are organised around complex cross-functional integration, knowledge centres, technically demanding customers, and various work procedures and systems. From the interview responses, it became clear that the synergy between these factors is critical to the management of successful new product developments.

For this reason, sociotechnical systems (STS) theory was selected to guide the interpretation of the findings. In it’s simplest form, sociotechnical systems theory states that an organisation must find the appropriate fit between the social (the people, their values and role) and technical (tools, knowledge, and procedures) system that fits the organisational purpose and the external environment (Trist & Bamforth, 1951). Within the context of this study, sociotechnical systems theory therefore argues that organisations must leverage and align their existing resources around common goals and objectives that are needed to develop new products that meet the customer requirements.

Sociotechnical systems theory is not new to the field of operations management research, having been successfully applied in past studies conducted by Niepce & Molleman (1996), Closs, Jacobs, Swink & Webb (2008), Manz & Stewart (1997), and Morgan & Liker (2006).

Cherns (1987) specifies 10 principles indicating how an organisation can achieve the appropriate fit between social and technical systems. These principles and their interpretation are summarised in Table 7.
Table 7: Sociotechnical Systems Principles

<table>
<thead>
<tr>
<th>No.</th>
<th>Principle</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compatibility</td>
<td>The design of a work system / structure must be compatible with its objectives.</td>
</tr>
<tr>
<td>2</td>
<td>Minimal Critical Specification</td>
<td>No more should be specified than is absolutely essential. The “what” of a task needs to be specified, but not necessarily the “how”. Employees must have enough freedom to perform tasks according to their own expertise.</td>
</tr>
<tr>
<td>3</td>
<td>Variance Control</td>
<td>Variances from expected norms and standards, if they cannot be eliminated, must be controlled as close as possible to their point of origin.</td>
</tr>
<tr>
<td>4</td>
<td>Boundary Location</td>
<td>Boundaries in the work process should facilitate the sharing of knowledge and experience. People who perform tasks that are closely related should be located in the same team.</td>
</tr>
<tr>
<td>5</td>
<td>Information Flow</td>
<td>Information must first go to the place where it is most needed for action.</td>
</tr>
<tr>
<td>6</td>
<td>Power and Authority</td>
<td>Individuals must exercise the power and authority needed to accept responsibility for their performances.</td>
</tr>
<tr>
<td>7</td>
<td>The Multifunctional Principle</td>
<td>Systems of social support must be designed to reinforce the desired social behaviours. Workers should be capable of performing a diverse range of jobs, giving insight into how related steps influence each other.</td>
</tr>
<tr>
<td>8</td>
<td>Support Congruence</td>
<td>Supporting systems and sub-systems need to be congruent. Systems, functions and procedures must be designed to reinforce the behaviours required by the organisation.</td>
</tr>
<tr>
<td>9</td>
<td>Transitional Organization</td>
<td>Organizations are constantly in transition from old to new. Transitional technology and society must be designed just as new organizations are designed.</td>
</tr>
<tr>
<td>10</td>
<td>Incompletion</td>
<td>New demands and conditions in the work environment mean that continual rethinking of structures and objectives is required. Design never stops.</td>
</tr>
</tbody>
</table>

The following section draws on these sociotechnical principles (Cherns, 1987) and the lean principles (Morgan & Liker, 2006) presented earlier to develop 8 propositions describing the effect of specific lean practices on new product development.

The case data was consistent with the literature review, which articulated that new product development can be broadly classified into the 3 broad dimensions of new product effectiveness, product-to-market delivery time, and lean manufacturing capability of new products. Although a degree of overlap existed, the propositions were developed within these dimensions, and provided a strong link to the 3 research questions posed earlier, thus ensuring that the study met its objectives.

The theory developed in the following section forwards distinct propositions which made it clearer to demonstrate how the case evidence linked to the theory (Eisenhardt, 2007, p. 29). Specific case practices as articulated by the interviewees were used to provide rich evidence in support of the propositions. At the same time alternative explanations and further understanding of cases that did not fit the propositions were explored.

10.2 Dimension 1: New Product Effectiveness

The literature review defined an effective new product as one that fits an organisation’s competencies and satisfies the market or customer need (Brown & Eisenhardt, 1995; Wheelwright & Clark, 1992). This is in alignment to sociotechnical systems theory principle 1 of compatibility, which argues that the design of a work structure or process must be compatible with its objectives (Cherns, 1987). At Fibres Inc., two themes were discovered to significantly impact on new product effectiveness: 1) the ability to develop a new product specification that explicitly understands the customer’s requirements, and 2) the compatibility of the new product with the organisation’s core competencies (Leonard-Barton, 1992). In line with these themes, the first two propositions are
forwarded.

**P1: New product developments that fully integrate the customer and the project team throughout the development phase are more likely to meet the customer’s requirements.**

Several studies (Bonner, 2004; Griffin & Hauser, 1992) argue that defining a product specification based on the customer’s preference is the key enabling step in a new product development project. Although all 5 new product development cases studied developed a specification with the customer at the start, it is argued that customer interaction must not stop at this point, but should continue throughout the project. Sociotechnical systems principle 4 of boundary location argues that boundaries should facilitate sharing of knowledge and experience (Cherns, 1987). In this context, it is argued that boundaries between the organisation, specifically the new product development project team, and the customer/s should be open to facilitate sharing of information throughout the project. This is particularly important for technically complex, niche products where the specification may need to be reviewed as more information becomes available, or downstream end-uses change during the project (Mishra & Shah, 2008). This stance is further supported by sociotechnical systems principle 10 of incompletion, which suggests that the organisation must be prepared to amend its objectives as new conditions and demands arise (Cherns, 1987).

With the exception of the airbag product development, the other new product developments incorporated mechanisms that integrated the customer throughout the product development. Mechanisms included joint technical workshops at defined stages of the project at Fibres Inc. and the customer’s premises, and frequent telephonic and email progress updates. The document analysis indicated detailed and informative workshop agendas and meeting minutes that were compiled by Fibres Inc., clearly noting follow-up actions and decisions made by both parties. Customer interaction during the airbag development was limited due to the language barrier, but this was negated by a detailed and
accurate specification that was developed upfront, the use of a Chinese agent, and a relatively less complex product requirement.

The benefits of integrating the project team and the customer were best demonstrated during the automotive and aeronautical product developments. The automotive product was for a second tier customer that converted the product into an automotive application. This was a new product stream for the customer and as a result, the customer had limited knowledge of the downstream requirements. Fibres Inc.’s R&D director was a world renowned expert in this industry and was able to leverage his knowledge and industry networks to articulate the product requirements and facilitate the introduction of the customer’s product into the market. Additionally, the automotive product development project leader was able to establish a working relationship with the customer’s technical manager which allowed both parties to continually assess technical requirements and ensure the product met the customer requirements. This was facilitated by both parties willingness to share technical data (sociotechnical systems, principle 4). The transparent relationship between the parties also resulted in the customer being more accommodating to accept delays in the development when they arose.

Evidence of close collaboration with the customer was also observed during the aeronautical product development. Fibres Inc. had extensive knowledge of the customer’s machines and processes and was able to leverage this knowledge to tailor the product for the customer’s machines, and recommend machine settings to the customer. As a result, the initial new product specification was revised 3 times during the project as more information became available from the customer. Without the integration of the customer, the aeronautical product development would have been dictated by the initial specification, and would not have satisfied the customer requirements.

However, simply integrating the customer with the organisation is not enough. Sociotechnical systems principle 5 of information flow advocates that information
must first go to the point where it is most needed for action (Cherns, 1987). This was apparent during the automotive and aeronautical product developments, where project team members were able to liaise directly with their counterparts at the customer. For example, the technical requirements for the products were discussed directly between Fibres Inc.’s R&D project members and the customer’s technical team. Increasing customer interactivity with functions that do not normally interact with customers (e.g. R&D and manufacturing), forces all project members to increase their knowledge of customer requirements and ensure that their activities are aligned accordingly (Bonner, 2004).

While the customer was closely involved during the polythread development, information flow was confined to the R&D director. Technical discussions with the customer were handled personally by the R&D director, who then filtered information through to the project technical team. This resulted in frustration amongst the project team, who struggled to articulate the product properties required for the customer’s application, and contributed to 4 additional product iterations to meet the customer requirements. The high number of product iterations resulted in the customer losing confidence in the organisation’s capability and in the project exceeding the deadline. Consequently, the customer decided to source the majority of the product from a competitor of Fibres Inc.

In line with the first proposition offered, Morgan & Liker (2006) contend that a lean product development must start at the customer. Properly articulating the customer requirements upfront allows an organisation to ensure that project teams focus on activities that are aligned to customer value, and wasteful activities are minimised (Morgan & Liker, 2006). In the context of the 5 cases studied at Fibres Inc., there is evidence to suggest that intimately integrating the customer during the development phase can ensure that the new product meets the customer’s needs despite changes to the specification that may arise during the development (Bhattacharya et al., 1998). This necessitates that each of the organisational functions explicitly understands the customer’s needs (Griffin & Hauser, 1992). Additionally sociotechnical systems theory builds on this, arguing
that information flow is critical – project team members must liaise directly with their counterparts at the customer to get a clear message of the requirements (Cherns, 1987).

**P2: New product developments that are compatible with an organisation’s people and technologies are more likely to meet the customer requirements.**

Sociotechnical systems principle 1 of compatibility advocates that the design of a work system must be compatible with its objectives (Cherns, 1987). Within the field of new product development, this principle is interpreted to mean that the development must be aligned to an organisation’s core competency (Leonard-Barton, 1992; Wheelwright & Clark, 1992; Cooper, 1979; Zirger & Maidique, 1990).

The interviews suggested that there was a strong relationship between the success of the 5 new products and the fit with Fibres Inc.’s core competencies. The requirements for the successful automotive, nylthread and airbag products were acknowledged by the interviewees to be within the technical, asset, people, and market expertise of Fibres Inc.

For example, Fibres Inc.’s technically astute quality division, consisting of a number of senior graduate scientists and engineers, was able to interpret the strict international regulatory requirements for the automotive product and incorporate this into the product development. Further, the newly appointed R&D director was internationally acclaimed as a leader in this field, and was able to bring his considerable technical and market expertise to the automotive development.

The nylthread and airbag products were part of a product group targeted at a market where Fibres Inc. was the global leader in terms of market share for the last 30 years. The accumulated knowledge of the market requirements, technical characteristics, and in-house systems therefore constituted the core
competencies of Fibres Inc., and facilitated the successful development and introduction of both products. For example, the R&D department had access to similar past product development reports, the learning’s of which could be applied to the nylthread and airbag products. Furthermore, many of the R&D engineers involved in the product group development over the last 30 years were still employed at the organisation, and provided a wealth of knowledge and experience to support the development. Compatibility of the nylthread and airbag products with existing production equipment and operator skills was also considered a core competency at Fibres Inc. (Cherns, 1987). Production machines installed over the last 30 years were designed specifically for the nylthread and airbag product groups and machine operators were highly skilled and experienced in the production of both product groups. These competencies were critical in delivering both products that met the customer’s requirements.

Additionally, Fibres Inc.’s core competencies in these two product groups had over time strengthened their reputation in the market and resulted in a “pull” effect from the customer rather than a “push” effect from the organisation to get the nylthread and airbag products into the market.

As described in proposition 1, the aeronautical product development benefited from Fibres Inc. extensive knowledge of the customer’s processes. This knowledge was developed by close collaboration with the customer over a period of approximately ten years, and the installation of pilot equipment at Fibres Inc. that simulated the customer’s process. It is thus argued that the accumulated knowledge of the customer’s process had developed into a core competency for Fibres Inc. (Leonard-Barton, 1992).

In contrast, the polythread product development necessitated a major modification of an existing platform that was later acknowledged by the project manager to be not within Fibres Inc.’s core competencies. The complexity of the engineering work required to achieve this was initially underestimated by Fibres Inc., who took a decision to modify machines using in-house engineering
resource without the support of the original equipment manufacturers. The tight deadlines of the project, limited engineering expertise, and inadequate resource levels resulted in sub-standard machine performance which impacted on product quality, and consequently the ability to meet the customer’s requirements. By the time senior management eventually agreed to allow the equipment manufacturers to get involved, the project had already progressed to the commissioning stage, resulting in the equipment manufacturers distancing themselves from the job.

The engineering complexity required for the polythread product development is an example of a “core rigidity” articulated by Leonard-Barton (1992) that should be managed to redefine organisations core capabilities or initiate new capabilities. Linked to the notion of developing new capabilities, is the ability for organisations to learn and continuously improve during lean new product developments (Morgan & Liker, 2006). In the case of the polythread development, senior management should have allowed external equipment manufacturers to work together with the project engineers for the modification of the machines. In addition to increasing the possibility of correctly modifying the machines, Fibres Inc.’s engineers would have been presented with an opportunity to learn from the equipment manufacturers, thus developing new core capabilities in machine modification (Wheelwright & Clark, 1992).

