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Integrated Framework for Design Thinking & Strategic Product Planning

Shannon Dare Wayne, Ph.D. and Ratna Babu Chinnam, Ph.D.
Department of Industrial & Systems Engineering
Wayne State University
Detroit, MI 48202, USA
Shannon.Wayne@wayne.edu, Ratna.Chinnam@wayne.edu

Abstract

This paper presents 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. 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.

Keywords: Design Thinking, Strategic Product Planning, Fuzzy Front End, Product Development, Goal Alignment

1. Introduction

Globalization combined with rapid technological advances are creating enormous challenges for companies developing advanced engineering products, such as automobiles (Pacheco & Librelato, 2023). Notably, consumers not only anticipate enhanced product quality but also demand expedited development cycles, leaving no margin for error in the new product development process (Chauhan et al., 2017). Researchers in the field of product development have underscored for decades the significance of firms that possess the capability to harmonize their product offerings with evolving consumer demands, as these firms are more likely to achieve success compared to those neglecting investments in these capabilities (Brown & Eisenhardt, 1995; Yadav et al., 2007; Chauhan et al., 2020). Existing research has consistently indicated that new product development projects also suffer from a low success rate (Cooper, 2003; Salavati et al., 2016).

As industry practitioners work to solve these issues, expanded awareness for new methodological frameworks for complex product development and associated processes and tools is essential. By articulating how "design thinking" complements traditional product planning and bridging 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 in complex product development. 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.

This paper presents 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 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 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 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. The rest of this paper is organized as follows: Section 2 reviews pertinent literature; Section 3 presents a proposed integrated framework for design thinking and strategic product planning; Section 4 provides summary recommendations; Finally, section 5 discusses potential avenues for future research.

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 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).

The literature review further demonstrated that there is a 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.

3. Integrated Framework for Design Thinking & Strategic Product Planning

This section 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.

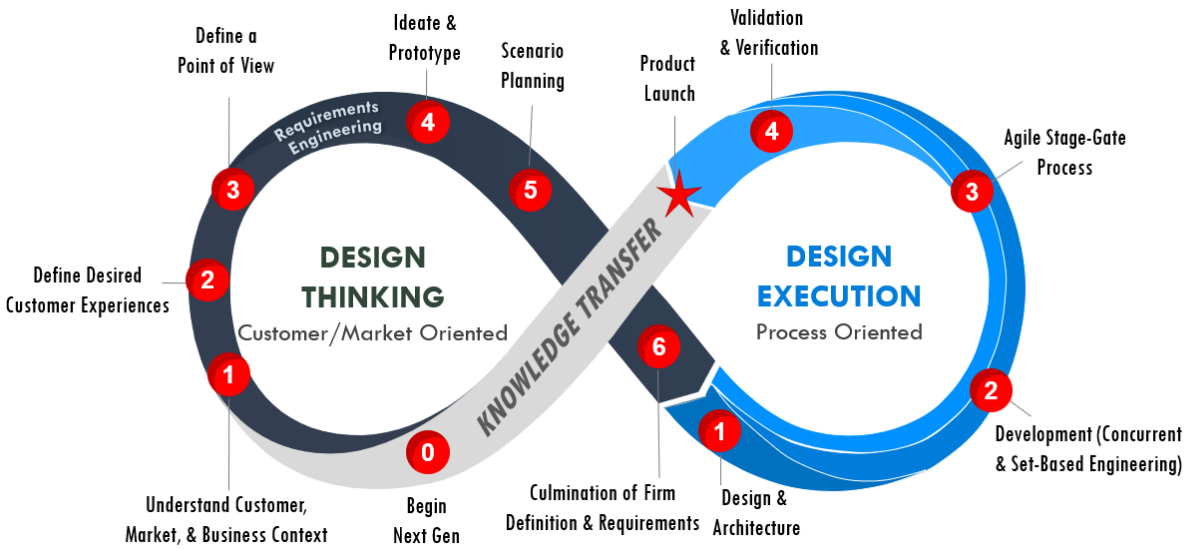

Figure 1. Integrated Framework for Design Thinking & Strategic Product Planning

The proposed integrated framework shown in Figure 1 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.

3.1 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).

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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.

3.1.1 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.

3.1.2 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, than 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 satisfies 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 2 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 2. SWOT Analysis (Kyle, 2014)

3.1.3 Stage II – Define Desired Customer Experiences

Putting the customer first is central to ensuring 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 the details of a customer's life (Liedtka, 2018). To understand customer expectations, product planning must consider 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 ensure 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, each 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.

3.1.4 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 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, 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 be developed and utilized.

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.

3.1.5 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 result 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) of acceptable standards as defined by the customer are 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.

3.1.6 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 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's 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 chance of a once-in-a-century storm and its impact on the product should be 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.

3.1.7 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 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.

3.2 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 standpoint, 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.

3.2.1 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's 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 into 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 companies such as 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.

3.2.2 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 to save time and to increase efficiency. 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 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, and regular reviews held to ensure that the overall project timing is not affected through delays in the process.

3.2.3 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.

3.2.4 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 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 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.

