January 2020

Design Thinking & Strategic Product Planning For Highly Engineered Products

Shannon Dare Wayne
Wayne State University

DESIGN THINKING & STRATEGIC PRODUCT PLANNING FOR HIGHLY ENGINEERED PRODUCTS

by

SHANNON DARE WAYNE

DISSERTATION

Submitted to the Graduate School

of Wayne State University

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

2020

MAJOR: INDUSTRIAL ENGINEERING

Approved By:

____
Advisor Date

____

____

____

____

____

DEDICATION

To my grandfather, John Flannery, who always believed in me. Though gone before my program commenced, he knew this dissertation would someday be written.

To the women before me with limited choices in life who worked to ensure that every generation thereafter had an easier road than their own.

To the 230,000 victims of COVID-19 in the United States and 1.2 million worldwide.

ACKNOWLEDGEMENTS

To my family, especially my husband, Kevin Wayne. To my older two children, Flannery and Mary-Katherine, who fell asleep in the evenings listening to me type. To my youngest, Kevin, who was born during the program and helped to demonstrate that women can have a baby and work on a doctorate at the same time.

To my dissertation committee, especially Dr. Ratna Babu Chinnam. Dr. Chinnam pushed me hard and challenged me to demonstrate my full capability and never to underestimate myself. To Dr. Julia Gluesing who taught me how anthropology permeates life and how understanding the discipline brings us all closer together. To Dr. Ken Riopelle for his support and annotation of the Integrated Framework. To my committee, Dr. Leslie Monplaisir, Dr. Nancy Philippart, Dr. Jeremy Rickli, and Art Hyde. Additionally, Mark Garrison, our Industrial & Systems Engineering Department Manager. Thank you for your guidance throughout this process.

To Ford Motor Company, including Dr. Derrick Kuzak, Jim VanSlambrouck, John Tatge, Dr. Donna Bell, and Scott Grandinett. Their sponsorship and work schedule flexibility allowed for work-life balance and program completion.

To my fellow students, thank you for the lively discussions in class and helping us all to become better scholars and leaders.

And to relatives and friends that cheered me on throughout the process: Josephine Dare, Sean Flannery, Cara Ruthenberg, Treena Ericson, and Michelle Heikka. Thank you for your endless support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

The purpose of this dissertation is to create an integrated framework to systematically address routine challenges plaguing early product development for highly engineered and complex products, such as automobiles. The framework includes up-front strategic product planning leveraging 'design thinking' and 'design execution' through a structured process to enable adaptation under uncertainties in the product development lifecycle for customer delight and program success. Included is product planning, from fuzzy front-end until product launch, and prioritizing aligned strategic initiatives while integrating design thinking throughout the process. Discussed are two real-world case studies to emphasize the efficacy of the framework and to demonstrate practical examples of how lack of design thinking and customer voice in the early stages of product planning may result in customer dissatisfaction issues downstream. Reduction of late design changes and realized efficiencies will result in reduced overall cost and faster speed to market. Also addressed is the need to better align and balance business, design, and engineering goals to achieve success. By leveraging this approach, practitioners can expect a more inclusive environment in which innovation is abundant and a more streamlined approach to product planning and design execution is achieved.

This dissertation is organized beginning with this introduction, including: purpose, research question, motivation, and contribution. Second will be the literature review where we explore prior research and academic insights around both product development and design thinking. The development of the integrated framework will follow including an explanation of the methodology used and exploration of the initial framework. The final integrated framework will then be introduced with case studies used to validate the framework in the following chapter. The conclusion will include recommendations and opportunities for future research.

Research Question

The overall research question is: How can we strengthen up-front strategic product planning leveraging design thinking and design execution through a structured process to enable adaptation under uncertainties in the product development lifecycle for customer delight and program success?

The main research goal of this dissertation is to create an integrated framework which creates a more robust approach to product planning. Through the framework, integration of design thinking and design execution brings together the best traditional elements of each in order to create a more robust and transformational approach to creating products for the future. Design thinking alone does not afford the discipline needed to bring a product to life from concept to launch. Conversely, traditional product development approaches are often leveraged in isolation and not coordinated to provide maximum results. Through an integrated approach, the customer becomes central throughout the process, and we can utilize a step-by-step approach where design thinking meets product development in order to create a transformational model. Creation of this framework will most especially help older, traditional organizations overcome hurdles which smaller start-ups do not encounter due to their leaner and more nimble nature. This framework will also help larger organizations overcome what is traditionally a siloed approach to product planning. Often, we see teams competing internally within organizations, which would be mitigated through the framework. The new framework will allow for a cross functional team-based approach where decisions are based on the customer in order to create more streamlined corporate decisions where choices become more profitable as customer and corporate priorities around products are established early and business cases are more robust.

The scope of this paper is limited to individual product programs, not product platforms or product portfolio management. Included is product planning, from fuzzy front end until launch, and prioritizing aligned strategic initiatives while integrating design thinking throughout the process. Two research case studies are used to emphasize the efficacy of the framework and to demonstrate practical examples of how lack of design thinking and customer voice in the early stages of product planning may result in customer dissatisfaction issues downstream. Additionally, a third research case study will demonstrate how to implement and deploy the framework within a large, mature organization.

Motivation

The motivation for the research is personal. I have spent years in product planning in a major automotive company and more efficient, alternative ways of increasing corporate productivity are necessary. I wanted to investigate how to obtain efficiencies in the early stages of product development in the face of an increasingly competitive and complex manufacturing industry that is continually in flux. Through research, I felt it was very important to conceptualize a framework for strategic product planning which would address the product planning challenges. As the research and practical experience evolved, it was evident that design thinking coupled with traditional product development processes offered opportunities to complement each other creating a synergistic opening for an integrated framework.

Despite spending years in product planning, it was not until 2019 that I started to leverage design thinking to understand ambiguous challenges within product development. Design thinking is a structured process to approach issues that are difficult to articulate. It is a human centered approach which leverages observation, collaboration, learning quickly, problem visualization, fast prototyping, and business analysis (Liedtka, 2018). The goal of design thinking is to solve challenges in an innovative and open-minded manner.

I quickly found that design thinking was the missing link to fully understand and effectively approach product planning. By bringing the true understood needs of the customer up-front, efficiencies were realized downstream. Through leveraging design thinking, our team was able to collaborate and avoid re-work and multiple iterations of business cases. However, I personally found design thinking to be difficult and cumbersome. As a practitioner in the industry with over 20 years of experience in a major automotive firm and as a trained industrial manager, it was initially difficult to embrace and leverage the design thinking tools and disciplines. This spurred my motivation to find a better way to approach product planning. Traditional methods of product planning are not enough anymore to remain competitive. Design thinking early in the process is key, and I set out to develop an effective hybrid framework to invent a new approach to product planning that incorporates design thinking in a way that product engineers can grasp and use in product planning and manufacturing execution.

There is no silver bullet or perfect way to approach early product planning. Through a review of the literature, I realized that there is no set standard for a structured product planning process, and the discipline of systems thinking is often lacking. It is my belief that upfront planning before execution, which includes design thinking and the integration of customer feedback throughout, is paramount to success. Therefore, I set out to propose a framework that could serve as a foundation on which to build and realize avenues leading to greater market success, especially as challenges in the global competitive marketplace increase in the future.

Contributions

There are four main contributions which this body of work offers. First, awareness of the need. As industry practitioners work to solve issues, expanded awareness of additional tools is essential. By articulating how design thinking complements traditional product planning and bridges the two disciplines, industry professionals and academic scholars can benefit from advancements in both theory and practice. This work creates efficiencies through the synergistic opportunities resulting from instituting design thinking practices upstream. By instituting the internal and external customer voice early in the product development process, the need for change could be reduced and both cost and timing improved. Additionally, through integration of design thinking into a historically product development-centric process, we revolutionize the system and allow for greater gains in engineering efficiency coupled with increased customer satisfaction.

Second, this is the first manuscript to offer a structured strategic framework for effective integration of design thinking and development of strategic product planning in multifaceted highly engineered products.

The third contribution is the validation of the proposed framework through real-world case studies. Through the integrated framework, actionable recommendations are defined which can be operationalized through functional and cross-functional teams. These recommendations will guide organizations to implement improvements within their own teams to create efficiencies.

Fourth, the integrated framework advances the theories of design thinking and couples it with the pragmatic product development disciplines. With the integrated framework, opportunities for additional research and studies can be conducted to validate the model in a multitude of organizations of varying types and sizes, thereby offering additional improvements.

It is important to not only add to the academic literature available but also provide solutions on how design thinking can complement early product development efforts. Design thinking has potential as a critical approach which offers a competitive advantage to organizations as they seek to optimize their portfolios and comprehensively address customer concerns and issues up-front leading to more robust product development practices.

This introductory chapter has explained the motivation and justification for the research undertaken in this dissertation. We also discussed the motivation for this research, and the contribution it makes to current knowledge and practice. In the next chapter will review the literature that is most relevant to the development of the proposed integrated framework.

CHAPTER 2 – LITERATURE REVIEW

In the literature review, it is important that elements of both product development and design thinking be considered on both the macro and micro levels. After such understanding, adjacencies to product planning were researched, as well as dimensions under consideration for inclusion in the integrated framework. In the literature review we find expert knowledge on components of both product development and design thinking but not a synthesis of both, which affords us opportunities to create knowledge through creation of an integrated framework.

Within the literature, the earliest phases of the new product development process, i.e. product planning and conceptual design, are considered the so-called front end. The early part of the design process is referred to as "fuzzy front end" (FFE) by Preston Smith and Donald Reinertsen who are credited with first popularizing the term (Smith & Reinertsen, 1992). The adjective "fuzzy" refers to the front end phases of product development, because this phase typically involves random processes and "ad hoc" decisions based on intuition, observations, discussions, or even accidents (Stasch, Lonsdale, & LaVenda, 1992; Montoya-Weiss & O'Driscoll, 2000; Flint, 2002).

Product planning involves the identification of customer needs, the analysis of current deficiencies within the market(s) and defining new product characteristics capable of fulfilling both current and anticipated customer expectations (Pahl, Beitz, Feldhusen, & Grote, 2007). Therefore, the outcome of this phase constitutes the product idea where companies concentrate their design efforts and resources (Montagna, 2011). The literature concentrates on the initial phases of product planning, which are considered critical to carry out innovation initiatives successfully (Kim & Wilemon, 2002; Reid & DeBrentani, 2004) (Reil, Neumann, & Tichkiewitch, 2013). Several researchers note that a great percentage of product failures can be directly attributed to inefficient planning activities up-front (Cooper, Edgett, & Kleinschmidt, 1999; Shinno & Hashizume, 2002). Up to 80% of the cost of a product is committed by the decisions made during the initial phases of product planning (Ulrich & Eppinger, 2011). Both managers and researchers maintain that improvements in the management and execution of the front-end phases can produce benefits far exceeding improvements implemented in the latter stages of product planning (Zhang & Doll, 2001).

Successful execution at the beginning of design and product planning cycles reduces problems in later product development stages (Cagen & Vogel, 2001; Flint, 2002), drives revenues and increases firms' profitability (Dahl & Moreau, 2002; Reid & DeBrentani, 2004; Alam, 2006; Kahn, 2011). In short, well-managed and executed initial design phases are required to create successful new products (Kim & Wilemon, 2002; Ernst, 2002; Gou, 2012). As claimed by Pahl et al. (2007), formal processes for the front-end phases help execute the whole product development cycle effectively. Despite the critical role that the front end phases play, researchers maintain that the initial design phases are still insufficiently supported (Koen, et al., 2001; Flint, 2002; Soukhoroukova, Spann, & Skiera, 2012).

Several proposals have been brought forward to successfully carry out the design of new products (Bacciotti, Borgianni, Cascini, & Rotini, 2016). However, despite some decades of research focused on new product development processes, those attempts have not obtained the expected results (Flint, 2002). This deficiency is especially evident as formal practices and methodologies have not been introduced within industry (Bacciotti, Borgianni, Cascini, & Rotini, 2016).

Some researchers feel that the absence of awareness and/or implementation of formal front end processes in companies is sometimes arguable (Nijssen & Frambach, 2000). Unsatisfactory results may be due to incorrect implementation of new product development methods within industry. Conversely, misalignments can be explained since the methods presented by academicians often lack industrial validation and/or are developed with no real connection with business settings (Cantamessa, 2003). Lopez-Mesa and Bylund investigated previous literature sources to prepare an ethnographic study conducted at Volvo Car Corporation, which assesses similarities and differences between decision-making strategies (considered as a crucial design activity) and the procedures suggested by academic new product development methods. They found that product development personnel were biased towards methods based on practices that match engineering thinking. The authors also cite that engineers feel they own the engineering value judgements, often at a cost to customer satisfaction. Further, tensions exist between short-term goals (customer satisfaction) and long-term planning (company wants) and must be balanced (Lopez-Mesa & Bylund, 2010).

Role and Objectives of Product Planning

Many professionals and researchers do not judge FFE as a structured process because of its intrinsic ambiguity and uncertainty (Koen, et al., 2001; Kim & Wilemon, 2002; Alam, 2006). Many companies have neither adopted a structured approach to follow, nor have they applied effective methodologies (Reid & DeBrentani, 2004; Achiche, Paolo Appio, McAloone, & DiMinin, 2013). This lack occurs since many organizations focus their attention on back end activities such as validation and product launch. These latter activities offer acknowledged methods which are more known and available, primarily reducing manufacturing errors. According to Cagan & Vogal (2001), this strategy is far riskier to companies since disregard of the FFE can lead to product failures. Focusing too heavily on back end activities and neglecting the fuzzy front-end can lead to increased expense when revising decisions or changing direction, which dramatically increases as the design process progresses (Kim & Wilemon, 2002; Cousineau, Lauer, & Peacock, 2004; Achiche, Paolo Appio, McAloone, & DiMinin, 2013).

Scholars such as Flint (2002), Alam (2006), and Soukoroukova (2012) suggest that FFE can become much less “fuzzy” if customers are involved in the initial stages of NPD. Proposals to better manage FFE include organizing teams in a more optimal manner (Kim & Wilemon, 2002), trying different techniques to manage the fuzziness related to customers, technology, and competitors (Zhang & Doll, 2001), and focusing on better capitalization of available resources within a company (Achiche, Paolo Appio, McAloone, & DiMinin, 2013). Studies about the management of early stages of new product development cycles (Adams, Day, & Dougherty, 1998; Ramesh & Tiwana, 1999; Garcia, Sanzo, & Trespalacios, 2008), and the strategic positioning of development projects (Balachandra & Friar, 1997; Henard & Szymanski, 2001) have already offered clear solutions. According to these sources, key aspects to achieve commercial success lie in internal collaboration between different units of the company, attention to organizational issues, fostering increased cross-functional integration, improved research and development effectiveness, and leveraging managers’ experience (Bacciotti, Borgianni, Cascini, & Rotini, 2016). Acknowledged success factors of the product development process do not pertain to what is directly designed, manufactured, and marketed. The literature suggests that few efforts have been devoted to analyzing activities that directly affect the product and features (Page & Schirr, 2008). Other researchers cite that product-led research has a greater economic impact than process-led research (Hicks, 2016). There are always additional opportunities to acquire more knowledge around the best practices and overall product planning execution (Bacciotti, Borgianni, Cascini, & Rotini, 2016).

In the literature, the term "Product Planning" has been used to define different design activities. Researchers maintain that the main purpose of product planning is to translate identified customer wants into product technical requirements using quality function deployment (QFD) (Akao, 2004; Lee, Kang, Yang, & Lin, 2010; Li, et al., 2012). Other authors claim that the main objectives of product planning are the assessment and selection of alternative product concepts (Jetter & Sperry, 2013). Kahn (2011) defines product planning as the process of envisioning, conceptualizing, developing, producing, testing, commercializing, sustaining, and disposing of organizational offerings. In other words, he considers the entire product lifecycle in his research. Beyond these definitions, it is widely accepted that the main purpose of product planning is to identify new product attributes capable of fulfilling customer expectations which will offer new market opportunities (Shinno, Yoshioka, & Marpaung, 2006; Pahl, Beitz, Feldhusen, & Grote, 2007).

One of the main outputs of product planning is the list of product requirements which must be taken into account in the subsequent design phases when defining, selecting, and developing the most optimal technical solutions (Bacciotti, Borgianni, Cascini, & Rotini, 2016). By referring to customer expectations, product planning must take into account the benefits generated by both physical goods and intangible services (Flint, 2002; Alam, 2006). The scope of product planning processes emerges by considering its main constituent activities. This is mainly focused on the generation of ideas about the new product to develop and optimize the subsequent selection of alternatives (Bacciotti, Borgianni, Cascini, & Rotini, 2016).

The idea generation stage is also referred to as the opportunity identification stage (Cagen & Vogel, 2001; Achiche, Paolo Appio, McAloone, & DiMinin, 2013). This stage is intended to identify attributes, features, or general ideas of the new product. Some researchers consider idea generation the basic function of product planning and the key to its success. Idea generation usually results in discovering several options. Therefore, this step must be followed by a convergent idea selection task (Reitzschel, Nijstad, & Stroebe, 2006). The idea selection, named opportunity analysis stage in some sources (Koen, et al., 2002), is the decision-making phase of the product planning process that offers choices of alternatives to be further developed.

Overall, it is clear from the literature that there is an absence of effective objective methods and processes for upfront product planning. The associated literature can be broadly categorized into the following three themes: 1) Requirements Management; 2) Requirements Engineering; and 3) Change Management. Often within the literature, these three topics (and terms) are used interchangeably.

Design Thinking

Several scholars have asserted that there is limited academic literature around the concept of design thinking. "Despite the wide interest in design thinking among practitioners, there is a lack of research on how organizations work with design thinking in practice. There is little knowledge about what managers actually do to make design thinking happen in organizations" (Rauth, Calgren, & Elmquist, 2014, p. 48). "The role of design thinking has shifted from a tactical level function to a more elevated strategic position in organizations. However, research on how companies organize and manage design thinking strategy is still very limited" (de Paula, Dobrigkeit, & Cormican, 2019, p. 557). De Paula et al. (2019) found that there are few empirical studies on design thinking in companies, and the understanding of benefits of design thinking within organizations is not thoroughly understood. "While a measurable proof of the impact of design thinking is often seen as the Holy Grail in large organizations, it is difficult to achieve in practice" (Paparo, Disti, & Vignoli, 2017, p. 368). "Design thinking's relative lack of attention in the scholarly literature has been attributed, not only to its newness in management circles, but also to its dismissal as merely a set of practical tools lacking any theoretical grounding and therefore not of interest to scholars" (Liedtka, 2018, p. 7). While literature exists citing the tools and approach for design thinking, there is no academic literature which defines how to measure design thinking's impact on an organization. This represents a gap between what can be found in the literature and the pragmatic need of organizations (Paparo, Disti, & Vignoli, 2017).