Involving the external equipment manufacturers is aligned to sociotechnical systems principle 8 of supporting congruence and principle 10 of incompletion (Cherns, 1987). Management must ensure that supporting functions like engineering and systems are designed to support the goals of the new product development. The engineering requirements for product polythread should have necessitated a review of the capabilities of the in-house engineering function at the start of the project.

Aligned to this stance is the importance of involving suppliers in a lean product development system (Morgan & Liker, 2006). The authors contend that in order
to leverage their technical expertise, organisations must manage and nurture their suppliers in the same way they manage internal engineering resources (Morgan & Liker, 2006).

10.3 Dimension 2: Product-to-Market Delivery Time

Product-to-market delivery time relates to the speed at which organisations introduce new products to the market (Wheelwright & Clark, 1992; Cohen et al., 1996; Schilling & Hill, 1993). At Fibres Inc. two central themes of organisational structure and frontloading the development process were found to have a significant impact on product-to-market delivery time. Almost all interviewees across the five cases highlighted the rigid organisational structure as the key factor impeding a reduced product-to-market delivery time. Interviewees expressed frustration was expressed at the long times it took for both information to become available, and decisions to be made.

The nylthread, airbag and automotive product developments indicated a medium-to-high level of frontloading the development process while the aeronautical and polythread developments indicated a low level of frontloading. In each of the cases, it became apparent that the degree of frontloading impacted on the project’s ability to meet the deadline.

Consistent with the literature (Lukas & Menon, 2004), product developments at Fibres Inc. were under constant pressure to balance the trade-off between product-to-market delivery time and new product quality. The business and marketing functions were constantly striving for reduced product-to-market delivery times, while R&D resisted in favour of increased product-to-market delivery times in order to ensure product quality. Contrasting patterns between the cases highlighted the project management system as a powerful tool to manage the trade-off.

Propositions 3 and 4 highlight the impact of organisational structure and
frontloading respectively on product-to-market delivery times. By contrasting the level of adherence to the project management system amongst the 5 cases, proposition 5 then describes how the trade-off between product-to-market delivery time and new product quality can be effectively managed.

P3: New product developments that occur within hierarchal and silo organisational structures increase product-to-market delivery time by hampering the flow of information and slowing decision-making.

The information flow principle of sociotechnical systems theory specifies that actionable information should be targeted towards employees who need it the most (Cherns, 1987). In the case studies, it became apparent that the hierarchal structure of Fibres Inc. impeded the flow of information during new product developments. In each case, interviewees highlighted the rigid organisational structure as the main obstacle to decreasing product-to-market delivery time. The slow flow of information between functional groups made it difficult for key decisions to be made and consequently, critical tasks took longer to be executed (Morgan & Liker, 2006).

Almost all interviewee respondents indicated the greatest organisational divide to be between the R&D and marketing functions. This was confirmed by the document analysis of the meeting minutes for each case. In line with the project management system, weekly project review meetings set up by R&D, were held to update all stakeholders on the progress of the new product developments. The attendance list indicated a low attendance level of marketing representatives at the weekly project review meetings. As a result, decisions that required the input from marketing could not readily be made. According to the interview responses, the divide between R&D and marketing was often due to the disagreement between both functions of the product-to-market delivery times, and the consequent poor relationship that developed between the R&D director and marketing manager. The strained relationship between the R&D director and the marketing manager often played itself out in meetings where subordinates
where present. Marketing would confirm a product delivery time to the customer or market without first getting agreement from R&D. R&D on the other hand, was more focused on ensuring that the new product met the customer requirements and often felt that marketing were imposing unrealistic deadlines on the project. This stand-off resulted in a breakdown in communication and the relationship between both functions, and consequently slowed down the project delivery.

Similarly, divisions between the engineering, production and R&D functions were found to impact on product-to-market delivery times. An example of this was the polythread product development where divisions between production, R&D, and engineering became apparent as problems surfaced during the development. The engineering team was aware of the challenges of modifying the machines but did not request support, fearing that this would reveal weaknesses in their department (Wheelwright & Clark, 1992). As a result, engineering regularly painted an overly optimistic picture of their progress and it was only during the machine commissioning phase that the problems became apparent. The division between R&D and production was highlighted by production distancing itself from the project as they felt that their input was not valued by R&D. Without production support, the R&D team found it difficult to plan and execute development work on production machines. Development work thus took longer than planned, and this increased the project-to-market delivery time.

Of the 5 cases studied, the nylthread and airbag product developments exhibited the highest level of cross-functional integration. However, it is worth noting that the degree of cross-functionality required from marketing was minimal since the R&D director had a strong relationship with the potential customers for both these products. He was thus able to directly negotiate product-to-market delivery times with the customer. Cross-functional integration between R&D and production was also aided by the techno-operations manager who led both projects and served as the link between both functions. This resulted in a high degree of cooperation as both functions were aligned to mutual goals and information was
readily available to decision-makers (Wheelwright & Clark, 1992).

An overview of Fibres Inc.’s organisational structure provided insight into the challenges of achieving cross-functional integration on new product developments. The challenge for new product development is to occur across the three rigid functional divisions of company services, R&D and manufacturing. These three functional divisions are then composed of a total of five sub-divisions.

Evidence from the interviews and project documentation indicates that Fibres Inc.’s organisational structure is typical of a hierarchal, silo structure that impedes the flow of information and serves functions and professions rather than the company, its products or customers (Morgan & Liker, 2006, p. 140). An example of this was the automotive product development where the R&D team focused on developing their intellectual knowledge on polymers with little regard for applicability to the plant or the customer. An analysis of the project meeting minutes indicated a disproportionate amount of time spent on understanding theoretical aspects of polymer science and very little regard for translating this learning into a new product. A second example was evident on the polythread development, where engineering was “fascinated” with the state-of-the-art control systems that were necessary for modifying the machines, but were not really

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**Figure 5: Organisational structure of Fibres Inc.**

Evidence from the interviews and project documentation indicates that Fibres Inc.’s organisational structure is typical of a hierarchal, silo structure that impedes the flow of information and serves functions and professions rather than the company, its products or customers (Morgan & Liker, 2006, p. 140). An example of this was the automotive product development where the R&D team focused on developing their intellectual knowledge on polymers with little regard for applicability to the plant or the customer. An analysis of the project meeting minutes indicated a disproportionate amount of time spent on understanding theoretical aspects of polymer science and very little regard for translating this learning into a new product. A second example was evident on the polythread development, where engineering was “fascinated” with the state-of-the-art control systems that were necessary for modifying the machines, but were not really
aligned to the requirements for developing a successful polythread product.

Cross functional integration is a key component of a lean product development system. Morgan & Liker (2006, p. 139) argue for a “product-focused” organisation rather than a “functional” organisation structure for a lean product development. The authors argue that having a “product-focused” structure breaks down barriers between the functions and aligns the whole organisation to a common goal that directly serves the customers. The resulting effectiveness of communication and coordination serves to reduce product-to-market delivery time (Morgan & Liker, 2006, p. 140).

A “product-focused” organisational structure as articulated by Morgan & Liker (2006, p. 140) is consistent with sociotechnical systems principle 4 of boundary location, which specifies that people who perform closely related tasks, should be part of the same team (Cherns, 1987). This notion is further supported by Wheelwright & Clark (1992) who argue that effective cross-functional integration for new product developments must be built on shared responsibility for the results. With the exception of the nylonthread and airbag product developments, very little shared responsibility was evident between the cases. This was exemplified in the polythread product development, where engineering was held responsible for delivering sub-standard machines, and production distanced itself from the project once it became clear that the product would not meet customer specifications.

There are several implications for senior management to overcome the challenges of cross-functional integration required for new product development. In addition to establishing a framework for integration, senior management must firstly set the example of interaction amongst themselves (Wheelwright & Clark, 1992, p. 185). Senior functional manager’s communication patterns, trust and respect towards each other influences the behaviour of the employees, and thus the overall pattern of integration in the new product development process (Wheelwright & Clark, 1992). As was evident at Fibres Inc., a strained
relationship between senior managers can easily filter through to the subordinate level, making cross-functional integration even more difficult as functions strive to outperform each other rather than to serve the mutual interests of the organisation.

Interestingly, the analysis of the cases suggest that strong product focused teams can also develop within an appropriate project management system. Project management tools such as the responsibility and accountability chart, resource loading chart, and weekly review meetings promotes shared responsibility for the outcomes of the project by clearly defining the role and expectations of each functional project member. This was evidenced on the automotive, airbag and nylthread projects where team members felt they knew exactly what was required of them during the project. The role of the project management system will be further developed in proposition 5.

**P4: New product developments that incorporate frontloading of the development process reduces the number of sample product iterations at the customer, thus reducing product-to-market delivery time.**

Frontloading is defined as the process of detailed, rigorous planning, by “thinking through all critical project details, anticipating problems, applying lessons learned, and exploring all alternatives” at the start of a new product development project (Morgan & Liker, 2006, p. 39). The authors argue that frontloading minimises the need for late product design changes which are often expensive and degrades product quality and process performance, by minimising the early variation in a product development. This stance is therefore synergistic with sociotechnical principle 3 of variance control, which argues that deviations, if they cannot be eliminated, must be controlled as close as possible to their point of origin (Cherns, 1987). At Fibres Inc., product developments that incorporated the frontloading process resulted in fewer sample product iterations at the customer, since inherent variation was either eliminated or minimised at the start of the
Due to the technical complexity of customer requirements, new product developments at Fibres Inc. often require several iterations (or prototypes) before commercialisation. It is difficult to predict and plan for the number of product iterations required. Further customer or market evaluation time periods of the sample product is difficult to estimate. Therefore, if a higher than planned number of iterations occurs, the product-to-market delivery time increases. The document and interview analysis indicated strong relationships between the level of frontloading in the project, number of sample iterations, and delivering the product within an agreed deadline. The aggregate relationship for the 5 cases is illustrated below.

**Figure 6: Effect of frontloading on sample iterations and project deadline.**

On average, the product developments (automotive, aeronautical, and polythread) with a low-to-medium level of frontloading required 3 to 4 product iterations at the customer, while the nylthread and airbag product developments which incorporated a high degree of frontloading required 0 and 1 product iterations respectively. Interestingly, the nylthread and airbag product developments were also completed within the initially agreed deadlines, while the automotive, aeronautical, and polythread developments exceeded the deadlines by an average of 40 days. While it is acknowledged that several other variables
may have impacted on the number of product iterations and project deadlines, the interview and document analysis provides valuable insights to the benefits of frontloading the development process.

Fibres Inc. defines the concept of “sighter trials” to encapsulate the process of frontloading. Sighter trials refer to work that is conducted before the start of the new product development project to help decision-making on asset utilisation, technical capability and people capability. It essentially provides decision-makers with “insight” into the development process; hence the name. This practice is thus very much aligned to the lean principle of frontloading articulated by Morgan & Liker (2006) earlier.

The nylthread new product development involved optimising a new raw material input (polymer) on an existing platform. A separate project remit was raised to handle the sighter trials prior to the new product development. Investigative work was thus completed on the existing polymer to develop response curves which could then be extrapolated to the new polymer. This was completed during the wait for the formulation and delivery of the required polymer raw material. Additionally, the work allowed the team to confirm the compatibility of several technical machine parts with the process conditions. The sighter trials therefore allowed the team to make decisions on process conditions, machines to be used, and the suitability of several machine parts (Morgan & Liker, 2006). This information helped the team to understand potential obstacles to meeting the new product development deadline. For example, if a spinneret (machine part) redesign was required, the team could have initiated this well in advance of the actual new product development. The initial results of the sighter trials were discussed with the customers, who shared the development team’s confidence and requested no sample evaluations. By frontloading the development and eliminating the need for sample evaluations, the team had thus reduced product-to-market delivery times.

Similarly, the airbag development incorporated a high amount of planning,
theoretical understanding and asset selection before physical development work started. Although no sighter trials were conducted, existing theoretical process models were used to model the customer’s required property specification (Morgan & Liker, 2006). The customer had requested the product “shrinkage” to be at a higher value than that of Fibres Inc.’s standard product range. Fibres Inc. was aware that the higher shrinkage requirement would require specific processing conditions on their drawing machines. The optimum machine was thus selected based on reviewing the machine design manuals. By completing this work upfront, it was not necessary to change machine types later in the product development phase which would have had negative implications for cost and time (Morgan & Liker, 2006).