3.2.5 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.

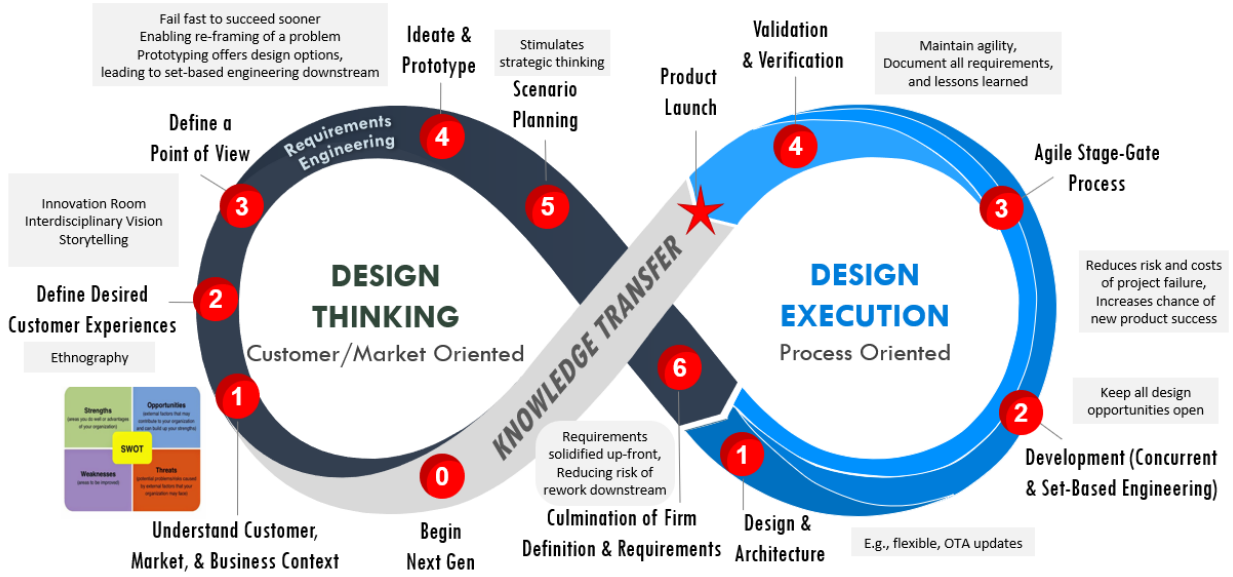

Figure 3. Annotated Integrated Framework for Design Thinking & Strategic Product Planning

4. Conclusion & Recommendations

This paper created 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.

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 integrates design thinking, thus maintaining the customer voice throughout the 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.

5. Further Research Avenues

The integrated framework was created based on product development experience and the need for discipline in design thinking in the product planning process. 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 1). 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 made of 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 research was the first study to integrate design thinking and design execution, further research expanding on the benefits of design thinking up-front in the process may demonstrate additional benefit. Quantifiable design thinking deliverables would incentivize organizations to better embrace design thinking, strengthening their own product planning and product development processes.
Additional 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 been 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 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 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 currently do effectively.

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Biographies

Dr. Shannon Dare Wayne has worked for Ford Motor Company for over 25 years. She is currently a Manager in Advanced Product Development & Technology Operations within Ford Motor Company's Model e division. Prior, she worked in Planning & Strategy for the Middle East & Africa region. She completed Ford's Manufacturing Leadership Program with rotations including Production Line Supervisor, Process Engineer, Industrial Engineer, Quality, Product Development Plant Resident Engineer, and 2007 National UAW – Ford Negotiations team. She teaches Operations Management courses at Lawrence Technological University in Southfield, Michigan and previously at Cleary University in Ann Arbor, Michigan. She holds a B.S. in Industrial Management and M.S. Industrial Operations from Lawrence Technological University in Southfield, Michigan. She also holds a M.S. in Manufacturing Engineering and Ph.D. 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.

Dr. Ratna Babu Chinnam is an expert in AI, Big Data & Business Analytics and is a Professor and Chair of the Industrial & Systems Engineering Department at Wayne State University. He authored over 150 technical publications with research interests in business analytics, big data, operations management, supply chain management, sustainability, healthcare, and smart engineering systems. He is currently the Associate Editor for the *International Journal of Modeling and Simulation,* the *International Journal of Quality, Statistics, and Reliability,* and the North American Editor for the *Journal of Remanufacturing*. His research is funded by the U.S. NSF, DoT, DoD, DoEd, and VA. He graduated over 50 doctoral students with many occupying academic positions and is awarded the 2012 Outstanding Graduate Mentor Award by Wayne State University. In 2022, he received an Outstanding Professor Award from the Industrial Engineering & Operations Management Society. His students have won a number of best paper and dissertation awards from professional societies such as INFORMS, POMS, and IISE. He received his B.S. degree in Mechanical Engineering from Manipal Institute of Technology of Mangalore

University (India) in 1988 and the M.S. and Ph.D. degrees in Industrial Engineering from Texas Tech University (U.S.A.) in 1990 and 1994, respectively.