When looking at traditional product development, we can see challenges which may seem insurmountable within an organization. "Engineers, policy makers, and others, like to try to understand the whole problem at once, all of its factors, do a big analysis and make a big recommendation. However, things never get done. Because you need political support, a huge budget, and it takes time" (Camacho, 2018, p. 633). As a result, Camacho states (2018) that over time, gradual interventions within a system with a clear aspiration which is people-focused will result in positive trajectory of change over time.

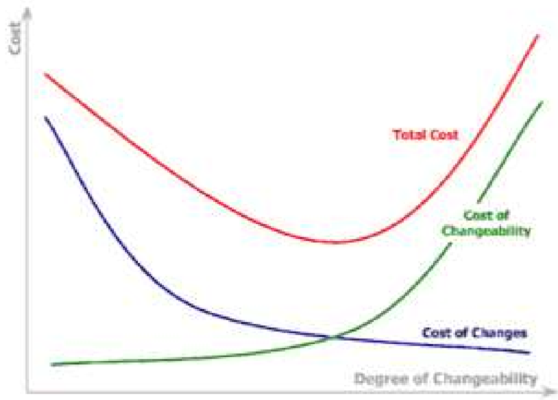
Design thinking offers a new perspective on shaping the product development process by putting the customer first. Application of design thinking principles can lead to new and greater innovative management practices, especially in engineering firms. Design thinking is unique through the varied application of tools available to its users. "Because it consists of a diverse bundle of tools and activities, design thinking can be most effectively grounded in various management literatures at the level of particular practices, rather than the abstract bundle" (Liedtka, 2018, p. 8). As Liedtka suggests, that is the intent of this dissertation – to couple design thinking principles and tools and apply them to early product development processes. This integration will help to facilitate solving wicked problems in the fuzzy front end. A "wicked problem" is nomenclature used "to describe a class of problems that were ill-structured and did not lend themselves to the accurate a priori assessment of the relationship between cause and effect" (Liedtka, 2018, p. 4).

While limited literature exists on the benefits of design thinking, there is the widespread belief that, "Design thinking can be a driver for innovation, and can take place at different stages in the company, the front-end phase being the most important" (de Paula, Dobrigkeit, & Cormican, 2018, p. 563). Literature does not associate systems thinking as an integral part of design thinking but as an accessory piece in the toolkit. (Camacho, 2018). Therein lies the opportunity; to create an association between design thinking and systems thinking in order to mutually strengthen both.

Set-Based Concurrent Engineering

It is also important to consider the balance of what aspects of planning must be declared in advance (i.e., which markets) and which decisions should be delayed until necessary (i.e., regulations). For this reason, the dissertation includes set-based concurrent engineering (SBCE). SBCE "begins by broadly considering sets of possible solutions and gradually narrowing the set of possibilities to converge on a final solution" (Sobek, Ward, & Liker, 1999, p. 68). Toyota employs SBCE and the process "may take more time early on to define the solutions, but can then move more quickly toward convergence and, ultimately, production, than its point-based counterparts" (Sobek, Ward, & Liker, 1999, p. 68).

Figure 1. Degree of Changeability vs. Sources of Cost (Fricke & Schulz, 2005)



As shown in Figure 1, studies show that 30% of work efforts are due to changes (Fricke, 2000). “If a product does not meet its requirements and has to be changed, two principally different reasons can be distinguished: 1) Actually changing requirements, or 2) Incomplete or incorrect requirements” (Fricke, Gebhard, Negele, & Igenbergs, 2000, p. 171). The author continues, “If a change in a later phase is ten times more expensive than a change in a previous phase, you have ten times more changes in an earlier phase at the same cost. Therefore, a lot of authors recommend front-loading changes in system development” (Fricke, Gebhard, Negele, & Igenbergs, 2000, p. 174). The author expands his theories in later publications adding, “Anticipated knowledge about a likely future evolution facilitates to already incorporate capacity, functionality, and performance reserves. Various anticipation practices are applicable, as there are forecasting, extrapolation, scenario techniques, or pattern recognition” (Fricke & Schulz, 2005, p. 355).

In order to maintain flexibility, “Architecture must remain changeable and evolutionary even after being introduced into the marketplace, as changing environments and evolving needs will affect their success throughout the lifecycle” (Fricke & Schulz, 2005, p. 343). We see examples of this flexibility when looking at optional features in automobiles. In the 1970s there were between 30-50 optional features in a vehicle. Today there are up to 500 features (Fricke & Schulz, 2005). Not only does the propagation of features suggest opportunities for late changes, there is also interdependence and complexity to be considered.

The desired state through this dissertation is to leverage product planning and to anticipate change. However, there are instances where change is inevitable due to inconsistent external factors that are difficult to anticipate such as changes required by regulatory agencies, competitor moves, and market changes. In such cases, it is important to have a SBCE type approach for critical elements which are prone to late changes.

Requirements Management

Requirements management is the process of managing engineering rules and guidelines. Again, there are few empirical studies on requirements management in industrial practice (Almefelt, Berglund, Nilsson, & Malmqvist, 2006). Development of requirements management requires integrated cultural elements. "In practice, not only are the product and the set of requirements complex, but so are the social system and the industrial system dealing with the development" (Almefelt, Berglund, Nilsson, & Malmqvist, 2006, p. 114). While specifically citing changing legal requirements as a valid concern, the paper illustrates the importance of flexibility within the organization. The organization must be, "flexible enough to allow new ideas to be adopted and brought into the specification" (Almefelt, Berglund, Nilsson, & Malmqvist, 2006, p. 127). Furthermore, when managing engineering requirements, "designing is a socio-cultural process, in which different participants, with different competencies, responsibilities, and interests harmonize their claims and proposals and finally agree about appropriate requirements and solutions" (Almefelt, Berglund, Nilsson, & Malmqvist, 2006, p. 129). This can also be referred to as negotiated culture, which are new norms created when parties are working together that form out of negotiating a new social order. Over time, colleagues agree upon new cultural expectations around how they will continue working together (Barmeyer & Davoine, 2019). Finally, to reinforce the point, "informal requirements management, such as interpersonal requirements dialogue, is essential" (Almefelt, Berglund, Nilsson, & Malmqvist, 2006, p. 133) to an organization's success.

A second article around requirements management written by engineers at DiamlerChrysler AG Research and Technology group is directly applicable to industry. The authors acknowledge that features and requirements change often within the development process due to strong market competition, cost pressure, and short product lifestyles (Hoffmann, Kuhn, Weber, & Bittner, 2004).

Requirements Engineering

While requirements management is about managing rules and guidelines, requirements engineering is the actual process of setting guidelines for designs. "Requirements for a defined system are defined, managed, and tested systematically. The purpose of requirements engineering is to ensure that a product development team builds a system that satisfies customer and user needs" (Kauppinen, Vartiainen, Kontio, Kujala, & Sulonen, 2004, p. 937). As with requirements management, "Even though research on requirements engineering has been active throughout the 1990's, there are not many studies concerning requirements engineering process improvement" (Kauppinen, Vartiainen, Kontio, Kujala, & Sulonen, 2004, p. 938). Also similar to requirements management, requirements engineering needs to include cultural change as "Product development personnel need to understand the importance of customer and user requirements and secondly, they must commit to define and manage requirements systematically" (Kauppinen, Vartiainen, Kontio, Kujala, & Sulonen, 2004, p. 938). Further reinforcing the cultural change, Kauppinen et.

al. (2004) state that engineers must change their perspective on product development from a technology-centric view to a customer-centric view. However, the author acknowledges that there may be push-back within an organization and the changes may be resisted. The essential point is that any process that is created must be useful for the users and practical – simple and flexible.

Another study, also authored through DaimlerChrysler's research department, contends that it is impossible to not eliminate changes during projects as some changes are justified. The researchers' central focus is how the organization chooses to deal with late and unexpected changes, approaching changes both with a cultural and technical perspective (Weber & Weisbrod, 2002). The authors conclude that the key is to provide an on-line repository tool to track changes and manage requirements. "The basic features of requirements management support are sufficient to provide this kind of review support: single source, user defined attributes, powerful viewing and filtering mechanisms, change history and base line facilities, as well as the generation of standard reports derived from specific views" (Weber & Weisbrod, 2002, p. 7).

Change Management

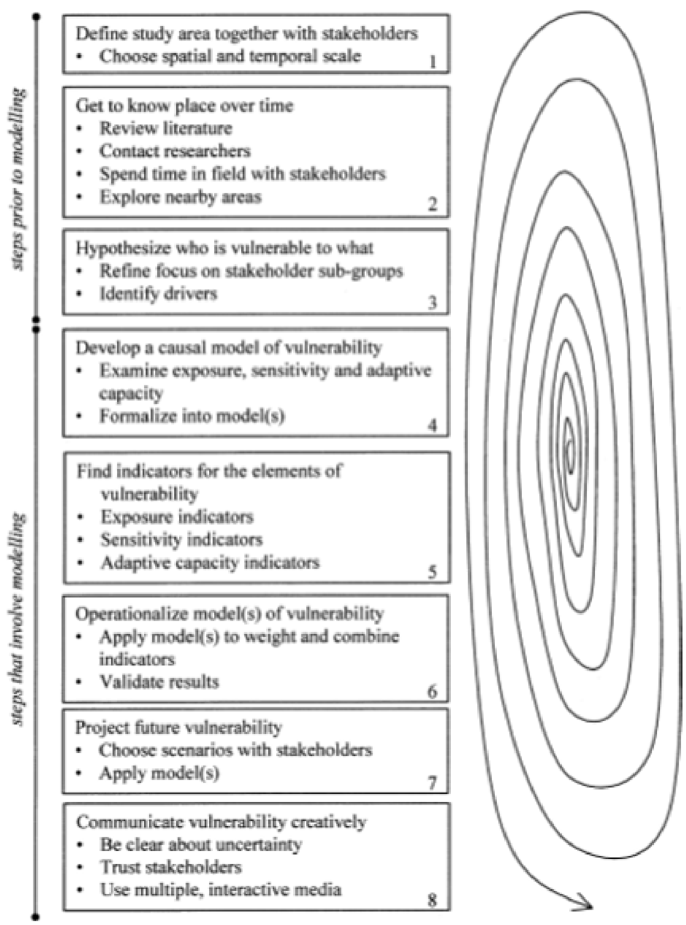
There is comparatively more literature available on change management as it pertains to the product development process, especially around process improvement. Change management is simply the process by which organizations track and manage change as the product moves from idea to launch. However, there is less research around process re-engineering (Wang & Wang, 2016).

There are two types of changes to be considered in change management: 1) Initiated changes which occur when new customer needs arise, and 2) Emergent changes which are weaknesses or defects in the product (Eckert, Clarkson, & Zanker, 2004). Eckert also acknowledges a third type of change which is very relevant to export concerns – certification requirements. "Certification rules themselves can change and changes might have to be made at any time to comply with the new rules" (Eckert, Clarkson, & Zanker, 2004, p. 6). This point coincides with Eckert's theory that while some changes cannot be predicted, this type of change can be foreseen. Therefore, anticipating changes in advance can decrease product development delays. To further mitigate delays, Eckert illustrates how engineering reserve margins are essential to build flexibility into the system (much like set-based design engineering). She concludes by stating, "The challenge in change management lies in predicting the effects of such changes and managing them so that the change process can be concluded on time and at minimum cost" (Eckert, Clarkson, & Zanker, 2004, p. 13).

The financial cost of engineering changes must also be considered. "It has been proved that the costs of an engineering change grow by a factor of five to ten as one moves from early design to manufacturing" (Wang & Wang, 2016, p. 406). Wang argues that optimizing knowledge flow is essential to efficient change management. However, there is currently no accepted definition for knowledge flow yet established. For the sake of his research, Wang defined knowledge flow as "A process of directed transmission of intellectual content between knowledge carriers when transferring conditions are met" (Wang & Wang, 2016, p. 407). Through optimizing engineering change processes, there is a significant impact on manufacturing cost and product delivery.

As an extension of change management, three articles feature scenario planning which is another opportunity area currently not being sufficiently addressed in industry. Scenario planning is also referred to as vulnerability assessments. While there had been increased attention to the concept of vulnerability in academic research, there has been little discussion on which methods are most appropriate to address it (Schroter, Polsky, & Pratt, 2005). Researchers define vulnerability as "a function of three overlapping elements: Exposure, sensitivity, and adaptive capacity" (Schroter, Polsky, & Pratt, 2005, p. 575). These assessments are designed to be conducted by an interdisciplinary team to reduce vulnerability and to test scenarios which may be encountered. Figure 2 illustrates the eight steps included for global change vulnerability assessments.

Figure 2. An Eight Step Method for Global Change Vulnerability Assessments (Schroter, Polsky, & Pratt, 2005)



By utilizing assessment tools such as the one illustrated in Figure 2, stakeholders will be familiar with risks in advance. Second, the cross-functional team approach lends credibility as viewed by senior management/stakeholders due to the inclusiveness and breadth of knowledge that the team collectively bring to the project. From Figure 3, we can find opportunities to look farther ahead to reduce risk early in product planning.

When considering vulnerability assessments, considerations may include: development, speed, market success, customer satisfaction, and other factors important to product development. Each consideration is important, but for validation purposes of a new framework, speed to market and elimination of delays are the easiest to articulate. Optimizing the system to foresee any delays and to make sure that decisions are made at the precise point in the engineering system will help to move the industry forward.

Regardless of whether we consider requirements management, requirements engineering, or change management, each contributes to improvements in product planning. While the overall literature is sparse, each researcher covered in the literature review offers suggestions on how engineering systems can be improved. In the case of this dissertation proposal, it is important to differentiate what is important to consider up front, and which elements are best reserved for set based engineering. When we consider how customer preferences and regulations change, optimizing the overall system is a priority.

Set-Based Planning

Set-based planning allows for several variations of a feature to be considered early in a program and the options become reduced as more information becomes available, such as cost and customer preference. "The most important issue with strategic product planning is that as the accuracy is reduced the farther we are to either the start of production or end of the product lifecycle" (Hyde, 2017). For this reason, it will be important to use set-based thinking and keep a life-cycle perspective throughout the research. This approach will require us to, “Begin by broadly considering sets of possible solutions and gradually narrowing the set of possibilities to converge on a final solution” (Sobek, Ward, & Liker, 1999, p. 68). “Eliminating ideas in stages allows participants to consider the most important alternative more fully and gives them time to influence each other’s narrowing process” (Sobek, Ward, & Liker, 1999, p. 79). Not only will the optimal solution need to be made, but the timing of the decision should be designed such that optimal inputs have been given and there is a reduced exposure to late changes.

Summary

The literature review demonstrated that there is significant need for design thinking within product planning. Design thinking is still considered to be new in management circles and there is a lack of scholarly literature available, primarily because tools associated with design thinking do not yet have theoretical grounding (Liedtka, 2018). While design thinking must permeate throughout an organization, there is a need to drive the discipline into the front-end phases (de Paula, Dobrigkeit, & Cormican, 2019). Current literature deems systems thinking as a complement to design thinking (Camacho, 2018), yet there are opportunities to strengthen this association between the two approaches to thinking, creating a vastly greater method. Design thinking literature is limited to the tools offered through the approach and does not address the measurement of impact on an organization (Paparo, Disti, & Vignoli, 2017). The literature demonstrates that while there is research around both design thinking and product development tools and processes, there is no current body of work combining the two disciplines, offering an opportunity to create a framework integrating the two approaches.

The next section will focus on the methodology used to develop the integrated framework, which brings together both traditional product development and design thinking disciplines to create a framework for practical application.

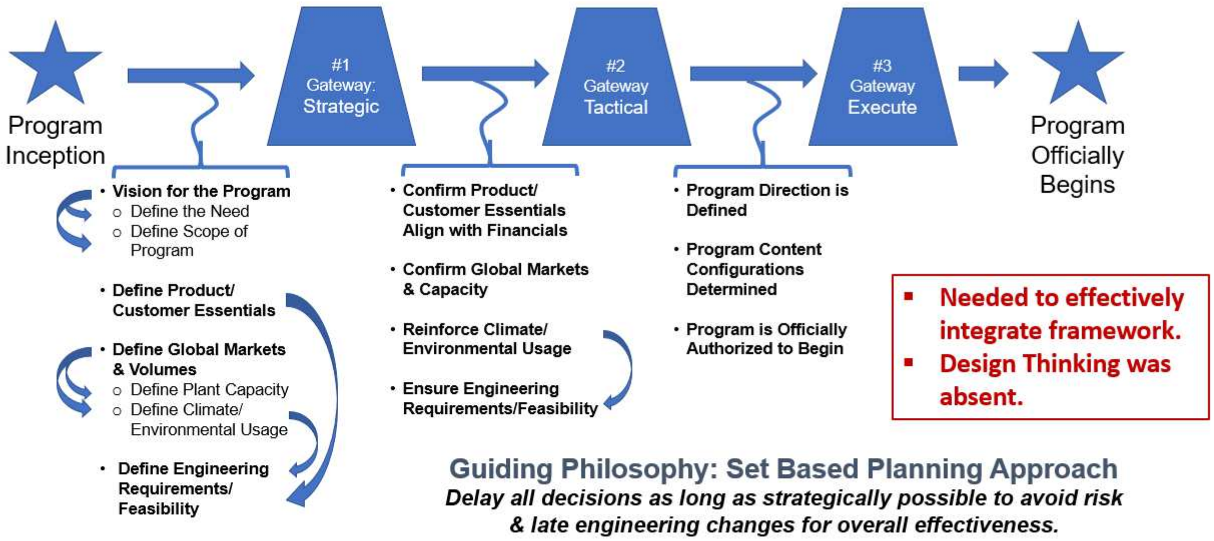
CHAPTER 3 DEVELOPMENT OF INTEGRATED FRAMEWORK

When I wrote my dissertation proposal in late 2017, my research direction centered around improving the product planning process focusing on: set-based planning, concurrent engineering, scenario planning, agile stage gate, high performance teams, and culminating with the power of converging these concepts within product development. For each of these, I turned to the literature and was able to find existing research around each concept, but none integrating all elements. Looking back, I had written that the dissertation proposal included 60 references, but none offered a comprehensive strategic product planning framework. This was an opportunity to bring the strategic product planning techniques used in industry into academia.