In contrast, both the aeronautical and polythread new product developments did not incorporate any sighter trials upfront. In both cases, the project managers stated that this was due to the time pressure of delivering the product to the market. The interview responses of the R&D project members indicated that in hindsight, the incorrect drawing machines were used for the product developments. This was only realised after most of the technical work had been completed, making it difficult to change the type of drawing machines (Morgan & Liker, 2006). For both the aeronautical and polythread projects, senior management dictated the drawing machines to be used in an effort to reduce the product-to-market delivery times. This practice is in contradiction with sociotechnical systems principle 2 of minimum critical specification which contends that the endpoint of a task should be specified but not necessarily the method to achieve it (Cherns, 1987). Senior management should therefore have allowed preliminary investigative work to identify the optimum machines to achieve the customer’s product specifications.

Despite struggling to meet the properties specified by the customer, management sanctioned the shipment of evaluation samples of the aeronautical and polythread products were shipped to the customer. Both samples failed at the customer, necessitating further redevelopment. Sociotechnical systems principle
3 of variance control argues that variances from a defined standard should be controlled as close to the point of origin as possible (Cherns, 1987). In this context, aeronautical and polythread product samples should not have been shipped for customer evaluation until all specifications were met. Several unsuccessful sample product iterations were conducted at the customer, before the aeronautical product was accepted at the customer, and the polythread project was eventually cancelled. As a result, the high number of sample iterations at the customer resulted in both product developments exceeding the agreed deadline.

Interestingly, when the organisation finally decided to select the optimum drawing machine for the polythread product development, the team was easily able to meet all the product requirements for the customer. The customer evaluation confirmed suitability of the product, but it was too late as the customer had already signed a long term supply contract with one of Fibres Inc.’s competitors. Fibres Inc. had thus incurred significant costs in developing the polythread product which was eventually rejected by the customer.

The analysis of the cases highlights the importance of conducting work upfront to help decision-making in the new product development project. The information that becomes available allows the correct decisions to be made early in the project, preventing significant rework later in the project (Morgan & Liker, 2006). As demonstrated by the aeronautical and polythread cases, rework conducted during the later stages of a new product development project has a significant impact on cost, quality and product-to-market delivery times (Morgan & Liker, 2006).

**P5: New product developments that adhere to a rigorous project management system balance the trade-off between product-to-market delivery time and product quality by facilitating joint decision-making amongst all internal stakeholders.**
Consistent with the literature (Cohen et al., 1996; Lukas & Menon, 2004; Roemer, Ahmadi & Wang, 1999; Sethi, 2000), new product development teams at Fibres Inc. are constantly challenged to reduce product-to-market delivery times, while maintaining the quality specification of the new product. These studies have all indicated an inverse relationship between product-to-market delivery times and product quality. As product-to-market delivery times are decreased, project teams come under pressure and are forced to take shortcuts that often compromise the quality of the new product (Sethi, 2000). The challenge then is for organisations to balance the trade-off between product-to-market delivery times, and new product quality. The challenge of this trade-off links to sociotechnical systems principle 10 of incompletion which contends that new demands in the workplace require continual rethinking of objectives (Cherns, 1987). The dynamic nature of new product developments requires organisations to continually rethink the trade-off between product-to-market delivery time and new product quality.

Evidence from the interview responses and project documentation indicate that strong adherence to the project management system helped Fibres Inc. to manage the trade-off between product-to-market delivery time and quality of the new product. To develop this proposition, it is first necessary to gain a brief overview of the dimensions of the project management system utilised by Fibres Inc. The main features of the project management system included a product specification, milestones, risk analysis, decision log, next step register and a responsibility and accountability chart. These features thus provide a structured platform for managing and organising the new product development projects (Wheelwright & Clark, 1992).

The degree of adherence of each new product development to the project management system was qualitatively rated using the interview responses and the project documentation. Factors such as discipline of review meetings, working towards milestones, recording and actioning of next steps and decisions, formed part of the document analysis. Accordingly, the automotive, nylthread,
and airbag projects indicated a “high” adherence, the aeronautical project indicated a “medium” adherence and the polythread project a “low” adherence to the project management system.

At Fibres Inc., there is evidence to suggest that different stakeholders exert conflicting pressure on the new product development project teams. The business and marketing functions constantly strive for reduced product-to-market delivery times while R&D resist, arguing for more time to ensure that product quality standards are met. High adherence to the project management system was found to help balance this tension on the automotive, nylthread and airbag projects.

The project management system of the nylthread and airbag new product developments indicated thorough and detailed project management documentation. In particular, the decision log indicated joint decisions by all stakeholders on project issues. Despite the lengthy paperwork, the importance of adhering to the project management system was acknowledged by all project members as key to meeting the deliverables. Decisions were taken at the weekly project review meetings with the key stakeholders present. An example of the benefit of joint decision-making was highlighted on the nylthread project, where R&D requested an extension of the deadline in order to conduct optimisation which was not part of the original plan. However, the marketing representative was able to share market intelligence of a competitor who was developing a similar product, thus emphasising the importance of not increasing the product-to-market delivery time. A risk analysis of not doing the additional work was conducted by the team and it was jointly agreed that the work was not critical to the quality of the new product – it was aimed largely at increasing the technical knowledge of R&D. The communication protocols (weekly review meeting) and decision-making protocol components of the project management system had guided the team to balance the trade-off between quality and product-to-market delivery time.
The automotive case provided an example of where the product-to-market delivery time was increased to ensure the product quality. At the halfway stage of the project, it became clear that complexity of the development had been underestimated by Fibres Inc and the customer. Knowledge from the first customer sample iteration indicated that a particular product property not originally included in the scope of the development would need to be optimised. R&D shared this position with marketing at the weekly project meeting, who agreed that the project deadline would need to be extended to complete the additional work. As a result the product-to-market delivery time was increased by one month, but this was an acceptable trade-off given the importance of meeting the quality specifications for the automotive product.

In contrast, the project management documentation for the polythread new product development indicated irregular meetings between stakeholders, partial completion of team next steps, and an absence of a decision register. The low adherence to the project management system was confirmed by the project manager and project leader who both argued that although the project started with a good adherence to the project management system, the level of adherence declined as the project progressed due to senior management overriding the system, and high time pressures on the project team which resulted in the team sacrificing the project management system.

The polythread project leader was often approached directly by the R&D director to add extra development work to the existing plan within the same time frame despite the protests of the project leader. As a result the team took several shortcuts which undermined the quality of the development work (Sethi, 2000). An example was the reduced samples produced to confirm a particular property of the product. Once the production was ramped up to produce customer samples, the particular property was measured to be below the customer specification, due to the design testing being statistically inconclusive. As a result the work had to be repeated, which resulted in an increase in the product-
to-market delivery time.

Proposition 5 builds on the assertion by Lukas & Menon (2004, p. 1260) that both formal and informal control are positively related to new product quality. In the context of the 5 cases studied, formal controls refer to the written management-initiated project management system. Proposition 5 further identifies the decision-making step of the project management step as the key to balancing product quality and product-to-market delivery times. In each of the cases, issues surfaced during the project that threatened to impact on either product quality or product-to-market delivery time. As illustrated by the automotive, nylthread and airbag product developments, the correct trade-off decision between product quality and product-to-market delivery was facilitated by joint-decision making within the project management system. The system provides a platform for the different organisational functions to share their knowledge and give credibility to the decision (Lukas & Menon, 2004). The polythread case highlighted the possible impact of not managing project decisions within the project management system. A decision was taken in isolation which impacted product quality, and the consequent rework increased the product-to-market delivery time.

Proposition 5 links to the earlier developed proposition 3 which emphasised the importance of cross functional integration on new product development projects. Without cross functional integration, information flow from different functions will be impeded, making it difficult to make the correct decision to balance the trade-off between product-to-market delivery time and new product quality.

While Morgan & Liker's (2006) Lean Product Development System model does not explicitly consider the project management system, and decision-making protocol as an enabler for lean new product development, there is significant evidence from lean manufacturing literature that highlights decision-making and tight control (standardisation) as important considerations for lean new product development. Analogous to the joint-decision making step described in this
proposition, the Japanese lean concept of “Nemawashi” specifies that problems and potential solutions should be discussed with all affected parties to collect all ideas and get agreement on a path forward (Liker, 2004). Additionally, the need for rigorous adherence to the project management system is encapsulated by Rule 1 of the Toyota Production System (TPS), which contends that “All work shall be highly specified as to the content, sequence, timing, and outcome” (Spear & Bowen, 1999, p. 98). As articulated by proposition 5, both lean notions have relevance to the organisation and control of new product development projects, particularly the trade-off decision between product-to-market delivery time and new product quality.

10.4 Dimension 3: Lean Manufacturing Capability of New Products

Lean manufacturing capability of new products refers to the state of the new product before it is handed over to the plant. In addition to satisfying the customer requirements, the product must be able to satisfy the internal manufacturing specifications. Although the customer requirements are often built into the manufacturing specifications, several key parameters that do not directly affect the customer must be met. For example, at Fibres Inc. prime conversion efficiency target, machine change-over complexity, and compatibility with existing plant systems are factors that must be considered prior to product implementation in the plant. A product that does not meet the prime conversion efficiency target, has a long changeover period, and is not compatible with existing plant systems at implementation can generate significant waste which impacts on the profitability of the product. Additionally, the product may require expensive post-launch rework. There is therefore a strong case for new product development teams to design products that meet internal manufacturing specifications. This notion is in accordance with sociotechnical systems theory principle 1 of compatibility, which posits that the new product design must be compatible with not only the customer requirements, but also the internal
manufacturing specifications (Cherns, 1987).

The 5 case studies revealed contrasting management practices that argue for greater integration with the manufacturing function during product development. The evidence suggested that the knowledge and experience of manufacturing employees must be integrated into traditionally R&D-led new product development projects. This position forms the basis for the final 3 propositions forwarded.

**P6: New product developments that are led by a plant engineer results in a new product that is already ‘wired’ for lean manufacturing before it is handed over to production.**

The interview and document analysis revealed that the functional leadership of new product development projects impacts on the success of the new product in manufacturing. The nylthread and airbag new product developments were led by the plant techno-operations manager, in contrast to the “traditional” R&D project leaders on the other three projects. The document analysis indicated that the two projects led by the plant techno-operations manager yielded the highest post-launch prime conversion efficiency percentage differential of 10.7% and 10.6% for the nylthread and airbag products respectively; and therefore the lowest waste percentage, easily surpassing the target prime conversion efficiency stated in the new product development specification. Although the high prime conversion efficiencies measured may partly be attributable to other factors, there is strong evidence to suggest that the leadership of the new product development had a significant impact.

The argument for plant-led new product development projects is strongly supported by sociotechnical systems theory (Cherns, 1987). For example, principle 7 of multifunctionality contends that workers should be able to perform a diverse range of jobs, giving them insight into how related work steps influence each other (Cherns, 1987). In the case of the nylthread and airbag product
developments, the techno-operations manager was able to leverage his considerable knowledge of the plant capabilities and systems to align the tasks of the new development projects.

In the case of the nylthread product development, the techno-operations manager was aware of production flaws that resulted in high waste generation in the existing product group. He was thus able to design additional steps in the new product development plan to ensure that these flaws were eliminated from the nylthread product. As evidenced by the project scope document, the existing production flaws were not readily apparent, or a priority to the R&D project members. By eliminating known product flaws during the design stage, product wastage was minimised once the product was introduced into the plant, eliminating the need for further rework by the plant team. In a related way, sociotechnical systems principle 3 of variance control supports the notion of not exporting existing variance or product flaws to a new product (Cherns, 1987).

Similarly, the airbag product development benefited from the quality of decision-making of the techno-operations manager. Again, his decision-making abilities were aided by production knowledge not apparent to R&D. An example of this was highlighted by the selection of the operating temperature for the drawing stage of the airbag product. R&D had initially specified the temperature based on technical trials to meet the product properties. However, the techno-operations manager was aware that the specified temperature was too high from a production perspective. The high temperature would result in excessive deposits forming on the machine which would necessitate longer cleaning times between production cycles. Consequently, this would decrease machine utilisation and increase the time the plant would spend on non-value adding activities. As the project leader, the techno-operations manager had the authority to challenge R&D to develop an alternative solution at a lower temperature. R&D complied and alternative machine settings were developed to achieve the required product properties at a lower operating temperature.
Perhaps the strongest argument for plant-led new product developments arises from the pull rather than push analogy that is a key requirement of lean thinking (Jacobs & Chase, 2008, p. 234). Several studies have described the difficulty of moving a new product development from R&D to the production plant (Swink & Song, 2007). As evidenced on these two cases, selecting a plant project leader overcomes this issue as the plant “pulls” the new product rather than the R&D team having to “push” the new product into the plant.