As a next step, I concentrated on creating a conceptual framework. The conceptual framework is a model of what to study in either graphical or narrative form. It is "The system of concepts assumptions, expectations, beliefs, and theories that supports and informs your research" (Maxwell, 2013, p. 39). There are four ways to construct a conceptual framework: "1) experiential knowledge, 2) existing theory and research, 3) pilot and exploratory research, and 4) through experiments" (Maxwell, 2013, p. 44). I have employed all four of these elements as will be explained through the development of the integrated framework.

My initial research question was: How can a strategic framework for upfront product planning be developed using convergence to provide both a structured architecture process and flexibility to accommodate changes in the product lifecycle? The term convergence used indicates that the power of product development tools was stronger when strategically executed in a structured combination and defined sequence. Figure 3 shows the initial framework as illustrated in my proposal defense.

Figure 3. Initial Framework for Strategic Product Planning



The initial framework included gateways and required questions from the early product planning process. Questions from the strategic portion of the framework included the vision for the program and definition of product and engineering requirements. The next stage was tactical, ensuring an aligned business case, capacity, use cases, and feasibility of engineering requirements. The final stage was the execute phase where program direction is defined, content articulated, and the program officially begins.

In early 2019, I began working in the Technology Strategy and Planning group of an OEM and was tasked with leading a team through a design thinking exercise: how to implement health and wellness features into a vehicle. My team was cross-functional and included: advanced researchers, product development engineers, planning, and marketing. Our task was to determine how to manifest health and wellness into a vehicle. Complicating the task was the abstract nature of health and wellness which means something different for everyone. The team worked and built a strategy around a set of desired experiences and integrated both technology and features. But it was a challenge. Traditional product development engineers, such as me, struggled with design thinking tools and processes. Dealing with the abstract in a creative manner is not intuitive for everyone, especially engineers. I turned to the academic literature to see if my experiences and challenges were unique. I quickly found out that my team's challenges were quite common, especially within an older organization that is large and complex.

Recent research highlights the need for large organizations to identify effective ways to integrate the goals of design, engineering, and business concurrently. "We found three typical stumbling blocks faced by technology organizations transitioning from engineering-driven toward design-driven operations: boxed-in design, unactionable design thinking, and fragmented efforts" (Bjorklund, Maula, Soule, & Maula, 2020, p. 108). Design may feel boxed in due to the organization's inability to work cross functionally. This is coupled with design thinking which becomes unactionable when the designers are not accepted in the wider organization. Finally, fragmented efforts result when pockets of design thinking approaches occur which are not integrated. "Sometimes it is even unclear who has the final say in decision-making across siloes, leading to standstills" (Bjorklund, Maula, Soule, & Maula, 2020, p. 112).

Design thinking cannot be implemented on its own and needs to be part of a stronger framework to be executed effectively. "In an organizational setting, design thinking lacks the rigor to function as a stand-alone end-to-end innovation process" (Calgren, 2016, p. 18). We also find that "Design thinking is an initiative approach that contrasts with the conventional new product development process, which is considered a linear process" (Redante, De Medeiros, & Cruz, 2019, p. 249). "The design thinking process is iterative and moves from generating insights about the end users, to idea generation and testing, creating fast solutions through the development of simple prototypes, to the final solution and implementation" (Redante, De Medeiros, & Cruz, 2019, p.

250). While this may be an oversimplification of design thinking, it encouraged me to think about the power of coupling design thinking elements with product development processes to create a framework integrating the two disciplines. Leveraging experiential knowledge is accepted because, “The explicit incorporation of your identity and experience in your research has gained wide theoretical and philosophical support.” (Maxwell, 2013, p. 45).

Through the evolution of my own professional experience, I found my original research question and framework to be deficient. I had gained additional knowledge which led me to include design thinking. This opportunity to combine design thinking with product development processes led to my revised research question: How can we strengthen up-front strategic product planning, leveraging design thinking and design execution through a structured process to enable adaptation under uncertainties in the product development lifecycle for customer delight and program success?

Integrated Framework for Strategic Product Planning, presented in Figure 4 at the beginning of Chapter 4, combines my professional experience and learning with the insights from literature as a structured process that leverages both design thinking and design execution. To validate the framework, I looked to prior professional challenges and projects that I had encountered and reflected on how using the updated framework would have eliminated redundancy and waste while improving customer satisfaction. I used two distinctly different cases. The first was the impact of the 2014 polar vortex on Canadian warranty and satisfaction. Desperate cold conditions had magnified cold weather-related issues in the field. All were known deficiencies, but the extreme conditions had magnified the rate of failure. The new framework highlighted the need to understand customer usage, failure modes, and business cases earlier in the product development process. The second case study was the development of a large off-road SUV for the Middle East. Eighty percent of customers report that they go off road at least once per month with their vehicles in the region. Off road travel coupled with larger family size, indicated there was unmet demand in the region. Understanding the market needs and competitive disadvantages earlier may have allowed the company to become more competitive in the region. In both cases, the framework could have led to better insight, stronger decision making, and faster development time.

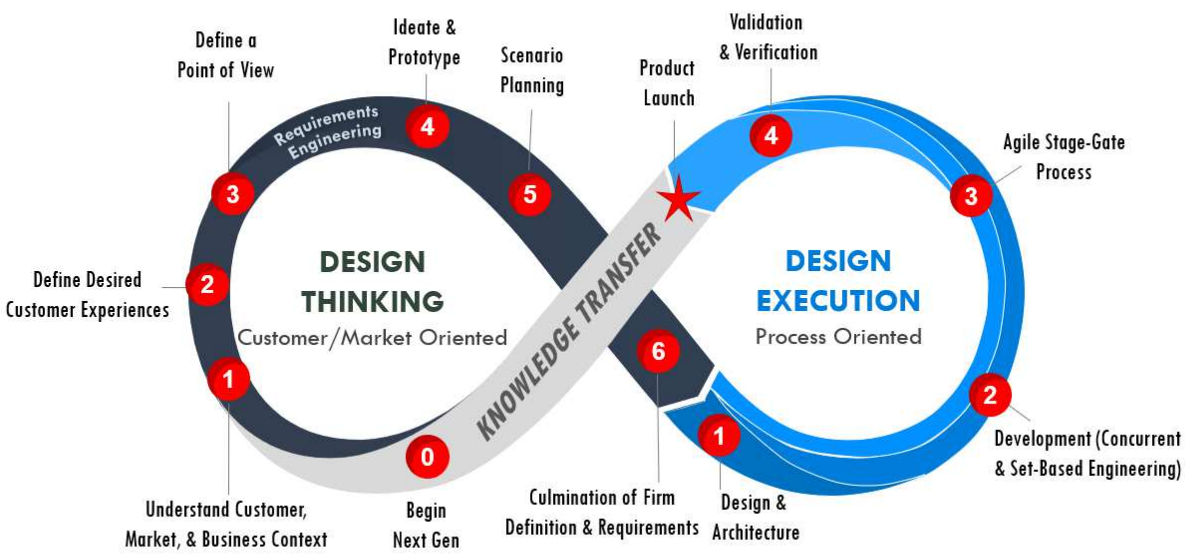
There is academic merit in using research case studies to validate theory framework. "The essence of a case study, the central tendency among all types of case studies, is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result" (Yin, 2018, p. 14). Other researchers agree, citing, "The opportunity to study an actual situation in a realistic setting in the principal advantage of case research. This type of research allows the researcher to determine not only what happened, but why it happened" (Naumes & Naumes, 2006, p. 64). In the case studies, we can consider the complexities that contributed to the outcomes of the situation and retroactively look at the situation through the lens of the framework, validating our theories. "Case studies allow researchers to study a variety of aspects of both the situation being analyzed as well as the theories and concepts under review" (Naumes & Naumes, 2006, p. 79). This is not to say that the case is being used to criticize the outcome of what did happen but as a positive means to leverage the example to validate the integrated framework.

In this chapter we discussed the methodology used to develop the framework. We discussed how the framework initially sought to improve product planning in generic terms. Through additional industry experience and academic research, it became evident that design thinking was valuable to the product planning process, especially coupled with more traditional product development processes. This insight led to a second iteration of the framework which was then tested against two research case studies derived from industry. In the next chapter we will look deeper into the individual elements of the framework.

CHAPTER 4 INTEGRATED FRAMEWORK FOR DESIGN THINKING & STRATEGIC PRODUCT PLANNING

In this chapter I will explain the elements of the final integrated framework model with research justification for each step. This figure represents the culmination of the literature review and experience used to create a final version of the integrated framework model.

Figure 4. Integrated Framework



The proposed integrated framework shown in Figure 4 couples the benefits of design thinking with design execution to create a more robust approach. For centuries, companies have demonstrated technical aptitude and the ability to manifest products through disciplined development processes. Through time, inefficiencies are identified, and improvements are instituted. Today, customers require more than just a functional, quality product. Through integration of design thinking principles, a more comprehensive framework can be created, focusing on early elements in product development. Understanding both the customer and market must be aligned with a strong business case for a product. Deep knowledge of the customer, product usage, and expectations up-front are pre-requisites to planning a product effectively.

Phase I - Design Thinking

Design thinking has evolved over the last 40 years to the point where its inclusion within the product development lifecycle is vital to achieve maximum efficiency. “One of the first design thinking process models was from Simon Herbert (1969) and consists of seven phases (define, research, ideate, prototype, choose, implement, and learn)” (Mitcheltree, Holtskog, & Ringen, 2019, p. 2359). Today, design thinking models range between three and seven phases. More importantly, design thinking has evolved over the decades offering more involvement in strategic activities. But this view varies, and we find that, “In literature, design thinking is described and understood in a variety of ways: A cognitive perspective referring to the creative and explorative activity of design, as a general theory of design, or as a strategic perspective referring to the strategic process of the organization and more generally to the managerial capability” (de Paula, Dobrigkeit, & Cormican, 2018, p. 558).

Further demonstrating the benefits of design thinking, we think of the approach as “A set of principles collectively known as design thinking – empathy with users, a discipline of prototyping, and a tolerance for failure chief among them the best tool we have for creating those kinds of interactions and developing a responsive, flexible organizational culture” (Kolko, 2015, p. 4).

There are vast opportunities realized when leveraging design thinking within the product development process. “Design thinking may be a sustainable way for organizations of the future to facilitate process and development opportunities beyond the initial creative phases of product development" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2366). Researchers find that "Applying design thinking to new product development can result in more useful, original, and appealing product concepts" (de Paula, Dobrigkeit, & Cormican, 2018, p. 561). Design thinking also offers an opportunity to reduce development time, "As design thinking emphasizes visualization and re-framing problems, it contributes to enhanced clarity, meaning and confidence in ideas and decisions. Design thinking in this way may impact strategy formulation and speed up complex innovation processes by pre-experiencing future situations" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2357). Other researchers agree that the benefits of using design thinking may also manifest in "Increasing speed and gaining process flow due to a deeper understanding and clarity between members within the process" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2363).

Design thinking dimensions both customers' wants and unarticulated needs. Additionally, design thinking is also used as a means of navigating the fuzzy front end and ambiguous problems. For this reason, application in early product development processes can be very powerful. "As a strategic and management capability, design thinking has been studied as a way to help address the challenges as faced by project managers" (de Paula, Dobrigkeit, & Cormican, 2018, p. 559). Further evidence states, "Design thinking can provide significant contributions to the challenges encountered by project management in terms of exploration, stakeholder involvement, and firm strategizing" (de Paula, Dobrigkeit, & Cormican, 2018, p. 559). It is essential that each of these dimensions be understood early in the product planning process.

With finite resources, companies must determine which investments are the best use of capital, which can be determined through design thinking coupled with business planning. Management must analyze their portfolio to determine gaps and opportunities. As they articulate the gaps, knowledge transfer from previous programs must inform the team of best practices moving forward. As a cross-functional team is formed, both a lead strategic planner and a chief product engineer must be identified. Leadership must support the team and ensure that proper resources are available for the team's success.

Stage 0 – Begin Next Generation

The baseline starting point is Stage 0. Since the framework is created through an infinity loop, Stage 0 can either be the very first generation of a product or a re-freshening of a prior model/new model year. During this phase, key cross-functional team members will be identified, including a Lead Strategic Planner who will be responsible until the hand-off to the Chief Product Engineer in Stage 6. In Stage 0 it is important that any available knowledge gained on previous programs and/or models are transferred to the new team.

Stage I – Understand Customer, Market, and Business Context

Within the first official stage, we work to understand the customer and the market in which the product will be utilized. Once the idea of a product is conceived, the context must also be understood. This is also known as the fuzzy front end where we start to define the product through understanding the business context and the holistic organizational need for the product. All companies have a finite set of resources, whether it be financial or people. An integrated framework approach ensures that a product is developed with a strong business case maximizing corporate business results. Understanding market conditions is also imperative to success. Whether a company is first to market with a product or offering a unique product to a crowded market, it is essential to map-out the competition and understand why customers will select your product.

Before a product is developed, the customer must be thoroughly understood. "Design is by definition dealing with the world of tomorrow; the users of today might not be the users of tomorrow, and the reasons for using something today might be very different for using something tomorrow" (Camacho, 2018, p. 632). Therefore, customers' needs should be understood, articulating who they are and what their needs are, both overt and implicit. This requires that an anthropologic approach be taken. Customers must be met in the environment in which they will utilize the product to identify usages which are both intended, and possibly, unintended. Customers may have a creative alternative use for the product, which may not have been initially understood or even identified. For example, couples can use their two iPhones to create a baby monitor. This use did not require purchasing any additional equipment and is not the primary intent of the device. While designers define the product, customers demonstrate the usage, which may be different, and even better, then what was originally conceptualized.

As a company begins to decipher the fuzzy front end of product planning, the business environment must also be thoroughly understood. Considering the right product for the market and conducting a full analysis of the competition is essential. Understanding business capitalization and market saturation is important as well. A company needs to determine whether it will be competitive in a mass market segment or if the product will fill a niche, as each strategy fills different needs.

Allocation of resources is a central consideration. Every company has finite resources, whether it be cash, talent within the organization, or overall corporate capacity. Therefore, the fuzzy front end must be defined as thoroughly as possible to reduce risk, which is why an integrated approach with both design thinking and product development offers many more solutions and better clarity.

Within this stage, companies can leverage strengths, weaknesses, opportunities, and threats (SWOT) analysis. See Figure 5 for an example. "When conducting strategic planning for any company - online and/or offline - it is useful to complete an analysis that takes into account not only your own business, but your competitors' activities and current industry happenings as well" (Kyle, 2014). Additionally, high level customer needs should be articulated based on experience with marketing clinics, focus groups, and quality surveys. At this point, marketing should be heavily involved with the needs and opportunities to be leveraged by the program under consideration. Marketing will look at the trends and future state, especially as strategic product planning is early in the process and the team must anticipate future needs.

Figure 5. SWOT Analysis (Kyle, 2014)

Stage II - Define Desired Customer Experiences

Putting the customer first is central to ensure success. Scholars suggest that the fuzzy front end can become much less "fuzzy" if customers are involved in the initial stages of product development. For a company to achieve full understanding, they must be interested in all details of a customer's life (Liedtka, 2018). By understanding customer expectations, product planning must take into account the benefits generated by both physical goods and intangible services (Flint, 2002) (Alam, 2006). To arrive at an understanding of desired customer experiences, we must consider several different dimensions. The first is understanding how the customer uses the product. This would include customer usage for routine day-to-day applications as well as those uses that may be extreme or rare. An example may be an automotive customer in a temperate climate which may experience occasional torrential rains and ensuring that the customer is protected. Beyond usage, deeper elements such as knowing how the customer feels while using the product, are also essential, which helps the development team understand customer experience. Knowing why the product is used also offers deeper insight into both the customer and the product. A product such as a light duty truck used for family transportation or heavy-duty truck used for business purposes, have customers with distinctly separate needs.

The use of ethnography is imperative to accumulating a deeper understanding of the customer. By leveraging design thinking and taking an anthropologic approach, the nuances of customer usage are collected and analyzed. Customers will not always know their direct needs or wants when defining the design of their ideal product. However, by studying customer behaviors holistically and getting to know their day-to-day lives, insight can be gained. Companies should employ anthropologic research methods to study people as they move through their day to understand how customers use current products as well as observe their daily human behaviors. Researchers find that "Ethnographic data gathering triggered a shift in perspective on the part of those designing from that of 'experts' to that of user, combatting a well-known cognitive bias - 'egocentric empathy gap,' in which decision makers consistently overestimate the similarity between what they value and what others value' (Liedtka, 2018, p. 13). "For some companies, observing customers in their own environment is their primary method of learning about the customers' latent and unformulated needs" (Ford, Auburt, & Ryckewaert, 2016, p. 18). Design thinkers see and understand the connections, the interactions and the dynamics of complex context (Paparo, Disti, & Vignoli, 2017). Effective use of ethnography also allows researchers to empathize with the product's users. "Empathy is the tool able to recreate abstractly a given situation and how individuals perceive it. The ability to 'put yourself in someone else's shoes' is essential if you want to understand desire, hopes and problem of users" (Paparo, Disti, & Vignoli, 2017, p. 372).

Design thinking teams must be able to experience and deeply understand usage issues through the lens of the customer. "Being part of the user experience will make decision makers less likely to solely look at their own past experiences as the source of new ideas (project bias), nor focus on their present state when assessing ideas (hot/cold gap)" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2361). "In a situation involving the end user, cultivation of empathy through understanding might also generate knowledge that makes it easier for a product development team to get the right picture of what is needed and why" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2364). Engaging both external and internal experts also provides insight and helps prevent cross-functional teams leveraging too much for their own bias. Utilizing these guidelines will help an organization define the desired customer experiences required for their product usage.

Stage III - Define Point of View

Defining a point of view is vital to effective product planning. By stage three, initial inputs have been gathered through understanding the market and business context, as well as defining desired customers' experiences. In this stage, an organization establishes a point of view on what the product will become and where it will be positioned in the market. Leveraging the business case and augmenting with corporate resources, it is at this point where design thinking can help bring the disciplines together to create a vision. "Design thinking is thought to increase imaginative abilities and makes sense of data that would otherwise be missed" (Mitcheltree, Holtskog, &

Ringen, 2019, p. 2364). Leveraging all data points, the team establishes a roadmap on how to proceed with the product creation.

This roadmap can be developed through an Innovation Room, which can be a dedicated physical space or virtual site for the team. Cross-functional teams can use this space as a meeting room and form synergies as they work to understand the customer and co-create the product. In this space, teams can form ideas and illustrate concepts on the walls as the strategy forms, defining their collective point of view. The space can also be used for executive and stakeholder reviews. The way that the information is presented is also critical to establishing a point of view. “Storytelling rather than presenting data encourages decision makers to attend and make sense of data that would otherwise be missed” (Mitcheltree, Holtskog, & Ringen, 2019, p. 2361). By storytelling vs. utilizing traditional corporate presentations, the product can come alive and the business case can be more illustrative, and the Innovation Room can help facilitate the team’s efforts. In addition, if it is not feasible to have employees meet in one central room due to geographic limitations, teams can also meet and collaborate virtually through teleconferencing and using a shared virtual workspace as technology is quickly eliminating the need for teams to always meet in person. Today, many teams use online record repositories for file sharing and virtual ideation tools where real-time changes can be made to documents by multiple members of the team, regardless of location. As teams continue to evolve globally, additional methods of virtual team communication will continue to evolve.

As the teams work together to define a point of view, they must be aware of risks when testing each early hypothesis. “It may relate to the context of product innovation uncertainty as it involves over optimism (the planning fallacy), inability to see disconfirming data (hypothesis confirmation bias), attachment to early solutions (endowment effect), or preference for the easily imagined (availability bias)" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2362). Teams must be cognizant of each of these potential pitfalls and conduct due diligence to maintain clarity in their decision-making.

After the customer, market, and business context are understood along with the fully defined desired customer experiences, a product planning point of view can be developed. This is where the design thinking teams will gather collected data points and augment customer needs with corporate objectives framed by business realities. As we define the corporate point of view, we begin to dimension the requirements engineering standards at the same time, incorporating product development processes into the design thinking side of the integrated framework. By defining the point of view while tracking requirements early, we reduce the risk of requirements being overlooked later in the process. Customer needs and corresponding product requirements must continually be validated through customer clinics. However, teams must "stay the course" on their product vision unless emerging and compelling evidence proves that there is a need to modify the product. As teams move through this phase, it is important that senior management does not let personal opinion sway the team's point of view or derail progress. All points of view must remain centered around the customer and remain fact-based.

Stage IV - Ideate and Prototype

Ideation and prototyping are critical dimensions of design thinking and help to manifest the actual product vision. "Prototyping in design thinking involves conceptualizing, building, testing, and evaluating a prototype" (Camacho, 2018, p. 636). "Prototyping being especially in the earliest phases of product development, a method to stimulate imagination" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2361). Prototyping can become a means to reduce product development time. Prototyping requires involvement and co-creation, which means that teams must communicate in the development process. Through prototyping activities, the increased creativity and communication may speed-up the overall development process (Mitcheltree, Holtskog, & Ringen, 2019). Furthermore, "Popular literature has made the following set of words part of the design thinking lexicon: Fail often, fail cheap, and fail fast to succeed sooner" (Camacho, 2018, p. 636). This experimentation mindset gives the teams permission to explore and push boundaries risk-free early in the product development cycle. Prototypes can take many forms. Often, people think of full-scale prototypes such as what are displayed at major auto shows. Renderings and even small-scale models can suffice to make the product's concept tangible. Prototyping has become easier and more accessible with technology such as 3D printing and virtual reality.

When to commence ideation and prototyping is critical. "Postponing ideation and encouraging innovators to explore the definition of the problem more fully before moving into a solution generation results in improved reframing of the problem in ways that are more likely to be productive" (Liedtka, 2018, p. 30). This exploration is important since, "Prototyping and co-creation insist that innovators flesh out salient details of the envisioned future" (Liedtka, 2018, p. 32).

Prototypes serve a very central purpose, "In design thinking, prototyping is a constant and simultaneous interplay between learning and creating. The function of prototyping in design thinking is to drive real-world experimentation in the service of learning rather than to display, persuade, or test" (Camacho, 2018). And, "Using prototyping to understand the problem from a human-centered system-oriented perspective enables re-framing of the problem" (Camacho, 2018, p. 636). Through re-framing, teams can empathize with the user and look at a variety of usages, articulating true customer need.

With ideation and prototyping comes ambiguity. "Ambiguity is therefore a lack of information beyond risk or uncertainty which requires an awareness of all possible outcomes" (Paparo, Disti, & Vignoli, 2017, p. 372). Ambiguity is not always a negative element within design thinking since, "Ambiguity is accepted as a natural part of the explorative process where information comes out spontaneously and is not predefined" (Paparo, Disti, & Vignoli, 2017, p. 372). Multiple iterations of a prototype are an important component to drive product development. "More recent research demonstrates however, that like other aspects of design thinking's success, prototyping alone was insufficient – it was the generation of multiple prototypes and the interaction of prototyping and iteration as teams actually worked to change and refine them, which led to successful innovative outcomes" (Liedtka, 2018, p. 23). Failures inherent within the prototyping process protected the teams from potentially larger failures further into the process. Teams can use "small bets" as prototypes, which is a popular method used with lean start-ups and agile development (Liedtka, 2018). Small bets may include low-fidelity versions of a product which are quickly made, even out of cardboard or plastic. This offers the team an opportunity to review the design and brings context to the product which is under development.

Prototyping offers options in the design, leading to set-based engineering downstream. "Research suggests that people are more open to select creative solutions when they are offered multiple alternatives, rather than a single one" (Liedtka, 2018, p. 24). Researchers find that "Experiencing failure in advance through prototyping, where a focus is put on potential future failure factors, may impact people to put more effort in the task by being mentally prepared" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2362). In this way, team members can safely give thought to their prototypes as the process allows thinking to evolve and mature as multiple solution options are considered.

Many decision makers select choices based on fear which leads to inaction in order to avoid failure (Liedtka, 2018). "The objective is to find the best trade-off between the available information and the possible risk of unclear situations" (Paparo, Disti, & Vignoli, 2017, p. 372). Prototyping on a smaller scale makes these bets safer and allows the teams to pursue alternatives, even in a low-fidelity state. "Design thinking also contributes to risk reduction through early emphasis on real world feedback and testing. Its ability to improve hypothesis-testing skills and minimize common decision-making errors is critical." (Liedtka, 2018, p. 31).

As we move through the prototyping phase, teams will start with "scrappy" designs. These are low-fidelity concepts which may start as sketches or ideas on paper. The designs then evolve into cardboard or plastic making their designs more tangible. "Working efficiently with low-resolution prototypes requires designers to take risks, and to have no fear of failure" (Camacho, 2018, p. 636).

Ideation and prototyping are core elements of design thinking and have a critical function in the integrated framework. Scrappy, low fidelity, designs help teams to better understand the product being created. Prototyping allows us to see the product and to further understand customer usage. Prototyping offers the opportunity to adjust the product and to visualize what is possible as the product continues to mature through the ideation process. This design testing is where teams are encouraged to think big and to fail fast. This phase of the process is still considered a sandbox environment as the product may be framed but still early enough in development to foster creative usage and designs of the product. Customer clinics during this time reinforce the direction of the team as the minimum viable product (MVP) is articulated and baseline customer requirements are confirmed. The scrappy prototypes can then be shared with users to gain additional insights.

"Design thinking tools support deep data collection (understood as user related insights) and idea generation and are an effective way to frontload problem and risk detection" (Mitcheltree, Holtskog, & Ringen, 2019, p. 2362). Bringing problem detection to the forefront of the product development process through the integrated framework in the prototype and ideation phase will create a more robust overall product planning outcome.

Stage V - Scenario Planning

The integrated framework brings scenario planning up-front and much earlier than has been typical in the product development process. We find through research that, "The literature on foresight as part of design thinking is scarce. Therefore, there is an opportunity for further research to connect foresight methods with design thinking" (Camacho, 2018, p. 635). We can evolve the academic knowledge by integrating scenario planning during the early design thinking stages and by creating a deep understanding of the customer's daily intended usage of a product as well as extreme applications which stretch beyond the customer's initial needs or intent.

Dealing with change and anticipating potential market disruptions has historically been a challenge for managers. Elements to consider include changes to the market, safety considerations, government regulations, or geopolitical circumstances which may evolve over time. Additionally, customers' tastes and preferences may change, and the product will need to evolve in order to stay relevant in the market. Included in scenario planning is futuring or considering multiple different ways in which the world may be different several years into the future. We also consider how each scenario would affect the customer needs and usage of the product.

"Scenario planning stimulates strategic thinking and helps to overcome thinking limitations by creating multiple futures" (Amer, Diam, & Jetter, 2012, p. 23). When considering multiple scenarios, “information should be both prospective and historical” (Schroter, Polsky, & Pratt, 2005, p. 5). The chances of a once-in-a-century storm and its impact on the product should costed so that appropriate trade-offs can be considered and risks acknowledged. We also find that, “The uncertainties associated with these projections should be explicitly communicated, especially for those dimensions where the uncertainty itself is uncertain or unknowable” (Schroter, Polsky, & Pratt, 2005, p. 12). There must be a distinction between scenarios which are highly probable and others which may be special cases, and an articulated business case should be considered for each. Quality, comprehensive, and efficient analysis can be completed by consulting both internal and external expert resources in addition to the knowledge and experience of the cross-functional team.

Just as with ideation, scenario planning should be considered beyond specific individual conditions may be encountered. “It is important to focus on interactions: interactions among people, between people, artefacts, and the environment” (Camacho, 2018, p. 636). When contemplating scenarios, singular events cannot solely be considered but also the interaction of variables which may present risk. Effective customer-based scenario planning will result in a more comprehensive and robust business case for the product. By considering situations which may arise through the life and usage of the product, failure modes can be assessed. It can also help to solidify what the product is and is not before the definition and requirements of the product are established. This look at scenario planning early in the product development phase will also reduce the need for changes downstream.

Stage VI - Culmination of Definition and Requirements

The last stage of the design thinking section of the integrated framework is the culmination of product definition and requirements. At this stage, the product has been planned and the organization has successfully gone through the fuzzy front-end processes. The team is committing to the product direction and has had time allocated to ideate and prototype in order to establish firm product definition. This phase sets firm product requirements for design execution and integration into the more traditional product development processes. The team continues to leverage storytelling, sharing details of the product and artifacts such as customer testimonials and mock-ups. Product definition has been finalized and documented as well as design requirements and attributes.

Through the proposed integrated framework, the requirements are more robust as the design thinking process has been leveraged throughout each stage. By using design thinking prior to traditional product development processes, we can encapsulate customer requirements effectively and fully represent the voice of the customer as the design is solidified and moves to the design execution phase. Through the process, we can anticipate design efficiencies as the requirements are solidified up-front and the risk of rework downstream has been reduced. This is also where the hand-off occurs from the lead strategic planner to the chief product engineer.

Phase II - Design Execution

The right side of the integrated framework involves the design execution and is an extension of the left side design thinking loop. The two sides do not operate independently but flow into each other as one streamlined process. As the product definition and requirements are articulated through the design thinking phase and concentrated on the customer/market orientation through the design execution side, the product development engineers can focus on design execution of the product. Design execution relies on more traditional product development disciplines. But without customer needs having been anticipated through design thinking, the product planning process would not be as robust. The design execution phase becomes stronger as the requirements have been defined with reduced risk of changes later in the process.

Diverse cross-functional teams are given a voice early in the process and product development engineers are central to the team. If a design is not feasible from an engineering, manufacturing, or service stand-point, discussions are held, and changes are made early. If a design is too expensive, finance can flag the business case early before the culmination of definition and requirements are set. The marketing community also is embedded into the team early to ensure alignment and include customer input. In short, all stakeholders are given a voice early in the product planning process which ensures that by the time the product is turned over to the engineering community for design execution, the risk of changes late in the process will be reduced and the teams can concentrate on bringing the envisioned product into production through the second half of the integrated framework.

Stage I - Design & Architecture

Designers and engineers had a voice earlier in the integrated framework process as part of the cross-functional team utilizing design thinking. As the process continues, architecture and dimensional considerations are defined, and development continues. The design will incorporate the customer desired experiences and usage requirements. Engineering requirements were written through the design thinking phase to be solidified and executed in this stage. It is important to design the product for flexibility and for changes in the future. "Architecture must remain changeable and evolutionary even after being introduced in to the marketplace, as changing environments and evolving needs will affect their success throughout the lifecycle" (Fricke & Schulz, 2005, p. 343). While customer preferences are integrated into the design, engineering in a way where changes are easy downstream allows for decreased costs later in the program and the ability to improve customer satisfaction should changes be necessary. Such changes must be available to be executed even after the vehicle is in the hands of customers. This approach is currently being taken by Tesla which offers over the air updates to adjust vehicle dynamics and performance, even after product delivery to the customer. Also, serviceability must be considered. Should ease of repair not be considered, increased warranty cost and decreased customer satisfaction will result.

As with previous stages, customer clinics must continue as the (MVP) has been set. Through the solidification of engineering requirements, documentation must be provided to the engineering teams articulating the product requirements. Through the documentation, respective engineering functions can commence work on the product that they had helped to create through the early conceptual phases.

***Stage II - Development (Concurrent and Set-Based Engineering*)**

As the product continues through the product development phase, we leverage concurrent and set based engineering, albeit through the additional lens of design thinking. Through traditional concurrent engineering, we can take multiple parts of the product and engineer them simultaneously in order to save time and to increase efficiencies. Just as with traditional set-based engineering, all options are kept open while we consider a wide variety of alternatives and delay any firm decisions until the last possible moment. With this approach we can optimize the process and keep all design opportunities open as we advance towards the end of the product development cycle.

While many of the unique requirements will be declared early in the strategic planning process, there are instances where work completed too early may not be beneficial. Elements such as regulatory requirements and corporate average fuel economy (CAFE) change often. "Product definition, development, launch, and product management methodologies are highly contingent on market uncertainty and other environmental characteristics” (Krishnan & Ulrich, 2001, p. 15). In this case, the teams need to be made aware of known requirements early, but such decisions must not be made until the last possible moment -- without delaying the program. This is also true with any technology selection needing to be considered in a project. “To minimize the adverse impact on subsequent downstream activities, it is often recommended that the specifications be frozen early in the development process” (Sanayei & Monplaisir, 2013, p. 1558). The authors add, “The development team may choose to remain flexible and defer commitment to a specific technology, developing its products concurrently with the validation of the prospective technology” (Sanayei & Monplaisir, 2013, p. 1558). The degree and timing of those delays should be optimized according to the technology level required. This approach demands authorization of resources and budget up-front, with the support of senior management. If the strategy is to defer some decisions until later in the program and keep options open, this decision must be consciously planned and resourced. This approach requires a delicate balance between freezing specifications early and maintaining set-based options to maximize engineering efficiency.

Leveraging both concurrent and set-based engineering, project management timing charts must be used to create a schedule of work and timeline. Resources must be dedicated but and reviews held to ensure that the overall project timing is not affected through delays in the process.

Stage III - Agile Stage Gate Process

Agile stage gate is a process where a company can leverage agile or nimble processes through the product development phase. It is “a structured gating process for product innovation with clear benefits: Such a system allows management to select the best ideas and projects with more insight and knowledge; it also reduces the risk and costs of project failure and increases the chance of new product success” (Vedsmand, Kielgast, & Cooper, 2016, p. 1).

Within stage-gate, there is a natural fit with design thinking. Scrums and the utilization of short sprints by focused teams are inherent in a design thinking approach. During these sprints, there is very close communication between all team members and several options are purposely left open to make the best decision possible for the product. Development and testing are the focus during this phase as teams operate in short two-week sprints with the ability to respond quickly to testing results and make design changes efficiently. This process allows the best ideas to come forward and reduces risk through garnering additional insight and knowledge, thereby, increasing success.

Although teams are empowered and agile, executive check-ins take place at defined intervals to ensure constant stakeholder alignment. This approach corresponds with design thinking as the teams were established very early in the process and constantly integrated the customer's voice. Further, the empowered teams have stakeholder feedback throughout the process offering senior management support at each stage and as the product approaches fruition.

Stage IV - Validation & Verification

The last stage of phase II is the validation and verification of the product. This is where the final testing is conducted during small build phases. Due to the early design thinking influence, fewer changes are anticipated within this stage. However, by maintaining agility within the high performing product development teams, any last-minute changes which may be encountered can be resolved quickly through the empowerment of the engineering staff. A comprehensive look throughout the process allows this integrated framework to transcend challenges which have historically been encountered through the product planning development processes.

Inherent within the framework is knowledge management and transfer. Since the integrated framework depends on nimble and cross functional teams, it is important to document all requirements and lessons learned both early and throughout the process. The teams should have a repository where they keep all documentation in order to help with future product launches. Teams often encounter issues when people transition off a team and tacit knowledge leaves with them. In this new economic landscape, employees do not stay in positions or with organizations with longevity as in the past. Due to the changing environment, it is important to maintain a central repository where the knowledge is easily accessible. Keeping records of knowledge and lessons learned helps to develop team members as they work on the next generation of products.