Fibres Inc. defines “product handover” as the penultimate step in the new product development project. It is during this step that R&D formally hands the product over to the plant. The interview responses suggest that often, very little consensus is reached between both parties during the handover step. Production argue that R&D forces products that are not yet ready for production while R&D contend that the products are in fact optimum, but production systems need to be improved to run the products. This was confirmed by the document analysis for each of the cases, which indicated lengthy ‘reservation lists’ developed during the handover step.

The automotive new product development was led by a senior R&D employee who, according to two members of the project team, was too far removed from the realities of the production plant. This stance was supported by the analysis of the project documents which subjectively emphasised administrative and pure scientific work, over activities to ensure product compatibility with the plant systems. Although the production manager and the plant engineer were part of the project team, they felt that project leader was not taking their input seriously. As a result, work activities to ensure the automotive product met the lean requirements of the plant was only recorded during product handover, and these activities continued for approximately 6 months after the product was implemented in production. Examples of these activities included operator training, optimising machine setup times and matching spinning and drawing throughputs (similar to “kanban” – regulate the flow of material only when it is needed). At the end of 6 month period, the waste generated from the automotive
process decreased by 3.6%, highlighting the potential benefits to be had if lean manufacturing capability tasks was included in the new product development project.

Similarly, the R&D-led aeronautical and polythread product developments experienced difficulties in integrating the plant, and consequently handing the product over to production. In both cases, the production team stated that the products were not compatible with their plant systems and requested several additional work steps before plant hand-over. In the case of the polythread project, the production team felt strongly that their input was not valued by the R&D team. After initially rejecting this view from production, the R&D interviewee later acknowledged that the input from production was only considered as a last resort to resolve machine and quality issues that the R&D team was struggling with.

In the context of Fibres Inc., there is strong evidence to suggest that new product development projects that are led by the plant instead of R&D, results in products that are already “wired” for lean manufacturing and therefore readily embraced by the production teams. As in the case of the nylthread and airbag products, the plant project leader ensures compatibility of the product with the existing plant systems which translates into a product that produces minimum waste once implemented in the plant. The corollary to this is that plant-led new product developments may bias project activities away from R&D activities that are essential for developing the product. However, as in the case of the nylthread, airbag and to a lesser extent, the automotive product development, this can be managed using a strong project management system which integrates R&D and other supporting functions into the project.

The argument for a plant project leader on new product developments has several similarities to the lean assertion of having a chief engineer to lead the development from start to finish (Morgan & Liker, 2006, p. 134). Morgan and Liker (2006, p. 138) contend that the chief engineer leads through personal
influence, technical knowledge and authority over product decisions. Most importantly, the chief engineer focuses more on decisions about system integration rather than project administration decisions (Morgan & Liker, 2006). In a similar way, the techno-operations manager was able to lead through his technical knowledge on the airbag and nylthread product developments and ensure that the new products were integrated into the plant systems. In contrast, by overly emphasising administrative activities and scientific work, the R&D-led automotive product development encountered problems with integrating with plant systems and acceptance by the plant.

**P7: New product developments that occur within the context of existing plant continuous improvement systems enable lean manufacturing of the new product.**

Continuous improvement is a key activity in lean production systems (Morgan & Liker, 2006). Continuous improvement is closely linked to learning, and represents an ongoing effort to improve products and services. In the context of production plants, continuous improvement tools include know-how databases, learning from focused problem solving, reflection, and review meetings (Morgan & Liker, 2006, p. 206). In accordance with sociotechnical systems principle 1 of compatibility, there is therefore a strong argument for new product developments to be compatible with existing plant continuous improvement systems, since these tools can ensure that new products are properly designed for lean manufacturing (Cherns, 1987).

Interviews with the production employees and an analysis of the “Manufacturing Operating System” in the relevant production plants indicated well developed continuous improvement systems at Fibres Inc. In addition to the tools highlighted by Morgan & Liker (2006), continuous improvement tools at Fibres Inc. included suggestion schemes, shopfloor involvement teams, best practice workshops, competitor analysis, skills matrices, and intensive training modules. Several examples from the cases highlighted the potential benefits to new
product developments that were able to leverage the strengths of the continuous improvement systems.

The first example was highlighted on the aeronautical product development where the shopfloor involvement team was able to specify a new practice that facilitated the start-up of the drawing machine, thus minimising waste. The processing conditions required to achieve the desired product properties had the adverse effect of making the machine start-up more arduous, thus creating more waste product. In consultation with the project leader, the shopfloor involvement team proposed increasing the air pressure of the start-up tool which consequently eliminated the difficult start-up procedure. This practice relieved the frustration of the operators, reduced the cycle production time, and reduced the amount of waste products produced at machine start-up. The shopfloor involvement team, which consisted primarily of machine operators, were thus able to leverage their tacit knowledge to improve the lean manufacturing capability of the aeronautical product during the development phase (Morgan & Liker, 2006, p. 204). Consistent with lean principles, the improvement was completed by the operators who were directly affected (Spear & Bowen, 1999, p. 104). The plant “Manufacturing Operating System” was subsequently updated to include the new start-up practice.

The second example emphasised the benefit of integrating a new product development within the plant’s daily review meeting. During the nylthread development, the project leader regularly attended the plant’s review meeting and updated the plant team on the project progress. At one meeting, the project leader shared a particular technical challenge that was resulting in inconsistency of the product quality that the development team was struggling to overcome. The plant maintenance supervisor, who was present at the meeting, suggested a minor modification to the machine part to overcome the particular challenge. This was discussed by the team who agreed that the supervisor’s idea warranted an evaluation. Within a few days, the modification was completed by the maintenance team and the test results indicated that the inconsistency had been
eliminated. If the project leader had not attended the daily plant review meetings, the product development team would have struggled to overcome the quality inconsistency measured on the nylthread product.

As part of the continuous improvement system, each of the plants at Fibres Inc. employs a “learning facilitator” on each production shift. This practice was highlighted as an important vehicle to transfer knowledge between the shopfloor and the product development teams. Consistent with the learning component of continuous improvement (Morgan & Liker, 2006), the learning facilitator was able to articulate the operator skills requirements of each new product and in consultation with the plant operators, was able to develop and implement best practices. These activities were completed during the product development phase, which ensured that the new product was “primed” for lean manufacturing once implemented in the plant.

The automotive product development provided an example of the potential manufacturing difficulties that can arise if a new product is developed in isolation of the plant’s continuous improvement system. The automotive product development progressed in isolation from the continuous improvement systems described earlier and as a result, required significant attention and rework to align it to the plant systems after it was implemented. Each production run required close attention from a dedicated team led by the plant engineer. As discussed in proposition 6, this team focused on the training of operators, resolving minor process issues, and updating plant procedures. This process took approximately 6 months during which time the percentage waste products decreased by 3.6%. Furthermore, the impact of allocating a dedicated team to “fix” the automotive product resulted in less resource available to maintain the overall plant performance and quality, which consequently deteriorated during production runs of the automotive product.

The analysis of the case data has emphasised the importance of new product developments occurring in synergy with existing plant continuous improvement
systems. The tools and practices of the system can be leveraged to ensure that capability for lean manufacturing is built into the new product during the development phase. New products developed in this manner were shown to result in less waste products, reduced production cycle times, and reduced rework after implementation in the plant – all important considerations in a lean system (Jacobs & Chase, 2008). The proposed linkage between new product developments and the plant continuous improvement systems is supported by sociotechnical systems principle 4 of boundary location, arguing that knowledge and information should flow freely between the product development project and the continuous improvement systems (Cherns, 1987).

**P8: New product developments that include the manufacturing team input to develop new product manufacturing specifications will result in more realistic expectations of internal product performance and product feasibility.**

Proposition 8 builds on the high level of cross integration required for information flow argued for in proposition 3 (Cherns, 1987). Specifically, proposition 8 contends that manufacturing input must be incorporated in the development of a new product specification. At Fibres Inc., the new product specification document consists of the customer requirements and the internal manufacturing specifications. The manufacturing specification typically sets targets that must be met by the plant in order for the new product to be successful. For example, the manufacturing specification may specify the maximum percentage waste that can be produced, the minimum prime product conversion efficiency, machine change-over times and statistical process control levels required. Each of these factors is critical to the success and profitability of the new product. If the new product does not meet one or more of the criteria specified, the profitability of the new product is likely to be negatively impacted. It is therefore important that each of these criteria is accurately estimated for the new product specification. Accurately estimating these criteria provides a realistic expectation of new product performance and profitability, and can therefore help the organisation
decide on the feasibility of a new product development.

The interviews revealed that at Fibres Inc., new product development specifications are typically co-developed by the marketing, business and R&D functions, with minimum input from manufacturing. The manufacturing specifications are often selected on the basis of "what is needed to make the business case work" rather than what is achievable based on technology and people capabilities. The consequence of this was that new products implemented in the plant, tended to not meet the organisational expectations of profitability, due to either a higher level of waste produced or less volume than budgeted for.

Examples of the consequences of not involving manufacturing in the development of the new product manufacturing specification were evident on the polythread and aeronautical product developments. The interview responses indicated that the actual prime conversion efficiency of the polythread product and the production rate of the aeronautical product could have been more accurately estimated if input from manufacturing was considered.

This practice of not including manufacturing input was best illustrated during the initial specification development of the polythread product where the managing director of Fibres Inc. effectively demanded a prime conversion efficiency greater than 90% from the project team. This is in contradiction to sociotechnical systems principle 6 of power and authority which contends that individuals must be able to exercise power and authority in order to accept responsibilities for their performances (Cherns, 1987). The project team should therefore have objected to this demand, and presented a realistic expectation of the prime conversion efficiency. Despite the managing director's demands, the polythread product achieved a significantly lower prime conversion efficiency of 75% for the three month period after implementation (Table 6). During the development, the production manager completed a "zero-based CE calculation" exercise, which effectively calculated the maximum possible prime conversion efficiency to be
77% based on inherent process characteristics such as utilisation, downtime for preventative maintenance, and waste from planned process change over frequencies, etc. Unfortunately, this information became available too late, as the project would probably not have gone ahead if Fibres Inc. had known that the maximum possible prime conversion efficiency would be 77%. Alternatively, a study would have been commissioned to investigate the feasibility of increasing the 77% prime conversion efficiency to 90%, before embarking on massive capital expenditure.

Similarly, the plant engineer’s input regarding the machine change-over time for the aeronautical product was ignored during the development of the aeronautical product specification. The plant engineer realised that production of the aeronautical product would require changing the standard “heating components” on each of the 120 positions on the drawing machine. Additionally the heating components would require temperature calibration every time it was changed. Using this knowledge, the engineer then calculated that the change-over time to be a lengthy 4 days compared to the 5 hours estimated by team developing the specification. The team (consisting of R&D, business and marketing) chose to ignore this input as they felt that the plant engineer was being overly conservative. The plant engineer’s change-over time prediction was validated once the aeronautical product was implemented in the plant, and the resultant low machine utilisation (high change-over time) contributed to lower than budgeted for production volumes which significantly impacted the profitability of the product.

In contrast, the nylthread, airbag and particularly the automotive product development provided valuable insight on how manufacturing should be involved in developing new production specifications. The automotive product development essentially followed the decision-making steps of a stage gate process (Cooper, 2009). This process demanded a cross functional team to scope and screen the idea before developing the business case (Cooper, 2009, p. 15). The production manager was included in the team that was involved in
scoping and screening the proposed new product. He was thus able to guide the team to a realistic internal manufacturing specification which could be fed into the business case. While the nylthread and airbag new product developments did not use a stage gate process, the plant was extensively involved in developing the internal manufacturing specification with R&D. This plant integration was facilitated by the techno-operations manager who led both new product development projects (proposition 6). These specifications were then built into business case to aid the “go/kill” decision of the project (Cooper, 2009). The accuracy of the manufacturing specifications for both products was validated after product implementation in the plant.

In accordance with sociotechnical systems principle 4 of boundary location, the knowledge of the production manager in the polythread example highlights the potential insight that can be leveraged if the manufacturing team is involved in developing the internal manufacturing specification (Cherns, 1987). Their knowledge and experience of the plant is vital to developing a realistic expectation of post-launch new product performance, and ultimately new product profitability. The notion of involving manufacturing during the development of the new product development specification is articulated within the lean practice of “kentou”, which refers to the study period during concept development to anticipate and resolve as many downstream issues as possible (Morgan & Liker, 2006, p. 98). This process encourages cross-functional integration by using process logic to determine who will do what and by when (Morgan & Liker, 2006). In the context of proposition 8, process logic would determine that manufacturing must be involved in developing the new product specification.
10.5 Application of Lean Product Development Systems Model

The interview responses and document analysis were used to rank each case against the 13 principles specified in Morgan & Liker’s (2006) Lean Product Development System model. Project engagement with each principle was ranked using the scale: 1 = absent, 2 = resistant, 3 = partial, 4 = embraced, 5 = proactive.