Product Launch

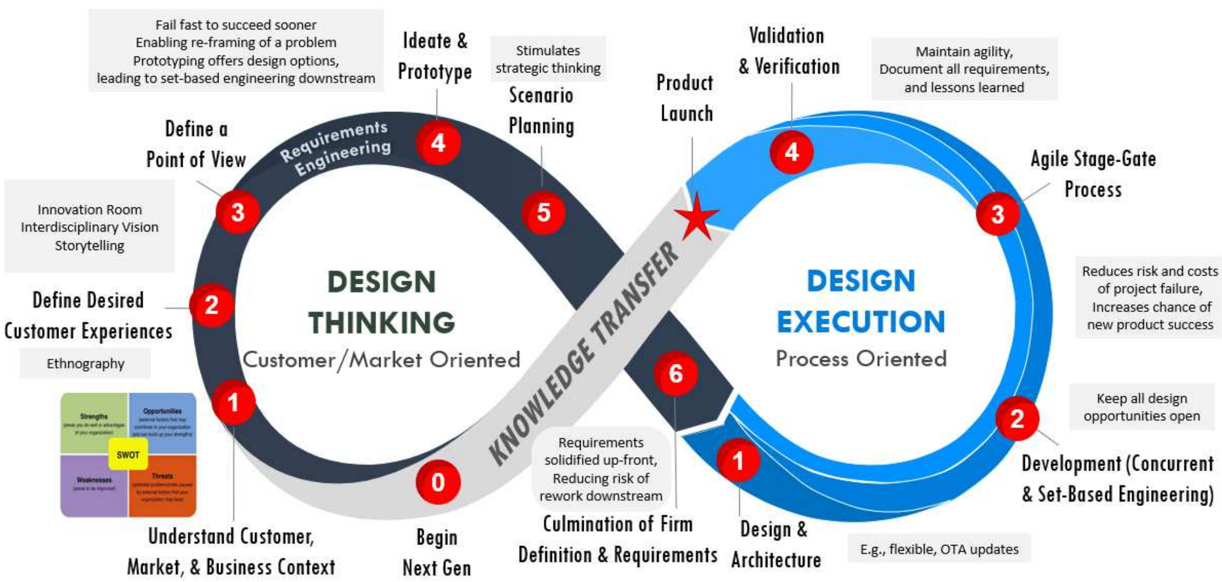
This is the final step in the integrated framework. At launch, the product is successfully built and distributed to dealers/customers. During this phase, the teams should celebrate their success in producing their product yet look ahead to the next new model of the same product or a replacement product, should that better serve the needs of the customer. Teams should continually be receiving feedback, whether it be from dealers, media reviews, or customers as well as reports on quality metrics

In this section we discussed the individual stages of the integrated framework. We began with Stage 0 where we began the next generation and moved through the infinity loop from design thinking to design execution where the process culminates with the product launch. Throughout the process we highlighted the benefits of design thinking. When combining design thinking with the strengths of traditional product development, the power of each is magnified and the process becomes much greater than the sum of its parts and synergistically creates more opportunity for teams to strengthen their product.

Summary

The framework evolved from the first iteration in the dissertation proposal (Figure 3) as a result of my professional exposure to design thinking and through combining design thinking with design execution, depicted in the Integrated Framework in Figure 4. In Figure 6 below, the annotated figure that illustrates how the literature ties to the framework offering additional context for understanding the link between academic knowledge and practice.

Figure 6. Annotated Integrated Framework



In the next chapter, we will introduce the case studies and demonstrate how each case validates the integrated framework.

CHAPTER 5 VALIDATION CASE STUDIES

Validation of the Integrated Framework can be executed through case studies to understand how application of the framework may have facilitated a more efficient outcome. This chapter will explore why and how the framework would have improved the outcome of each case. Analysis will be conducted through pattern matching against theory derived from both the framework and the literature.

There are two cases for validation that represent two distinct examples from automotive companies where up-front analysis and customer understanding would have decreased warranty cost, increased customer satisfaction, and resulted in more robust business outcomes had the customer been central to the early product planning process.

Case 1 – Environmental Change and the Automotive Industry: Lessons from the Polar Vortex

In early 2014, North America experienced an extreme cold weather event lasting from January to April 2014. This weather was part of an unusually cold winter affecting parts of Canada and the Eastern United States. The weather phenomenon was caused by a southward shift of the north polar vortex. In total, more than 200 million people were affected in an area ranging from the Rocky Mountains to the Atlantic Ocean and extending south to include roughly 187 million residents of the continental United States. Over twenty deaths were attributed to the cold wave, with dangerous roadway conditions and extreme cold cited as causes (Smith, Bosman, & Davey, 2019). The winter storms in the Northeast and Midwest correlated to a spike in issues customers in those states experienced with their automobiles' climate-control systems, exterior, and engine/transmissions, whereas customers in the South and West saw no changes. These concerns were industry-wide and not just isolated to one company (Halvorson, 2014).

Quality Measurement and North American Cold Weather Customers

USA Motors uses Something Not Right (SNR) as a measurement and indicator of customer concerns. While defects can be measured by dealership claims and warranty expenditures, measuring SNRs gives customers an opportunity to indicate items that may not necessarily be defective but that the customer may not like. For example, if a customer does not like the comfort of their seat, there may not be an actual defect involved. Regardless, customer dislike of a seat would be documented and tracked to increase customer satisfaction in future designs. SNR measurement is part of USA Motors' global market research department and both USA Motors and their competitors' customers are surveyed. Surveys are conducted globally, and specific countries are targeted based on business needs. One important note in this case is that there are privacy laws in Canada which prohibit companies from surveying competitors' customers. This privacy rule is one of the main reasons that data from the United States was relied on so heavily during the polar vortex investigation.. While USA Motors does not have competitive information for customers in Canada, they do from the United States. Therefore, a subset of cold weather states was required for comparative analysis in place of Canadian provinces.

Four-Part Approach to Resolving Cold Weather Issues

Investigating the issues quickly pointed to the need for a multi-faceted approach. The teams recognized that without cross-functional collaboration and an innovative approach, their work would not produce results. The quality team analyzed the data and developed a four-part approach to create a cold weather strategy to reduce concerns in future model years. The plan stated: 1)

Resolve error states; 2) Improve cold weather standards; 3) Reduce deviations; and 4) Create cold weather option packages. An overview of the plan is illustrated in Fig 7.

Figure 7. Four Part Strategy to Reduce Cold Weather Issues

Resolve Error States. The first order of business was to determine which engineering functions were generating the most cold weather-related SNRs. The top engineering function attributed to SNR degradation was body interior (40 SNR) which also includes climate control features. Following interior were body exterior (22 SNR); vehicle engineering (19 SNR), and chassis (8 SNR). Top issues included: slow travel on opening or closing window glass, exterior door handles which did not return fully to the flush position after opening the door, and snow ingestion into the engine compartment which affected the heater/defrost performance.

The list below outlines each function's area of responsibility to show who was impacted by cold weather related SNRs:

- Body Interior: Includes climate control, instrument panels/consoles, seats, restraints, carpet, headliners, and interior trim components.

- Body Exterior: Includes door panels, sheet metal, front end grilles, glass, headlamps/tail lamps, and exterior trim components.
- Vehicle Engineering: Powertrain configuration and sizing to optimize between fuel economy and performance requirements; Suspension design for ride comfort and noise/vibration/handling; and Body structure to maximize stiffness while minimizing weight.
- Chassis: Includes brakes, suspension/frame, steering systems, wheels, & tires.

Figure 8 demonstrates the breakdown of concerns by engineering function. Seventy percent of the concerns attributed to cold weather were from either body interior or body exterior's engineering functions, which became the primary focus of improvement initiatives.

Figure 8. Product Development Contributors to the Cold Weather Increase (SNRs)

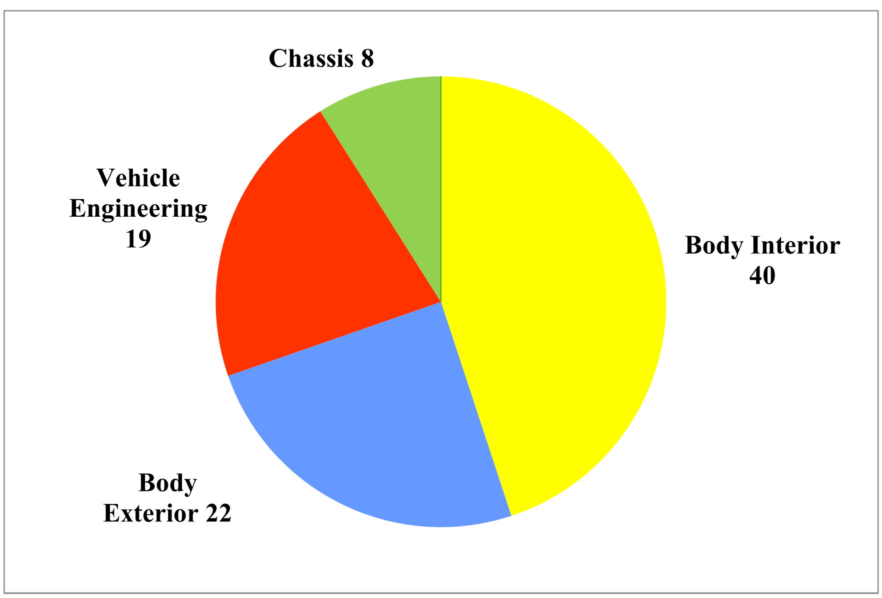


Table 1 demonstrates immediate actions taken based on engineering function. These fixes were relatively quick and easy to both identify and implement. Unlike new technology or feature availability changes, the improvement actions in Table 1 were all implemented with compressed timing.

Table 1. Cold Weather Performance Improvements – Immediate Booked Actions

Engineering Function	Improvement Action
Interior/Climate	• Heater performance logic change • Active transmission warm-up to increase coolant flow during idle
Exterior	• Improve slow glass travel performance with seal change • Door latch lube added to prevent freezing • Front wiper blade alignment • Front wiper blade hinge improvement
Chassis	• Grease rear stabilizer-bar to eliminate creak noise • New larger rear shock to reduce rear creak noise • Brake squeal improvements
Electrical	• Addition of a low washer fluid sensor

Improve Cold Weather Standards. As part of improving Cold Weather standards, the team decided to take a holistic global approach. Issues that customers were experiencing in North America due to the polar vortex may have been harsh, but they were no different from conditions in Russia, Sweden, and Northern China – all countries which sell similar USA Motors products. Commonalties among both products and geographic regions were identified in order to improve global standards. Through this process, it was discovered that the European region had already begun investigating a Russian problem resolution process as the company response to emerging growth in the region. Included in the European study were strategies to improve engineering response to local market conditions, which included cold weather performance. Based on the Europe region's assessment of SNRs and through additional in-market evaluations, the teams discovered 22 Russian items that needed updates to engineering standards and corporate knowledge. This update was an opportunity to align Canada and Russia's processes to remedy cold weather deficiencies using a common global approach. This allowed the product development teams to synergize on a global scale and to implement changes globally.

In addition to understanding the similarities between Canada and other cold weather countries, it was also important to consider what makes the Canadian market different than the United States. The most significant distinction was the extreme cold temperatures. In early 2014, there were multiple weeks in the Northwest Territory of temperatures reaching -40^{o}C (-40^{o}F) with one report of -47^{o}C (-53^{o}F). The industries that utilize vehicles in Canada also operate under much harsher conditions. Customers in northern Alberta mine tar sands as a source of energy, log trees in British Columbia, and operate diamond mines in subarctic tundra provinces of the Northwest Territory. Product development standards were re-visited considering extreme usage to determine if they were stringent enough to satisfy market requirements.

Reduce Deviations. Investigating cold weather deviations uncovered only three for the North American product. None of the three had a large effect on the total SNR degradation. In product development, teams seek deviations from design specification on an exception-basis. The first deviation was that one vehicle model had a hood-latch hard-to-open concern when functioning in temperatures below -40^{o}C (-40^{o}F), expected to be encountered more frequently in Canada. The second deviation concerned block heaters; block heaters are standard on vehicles built for Canada. There was one small engine that could not accommodate a block heater and, therefore, was not able to achieve the -40^{o}C (-40^{o}F) cold start requirement but could proceed to production under an exception. The last concern was around battery vehicle performance in cold temperatures, although none of the affected vehicle models were sold in Canada.

Each concern was evaluated, and engineering requirements were re-visited through the knowledge management feedback loop. When it made business sense through a time-adjusted rate of return (TARR) accounting formula, requirements were adjusted to avoid failure at extreme low temperatures. Additionally, deviations were scrutinized to determine if approving them could cause additional customer dissatisfaction in the Canadian/cold weather markets.

Development of Cold Weather Option Packages. The development of cold weather option packages was led by the product development quality team. While it was product development led, no changes could be made without the concurrence of each affected vehicle's chief engineer affected or marketing teams. The analysis illustrated in Table 2 was based on the eight features which were determined to have the highest rate of concerns according to customer satisfaction in Canada and showed a high concentration of concerns around body exterior and body interior function (which also included climate control). Additionally, the team reached out to dealers in Canada to get their feedback. Dealers indicated that customers in Canada show a high preference for heated interior components, and not just during a Polar Vortex.

The team then conducted web-based competitive research evaluating other OEM's products to determine which cold weather-related features were most prevalent in the market. While time consuming, this exercise helped the team understand how USA Motors' models were equipped vs. the competition. The team found that newer technology such as heated wiper park was prevalent with the competition (lower portion of windshield heated to prevent frozen snow/ice on wipers). There were also additional opportunities with the heated steering wheel and heated rear seats.

Table 2. 2015 Model Year Competitive Analysis of Features by High, Medium, and Low Model Series

Option/Feature	Series	USA Motors SUV	Japan SUV #1	American SUV #1	Korea SUV #1	Japan SUV #2	Japan SUV #3	American SUV #2	Korea SUV #2 (Canada Only)
Heated Wiper Park	L				CA - S			O	O
	M		CA - S		CA - S	CA - S		O	S
	H		CA - S		S	CA - S		S	S
Heated Front Seats	L		CA - S		S	S		CA-O	O
	M	US - O CA - S	S	US - O CA - S	S	CA - S	US - O CA - S	CA-O	S
	H	S	S	S	S	S	S	S	S
Heated Side Mirrors	L		CA - S		CA - S	CA - S	CA - S	O	S
	M	US - O CA - S	CA - S	S	S	S	US - O CA - S	O	S
	H	S	S	S	S	S	S	S	S
Remote Start	L	US - O	US - O	US - O	US - O	US - O	US - O	O	
	M	US - O	O	S	US - O	US - O	US - O	O	
	H	S	O	S	US - O	O	US - O	S	
Heated Steering Wheel	L							O	
	M				CA - S			O	S
	H				CA - S			S	S
Heated Rear Seats	L								
	M				CA - S				
	H				CA - S				S
Winter Floor Mats		O	O	O	O	US - O	O	O	
Washer Fluid Indicator		S	CA - S			S	S	S	S

Key: S = Standard Equipment; O = Optional Equipment; US = United States; C = Canada

Table 3 is an example of USA Motors small SUV program's evolution of cold weather packages. Beginning in 2014, features began to be added to satisfy market needs. Initially the package was called "Leather Comfort Package." Over the next two years, through responding to satisfaction and competitive data, the quality team convinced marketing team to add additional features in 2015 and 2016 as "Cold Weather Packages" to address customer needs and improve corporate competitiveness. Content slowly grew as technology became available in order to satisfy cold weather markets such as Canada.

Table 3. USA Motors Cold Weather Influenced Packages by Model Year

Model Year	Package Name	Package Content
2014	Leather Comfort Package	Heated Mirrors, Heated Leather Front Seats, Leather Steering Wheel & Shift Knob, & Global One-Touch Up/Down Windows
2015	Cold Weather Package	Heated Mirrors, Heated Cloth Front Seats, All Weather Floor Mats, Positive Temperature Coefficient Heater, & Global One-Touch Up/Down Windows Remote Start: Optional
2016	Cold Weather Package	Heated Mirrors, Heated Cloth Front Seats, All Weather Floor Mats, Positive Temperature Coefficient Heater, Global One-Touch Up/Down Windows, & Heated Wiper Park Remote Start: Optional

USA Motor's United Approach to Cold Weather Improvements - Conclusion

While the polar vortex was a rare climate event, it highlighted the need for quicker response time – specifically within the product development structure. To remedy the 2014 cold weather situation, product development worked to implement the identified weather-related changes immediately. The urgency of the crisis also forced cold weather regions to work together to remedy common systemic issues (like Canada and Russia with their climate similarities). It also resulted in product development and marketing working collaboratively to identify solutions for available features and options to be included as cold weather packages.

The changes made by the team were real and sustainable as vehicle cold weather performance improved between first quarter 2014 and first quarter 2015. The teams were able to reduce cold weather SNRs by 50%. There were 45 SNR improved in one model year just from the identified cold weather items. In first quarter 2015, Canada reported its best-ever SNR results and customer satisfaction rose over four percentage points. Success would not have been possible without the support of senior management and their participation in status reviews every six weeks. This quality meeting was regularly attended not only by the quality directors but also the president of the Americas, and vice president of quality as well. The changes were mandated from a top-down approach and the teams were encouraged to respond quickly from external customer feedback

How the Integrated Framework Could Have Helped

There are several ways that the Integrated Framework would have helped reduce the number of changes that were required downstream. The following paragraphs demonstrate of the Integrated Framework benefits within this case.

Understand Customer, Market, and Business Context. For such significant improvements to occur in a region, the customer needs and engineering gaps must be properly understood. Leadership endorsement is key to supporting the team and driving results. A cross-functional team could then be formed to identify regionally-dependent failure modes. For teams who that all reside in the same region/office setting, an Innovation Room could be established where the team would identify cold weather specific customer challenges and a means to better understand unique customer requirements in the region. For those teams that interface between different regions, virtual global teams will need to be fostered. Teams can meet through Zoom/Webex calls and collaborate in real-time during mutually satisfactory meeting times with workspaces located in the Cloud. Through team efforts, customer experience feedback can be used to identify both routine and rare weather-related inconveniences. Outside experts could be leveraged to offer deeper regional insight.

Additionally, business cases must be run to properly understand market sensitivities (for example, the Canadian market is more price sensitive than the US) and must include an analysis of the competition. Financial analysis needs to be positive in order to add more features to a vehicle that may be required in a market. While Canada is the second largest regional market for sales, behind the United States for this specific OEM, opportunity for profits would need to be established for consideration of increased usage requirements.

Define Desired Customer Experiences. Often engineers design vehicles based on their own experiences. For customers who experience extreme cold for over half of the year, the Canadian market presents additional challenges. Some failure modes were already known industry wide, for example, it was known that Canadian car windows regularly froze-up and customers frequently had to open their doors instead of windows when picking-up at fast food drive-thrus like Tim Horton's. To accommodate Canadian customers' unique needs, detailed profiles of target customers must be established, along with their experience expectations. Detailed ethnography will be required for both USA Motors and competitors to develop deeper insight into the regional customer. For example, where a vehicle is typically parked overnight, whether in a garage or outside, is an important consideration. Despite the engine block heater feature, if a vehicle is not near a power source, there will still be cold start issues. Also, commute distance and driving frequency are important parameters to identify for personal consumers. For commercial vehicles, a better understanding of the oil and logging industries and how workers use their vehicles, is also important.

Define a Point of View. After understanding customers and their needs the team could leverage either a co-located or virtual Innovation Room for teams which are co-located in the same building to develop a point of view. Should a team be spread between regions, strategy sessions can be conducted through telecommunication and video means and a mutually agreeable time which is conducive to multiple time zones. While in-person meeting is the most effective, advances in technology for videoconferencing and collaborative software make it effective for global teams to work together virtually.

Strategy sessions, customer journeys, or storytelling a customer's experience can powerfully illustrate unique customer challenges. In the case of the polar vortex, customers endured situations where both doors and windows were frozen shut which prevented entry into the vehicle. Through studying specific examples centered around the customer, the cross-functional team could start formalizing a point of view on whether it makes economic sense to protect for a rare event such as a polar vortex or understand the inherent risk of not addressing the customer's challenges. Should engineering changes be agreed to collectively, all stakeholders must concur, and formal product requirements would then be written. Validation would then occur through customer clinics to ensure that customers are satisfied by the agreed-upon designs.

Ideate and Prototype. Prototyping can be used to identify solutions which would improve customer experiences. The Integrated Framework would allow for deeper analysis through ideation and prototyping to determine how often extreme weather conditions could occur and to make decisions on whether it is appropriate to adjust requirements for situations that may occur only once in a hundred years. This analysis would establish firm definition of requirements early in the process to protect customers who experience situations uncommon to the region in which the vehicle was designed.

The action of prototyping solutions would allow for bold designs from the team. Maintaining a customer-first mentality, a prototype could be rendered around the "perfect" vehicle for the region, including which features should be improved and what new technology could be introduced. Through this process, customer requirements would continue to be refined through clinics and the MVP would demonstrate the customers' baseline requirements. This process would also help to reduce ambiguity and resolve any anticipated issues early in the product development process.

Scenario Planning. In this case, deeper scenario planning could be done which considers alternative futures. Additionally, multiple factors should be considered, including the variations of interactions between temperature, snow, and ice. Government regulations are also an important consideration in Canada. Should fuel economy standards in the region become more stringent, the implications would need to be assessed for cold weather features. For example, the start/stop feature was implemented to increase fuel economy of a vehicle but may derogate the climate control system performance. Dimensioning the effects at ultra-low temperatures may better define customer satisfaction concerns. Geopolitical concerns should also be accounted for as trade deals often change between countries.

Culmination of Firm Definition and Requirements. Unique product requirements can then be established that illustrate the struggles that regional customers experience in harsh cold climates. Through business cases and stakeholder alignment, the product definition can be finalized and documented. Included would be any unique design requirements or attributes necessary to satisfy uniqueness in the region. Details of the definition can be illustrated through customer testimonials and artifacts which may include pictures and videos of customer challenges unique to the region. This step is also the hand-off from the lead strategic planner to the chief product engineer to implement changes in the next generation vehicle.

Design Execution. In the case of USA Motors' SUV, improvements were made to future models based on failure modes detected in the field during extreme weather conditions disproportionately affecting the Canadian region. Also included were slight improvements to multiple functions; such as heater performance logic change and additional lubrication added to the door hinges, but not a whole new redesign of the entire vehicle.

Through the investigation of regional cold weather concerns, the teams remain cross-functional giving product development engineers a voice through the process to ensure feasibility. Customer validation of the proposed changes should be completed and the new MVP set. Documentation of the new requirements would be cascaded to the product development teams highlighting changes.

Final validation and testing would be done in small build phases as there should be fewer changes anticipated late in the process due to the comprehension of customer voice and participation of multiple functions on the team. Teams would be responsive should there be unexpected last-minute changes due to their nimble structure and authority. Stakeholders would continue to be aligned through the process.

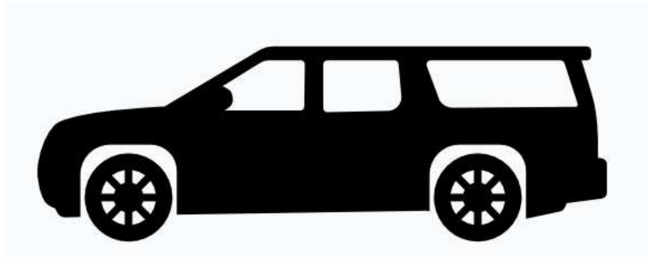
Finally, knowledge management will need to be thoroughly maintained. In this case, it is acknowledged that the polar vortex itself is an uncommon weather occurrence. However, none of the issues which were identified were unique, just experienced to a greater extent as the weather spread beyond the borders of Canada and into most parts of the United States. The cold weather-related changes were due to failures found in the field resulting from lack of understanding of external, extreme environmental factors and customer interaction. Findings and improvements should be tracked not only for corporate knowledge on future products, but also to dimension the full extent of improvements and to validate how design thinking can contribute to improvements and the corporate bottom-line.

Conclusion

The polar vortex is a single research case which contains elements of both extreme cause and common cause. With an extreme case, we illustrate, "deviating from theoretical norms or even everyday occurrences" (Yin, 2018, p. 50). Because the polar vortex was an extreme weather phenomenon, it was a highly unlikely event. However, the case also represents common cause when you consider the Canadian customer base. With a common cause, the researcher "captures the circumstances and conditions of an everyday situation" (Yin, 2018, p. 50). The cold weather failure modes were not unique to the conditions experienced in the polar vortex. In fact, customers of similar products in Europe (specifically Russia) were experiencing similar failure modes. It was only when the polar vortex magnified the number of customers exposed to the conditions, that management increased urgency around the concerns. In this case, a greater percentage of Canada and the northern United States experienced the failures, but they were not new or even unique concerns.

The integrated framework would have helped to put the customers most exposed to cold weather issues first. Through the framework, customers in Canada would have been better understood through ethnographic research and a deeper understanding of challenges experienced by the customer. With that insight, the organization could have made a business case for how robust the product would need to be to satisfy the market.

Case 2 – Development of a Large Traditional Utility (LTU) Vehicle Off-Road Variant for the Middle East



Background

Historically, Large Traditional Utility (LTU) vehicles have been a strong sales performer within the Middle East region. This case study illustrates the business and engineering decisions made by an American-based automotive manufacturer to increase its competitiveness through stronger consideration of regional preferences.

USA Motors is an American automotive manufacturer based in Detroit that is over 100 years old. It produces over five million vehicles globally with annual revenues in excess of $150 billion per year. USA Motors is managed through a board of directors and is listed on the New York Stock Exchange. Worldwide, the company employs nearly 200,000 employees and sells its products throughout the world.

Within the Middle East, the Gulf Cooperation Council (GCC) is a regional intergovernmental political and economic union which includes all Arab states within the Persian Gulf, except Iraq. GCC Member states include: Bahrain, Kuwait, Oman, Qatar, Kingdom of Saudi Arabia, and the United Arab Emirates. Within the region, most sales are concentrated in the Kingdom of Saudi Arabia (KSA) and the United Arab Emirates (UAE). The benefit to the auto manufacturers is that all automotive standards are consistent throughout the GCC and primarily follow governmental regulations based on country of manufacture. In this case (with few exceptions), GCC automotive regulations would be the same as the United States Federal Motor Vehicle Safety Standards (FMVSS).

The USA Motors LTU is offered in both 4x4 and 4x2 versions to accommodate varied usages in the region. The interior allows for seating for seven or eight people, depending on the selected configuration.

There are two distinct needs from an LTU in the GCC, depending on the country. KSA customers look for a roomy and efficient vehicle to transport larger families - the average household in KSA is 6.4 people (Abdul Salam, Elsegaey, Khraif, & Al-Mutairi, 2014). Additionally, it is only since 2018 that women were granted the right to legally obtain drivers licenses (Hutcherson, 2018). This meant that the LTU vehicles in KSA were primarily driven by chauffeurs or male guardians to transport women and their large families.

UAE is also a strong market for LTU. However, its customers' needs were slightly different. In the UAE, over 80% of owners take part in off-road sand driving, often on the weekends as part of a camping trip. Food supplies are picked-up in the local supermarkets and the weekends are spent enjoying desert driving, especially around Abu Dhabi. To increase vehicle performance, customers reduce the pressure in their tires in order to better grip the sand and put the vehicles into four-wheel drive (Groundwater, 2018). The need for an LTU for sand driving dictated that USA Motors should create an off-road variant (ORV) of the LTU. Additionally, this variant was deemed necessary to compete in the Middle Eastern market with two Japanese OEMs, who offered off-road versions of their products with better sand driving capability.

Team Structure

The product development team was led by the Middle East Strategist with a cross-functional team, which included: LTU chief engineer, truck lifecycle planning manager, truck planning supervisor, middle east marketing managers (US and Dubai based teams), global strategy manager and supervisor, vehicle architecture supervisor, and design/release engineers. All engineering activities were completed in Detroit with input from resident product development engineers in Dubai.

Planning Process and Product Development Execution

The global product planning and strategy team began work at the first planning gateway four years before the first unit build. The team's objective was to get an ORV variant of their LTU approved quickly. Marketing representatives in the USA Motors regional office in Dubai were enthusiastic about the new variant and estimated that ORV's sales would account for over half of GCC's planned LTU volume.

The first product planning cost estimate for the build was $150 million, an exorbitant cost for a program which would be a variant of an existing product and unlikely to be approved by senior management. The $150M investment figure did not come from a robust cost study but was simply derived from rough estimates from the planning community based on prior experiences with other programs. No structured cost calculations or assessments were completed up-front. Despite the high initial cost, there was excitement around the program, especially within the GCC regional office. Historically, Middle East volumes are relatively small compared to global volumes; however, this was not the case for the LTU product. The USA Motors LTU vehicle was the only product where the Middle Eastern region had the leverage of volume and revenue to drive the requirement of a program that would be unique to the region. For some model years, the ORV accounted for up to 50% of the total production volume. Additionally, more units could be achieved if the United States and Canada took supplementary volume for the new program variant. As illustrated in Table 4, offering an ORV variant to the existing LTU line-up, could increase volume for the region by seven-fold.

Table 4. Middle East Forecasted Regional Volume

	CY2018	**CY2019**	**CY2020**	**CY2021**	**CY2022**	**CY2023**	**CY2024**	**CY2025**	**CY2026**
LTU	X	1.1x	1.8x	2.9x	4.8x	6.5x	6.9x	7.0x	7.1x

The LTU vehicle was a North American-led program whose chief product engineer was interested in expansion into additional countries beyond the Middle East like Africa. More so, he was open to considering design changes to account for regional differences/preferences. This chief engineer saw opportunities that abounded in the region and took the time to visit dealers in the Middle East and understand the customer. He was open to regional needs and requests, such as a refrigerated center console to store insulin for a region where one in eight people have diabetes (IDF Diabetes Atlas, 2020). Other requests included luxurious seat materials that would not retain heat like leather. These customizations and/or accessories offered an additional revenue stream in the region and could also be available for North American customers.

The Middle East proved to be a very price-sensitive market. To remain competitive, LTU prices and therefore revenues in the Middle East are typically 40% less than in North America. What the region lacked in revenue, the team planned to make up through increases in regional volume (see Table 4). The team was confident that they had a winner in their plan for an ORV version of the vehicle. Cross-functional off-road team meetings were held on average three times per week and led by vehicle architecture/vehicle integration teams.

Engineering Scrums

A scrum is a set of powerful tools combined to achieve quick results. Scrums are cross-functional teams which break tasks into small pieces that can be completed quickly through short cycles. Essential elements included in scrums are: Fast feedback, continuous improvement, rapid adaptation to change, and accelerated delivery (Vedsmand, Kielgast, & Cooper, 2016).

USA Motors used scrums to kick-off the workstream to create an ORV derivative of their LTU. Off road meetings were held an average three times per week and led by vehicle architecture/vehicle integration teams. The 8:00 a.m. Eastern time worked well to accommodate the Dubai participants at 5:00 p.m. Gulf Standard time. The meeting had an agenda that was published the day before. Minutes that documented agreements were issued through email by close of business on the same day.

Scrums began in February of 2018 and regular formal meetings continued into November of the same year. The frequency and intensity of meetings increased at two intervals: March when the teams were forming and August when initial formal program approval was sought. Meetings continued August through November as-needed until the program was approved, and the vehicle program received authorization for the Program Start milestone. In total, there were almost 40 people that appeared on agendas as contributors to the scrums. The team was cross-functional to encompass each engineered element that would be affected on the vehicle, as several engineering functions were affected.

Agenda topics within the ORV scrum were mainly dedicated to Powertrain, Chassis, Underbody Protection, and Sheet Metal concerns. Ground clearance was a main concern as the approach/departure angles needed to be increased for regional competitiveness (See Table 5). As increased ground clearance was considered, this impacted the center of gravity and vehicle dynamics. Both the size and off ride usage created challenges for the center of gravity. “A taller car with a higher centre of mass will roll when it goes round corners, but the higher centre of mass will also adversely affect the vehicle when accelerating or braking” (Oppositelock, 2013). Engineers would have to compensate for load transfer affecting the center of gravity and make changes to mitigate the realities of physics.

Table 5. Current Competitive Off-Road Capability of LTUs

Vehicle Off Road Platform Dimensions	Current USA Motors LTU	Japanese Competitor #1	Japanese Competitor #2	American Competitor #1	American Competitor #2
Ground Clearance (mm)	234	231	275	200	204
Approach Angle (deg)	24.8	32.3	34.3	15.5	15.3
Departure Angle (deg)	22.9	24.4	26.2	23.2	23.2
Break-over Angle (deg)	19.4	21.1	20.7	12.2	10.0

Since creation of this ORV derivative was driven by the needs in the Middle East including sand driving at high temperatures, powertrain cooling was examined as well as underbody protection such as skid plates. As these changes were considered, it was also discussed how CAFE standards would be affected, especially since both the United States and Saudi Arabia must meet these government mandated standards. Finally, manufacturing complexity was discussed as addition of a new body style would have implications for the plant, which was already capacity constrained with the three vehicles currently being assembled there. The manufacturing facility was land-locked with no further expansion opportunities.

Program Challenges

Despite the off-road derivative being a Middle East-led initiative, all engineering was done in the United States. North America would have to participate and commit to a specified level of volume for the business case to be viable. Regional differences in requirements began to occur immediately, for example, among customers in the Middle East, specifically UAE, who value performance, over visual upgrades to the exterior. Conversely, the US market required both interior and exterior appearance upgrades as design of the vehicle was thought to be more important to owners than performance. It was clear that to comprehend requirements of both the US and Middle Eastern markets for the ORV derivative, both design and performance would need to be addressed. Compromises were necessary as both regions needed to share program volume to meet the corporate Target Annual Rate of Return (TARR) threshold. The TARR is a comparative measurement to evaluate the business cases of competing projects. The TARR offers an objective measure by which to evaluate project opportunities when there are only finite resources available.

A proper off-road package suitable for the Middle East would require a re-grid, which is a whole new vehicle architecture, and all approach angles would have to be improved: approach, departure, and break-over. Approach is the angle between the front tires and the lowest point on vehicle in front of them. Breakover is the angle from the bottom of either the front or rear tires to the point at which the opposite tire meets the lowest point on the vehicle. Departure is the angle from the bottom of the rear tire to the lowest point behind it. In all cases, “bigger angles are better” (Siler, 2019).

Initial discussions were around a re-trim only (purely cosmetic design changes) which would not have offered the ground clearance opportunities necessary to justify the ORV. A re-grid, however, had implications for the plant since the track width (which is the measurement between the two front tires) would increase from current specifications and it would need to be determined if the plant's assembly line could accommodate a wider vehicle. This would require a feasibility study conducted with manufacturing.

Concerns about derogation of fuel economy in United States and Saudi Arabia arose as both countries have CAFE standards. More importantly, the 4x4 version of the vehicle held an exemption on Saudi CAFE due to weight requirements that classified it as a heavy-duty vehicle. Scenario planning should be conducted to determine the impact should these regulations change with little to no notice. Things to also consider were: Would there be an increase in price of the product? Would the profitability be decreased? How would a reversal of the CAFE exemption impact USA Motors entire corporate fleet compliance?

Investment Cost. Investigation and refinement of initial engineering estimates for the ORV reduced investment over 50% from the $150M initial estimate to $70M. This was accomplished through refined project scoping, actual breakdown of anticipated engineering cost, and additional cost reduction opportunities identified by powertrain engineers. In the revised cost, the ORV proposal was 35% above the TARR required for investment approval. Initially, engineering estimates were used based on previous applications and historical knowledge. In order to save $80 million, engineers were tasked with establishing realistic costs based on the project's actual engineering requirements. Initially, the requirements were generic and inflated in order to protect for unanticipated issues in implementation, and to avoid downstream costs should there be late engineering changes. By using the initial cost estimates, which were inflated, waste was created in the system and senior management did not support the initial costs. Additionally, there were no dedicated product development engineers involved with a program so early in the product planning process. Dedicated product development engineering teams are not assigned until after the Program Start milestone, which is a primary reason why only estimates were used initially.

Senior Review Cadence. Reviews were conducted on a weekly basis with senior executives at corporate headquarters. The company operates with a traditional hierarchy. The President of the Americas was the highest-ranking executive in the room. There was no executive-level representation from the Middle East involved with the daily meetings. Decisions on off road initiatives important to the Middle East were often delayed or derailed by the president's North American-centric position. An ORV variant was not a priority for his designated region in North and South America, and no one in the room wanted to argue with the boss.

The weekly reviews continued June through September and were conducted in person with physical boards created in the strategy room at Corporate Headquarters and there was no call-in option. The meeting was held at 2:00 p.m. Eastern time, which was 11:00 p.m. Gulf Standard time, which was not conducive to global representation by Middle East senior management. The Detroit-based Middle East representatives did not have the "stripes" to fight with a senior executive and were simply there to report back final decisions to the Dubai office.

The team also encountered insufficient management buy-in prior to engineering work commencing. There is only a finite amount of annual corporate funding and the ORV had to compete with other high-end content package proposals, which was difficult when the US-based team wanted different derivatives with different targets for North American products. Approval was a challenge for a vehicle being created to satisfy customers specifically in the Middle East.

How the Integrated Framework Could Have Helped

Had the Integrated Framework been utilized, evaluation of the project and approval would have been a more organized and focused endeavor. While there was teamwork, it was fractured and the engineers on the program were not engaged until late in the process making engineering estimates difficult to obtain. Furthermore, while there was nominal input from marketing in the region, true customer preferences were not obtained through research. There are clear benefits to coupling both the design thinking elements of the framework, which focuses on customers, business needs, and design thinking prior to the product development execution.