Table 8: Specific case ranking against LPDS Principles.

<table>
<thead>
<tr>
<th>LPDS Principle (Morgan &amp; Liker, 2006, p. 18)</th>
<th>automotive</th>
<th>aeronautical</th>
<th>polythread</th>
<th>nylthread</th>
<th>airbag</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Establish Customer-Defined Value to Separate Value-Added Activity from Waste.</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3.6</td>
</tr>
<tr>
<td>2 Front-Load the Product Development Process While There is Maximum Design Space to Explore Alternative Solutions Thoroughly.</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>3 Create a Leveled Product Development Process Flow.</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>4 Utilize Rigorous Standardization to Reduce Variation, and Create Flexibility and Predictable Outcomes.</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4.2</td>
</tr>
<tr>
<td>5 Develop a Chief Engineer System to Integrate Development from Start to Finish.</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>6 Organize to Balance Functional Expertise and Cross-functional Integration.</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>3.8</td>
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<tr>
<td>7 Develop Towering Technical Competence In All Engineers.</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3.4</td>
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<tr>
<td>8 Fully Integrate Suppliers into the Product Development System.</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>9 Build in Learning and Continuous Improvement.</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3.6</td>
</tr>
<tr>
<td>10 Build a Culture to Support Excellence and Relentless Improvement.</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>11 Adapt Technology to Fit Your People and Processes.</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>3.0</td>
</tr>
<tr>
<td>12 Align your Organization through Simple, Visual Communication.</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3.6</td>
</tr>
<tr>
<td>13 Use Powerful Tools for Standardization and Organizational Learning.</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Average 3.7 3.4 2.8 4.1 4.2
In order to understand the relationship between the degree of engagement with the Lean Product Development Systems model (Morgan & Liker, 2006), and the success of the new product developments, it was necessary to define a quantitative measure for new product development success. Fibres Inc. uses “percentage prime conversion efficiency differential” as a measure of product performance, and this was adopted as a measure for new product success. This measure is articulated as follows:

Percentage prime conversion efficiency at Fibres Inc. is calculated as follows:

\[
\text{Mass Prime Production} = \frac{\text{Mass Prime Product} + \text{Mass A4 Product} + \text{Mass F Product} + \text{Mass Waste}}{\text{Mass Prime Production}} \times 100
\]

Where:

- Prime product is product that meets all quality standards (number of defects, unit size, physical properties) specified by the customer.
- A4 product is product that meets all the other quality standards but not the unit size specified by the customer.
- F product is product that does not meet one least one quality standard, except unit size.
- Waste is product that cannot be sold into product applications, usually resulting from product changeovers, machine stoppages, etc.

The percentage prime conversion efficiency differential can then be calculated as follows, where specified prime conversion efficiency is the target value specified by the business case to ensure profitability of the product.

\[
\frac{\text{Actual Prime Conversion Efficiency} - \text{Specified Prime Conversion Efficiency}}{\text{Specified Prime Conversion Efficiency}} \times 100
\]
In applying this measure to new product development success, manufacturing data from only the first 3 months after product implementation in the plant was used to calculate the prime conversion efficiency. This allowed the researcher to measure product performance before any rework was conducted. Consistent with propositions 6, 7 and 8, this tactic provided a measure of the lean manufacturing capability of the new product, i.e. how well, the new product was primed for lean manufacturing during the development phase.

The percentage prime conversion efficiency differential (Table 6) thus indicated a new product’s ability to match or exceed the target prime conversion efficiency agreed in the new product specification.

![Graph](image)

**Figure 7: Correlation between prime CE differential and LPDS rankings**

The percentage prime conversion efficiency differential for each new product was then correlated against each new product’s average engagement with Morgan & Liker’s Lean Product Development System (Table 8). Figure 7 indicates a fairly strong correlation between engagement of the Lean Product Development systems model (Morgan & Liker, 2006) and percentage prime conversion efficiency differential.
As engagement with the model increases, the percentage prime conversion efficiency differential becomes positively larger, meaning that the prime conversion efficiency of the product exceeds the target. The squared correlation ($r^2$) of 0.7449 indicates that engagement with the principles of Morgan & Liker’s (2006) Lean Product Development System explains 74.5% of the variation observed in prime conversion efficiency differentials. Thus in the 5 cases studied, the degree of engagement with Morgan & Liker’s (2006) Lean Product Development Systems model is shown to have a significant impact on new product success.

Consistent with the view of Fibres Inc. and the articulation in the propositions that the nylthread and airbag product developments were the most successful new product developments, both products scored the highest ranking in terms of engagement with Morgan & Liker’s (2006) Lean Product Development Systems model.

### 10.6 A framework for lean new product development

This research identifies and synthesises a framework for the application of lean principles to new product development. Eight theoretical propositions were developed within 3 broad dimensions of new product development; new product effectiveness, product-to-market delivery time and new product lean manufacturing capability, each identified as key enablers in the literature and case study data.

Figure 8 illustrates a framework summarising the findings and establishing the practical form of the propositions. Consistent with the study objectives, the framework provides a practical guide for managers and organisations to apply lean principles to new product development. Lean applications that support management and organisational practices are related to outcomes necessary for successful new product development. Thus in addition to providing practical
guidelines, the framework identifies the lean "how to" for managers.

Figure 8: A framework for lean new product development.
10.7 Research Limitations

During the literature review, it became apparent that case study research design in operations management is a relatively new field and as a result the tools and techniques are not as well developed as for other research designs. The researcher acknowledged that this may limit the rigour of the findings. To ensure rigour, the data analysis method (Table 4) was developed using guidelines from authoritative sources in operations management case study research (Eisenhardt, 1989, 2007; Yin, 2003a; McCutcheon & Meredith, 1993; Meredith, 1998; Voss et al., 2002).

A particular challenge of case study research is the ability to balance the “rich story” with “well-grounded theory” (Bryman & Bell, 2007; Eisenhardt, 2007, p. 29). In accordance with the guidelines specified by Eisenhardt (2007), this study overcomes the limitation by developing the theory by distinct propositions, and using case evidence to support each theoretical proposition. The richness of the context is thus maintained while meeting the overall study objective of theory development. Further, while it was not possible to support every theoretical proposition with every case, tables (Table 5, Table 6, and Appendix 3) were used to summarise the related case evidence supporting each dimension and proposition (Eisenhardt, 2007).

Despite external validity being aided by theoretical case sampling (Eisenhardt, 1989), and generalising to the theories of sociotechnical systems (Cherns, 1987) and the Lean Product Development System model (Morgan & Liker, 2006), a major limitation of this study is that the findings are restricted to a single, textile manufacturing organisation (Meredith, 1998). As a result, the propositions developed may not be applicable to the development of new products for other product and service types.

Another important limitation of this study is its emphasis on lean in new product development and manufacturing and its neglect of lean application in functions
such as marketing, procurement, and engineering. As evidenced in the propositions, cross functional integration is a key requirement for lean new product development, and it is therefore likely that lean application in these functions will significantly impact the lean product development process.

A final limitation of this study is the relatively unexplored role of the supplier in lean new product development. Many of the suppliers to Fibres Inc. are internal to the organisation, and as a result it was difficult to articulate the theoretical considerations of integrating the supplier into the lean product development system (Morgan & Liker, 2006). Although the polythread new product development case provided an argument for integrating equipment suppliers, this notion was largely unexplored in this study.

11 RESEARCH CONCLUSIONS

Based on the 8 propositions developed, several contributions to the research field of new product development and implications for operations managers are presented.

11.1 Contributions to the research field

As far as the researcher is aware, this study is the first to validate the applicability of Morgan & Liker’s (2006) Lean Product Development System model in a context beyond the automotive industry. New product development projects that proactively embrace the 13 lean principles of the model have been shown to result in a new product that is more successful (using prime conversion efficiency as the measure). Further, the study identifies a potential gap in the Lean Product Development System model, contending that the lean principle of joint decision-making is an important enabler to manage the trade-off between new product product-to-market delivery time and quality. Thus, a fourteenth additional principle, under the process subsystem in the Lean Product Development System model (Morgan & Liker, 2006), is argued for: “Discuss problems and
potential solutions with all internal stakeholders to leverage their knowledge before establishing the way forward”.

Secondly, the study contributes to the debate on the trade-off decision between product-to-market delivery time and product quality (Lukas & Menon, 2004; Cohen et al., 1996; Roemer, Ahmadi & Wang, 1999; Afonso et al., 2008; Schilling & Hill, 1993). For technologically complex niche products, product quality must not be traded off against product-to-market delivery times. Products that do not explicitly meet the customer’s requirements are doomed to fail, and result in expensive rework, or in the worst case, the loss of the customer altogether. Evidence from the study suggests that when project progress, including delays, are openly communicated with the customer, the customer is more accommodating to accept increased product-to-market delivery times.

Thirdly, the study contributes to the competing positions of organisational fit and new product effectiveness articulated in the literature review. Leonard-Barton (1992), Wheelwright & Clark (1992) and Thomke & Ashok (2001) argue that new product developments that do not fit the organisation’s core competencies must be embraced in order to develop new capabilities. Cooper (1979) and Zirger & Maidique (1990), argue that for successful new product developments, organisations must avoid customers, markets, products and technologies that are new to the organisation. This study lends weight to the former position, arguing that, consistent with Leonard-Barton (1992), learning and development is critical to overcome the change that is required to develop new capabilities. Consistent with a number of sociotechnical systems principles (boundary location, information flow, support congruence, incompletion and transitional organisation), organisations must first recognise capabilities that are not part of their core competence and leverage external sources to redefine in-house capabilities (Cherns, 1987). This is particularly the case for new technologies where project team members can benefit and learn from the expertise of the technology suppliers.
Perhaps the most important contribution to the research field is the importance of designing new product lean manufacturing capability steps into the new product development project. In addition to satisfying customer requirements, new products must be developed within the existing lean manufacturing systems to minimise waste and expensive rework post-launch of the product. This is an important component that is ignored in the current literature (Kim & Kim, 2009). The research findings suggest that the manufacturing function must be closely integrated into the new product development project. In fact, there is a strong argument for the project to be led by a plant engineer rather than a R&D engineer. Production-led projects benefit from production expertise and knowledge not easily available to other organisational functions, and serve to “pull” new products into the plant.

Finally, by utilising a qualitative multiple case study design, this research has addressed the call for more field-based, case study research in the operations management field to bridge the growing gap between academia and operations managers (McCutcheon & Meredith, 1993; Meredith, 1998; Voss et al., 2002; Yin, 2003a). The theoretical propositions developed present workable answers for operations managers.

11.2 Implications for managers

The primary implication for managers is that applying lean principles to new product development can increase new product effectiveness, decrease product-to-market delivery time, improve decision-making for the trade-off between product-to-market delivery time and product quality, and enable the new product for lean manufacturing. The propositions and model presented bridges the gap to theory, providing practical guidelines for operations managers.

Consistent with lean thinking, a new product development starts with understanding the requirements of the customer. Jointly developing a specification at the start of the development should not be the sum of the
customer interactivity. New product developments that integrate the customer throughout the project ensure that the project team is continuously attuned to the changing requirements of the customer and ensures wasteful activities are eliminated. The integration with the customer facilitates mutual exchange of knowledge and expertise that ensures the new product will serve its intended end-use. Management must encourage customer integration at all positional levels, ensuring a high quality, first-hand information exchange between project members and their counterparts at the customer.

Management must be conscious of the core capabilities and rigidities within their organisation. New products can be developed despite the existence of rigidities in the organisation. The challenge is for management to overcome the rigidities by ensuring employees are given the correct support which could be in the form of training and external collaboration.

Despite the temptation, new product quality must not be compromised in the pursuit of a reduced product-to-market delivery time. This trade-off can be managed by the adherence to a rigorous project management system that emphasises joint-decision making by all organisational stakeholders to ensure the optimum decision is taken. As demonstrated in this study, project decisions taken in isolation can inadvertently increase the product-to-market delivery time, resulting in the loss of potential customers.

Product-to-market delivery time can be reduced by frontloading the development process and ensuring that the organisational structure is “product-focused” rather than “functional-focused”. By thoroughly exploring alternatives early in the development stage, the need for expensive and time-consuming rework later in the project is minimised. Management must structure product development teams that overcome purely functional objectives and focus on the product being developed. Management’s communication patterns, trust and respect towards each other must set the example for employees own interaction amongst themselves. Consistent with lean thinking and sociotechnical principles, this
allows information to flow freely between functions, and aligns the whole
organisation to a common goal that serves the customer.

While satisfying customer requirements is of primary importance, management
must also ensure that the new product satisfies internal manufacturing standards.
It is of little value if a product performs exceptionally well at the customer, but is
very expensive to produce in-house due to the high levels of waste generated
during manufacturing. Management must thus leverage the knowledge and
expertise of the manufacturing function to ensure that new products meet the
required manufacturing standards. The manufacturing function can highlight
current product group deficiencies, specify realistic product performance targets,
introduce / adapt systems and procedures accordingly, and facilitate a smooth
product handover to the plant. To aid this, there is evidence from the study to
suggest that new product development projects may be better served by
manufacturing rather than R&D leadership.

12 FUTURE RESEARCH DIRECTIONS

Finally, questions for future work are considered. The present work has indicated
the applicability of lean principles, particularly Morgan & Liker’s (2006) Lean
Product Development System model to new product development. Given the
high cross-functional integration required for successfully executing new product
development projects, it is posited that lean principles may be of value in other
areas of the value chain. How can lean principles improve the efficiency and
effectiveness of functions such as sales, planning, marketing and procurement?
A value chain constructed on lean principles will present synergy to organisations
already employing lean principles in new product development and
manufacturing.

At Fibres Inc., the role of the project management system was highlighted as key
to managing and organising new product development projects. While several
components, notably communication protocols, milestones, product
specifications and decision-making protocols of the project management system have been highlighted, the selection and role of the project manager was largely unexplored. A strong theme emanating from this study is the degree of empowerment of the project manager and its impact on product-to-market delivery time. Several cases indicated interventions by senior management without considering the views of the project manager or the project team. In accordance with sociotechnical systems theory principle 6 of power and authority (Cherns, 1987) and the “heavyweight project manager” concept posited by Wheelwright & Clark (1992), what degree of authority should a project manager have during the execution of a new product development project?

Organisational culture determines what goes on in the workplace and is essential for embracing and sustaining the tools of lean new product development (Morgan & Liker, 2006). This study does not explicitly investigate culture and the role of leaders in shaping a culture that embraces lean new product development. A possible research question then arises: What role does leadership play in developing a culture that embraces lean new product development?

Supplier involvement in the cases studied was limited to a single case. Supplier integration in product development is a fundamental tenet in Morgan & Liker’s (2006) Lean Product Development System model, arguing for organisations to manage and nurture suppliers as they would in-house functions. This facilitates leverage of their expertise and capabilities during the product development (Morgan & Liker, 2006; Brown & Eisenhardt, 1995). A possible explanatory research question would be: “How can integrating suppliers into the new product development project improve product quality and reduce product-to-market delivery time?” The polythread product development provided an example of the disastrous consequences on product quality and product-to-market delivery time when equipment suppliers were not properly integrated into the project.

As with any case study research, there are limits to the generalisability of the findings (Meredith, 1998). The research study focused on a single textile
manufacturing organisation, which begs the question of the applicability of the findings to other industries, including the service industry. There are therefore opportunities for researchers to replicate these findings in a different context.
13 BIBLIOGRAPHY


### 14 APPENDIX 1: TABULATION OF SEMINAL LITERATURE

<table>
<thead>
<tr>
<th>Study</th>
<th>Research Strategy</th>
<th>Research Approach</th>
<th>Research Design</th>
<th>Research Instruments</th>
<th>Context</th>
<th>Performance Measure (dependant variable)</th>
<th>Key Results (independent variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hines, Francis &amp; Found (2005)</td>
<td>Inductive</td>
<td>Qualitative</td>
<td>Case study</td>
<td>Direct observation, semi-structured interviews, document analysis.</td>
<td>Industry cases, e.g. General Motors, 3M.</td>
<td>Framework for lean product development</td>
<td>Understanding customer needs, project management techniques, leveraging skilled and talented employees.</td>
</tr>
<tr>
<td>Leonard-Barton (1992)</td>
<td>Inductive</td>
<td>Qualitative</td>
<td>Case study</td>
<td>Semi-structured interviews, filed observations.</td>
<td>20 projects, 5 firms.</td>
<td>Constant organisational renewal with NPD.</td>
<td>Knowledge &amp; skills, values and norms, technical systems, managerial systems.</td>
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<tr>
<td>Study</td>
<td>Research Strategy</td>
<td>Research Approach</td>
<td>Research Design</td>
<td>Research Instruments</td>
<td>Context</td>
<td>Performance Measure (dependant variable)</td>
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<td>Datar, Jordan, Kekre, Rajiv &amp; Srinivasan (1997)</td>
<td>Deductive</td>
<td>Quantitative</td>
<td>Longitudinal</td>
<td>Semi-structured interviews, document analysis</td>
<td>3 electronic manufacturing companies.</td>
<td>New product time to market.</td>
<td>Number of customers, engineering expenditure, time to prototype, number of prototype projects, time to volume production, number of volume production projects.</td>
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<tr>
<td>Study</td>
<td>Research Strategy</td>
<td>Research Approach</td>
<td>Research Design</td>
<td>Research Instruments</td>
<td>Context</td>
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<td>Nihtilä (1993)</td>
<td>Inductive</td>
<td>Qualitative</td>
<td>Multiple case study</td>
<td>Fieldwork: observations &amp; semi-structured interviews.</td>
<td>5 NPD projects, 3 different companies.</td>
<td>R&amp;D-production integration.</td>
<td>Project planning, mission, formal controls, functional, line organisation.</td>
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<td>Research Design</td>
<td>Research Instruments</td>
<td>Context</td>
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<td>Langerak &amp; Hultink (2008)</td>
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<td>Quantitative</td>
<td>Survey</td>
<td>Self completion questionnaires.</td>
<td>233 manufacturing firms</td>
<td>NPD development speed.</td>
<td>Supplier involvement, lead user involvement, speeding up activities &amp; tasks, reduction of parts, training and rewards, support systems, interfunctional cooperation, customer value,</td>
</tr>
<tr>
<td>Study</td>
<td>Research Strategy</td>
<td>Research Approach</td>
<td>Research Design</td>
<td>Research Instruments</td>
<td>Context</td>
<td>Performance Measure (dependant variable)</td>
<td>Key Results (independent variable)</td>
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<tr>
<td>Clark (1989)</td>
<td>Deductive</td>
<td>Quantitative</td>
<td>Survey</td>
<td>Structured and unstructured interviews, self completion questionnaires.</td>
<td>29 major automobile projects in 20 companies.</td>
<td>Lead time, engineering productivity.</td>
<td>Project scope.</td>
</tr>
</tbody>
</table>
15 APPENDIX 2: INTERVIEW GUIDE

Name:

Age:

Gender:

Position in Company:

Department:

Number of Years Employed:

Project worked on:

**General:**

1. How important do you consider NPD to be to your organisation?
2. How many new product development projects have you been involved in at this organisation?
3. What particular organisational/team strengths or weaknesses have an impact on project delivery?
4. What do you think is the role of organisational / team culture in NPD success?

**NPD Effectiveness**

5. Do you think that it is important to involve the customer during NPD? What mechanisms were used to involve the customer?
6. How much interaction did you personally have with the customer during this project?
7. How did you ensure that the project was focused exclusively on meeting the customer / market requirements? Do you think that there were any wasteful activities that took your attention off the customer requirements? What were these activities?

8. How did you agree on the target characteristics or specifications and quality of the new product?

9. Were any suppliers involved in the project? How were they involved? Do you think it was important to meet your project goals?

10. How did company procedures, rules, work standards impact on project delivery (reduced variation, flexibility and predictable outcomes)?

11. Do you think that the requirements for this project were within your own; the organisation’s or teams core strengths? Please elaborate.

12. What measures do you use to measure NPD success? Order of priority?

13. Would you consider this project to be successful?

14. Did you use a project management system? What were the key benefits and weaknesses of this system?

15. How important is the role of the Project Manager? Please highlight strengths and weaknesses of the Project Manager and the impact on project delivery?

16. How are NPD project teams set up? Was there sufficient skills and diversity to support the project?

17. Did you find that the organisational training and development programmes were geared towards developing the skills and competence required for this project? Did this project provide learning opportunities for you or any other members on the project team? If not, how could this have been
achieved?

18. Were you aware of how this particular NPD project fitted into the corporate goal or strategy? Was there alignment between this strategy and your project goals? Elaborate.

19. Were there any learning’s from this project and how were they conveyed to the rest of the organisation? Highlight any formal learning and continuous improvement systems.

**Product-to Market Delivery Time**

20. What factors were found to affect product-to-market delivery time? Please explain the relative importance of each of these factors.

21. Did you find a trade-off between new product quality and time-to-market? If so, how did your team balance this trade-off?

22. Do you understand what “frontloading the development process” is? (explain) How was this achieved?

23. Do you feel that you get sufficient, clear direction from senior management?

24. What role did the organisational structure play in influencing product-to-market delivery time?

25. Do you believe that the project could have been completed sooner, without impacting the quality of the new product? If yes, please state how this could have been achieved.

**Lean Manufacturing Capability**

26. What do you understand by “lean principles”?

27. Were manufacturing employees involved in the project? Do you think it
was important to involve them?

28. Did the new product have a manufacturing performance specification at the start of the project? What was this? How was this agreed?

29. How did you ensure that the new product once developed and accepted at the customer, will meet the manufacturing performance specification?

30. Did your new product compare against these manufacturing standards? Why?

31. Was the new product compatible with the plant employee skill level and the available technologies (e.g. machines)? Elaborate.

32. Did you identify any training requirements prior to manufacturing implementation? If yes, how were they implemented?
### 16 APPENDIX 3: DATA: PARTIALLY ORDERED META-MATRIX

<table>
<thead>
<tr>
<th>Dimension</th>
<th>New Product Development Case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>New Product Effectiveness</strong></td>
</tr>
<tr>
<td></td>
<td>High customer involvement during all phases of development. Customer located in SA, had frequent visits between both parties. Technical workshops were held at which customer’s MD and Technical Director visited. Numerous phone conversations and email correspondence. (DR, DLT)</td>
</tr>
</tbody>
</table>
customer and understand the end use (DR, DLT).

Certain senior members on the project team were not convinced of the technical viability of the project. Throughout the project they raised issues like insufficient resource, plant capabilities, etc. This caused frustration, which caused a lot of internal bickering. Took too long to make decision on which assets to use (DR).

Agreed specifications with customer technical manager. We were able to guide him on requirements due to Technology Directors past experience with airbag developments (DR). Customer shared his processing route, which helped us establish quality standards. Quality standards are also times during the project. Project technical team interacted directly with customer technical team (SK, DG)

Project wasteful activities included making decisions based on perceptions rather than data and initial poor sample evaluation planning at the customer (at times no project members were present at the customer evaluation) (SK, JW).

Product quality specifications were jointly agreed between R&D and customer based on requirements, benchmarking competitor products, and internal capabilities (SK, CPS).

Important to involve spin finish supplier to meet product specification. Spin finish required was volume or commercialisation plan from customer (DLT). Regular telephonic and email discussions occurred between the customer and R&D Director on project progress. However, not all feedback received from the customer was shared with the project team – lack of information and secondary information caused frustration and delays (AP, SK, DLT).

Customer visited to share requirements, and do a presentation on product quality requirements (AP, GTP). R&D Director communicated weekly updates to customer (DLT, AP).

Project Manager, key R&D members and plant personnel were present during initial customer visits/presentations (DLT). Project leader was only involved in initial

Mechanisms to involve the customer included joint workshops and correspondence by email (DLT, CPS, DG).

Project team members had necessary direct interaction with customer. Customer services coordinated the relationship with the customer. Two customer visits during the project. Senior management liaised directly with customer’s global office regarding commercial issues (DG, DLT).

Spinning tube specialist was involved to ensure correct package build. Was important for supplier to see our requirements before designing the tube (MCB, GV).

Strong adherence to project management system. Viewed as
Supplier involvement was limited due to the secrecy of the work. Process conditions were shared with the polymer and spin finish supplier to get their input on suitability of existing raw material supply. Should have signed a secrecy agreement with the polymer supplier to get their expertise on a suitable polymer for this polymer – they would have had past knowledge working with customers (DR, DLT).

Company systems helped to keep the focus on the deliverables, but there were times when all the systems caused the project to bog down (DR, DLT). It reduced flexibility specifically formulated for the product. Shared full requirements with supplier who developed suitable finish (SK, JW).

Project management system slowed down project delivery – too much focus on process rather than outcomes. Caused the team to lose focus on priorities and reduced flexibility and innovativeness.

Requirements for the project were within team’s capabilities: technical knowledge, experience, customer processes (sometimes knew it better than the customer), although there was some concern about the winders (SK, CPS).