Design Thinking. At the time of this project, design thinking was not fully instituted at the company. While there was a some cross-functionality in the team working on the ORV, the team was primarily comprised of engineers responsible for parts that might have been affected. Better understanding the customer, market, and business context in both the Middle East and the global business landscape would have helped to give better insight. Better insight also would have offered a more fact-based perspective when looking at the business case. Adding a small product development staff of engineers early in the process would have saved time and led to better cost analysis up-front. A comprehensive cost analysis would give a more accurate estimate up-front and would allow more informed decision-making, reducing delays which were encountered by employing inflated costs. This improved cost analysis would also allow for senior management to balance competing project proposals due to finite corporate resources.

While marketing from the Dubai office gave insight into customers in the Middle East, desired customer experiences could have been better defined beyond the fact that customers were looking for a more robust product, especially in UAE. Improved customer insight and analysis would have helped to define the team's point of view earlier in the process. Early customer insight and establishment of a corporate point of view would have allowed for more opportunities to ideate and prototype, resulting in strong product definition and articulation of engineering requirements.

Requirements Engineering. The requirements should have been clearly identified prior to beginning the daily scrums. Further, senior management buy-in should have been secured prior to the daily scrums rather than four months into the process. Without a clear vision and alignment, it was unfair for the teams to begin work on ORV, which was incremental to their existing responsibilities. Most of the time spent in the scrums was spent trying to understand the market requirements. Without knowing the market requirements up-front, questions and coordination with the region often resulted in a one-day lag for answers due to the nine-hour time zone difference. Had regional requirements been clearly documented, and in a repository, the daily scrums would not have had to repeat the same agenda items day-after-day. Information was readily available such as for ground clearance differences in competitive models within the region (see Table 5).

In the culmination of definition and requirements, the vehicle attributes would have been available for senior management to make an informed decision through the Integrated Framework. With this model, information would have been available for the senior management from both sides to discuss in advance and potentially align earlier in the process on whether the corporate position would be to grow volume in the Middle East or pursue other endeavors with the finite funding. Resources would not have been wasted in completing an engineering analysis that did not match strategic direction.

Scenario Planning. LTU currently held an exemption for Saudi Arabia's CAFE standards since it is above the gross vehicle weight threshold on the 4x4 models. It was never discussed what would happen if this regulation were to be repealed. Would the vehicle still be profitable without the Saudi Arabia CAFE standard exemption? Should the exemption be revoked, the impact on corporate financials and cost of ownership should have been articulated to protect financial viability of the product.

United States and Middle East gas prices and sensitivity needed also to be discussed due to potential miles per gallon (MPG) implications of an ORV. Since this is a larger vehicle, it was likely to get lower MPG and sensitivity of buyer behavior needs to be dimensioned. Knowing at which price point customers stop considering purchasing an LTU due to the higher fuel consumption and total cost is also critical.

The political landscape with countries within Middle East and their relationship with the United States is also a very important consideration. Geopolitical issues should be in the forefront, including trade disputes and potential regulatory changes. Furthermore, some Americans became weary of doing business with KSA under their administration during the period where the ORV was being planned. However, we find that,

> “The U.S.-Saudi Arabia alliance is built on decades of security cooperation and strong business ties dominated by U.S. interests in Saudi oil. The relationship has survived severe challenges, including the 1973 oil embargo and 9/11 attacks, in which fifteen of the nineteen passenger jet hijackers were Saudi citizens. Successive U.S. administrations have held that Saudi Arabia is a critical strategic partner in the region (Council on Foreign Relations, 2018).

While the relationship remains on good terms with the Trump Administration, a change in either the United States or KSA leadership could threaten the amicable status.

Plant Manufacturing Considerations. There was already a known capacity issue with assembling three vehicles of varying configurations within the same plant. and since the plant is landlocked, there is no opportunity for building expansion. An analysis should be conducted early to determine actions necessary to accommodate the additional volumes and plant complexity. Should the plant capacity need to be increased, the cost would need to be considered. Furthermore, the team should see if it makes sense to dual-source the product from another manufacturing facility, which means build the vehicle at more than one facility. Additionally, a local source could be considered for products to be delivered in the Middle East. The company could also evaluate another manufacturing location in Europe, Northern Africa, and/or South Africa to reduce shipping costs and tariffs.

Concurrent Engineering. The team did a good job through the scrums handling multiple engineering workstreams. In accordance with concurrent engineering principles, the process could be optimized in order to meet condensed decision timelines. Through concurrent engineering, we can take multiple parts of the product and engineer them simultaneously in order to save time and to increase efficiencies.

Items which could be concurrently engineered: Increase to vehicle wheelbase, fascias, shocks, tires, grilles, and skid plates. While the re-grid included increasing the dimensions of the chassis and width of the vehicle, target dimensions were known. Fascias and grilles could begin design to coordinate with changed front end architecture. Dimensions for shocks and wheels would also be known, so these components could concurrently be engineered during the re-grid process. Skid plates were required in the region to protect the front of the vehicle when purposely scaling sand dunes. The skid plates located below the front fascia on the underside of the vehicle and help to avoid damage during off-road maneuvers on sand dunes. This is a component that is not generally required in the North American markets but needed to be accommodated in the design of product exported to GCC.

Set-Based Engineering. With set-based engineering, all options are kept open while a variety of considerations are evaluated. Any firm decisions are delayed until the last possible moment. With this approach, the process can be optimized.

Elements of the program should have used set-based planning. There were choices to be made about such components as skid plates, shocks, tires, roof rack, etc. and each of these parts could have been designed up-front with several options available to the product planners. While design engineers could start work on the components as soon as the initial requirements were detailed, many of these parts would be dependent on the re-grid dimensions which were yet to be determined. Once that occurred, there were options for each of the additional components. Skid plate engineers could consider several different materials and/or composites to design these protection plates. Options could be offered on the area of coverage and materials and decisions on which alternative to use should be delayed until the last possible moment.

For shocks, once the usage and requirements were determined, there was additional investigation around whether these shocks should be "branded," meaning that these exposed performance parts could be leveraged as a marketing opportunity. By choosing the right partner, a shock from a performance company with visible branding on the component could lead to additional revenue. Discussions were held to determine if the shocks should be painted to offer an additional "tough" visual imagery.

A variety of roof racks could be considered based on the anticipated usage in the region. While some roof racks are simply for aesthetics, in the Middle East, many customers enjoy camping in the sand dunes and require functionality to carry their gear. As for the tires, heat and sand impact performance and reliability and must be considered for Middle East usage. Speed ratings on tires are also higher in Middle Eastern countries since wide-open roads afford higher driving speeds. Designed tire deflation and wide tires/side walls help to prevent the vehicle from sinking in the sand. Tread should be narrowed since wider tread allows the vehicle to dig into the sand and makes it difficult to maneuver in sandy conditions.

With usage articulated, each of the components can leverage set-based engineering. There are many options available for each component and decisions should be delayed, if possible, in order to make the proper decision. While final decisions may have been deferred, stakeholders were involved through the process in order to avoid failure modes which could result when decisions are made in isolation.

Agile Stage-Gate Process. Agile stage gate is a process where a company can leverage agile or nimble process through the product development phase. While there were near-daily scrums, meeting topics were often delayed due to absence of key participants in meetings. Effectively, there were no strict timelines or deadlines for the scrums. If stage gates were implemented (and resources properly allocated by management), decisions could have been made faster. The engineers who managed skid plates, shocks, tires, and roof racks could have each conducted their own sub-scrums and reported back to the greater team.

Senior management reviews were held weekly at corporate headquarters located in Detroit. These reviews could have been optimized through better alignment internally. While still a very hierarchical company, management aligned at lower levels should have sent representatives who may have felt empowered to challenge the president of the Americas who did not put priority on ORV which was not focus on his region of responsibility. Furthermore, the 2 p.m. Eastern time slot was not conducive to senior management in Dubai participating. An engineering supervisor was the only participant from the Dubai team at reviews; she was not senior enough in the corporate structure to be much more than a note taker at these meetings. Participation from senior regional marketing management within the region was also critical to represent the interests of any non-US market since final decisions are centralized in the Detroit office.

Team Structure. The team felt strongly that the proper engineering team was formed and aligned for the ORV scrums which were three times per week. Meetings to resolve technical aspects were productive and the cadence was appropriate due to the structured agenda and steady team of 40 participants from the engineering functions. However, further customer data from GCC should have been gathered and evaluated to better contribute to the business case and to include the voice of the customer.

In this case, co-location did not occur, nor was it necessary. Scrum meetings were conducted through Webex and the team communicated off line as well. Technology was utilized, including telephone calls and Skype, which were convenient for quick responses internationally. One way that co-location may have helped was when occasionally engineers were not available for their scheduled dates/times on the scrum agendas. Co-location could have facilitated employees walking to each other's desks for immediate assistance. However, by confirming scheduled presenters and the target audience in advance of each meeting, such delays could have been avoided.

As a multi-national team, considerations were made around the Scrum meeting time. At 8 a.m. Eastern, it was 5 p.m. in Dubai, which was a reasonable time for all parties. Further, the scrum rarely (if ever) met on a Friday as the Dubai work week is Sunday through Thursday. While travel costs are often prohibitive, it would have been beneficial for the vehicle engineering manager in Dubai to visit the Detroit office once or twice through the process to meet with the team in person. The team felt that it became fragmented with silos formed by function and business units. In-person meetings would have helped to foster closer relationships. Even those employees located in Detroit would call into meetings from their desks, which did not help to reinforce a strong team bond.

Conclusion

After 12 months on the proposal work and three months of weekly senior management reviews, the LTU ORV was approved. Although challenging, the team was successful in bringing a product to the Middle East that was aligned with regional needs. The LTU ORV set a precedent, and the Dubai team was able to replicate its success and have a stronger voice. As a result, the region was able to secure regional-specific content in other programs. Improvements could have been made by integrating design thinking into the process earlier. This integration was essential to understanding the customer needs as well as the business necessity for offering the variant into the market. For this reason, adhering to the Integrated Framework would have helped to streamline the process resulting in a robust program being dimensioned early and quickly in the product development process.

In this chapter we explored two case studies and validated them against the Integrated Framework. Through these research case studies, we were able to analyze the Integrated Framework to determine areas in the product planning process which would have benefitted from additional design thinking opportunities and more robust design execution. The Integrated Framework may not address issues like non-collaborative corporate culture, senior managment politics, and other organizational behavior issues. However, it can help to provide the organization with a better targeted product that meets customer needs for management to make better informed decisions. In the next chapter we will cover overall conclusions, recommendations, and directions for future research

CHAPTER 6: CONCLUSION & DIRECTIONS FOR FUTURE RESEARCH

This dissertation proposed an integrated framework to systematically address routine challenges plaguing early product development for highly engineered and complex products, such as automobiles. The framework includes up-front strategic product planning leveraging 'design thinking' and 'design execution' through a structured process to enable adaptation under uncertainties in the product development lifecycle for customer delight and program success. Included is product planning, from fuzzy front-end until product launch, and prioritizing aligned strategic initiatives while integrating design thinking throughout the process. We also discuss two real-world case studies to emphasize the efficacy of the framework and to demonstrate practical examples of how lack of design thinking and customer voice in the early stages of product planning may result in customer dissatisfaction issues downstream. Reduction of late design changes and realized efficiencies will result in reduced overall cost and faster speed to market. We also address the need to better align and balance business, design, and engineering goals to achieve success. By leveraging this approach, practitioners can expect a more inclusive environment in which innovation is abundant and a more streamlined approach to product planning and design execution is achieved.

In both the polar vortex and off-road vehicle (ORV) research case studies discussed, we saw instances where clarity of requirements was not present. In the case of the polar vortex case, the product was inadequate for the region where the vehicle was being shipped. While the polar vortex may have been a natural phenomenon which occurred irregularly, the company needed to declare whether they should commit to engineering actions to avoid warranty and product performance issues or dedicate the funds to build a more robust product to withstand any weather event, whether it be due to extreme heat or cold (depending on the region).

In the case of the ORV, corporate decisions needed to be made and there were only finite resources available. By defining exactly what the customers in the GCC region of the Middle East desired, engineering requirements could be stated early and be based on actual customer needs. Furthermore, a robust framework would help to dimension cost of the program early and expenditures would not have been inflated by estimating from historical costs. All decisions would be fact-based and customer centric in order to determine the most cost-effective business approach to the proposal.

In both cases, additional customer insight was required. Cold weather usage requirements could have been better determined through a deeper understanding of the customer. By understanding the daily struggles customers experience in cold climates, customer satisfaction could be increased. Furthermore, scenario planning for instances where once in 100-year storms occur, would also help to create business cases and justification for more stringent requirements. For the ORV case, understanding usage requirements up-front in the Middle East would have shown that 80% of the customers take their vehicles off road at least once per month. Additionally, larger family size dictated the need for a larger vehicle. Competitors were already offering more capable offerings. Such insights could have led to business alignment earlier whether a new product variant would be successful in-market and would have given the customers a voice in the planning process. Furthermore, on the design execution side, the Integrated Framework could have offered additional opportunities for quicker implementation.

The first step to instituting the Integrated Framework is to embrace the concept of design thinking. While this is often difficult for traditional product development engineers, it brings integrity to the process. A clear vision and approach provided by the Integrated Framework offers the discipline of the best product development approaches and creates the needed structure. This approach will allow organizations to overcome the ambiguity of the fuzzy front end as program ideas commence and provide a resilient construct to ensure effective and efficient implementation.

The proposed Integrated Framework incorporates design, engineering, and business objectives, resulting in a robust product. Efficiencies are created through the Integrated Framework as consumer-centric decisions are made early, reducing the need for expensive downstream changes. Empowered cross-functional teams work and ideate together. Through design thinking and empowerment, teams coalesce and transcend historical organizational barriers. When teams are unable to physically be together due to geographic limitations, they depend on video teleconferencing and Cloud-based workspaces as collaborative technology continues to improve. Leadership buy-in throughout the process increases the likelihood of success as stakeholders remain vested and status checks are done at regular intervals to ensure consistent alignment. Program timing is also optimized through product development processes (such as concurrent and set-based engineering, which now integrate design thinking, thus maintaining the customer voice throughout the process. Case studies demonstrated how customer-centric considerations early in the Planning Process would have resulted in fewer downstream changes and optimization of the overall process.

Getting the process right early ensures overall team success. By leveraging this approach, practitioners can expect a more inclusive environment in which innovation is fruitful. Reduction of late changes and realized efficiencies will result in reduced overall cost and faster speed to market. This approach addresses the need for academic literature to illustrate business practices. By integrating design thinking into a historically product development-centric process we revolutionize the system and allow for greater gains in engineering efficiency coupled with increased customer satisfaction.

Discussion

The integrated framework incorporates design, engineering, and business objectives, resulting in a robust product. Efficiencies are created through the framework as consumer-centric decisions are made early, reducing the need for expensive downstream changes. Empowered cross-functional teams work and ideate in dedicated Innovation Rooms where the team can coalesce and transcend historical organizational barriers. Leadership buy-in throughout the process increases the likelihood of success as stakeholders remain vested and status checks are done at regular intervals to ensure consistent alignment. However, it must be noted that that leadership buy-in is not a given and the Integrated Framework on its own cannot fix any dysfunctional cultures which may exist.

Program timing is also optimized through both concurrent and set-based engineering approaches, now integrated with design thinking to maintain the customer voice through the process.

Research case studies demonstrated how customer-centric considerations early in the planning process would have resulted in fewer downstream changes and overall optimization. The Integrated Framework used these research case studies to demonstrate challenges which would have been reduced had design thinking been implemented into a structured, repeatable process. In both the polar vortex and ORV examples, it was demonstrated that the lack of understanding of customer needs led to inefficiencies causing variants and features to be implemented post-launch.

While there is no silver bullet, proposed Integrated Framework offers a solution which bridges both academic literature and best practices within industry. Getting the process right early ensures overall team success. By leveraging this approach, practitioners can expect a more inclusive environment in which innovation is fruitful. Reduction of late changes and realized efficiencies will result in reduced overall cost and faster speed to market. By integrating design thinking into a traditional product development-centric process, we revolutionize the system and allow for greater gains in engineering efficiency coupled with increased customer satisfaction, increasing revenues and leading to stronger business models.

Directions for Further Research

The integrated framework was created based on product development experience and the need for discipline in design thinking in the product planning process. Two research case studies representing two different contexts were offered. The first was the customer desire for regional variants of a product but requiring a corporate business case. The second case illustrated instances where companies need to consider extreme usage requirements which may happen only once every 100 years and determine an aligned business case and direction. In both these cases, the design thinking elements were missing and both scenarios illustrated a lack of understanding of customer need. Research which quantifies the effectiveness of the proposed integrated framework would be welcome as additional validation of the framework. Should a program be executed utilizing the framework, further suggestions for refinement may result. While this study was automotive focused, other organizations should apply the framework to validate its application in other industries.

Research from firms of various sizes and complexities should be conducted with the framework to evaluate its scalability. In addition to scalability, research can be conducted creating subsystems and the tiered aspects of the Integrated Framework for further refinement. Especially in more complex organizations, we can expand the Integrated Framework a level deeper and highlight areas which are more iterative, as do-loops are inherent in design thinking and should permeate throughout the process.

Within the Integrated Framework, prototyping is included in phase I, stage 4 (see figure 4). A further opportunity is to investigate further types of prototyping that would be appropriate, including articulation of timing and cost. With the integration of design thinking, there are many different elements and types of prototyping that can be done, from "scrappy" designs from cardboard to virtual prototyping and full-size models. Research dedicated to the proper type of prototyping and quantifying the benefit of such could lead to advancements and even further refinement of the Integrated Framework.

Further integration of design thinking deliverables within early product development can also be developed to advance the Integrated Framework. While this dissertation was the first study to integrate design thinking and design execution, research expanding on the benefits of design thinking up-front in the process may demonstrate further benefit. Additionally, quantifiable design thinking deliverables would incentivize organizations to better embrace design thinking, strengthening their own product planning and product development processes.

Further research can be conducted to further tie the Integrated Framework with 'systems engineering' processes. The 'architecture' of any highly engineered product is key to success and design thinking must be fundamental in the product's development. Both design thinking and systems engineering leverage feedback loops but have historically be operating in isolation. Forming a closer tie between systems engineering and design thinking through operationalizing may also yield additional benefits to organizations. Looking back at the Toyota Product System and their "Rigid Flexibility" approach through the lens of the Integrated Framework may help to articulate the best point where disruption yields the most benefit.