Order of priority of NPD success measures: achieving customer requirements, meeting specification – after that handled by R&D. Director due to confidential nature of project (AP, SK, DLT).

Project wasteful activities included incorrect hardware design which required rework, poor product translation from pilot machine to production machine, no clear responsibilities and accountabilities amongst the team, and poor trial planning in production that resulted in delays (GTP/DLT). Strong personalities on marketing side resulted in constant conflict with R&D and operations (DLT). No direct communication between project leader and customer regarding technical issues which resulted in time wastage – too long for information exchange (AP, DLT).

Adherence to company procedures, particularly the project management system was instrumental in project success. Lots of paperwork involved, but it helped very cumbersome by most people but ensures all upfront work is done and the right questions have been asked (GV). Procedures such as covering spun yarn with polybags, not loading over-aged yarn onto creels reduced variability in results. Shift checks prevented out of specification temperatures and speeds. Machine cleaning procedures, machine hygiene expectations were clear, hence Operators knew exactly what to do (MCB).

Requirements of project well within team’s capabilities. Had successfully completed similar projects in the past. Strong knowledge of particular machine capabilities since machine was designed and built by internal teams. (GV, ...)
as team could only operate within the confines dictated by senior management. Some technical team members spent more time documenting meeting minutes than doing scientific work but overall the stage gate process used was an excellent process that involved all key people (DR, CPS).

Very much so. Newly employed Technology Director brought his international experience in airbag production. Strong quality department had already unpacked international quality standards applicable to the NPD. Company had always invested in strong R&D and this was well within their capabilities (DR, CPS).

Profitability of product (does it meet timeline and budget, learning (SK).

Project ‘probably’ unsuccessful – did not consistently meet customer’s requirements, customer demand fell soon after commercialisation (SK, CPS).

Project management system was used. Benefits: structure, milestones, communication protocol, resource allocation, defined objectives. Weaknesses: lack of flexibility, cramped creativity and innovation (SK, DG).

Project manager coordinated all activities. Strengths included technical knowledge, hands-on attitude, and passion. Weaknesses included poor delegation and imposing himself whenever problems set by the customer who was not very specific – required a lot of trial and error to test specifications (AP, DLT). R&D Director stated specifications but did not justify why (DLT). Input from Fibres Inc. was not acknowledged by customer. Spec. was clear enough to get the project off the ground, but not explicitly clear. For example had to initially target ranges for certain parameters (AP).

No external suppliers were involved as existing raw materials were used. However, equipment suppliers for new hardware were used but were not actively involved – supplier requests for process data to aid design were not provided in sufficient detail. As a result, suppliers were not willing to assist in defining the specifications upfront and the deadlines (DLT).

Requirements for the project were well within the team’s capabilities. Technical knowledge of polymer (R&D) and processing conditions was strongpoint.

Order of priority of NPD success measures: customer satisfaction, delivery on project milestones, meets profitability targets.

Project was successful – met specification and became a commercial product (CPS, DG, DLT).

Project management system was used. Benefits: Allows monitoring of budget, deadlines and quality. No weaknesses (DLT, DG).

MCB, DG). Technology operations manager had extensive NPD experience and, knowledge with this platform. Theoretical process models for this platform had been developed in the past and made it easier to understand capability (MCB).

Order of priority of NPD success: Customer satisfaction, product profitability (DG). Customer satisfaction, Internal – Breaks below target, no or low level of downgrades, achieving target full doffs yield (%), meeting target physical properties, low warping fault rate no particular order of priority. Customer targets and internal targets are important (MCB).

Project was successful. Met deliverables of higher strength at the
business case?), customer satisfaction, new knowledge generated, new organisational capabilities (DLT).

Yes – it met the customer’s requirements and was profitable. Product required several minor redevelopments after handover to manufacturing and some manufacturing challenges persisted (CPS, DLT).

Project management system was used extensively. Strengths: helped with decision-making, managing resources and deadlines, could give a snapshot of project status at any time. Major strength for this NPD was the risk analysis particularly since this was a NPD that was a new “area” for the organisation. Weaknesses: too surfaced (JW, DG).

Project team had sufficient skills and diversity to support the project. Any skills or knowledge that was lacking was easily accessed, e.g. technical associates (JW, SK, DG).

No formal organisational training and development programmes geared to support the project. Most development was done through mentorship and experience. No direct training of junior members of customer processes (CPS, SK).

Project provided learning for team members in terms of customer processes and teamwork (SK).

Project team was aware of how project fitted to broader company strategy: entering new markets, maximising asset failures during commissioning (DLT/AP). Could have involved spin finish supplier, but were not allowed to due to the confidential nature of the project (AP).

Project management system was initially adhered to but fell away due to time pressures. Informal, “on-the-run” discussions and decisions (AP, DLT).

Company procedures such as flexi-time, and time-off helped team members as the project demanded long hours and after-hours work (GTP, SK). Did not cramp innovation or flexibility. Lack of stage gate process did not stop project when it looked marginal (DLT).

Technical and marketing requirements were

Project manager played the role of a ‘conductor’ – keeps everyone focused on delivery. Strengths included coordination, motivation, overall business understanding and conflict management amongst team members. Weaknesses included being too far removed from day-to-day activities (DLT, DG).

Project team was setup by the R&D Director. Project Manager had no input which was wrong. However, there were sufficient skills on the team. Development work was led by a junior engineer under the guidance of the techno-operations manage (DLT).

There is no organisational rule book or specific training for NPD or project management. Most of it is based on customer, internal conversion efficiency target, and capacity increase targets (GV, DG, MCB, CPS).

Project management system was used. Helps to meet quality and time deliverables. (GV, DG). Information easily and always available, recording of decision making and capturing of outstanding issues (MCB). No weaknesses of project management system (MCB DG).

Project manager role is very important – links the project team, plant team and customer. On this project, project manager strengths included time management, technical knowledge, NPD knowledge, hands-on approach, and quick decision making (CPS).

Project team was set-
Project Manager role is very important, especially for multi-disciplinary NPDs like these. Must take ownership and drive the project. Project manager ensured that all milestones were adhered to. He was also technically experienced and could guide the technical team. Weaknesses: Was an R&D member and did not have strong relationships with other functions, notably production.

Learning’s from project were shared via knowledge sharing workshops, project reviews, cross pollination of teams, informal discussions and by the use of multi-functional teams (SK, CPS).

Within organisations’ strengths. However, poor relationship with engineering suppliers required significant rework – internal engineering team felt they had all the answers (DLT, AP). View that operations team did not have the competency to consistently produce the product to the required quality standards. If there was more time, project would have met deliverables (DLT, SK, GTP). Overall, project scope was beyond team’s capabilities – did not have the knowledge to redesign machines, this was not our core strength. Should have had more outside supplier involvement (AP).

Order of priority of NPD success: Profitability, meet customer’s requirements, on time and within budget.

mentorship and experience. The learning was great for the junior engineer who learnt technical and operational skills. For the organisation, the learning was that meeting internal product performance specifications was very important for success (DG, CPS).

Was aware of how project fitted into overall company strategy. Technically superior polymer to enhance internal processing efficiency and customer performance (DLT, DG, CPS).

Learning was not shared formally across the organisation. Learnings were only captured in the project close-out report. Rarely celebrate success (DLT).

up by senior management (although R&D Director had the most input) based on requirements. For example no engineering work was required so no representative on the project (DG). Small team included customer service rep, production STO and R&D engineer.

No specific training in NPD. Built up knowledge over years with working with the machines and processes. Friday afternoon knowledge sharing sessions were useful for understanding the science behind the processes. Development and training manuals are useful to get a strong foundation of the equipment and processes (MCB). A lot of learning is gained informally by discussing with
and the business managers. Not strong on decision making – more concerned with protecting his back. Tried too hard to appease the R&D Director – had difficulty conveying bad news (DLT, CPS).

R&D Director was in charge of setting up NPD teams, in consultation with managers from other functions. There were sufficient skills to support the project. Production manager was involved in scoping the project. Production engineer was on team, but only partially. Should have had a dedicated production representative (DLT).

Formal organisational training programmes were too basic. Had to rely on experience of senior members. Weekly knowledge (DLT). From (AP): meeting customer requirements most important.

Project unsuccessful – could not consistently meet the customer requirements. Amount of rework pushed project too far behind schedule – product price out of kilter and customer had sourced alternative options (AP/DLT).

Project management system was used and was driven from R&T. Helped guide the team through various project phases. Weakness: Operations and engineering did not buy into the system (frequently did not pitch for meetings), business case is outside the system, and no stop/go project prompts. Start of project should not have been the technical associates and STOs (DG).

Learning was that with proper planning (machine time, technical work, etc.) upfront, we can easily meet deadlines (MCB).

Was aware of how corporate strategy was related to project. Aim was to grow our market share in Asia, and grow with this particular customer. Plan was to also fill the excess capacity of the asset (DG, CPS). Important to meet customer requirements to ensure return on the newly installed drawing equipment (MCB).

No formal sharing of learning occurred – shift operators were coached in operating the new processes. Should have shared “relax length” learning with the rest of R&D
| sharing sessions helped but were also very generic. Lots of in project learning opportunities were created during the development. This was mostly informal, where a senior technical person would share knowledge on a specific technical subject. (DR) Greater learning for project members could have been achieved by granting members responsibilities that challenged them and forced them to learn (DLT).  
Was aware of how project fitted into corporate strategy. Strategy was to move away from commodity products towards technically demanding, niche products. Therefore was alignment (DR).  
There was significant learning regarding production and |
| directive from senior management but should have been when the business case development was initiated - should have been more integrated into the project (DLT). Struggled to get operations to agree to handover criteria. Benefits: Able to track progress, plan resource, and anticipate potential problems. Weaknesses: very complex and not very user-friendly (AP/SK/DLT). Project Manager should manage high level plan. His key focus was to foresee any issues and try to resolve them without causing delays to the project. Strengths: good coordination, good working relationships. Weaknesses: Did not challenge senior management about business case, did not |
| (MCB, GV). |
machine maintenance standards required to meet the product quality. This was not conveyed to the rest of the organisation. If it was, product quality could have been improved across the plant (CPS).

have enough knowledge to make key decisions on the project. Did not have enough accountability or authority (DLT). Project manager had to coordinate various teams and guide the overall deliverable. Strengths: Good at adhering to company systems. Weakness: Not good with handling conflict – refused to get involved in engineering issues (AP).

Project team was set up by the R&D Director – relatively young, inexperienced team for such a technically complex new product development. Senior technical associates were “outside” the project team and played a consulting rather than active role – they refused to take accountability or get their hands “dirty”. Not enough technical
knowledge or experience on project to meet requirements (DLT). Project Leader had a say in technical team members (AP).

No formal learning programmes with respect to NPD. In-house knowledge sharing sessions and plant manuals provided a broad technical knowledge that helped, but problems experienced on the project were too complex. However, the project provided good opportunities for inexperienced technical people to lead sub-projects and thus develop leadership skills (GTP). Many of the project members who were in the company for < 1 year had valuable process learning. Most of the lessons learnt were from mistakes: cost control within budget (7% overshoot),
importance of meeting deadlines, assumption of replicability between pilot and production machine, and importance of relationship between R&D and Marketing (DLT). Most learning with regards to NPD happens with experience rather than formal training programmes. On this project learning gained included conflict management, technical skills, reporting, writing, and problem solving skills – particularly for junior members (AP). Was difficult to understand strategic objective of the project. Overall strategy was to get out of ‘commodity’ products but company was investing heavily in ‘commodity’ products. Did not fit goals of reducing product portfolio complexity (DLT). Project team
was told that project was about developing a partnership to grow the business and make us more sustainable. Told that it was a niche market, but not enough clarity on this (AP, GTP).

The product required higher quality standards (strong disciplines) in manufacturing. Current best practices were reviewed, standards implemented and plant personnel were trained by the project team. Project team members attended daily focus group meeting to share knowledge and coach plant personnel (GTP). No learning from mistakes. Poor communication from senior management – team/organisation was not told why project was shelved (AP). Should have used the learning to prevent making
<table>
<thead>
<tr>
<th>Product-to-Market Delivery Time</th>
<th>Similar mistakes in future.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample evaluation at the customer delayed product-to-market time.</strong> Although time was spent understanding the requirements upfront, unplanned product iterations resulted in a longer time-to-market. New end-use for the customer, had to work together to understand requirements. Downstream testing of the customer's final product was also complex and added extra time to the project (DR). No trade-off. Importance of product quality was known upfront – sub quality could cause failure and loss of life in automobile accidents. Customer was made aware of instances.</td>
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<tr>
<td><strong>Factors that affected product-to-market delivery time included speed of decision-making, prioritisation, understanding of customer requirements, and planning. Autonomy of decision making allowed quick decisions to be taken (SK). Intermingling specification was not clear – required several iterations (JW). Development work on production machines was not properly planned in which caused delays (DG, CPS). Was a trade off between new product quality and time-to-market. Plant demand of high processing efficiency (&gt;75%) could not be met within the</strong></td>
<td><strong>Product-to-market delivery times were affected by the long time taken to get the capital case approved, rework on the hardware installation, too many customer trials, and poor planning of development work on production machines (DLT). The logistical exercise of preparing samples for shipment to China also took a long time (GTP). Lack of technical competency to transfer product spec onto machine, too much engineering rework, poor planning on production machines, and inefficient communications between project team and customer negatively impacted product-to-market</strong></td>
</tr>
<tr>
<td><strong>The delay in specifying the polymer required increased product-to-market time. Concerns over the supplier quality necessitated an audit at their US plant (DLT). Decision-making was quick which helped to shorten the internal development process. A lot of upfront process work was done with the old polymer, with knowledge on how to extrapolate the results (DG, CPS). No trade-off. Did not want to compromise on quality (DLT, DG). Project team did not understand what frontloading the development process means. However,</strong></td>
<td><strong>One parameter (shrinkage) was not specified correctly as either the customer or we knew which would work optimally. 4 different samples were produced for testing, before the specification was finalised and production could be scaled up. This was a good practice compared to evaluating single samples at a time. Effectively decreased the product-to-market time (DG, GV). Customer was located in China – large distance resulted in feedback of evaluations taking longer, which impacted product-to-market delivery time (MCB). No trade-off in quality</strong></td>
</tr>
</tbody>
</table>
Frontloading means to explore many possible alternatives upfront while there is still scope for it. This was considered by evaluating several different process regimes (e.g. spinning speed, polymer RV) at the start of the project. Project team brainstormed alternatives and built time in the plan to evaluate it (DR, DLT). Yes. There was sufficient direction from senior management, particularly from the R&D Director who had an in depth technical understanding of the new product (DR, DLT). Market conditions were also clearly communicated by the Business deadline set by the customer. Project team were driven in different directions by the plant and the customer. Eventually product efficiency was sacrificed to meet customer deadline (SK). Agreed to improve efficiency once product was implemented in production (SK, CPS).

Project team did not understand what frontloading the development process means. No frontloading occurred (SK, JW).

There was sufficient, clear direction from senior management who allocated priority for the development, distributed work load, and shared the commercial importance of meeting milestones (SK).

Company structure had too many silos which had a negative times (AP). No decision making at STO level who acts as a ‘doer’ and does not challenge the executive (SK, DLT).

Was a trade off between quality and time-to-market. Because of delays in equipment commissioning, the time for product development decreased and NPD team tried to do too much in a shorter period of time. Quality was inconsistent between batches (DLT). Issue was raised by project manager with senior management who refused to share the delay with customer and renegotiate deadlines – more concerned about maintaining credibility. Senior management was very clear. Project team were involved in supplier discussions. Senior management met with the project team on a weekly basis to review project (DLT).

Although company structure is very hierarchal, product-to-market time was improved due to presence of techno-operations manager on the team – this bridged the gap between R&D and production (CPS, DLT).

Project could have been completed sooner if integrity of the polymer supply was established before the project. and product-to-market time. Met the quality requirement and project completed before deadline (DG, MCB, GV). Project Manager was the techno-operations manager, whose responsibility was to maintain quality once product was commercial – he was therefore very tough on quality standards and did not allow any compromise (MCB, GV).

Frontloading meant good preparation in the beginning of the program, bringing together all role players to brainstorm, properly plan before starting NPD. Careful planning upfront (MCB). Frontloading considered theoretically understanding which shrinkage conditions is most likely to work and minimising the number of samples to be produced (DG).
| Manager (DLT). | Impact on project delivery. Slowed down the development since there was conflict between marketing, sales and production. A stage-gate process or portfolio management team would have helped. R&D input was not respected (SK, JW). Project could have been completed sooner without impacting quality if more time was spent jointly developing specifications and understanding customer requirements upfront. The specification was developed with only the customer representative involved with the customer (SK, JW). | Customer ‘something’ rather than ‘nothing’ (AP). Project team was not familiar with frontloading the development process (DLT/GTP). Try to do as much as possible upfront. However, no examples of frontloading were evident in the process – most of the decisions (e.g. Asset utilisations) were made by the business people who did not want to consider technical details or alternatives (AP). There was sufficient direction from senior management at the start of the project in terms of setting up the scope. However, once problems arose, senior management did not give clear direction – refused to acknowledge the real issues and became very dictatorial. They should have discussed polymer capacities with supplier right at the start. Internally, the project actually beat the deadline without compromising quality (DLT). | Various drawing stage assets were evaluated upfront for internal decisions before selecting asset for commercial production (GV). Sufficient direction from senior management regarding delivery dates, and capacity requirements (MCB, DG). | Project team was not familiar with frontloading the development process (DLT/GTP). Try to do as much as possible upfront. However, no examples of frontloading were evident in the process – most of the decisions (e.g. Asset utilisations) were made by the business people who did not want to consider technical details or alternatives (AP). There was sufficient direction from senior management at the start of the project in terms of setting up the scope. However, once problems arose, senior management did not give clear direction – refused to acknowledge the real issues and became very dictatorial. They should have discussed polymer capacities with supplier right at the start. Internally, the project actually beat the deadline without compromising quality (DLT). |
were not willing to “test risks” to develop alternative paths (DLT/AP).

Company structure is very defined in terms of the different roles each department plays. Engineering department was seen as isolated- became even more so once delays and rework on equipment occurred. Should have been more integrated into the project.

Operations team initially worked closely with the R&D team, but distanced themselves as they felt that their input was not valued and became aware of the difficulties of producing the product (DLT/AP).

Project deadline was missed and a low quality product was delivered to the customer – which customer eventually rejected. Should have

been completed sooner: it was already completed in a record breaking time in the company’s history (MCB). Longest time was waiting for spinnerets to be delivered from Germany (6-week lead time) – should have anticipated this and placed order earlier (DG).
made the decision to cut project earlier. In fact, project should not have proceeded in the first place. More development time could have been planned on the machines to allow R&D more time to properly develop the product – there was conflict between the needs of production and the priority of the development (DLT). Product development time was forced by commercial, without regards for technical complexities (AP).

<table>
<thead>
<tr>
<th>Manufacturing Capability Enablers</th>
<th>Lean principles removing wasteful activities from the system. Wasteful activities refer to those that do not add value to the customer. It's about working smarter and more efficient (DR, CPS).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project team had good understanding of lean: streamlining of processes, removing waste, push and pull systems, and focusing on need (SK, CPS). Plant manager and Plant senior technical officer were involved.</td>
<td>Good understanding of lean principles from the project team: it provides guidelines on how to remove various forms of waste from the business (DLT/AP). R&amp;D project members believed that there was sufficient.</td>
</tr>
<tr>
<td>Lean principles are a set of rules designed to eliminate waste from all activities in the delivery of product to the customer (DLT, DG, CPS). The techno-operations manager and plant technical</td>
<td>Use minimum raw materials. Parts should arrive “just in time” and move through process quickly (MCB). All wasteful activities (not focused on the customer) should be eliminated or minimised (DG).</td>
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<td>Plant manager and Plant Senior Technical Officer were involved. Very important to involve them as it facilitates product handover and allows input to production requirements. Plant personnel were not involved at the start, but only during product handover phase (DR). R&amp;D team did not think that plant personnel had expertise to contribute during the development phase (CPS, DLT). Manufacturing specification was agreed with the Plant Manager during the stage gate. It stated %prime quality and physical property targets. A PPAP was also developed (DLT, CPS, DR). Product managed to meet the manufacturing specifications, but it in project to get buy-in and knowledge transfer. Formal handover document completed (SK). No plant employees were involved in detailed project scoping – no input requested from R&amp;D. Production manager got more involved during trials to ensure correct support and minimum disruptions to normal production (CPS). Manufacturing specification included a minimum conversion efficiency, and consistent achievement of physical properties. These were based on similar existing products and the minimum efficiency required for the business case (SK, DG). Trade evaluation runs (1 week) were conducted to test capability before product handover to manufacturing involvement: Several shift operators were involved to pass on learning and expectations. Plant operations and techno-operations personnel were also consulted, but not involved in decision making (GTP/AP). However, plant and techno-operations personnel disagree, claiming they were only consulted once project team became aware of the pending failure of the project. Started to point fingers and blame operations SK, DLT). Manufacturing prime CE was agreed to be &gt;90%. This was forced onto the team from senior management based on the business case. Started to point fingers and blame operations SK, DLT). Once initial samples were accepted at the customer, process was benchmarked by the project team before handover to plant (CPS). Data collected indicated production exceeded manufacturing specifications (CPS). Feedback of the project was given to the plant shift teams during the daily focus group meetings. This was important to ensure product performance sustainability once product gets handed over to plant and project team steps back (MCB). Manufacturing specification was developed based on what the known capability of equipment was (A1 CE &gt; 90%), &lt; 1% downgrades and Cpk &lt; 1.aeronautical). Agreed upfront with the techno-operations manager and production manager (MCB, GV). Recording performance throughout NPD and calculating targets for manufacturing teams. Based on results achieved during the project, it was clear...</td>
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required high technical resource during production in order to achieve specifications. Senior technical officer had to spend disproportionate time overseeing the production (DR, DLT).

Compatible with the plant employee skill levels but there were some concerns regarding compatibility with drawing machines (DLT). Product size was adapted late in the project to fit machine capabilities. Customer was initially unhappy, but accepted the product. Team should have reviewed the machine spec. upfront (CPS).

Product was more difficult to string-up on the drawing machines. Operators initially struggled. Intensive training programme was implemented led by plant (CPS, SK, JW).

Product did not meet manufacturing specifications (conversion efficiency) due to lack of operator skills for a more demanding product, and production management not embracing the new product (SK, JW). It was difficult for the plant to accept change (SK). Plant was not prepared to accept a product that did not meet the specified standards. Operator skills should have been developed as part of the project (CPS).

Operator string-up technique was identified as a key training requirement before manufacturing implementation. Training was completed with the training department and project team but it took too long for the operators to develop CE of only 77% was possible (AP, SK).

After each stage of the project, a review of the verification of the deliverables was done. However, there were instances where data was manipulated to show senior management the "answers they wanted to hear". Although certain specifications were not met, it was agreed to carry on with the project with the intention of correcting the problems during later phases of the project – however, these corrective actions were never planned in (AP, DLT).

The project did not meet manufacturing standards – underperformed on CE. Documentation also indicates that product did not meet target CEs. Could not overcome the technical challenges that the process would perform well and meet manufacturing performance standards (MCB).

Product developed on existing platform. Process was optimised (lower spinning speed) to improve robustness on existing equipment without reducing capacity (DG, CPS).

Product exceeded the specified manufacturing standards – CE’s, CpK’s, etc. (MCB, CPS).

Product was compatible with skills and equipment. Slightly different type of machine start-up, but operators were trained in this. Drawing machines were designed with additional capabilities which made them robust for this product.
<table>
<thead>
<tr>
<th>Learning coordinator and Training Department (CPS).</th>
<th>the skill (CPS).</th>
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<td>and equipment failures (AP).</td>
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<tr>
<td>Product was not compatible with existing equipment and plant skill levels. Required major modifications to the spinning platform and upgrades to the existing 2\textsuperscript{nd} stage process. Plant operators struggled to string up 2\textsuperscript{nd} stage machines – only the most experienced were used to start up the machines. No formal training or skills development of operators were done (AP/GTP).</td>
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<td>Worked with plant management to implement new machine start up techniques for operators. Very difficult procedure and caused lots of frustration on the shop floor (AP).</td>
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<td>Minimal training requirements were identified prior to implementation. Only minor changes such as number of wraps on rolls. Changes were highlighted on the Machine Headboards and verbally communicated. Shift trainers coached each operator individually until they were audited by the Supervisor and deemed competent (MCB, DG).</td>
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Master of Business Administration

Subject: Research Thesis

Declaration

1. I know that plagiarism is wrong. Plagiarism is to use another’s work and pretend that it is one’s own.

2. I have used a recognised convention for citation and referencing. Each significant contribution and quotation from the works of other people has been attributed, cited and referenced.

3. I certify that this submission is all my own work.

4. I have not allowed and will not allow anyone to copy this work with the intention of passing it off as his or her own work.

Fulltime:  □

Modular:  □

Signature:  Exam Number: MOD717

Date:  10 December 2009