The dimension of corporate culture also has a large influence on product planning and additional research on how to implement and institutionalize the proposed framework would be beneficial, especially in large and established companies. While the Integrated Framework will never be a ‘cookbook’, it operationalizes strategic product planning. But without leadership and a cultural change within organizations, especially those that are older and more established, the framework will not be successful. Leadership needs to realize the benefit and support the organization embracing the change needed to become nimble and remain competitive. Teams must be empowered, and leadership aligned on strategic decisions, always keeping customer needs at the forefront. The leadership hand-off from Strategic Product Planner in phase I must be smooth, gradual, and aligned with the Chief Product Engineer in Phase II. Furthermore, the knowledge transfer of lessons learned and best practices must be robust in order to cease making repeat mistakes and capitalizing on the many things that organizations do right.

REFERENCES

Abdul Salam, A., Elsegaey, I., Khraif, R., & Al-Mutairi, A. (2014). Population Distribution and Household Conditions in Saudi Arabia: Reflections from the 2010 census. *Springerplus*.

Achiche, S., Paolo Appio, F., McAloone, T. C., & DiMinin, A. (2013). Fuzzy Decision Support for Tools Selection in the Core Front End Activities of New Product Development. *Research in Engineering Design*, 24(1), 1-18.

Adams, M. E., Day, G. S., & Dougherty, D. (1998). Enhancing New Product Development Performance: An organizational learning perspective. *Journal of Product Innovation Management*, 15(5), 403-422.

Akao, Y. (2004). *Quality Function Deployment: Integrating customer requirements into product design.* New York: Productivity Press.

Alam, I. (2006). Removing Fuzziness from the Fuzzy Front-end of Service Innovations through Customer Interatctions. *Industrial Marketing Management*, 35(4), 468-480.

Almefelt, L., Berglund, F., Nilsson, P., & Malmqvist, J. (2006). Requirements Management in Practice: Findings from an empirical study in the automotive industry. *Research in Engineering Design*, 17(3), 113-134.

Amer, M., Diam, T. U., & Jetter, A. (2012). A Review of Scenario Planning. *Futures*, 23-40.

Bacciotti, D., Borgianni, Y., Cascini, G., & Rotini, F. (2016). Product Planning Techniques: Investigating the differences between research trajectories and industry expectations. *Research in Engineering Design*, 27(45), 367-389.

Balachandra, R., & Friar, J. H. (1997). Factors for Success in R&D Projects and new Product Innovation: A contextual framework. *IEEE Transactions on Engineering Management*, 34(1), 276-287.

Barmeyer, C., & Davoine, E. (2019). Facilitating Intercultural Negotiated Practices in Joint Ventures: The case of a French-German railway organization. *International Business Review*.

Bjorklund, T., Maula, H., Soule, S. A., & Maula, J. (2020). Integrating Design into Organizations: The coevaluation of design capabilities. *California Management Review*, 100-124.

Cagen, J., & Vogel, C. M. (2001). *Creating Breakthrough Products: Innovation from product planning to program approval.* Upper Saddle River: Prentice Hall.

Calgren, L. (2016). Design Thinking in Innovation: The case of Kaiser Permanente. *European Academy of Management.* Paris: EURAM Conference Proceedings.

Camacho, M. (2018). An Integrative Model of Design Thinking. *21st DMI: Academic Design Management Conference*, (pp. 627-641). London, United Kingdom.

Cantamessa, M. (2003). An Empirical Perspective Upon Design Research. *Journal of Engineering Design*, 14(1), 1-15.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2002). Portfolio Management: Fundamental for new product success. Retrieved from http://www.stage-gate.net/downloads/wp/wp_12.pdf

Cooper, R., Edgett, S., & Kleinschmidt, E. (1999). New Product Portfolio Management: Practices and performance. *Journal of Product Innovation Management*, 333-351.

Council on Foreign Relations. (2018, December 7). U.S.-Saudi Arabia Relations. New York, New York, USA.

Cousineau, M., Lauer, T. W., & Peacock, E. (2004). Supplier Source Integration in a Large Manufacturing Company. *Supply Chain Management*, 9(1), 110-117.

Dahl, D. W., & Moreau, P. (2002). The Infouence an dValue of Analogical Thinking During New Product Ideation. *Journal of Marketing Research*, 39(1), 47-60.

de Paula, D., Dobrigkeit, F., & Cormican, K. (2018). Design Thinking Capability Model (DTCM): A framework to map out design thinking capacity in business organisations. *International Design Conference - Design 2018*, (pp. 557-566).

de Paula, D., Dobrigkeit, F., & Cormican, K. (2019). Doing It Right: Critical success factors for design thinking implementation. *ICED19* (pp. 3851-3860). Delft, The Netherlands: International Conference on Engineering Design.

Eckert, C., Clarkson, P. J., & Zanker, W. (2004). Change and Customisation in Complex Engineering Domains. *Research in Engeineering Design*, 15(1), 1-21.

Ernst, H. (2002). Success Factors of New Product Development: A review of the emperical literature. *International Journal of Management Reviews*, 4(1), 1-40.

Flint, D. J. (2002). Compressing New Product Success-to-Success Cycle Time: Deep customer value understanding and idea generation. *International Journal of Research in Marketing*, 31(4), 305-315.

Ford, S., Auburt, C., & Ryckewaert, E. (2016). Reducing the Risk of Failure in New Product Development: Getting it right at the front end of innovation. *University of Cambridge Institute for Manufacturing*.

Fricke, E., & Schulz, A. P. (2005). Design for Changeability (DfC): Principles to enable changes in systems throughout their entire lifecycle. *Systems Engineering*, 8(4).

Fricke, E., Gebhard, B., Negele, H., & Igenbergs, E. (2000). Coping with Changes: Causes, findings, and strategies. *Systems Engineering*, 31(4), 169-179.

Garcia, N., Sanzo, M. J., & Trespalacios, J. A. (2008). New Product Internal Performance and Market Performance: Evidence from Spanish firms regarding the role of trust, interfunctional integration, and innovation type. *Technovation*, 29(11), 713-725.

Goldenese, B. (2017, February 22). The 5 Risks of Product Development: Does your company actively manage innovation risk? *Machine Design*.

Gou, W. (2012). A Research on Fuzzy Front End of NPD in Chinese Equipment Manufacturing Firms: A theoretical model. *IEEE Control and Decision Conference.* Taiyuan, China.

Groundwater, B. (2018, June 12). Abu Dhabi Desert Driving Adventure: The most spectacular experience you can have in a desert. *Traveller*.

Halvorson, B. (2014, June 18). New-Car Problems Up: Blame technology and... the Polar Vortex? *The Car Connection*. Retrieved from Halvorson, B. (2014). New-Car Problems Up: Blame technology and... the Polar Vortex? The Car Connection. Retrieved from https://www.thecarconnection.com/news/1092805_new-car-problems-up-blame-technology-and-the-polar-vortex

Henard, D. H., & Szymanski, D. M. (2001). Why Some New Products are More Successful than Others. *Journal of Marketing Research*, 38(3), 362-375.

Hicks, B. (2016). Patterns and Paths for Realising Design-led Impact: A study of UK REF case studies. *Impact of Design Research on Industrial Practice*, 45-65.

Hoffmann, M., Kuhn, N., Weber, M., & Bittner, M. (2004). Requirements for Requirements Management Tools. *12th IEEE International Requirements Engineering Conference*, (pp. 222-289).

Hutcherson, K. (2018, June 5). Saudi Arabia Issues its First Driver's Licenses to Women. *CNN.com*.

Hyde, A. (2017, December 16). Personal Email Communication. (S. Dare, Interviewer)

IDF Diabetes Atlas. (2020). Retrieved from International Diabetes Federation: https://www.diabetesatlas.org/data/en/world/

Jetter, A. J., & Sperry, R. C. (2013). Fuzzy Cognitive Maps for Product Planning: Using stakeholder knowledge to achieve corporate responsibility. *IEEE Hawaii International Conference on System Sciences.* Wailea, Hawaii.

Kahn, K. B. (2011). *Product Planning Essentials.* New York: M. E. Sharpe.

Kauppinen, M., Vartiainen, M., Kontio, J., Kujala, S., & Sulonen, R. (2004). Implementing Requirements Engineering Processes Throughout Organizations: Success factors and challenges. *Information and Software Technology*, 46(14), 937-953.

Kim, J., & Wilemon, D. (2002). Focusing the Fuzzy Front-end in New Product Development. *R&D Management*, 32(4), 269-279.

Koen, P., Ajamian, G., Boyce, S., Clamen, A., Fisher, E., Fountoulakis, S., & Siebert, R. (2002). *Fuzzy Front End: Effective methods, tools and techniques.* New York: Wiley.

Koen, P., Ajamian, G., Burkhart, R., Clamen, A., Davidson, J., & Wagner, K. (2001). Providing Clarity and a Common Langage to the "Fuzzy Front End". *Research-Technology Management*, 44(2), 46-55.

Kolko, J. (2015, September). Design Thinking Comes of Age. *Harvard Business Review*.

Krishnan, V., & Ulrich, K. T. (2001). Product Development Decisions: A review of the literature. *Management Science*, 47(1), 1-21.

Kyle, B. (2014). SWOT Analysis: Strengths, weaknesses, opportunities, and threats. Retrieved from http://marketing-skills.blogspot.co.uk/2014/09/swot-analysis-strengths-weaknesses.html

Lee, A. H., Kang, H. Y., Yang, C. Y., & Lin, C. Y. (2010). An Evaluation Framework for Product Planning using FANP, QFD, and Multi-choice Goal Programming. *International Journal of Production Research*, 48(13), 3977-3997.

Li, Y. L., Tang, J. J., Chin, K. S., Lou, X. G., Pu, Y., & Jiang, Y. S. (2012). On Integrating Multiple Type Perferences into Competitive Analyses of Customer Requirements in Product Planning. *International Journal of Production Economics*, 139(1), 168-179.

Liedtka, J. (2018). Exploring the Impact of Design Thinking in Action. *Darden Working Paper Series.* Charlottesville, Virginia: University of Virginia.

Lopez-Mesa, B., & Bylund, N. (2010). A Study of the Use of Concept Selection Methods from Inside a Company. *Research in Engineering Design*.

Lopez-Mesa, B., & Bylund, N. (2011). A Study of the Use of Concept Selection Methods from Inside a Company. *Research in Engineering Design*, 22(1), 7-27.

Maxwell, J. A. (2013). *Qualitative Research Design: An interactive approach* (Third ed.). Los Angeles: Sage.

Mitcheltree, C. M., Holtskog, H., & Ringen, G. (2019). Studying Design Thinking as a Forthcoming Source to Innovation Speed. *Proceedings of the 22nd International Conference on Engineering Design (ICED19)*, (pp. 2357-2366). Delft, The Netherlands.

Montagna, F. (2011). Decision-aiding Tools in Innovative Product Development Contexts. *Research in Engineering Design*, 22(2), 63-86.

Montoya-Weiss, M. M., & O'Driscoll, T. M. (2000). From Experience: Applying performance support technology in the fuzzy front end. *Product Innovation Management*, 17(2), 143-161.

Naumes, W., & Naumes, M. J. (2006). *The Art & Craft of Case Writing.* Armonk: M. E. Sharpe.

Nijssen, E. J., & Frambach, R. T. (2000). Determinants of the Adoption of new Product Development Tools by Industrial Firms. *Industrial Marketing Management*, 29(2), 121-131.

Oppositelock. (2013, July 3). Lower is Better, So Why Do We Buy So Many SUVs? New York, New York, USA.

Page, A. L., & Schirr, G. R. (2008). Growth and Development of a Body of Knowledge: 16 years of new product development research. *Journal of Product Innovation Management*, 25(3), 233-248.

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007). *Engineering Design: A systematic apporach.* London: Springer.

Paparo, M., Disti, C., & Vignoli, M. (2017). Towards a DT Mindset Tool: Factors Identification from Theory and Practice. *Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 2: Design Processes | Design Organisation & Management*, (pp. 367-376). Vancouver, Canada.

Ramesh, B., & Tiwana, A. (1999). Supporting Collborative Process Knowledge Manaement in New Product Development Teams. *Decision Support Systems*, 27(1-2), 213-235.

Rauth, I., Calgren, L., & Elmquist, M. (2014, October). Making it Happen: Legitimizing design thinking in large organizations. *The Design Management Institute*, 46-60.

Redante, R. C., De Medeiros, J. F., & Cruz, C. M. (2019). Motivators and Barriers for Using Design Thinking in New Product Development. *New Global Perspectives on Industrial Engineering and Management*, 249-257.

Reid, S. E., & DeBrentani, U. (2004). The Fuzzy Front End of New Product Development for Discontinuous Innovations: A theoretical model. *Product Innovation Management*, 21(3), 170-184.

Reil, A., Neumann, M., & Tichkiewitch, S. (2013). Structuring the Early Fuzzy Front-end to Manage Ideation for New Product Development. *CRIP Journal of Manufactuing Science and Technology*, 62(1), 107-110.

Reitzschel, E. F., Nijstad, B. A., & Stroebe, W. (2006). Productivity is Not Enough: A comparision of interactive and nominal brainstorming groups on idea generation and selection. *Journal of Experimental Social Psychology*, 42(2), 244-251.

Sanayei, A., & Monplaisir, L. F. (2013). Manageing Technology Selection and Development Decisions in New Product Dvelopment Process. *PICMET '13 - Technology Management for Emerging Technologies.*

Schroter, D., Polsky, C., & Pratt, A. G. (2005). Assessing Vulnerabilities to the Effects of Global Change: An eight step approach. *Mitigation and Adaptation Strategies for Global Change*, 10, 573-595.

Shinno, H., & Hashizume, H. (2002). Structure Method for Identifying Success Factors in New Product Development of Machine Tools. *CIRP Journal of Manufacturing Science and Technology*, 51(1), 281-284.

Shinno, H., Yoshioka, H., & Marpaung, S. (2006). A Structured Method for Analysing Product Specification in Product Planning for Machine Tools. *Journal of Engineering Design*, 17(4), 347-356.

Siler, W. (2019, March 25). What Actually Makes a Truck Good Off-Road.

Smith, M., Bosman, J., & Davey, M. (2019, January 31). Extreme Cold Weather Spreads East. *The New York Times*.

Smith, P. G., & Reinertsen, D. G. (1992). Shortening the Product Development Cycle. *Research-Technology Management*, 35(3).

Sobek, D., Ward, A. C., & Liker, J. K. (1999). Toyota's Principles of Set-Based Concurrent Engineering. 40(2), 67.

Soukhoroukova, A., Spann, M., & Skiera, B. (2012). Sourcing, Filtering, and Evaluating New Product Ideas: An empirical exploration of the performance of idea markets. *Journal of Product Innovation Marketing*, 29(1), 100-112.

Stasch, S. F., Lonsdale, R. T., & LaVenda, N. N. (1992). Developing a Framework for Sources of New Product Ideas. *Consumer Marketing*, 9(2), 5-15.

Ulrich, K. T., & Eppinger, S. D. (2011). *Product Design and Development.* New York: McGraw Hill.

Vedsmand, T., Kielgast, S., & Cooper, R. G. (2016). Integrating Agile with Stage-Gate: How new agile-scrum methods lead to faster and better innovation. *Innovation Management*.

Wang, Y., & Wang, M. (2016). Process Optimzation Based on Knowledge Flow in Engineering Change. *9th International Conference on Digital Enterprise Technology*, (pp. 4016-411).

Weber, M., & Weisbrod, J. (2002). Requirements Engineering in Automotive Development-experiences and Challenges. *IEEE Joint International Conference on Requirements Engineering*, (pp. 331-340). Essen, Germany.

Yin, R. K. (2018). *Case Study Research and Applications: Design & methods* (6th ed.). Los Angeles: SAGE.

Zhang, Q., & Doll, W. J. (2001). The Fuzzy Front End and Success of New Product Development: A causal model. *European Journal of Innovation Management*, 4(2), 95-112.

ABSTRACT

DESIGN THINKING & STRATEGIC PRODUCT PLANNING FOR HIGHLY ENGINEERED PRODUCTS

by

SHANNON DARE WAYNE

December 2020

Advisor: Dr. Ratna Babu Chinnam

Major: Industrial Engineering

Degree: Doctor of Philosophy

This dissertation proposes an integrated framework to systematically address routine challenges plaguing early product development for highly engineered and complex products, such as automobiles. The framework includes up-front strategic product planning leveraging 'design thinking' and 'design execution' through a structured process to enable adaptation under uncertainties in the product development lifecycle for customer delight and program success. Included is product planning, from fuzzy front-end until product launch, and prioritizing aligned strategic initiatives while integrating design thinking throughout the process. We also discuss two real-world case studies to emphasize the efficacy of the framework and to demonstrate practical examples of how lack of design thinking and customer voice in the early stages of product planning may result in customer dissatisfaction issues downstream. Reduction of late design changes and realized efficiencies will result in reduced overall cost and faster speed to market. We also address the need to better align and balance business, design, and engineering goals to achieve success. By leveraging this approach, practitioners can expect a more inclusive environment in which innovation is abundant and a more streamlined approach to product planning and design execution is achieved.

Keywords: Design Thinking, Strategic Product Planning, Fuzzy Front End, Product Development, Product Planning, and Strategy

AUTOBIOGRAPHICAL STATEMENT

Shannon Dare has worked in the automotive industry for over 20 years. She is currently a Supervisor in Enterprise Line Management department integrating Technology into future vehicles. Prior, she was responsible for Planning & Strategy for the Middle East & Africa region. Shannon completed Ford's Manufacturing Leadership Program with rotations including: Production Line Supervisor, Process Engineer, Industrial Engineer, Product Development Plant Resident Engineer, and 2007 National UAW – Ford Negotiations team.

Shannon holds a BS in Industrial Management & MS Industrial Operations, both from Lawrence Technological University in Southfield, Michigan. She holds a second MS in Manufacturing engineering and is pursuing a PhD in Industrial Engineering from Wayne State University in Detroit. Through the American Society for Quality, she is a Certified Manager of Quality and Certified Quality Auditor. Shannon is also past-president of Ford Toastmasters.

Shannon also makes time for her community of Milan, Michigan. She is Chairperson of the Milan Beautification Commission. Shannon is Secretary of Milan's Downtown Development Authority/Milan Main Street aiding in the city's revitalization. Additionally, she is on the Parish Council of her local Catholic Church.

Shannon is married to Kevin Wayne and they have three active children: Flannery (15), Mary-Kate (12), and Kevin (8). On most evenings and weekends, you can find her cheering for her kids at either the pool, football field, volleyball and tennis courts, or track.