Supporting management of new product development via a novel conceptual model: an interview driven approach

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Abstract

Purpose – This study aims to gain a deeper understanding of the industry practice to guide the formation of support tools with a rigorous theoretical backing. Cross-functional teams are an essential component in new product development (NPD) of complex products to promote comprehensive coverage of product design, marketing, sales, support as well as many other activities of business. Efficient use of teams can allow for greater technical competency coverage, increased creativity, reduced development times and greater consideration of ideas from a variety of stakeholders. While academics continually aspire to propose methods for improved team composition, there exists a gap between research directions and applications found within industry practice.

Design/methodology/approach – Through interviewing product development managers working across a variety of industries, this paper investigates the common practices of team utilization in an organizational setting. Following these interviews, this paper proposes a conceptual two-dimensional management support model aggregating the primary drivers of team success and providing direction to systematically address features of team management and composition.

Findings – Based on this work, product managers are recommended to continually address the positioning of members throughout the entire NPD process. In the early stages, individuals are to be placed to work on project components with explicit consideration toward the perceived complexity of tasks and individual competency. Throughout the development process, individuals' positions vary based on new information while continued emphasis is placed on maintaining a shared understanding.

Originality/value – Bridging the gap between theory and application within product development teams is a necessary step toward improved product develop. Industrial settings require practical solutions that can be applied economically and efficiently within their organization. Theoretical reflections postulated by academia support improved team design; however, to achieve true success, they must be applicable when considering product development.

Keywords Product development, Team construction, Team management, Design models, Teamwork, Product design, Teamwork

Paper type Research paper

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1. Introduction

Cultivating successful new product development (NPD) hinges on the robust application of cross-functional and multidisciplinary teams (Ulrich, 2003). Frequently identified components for successful products all have, at the core, efficiently operating teams such as quality R&D departments, technical product performance, adherence to customer values and strong managerial support (Zirger and Maidique, 1990). The realization of a successful new development is contingent on both internal factors related to an organization's structure and external factors related to the market, the former of which are explored throughout this paper.

NPD presents unique challenges for organizations compared against their ongoing operating procedures (Ayağ and Özdemir, 2007; Blindheim *et al.*, 2020; Leonard-Barton, 1992; Unger and Eppinger, 2011). Performing NPD comes with much greater risk and uncertainty and can result in excessive losses if not conducted efficiently (Borgianni *et al.*, 2018; Chin *et al.*, 2009; Lasso *et al.*, 2020). At the same time, NPD is often used with the goal of increasing creative output of a team, leading not only to viable products but also to market success. Because of this, it is paramount for a firm to increase their probability of success when performing NPD. Some of the earliest works advocating for increased attention on NPD processes date back to the 1960s by identifying factors leading to success (Marquis, 1969; Morison, 1966). In the late 1980s through the 1990s, the number of studies focusing on these success factors continued to surge (Ernst, 2002), arguably led by numerous works from Cooper and Kleinschmidt (1986, 1987a, 1987b, 1988, 1995) and Kleinschmidt and Cooper (1995). These fundamental pieces of literature empirically analyzed what factors were most influential in the success of NPD, of which the concept of performing quality planning before beginning the development process became evermore apparent. While these early works also determined additional success criteria, primarily related to market acceptance and forecasting, the current work accentuates the use of a rigorously developed NPD process focusing on team composition and management.

Optimizing the composition and management of teams for NPD is an ongoing challenge that has seen significant attention from the academic community (Sivasubramaniam *et al.*, 2012). Empirical studies of product development teams exploring the outcomes of various group interaction patterns have been conducted, while emphasizing the resources required for compiling and analyzing the data (Badke-Schaub and Frankenberger, 1999). However, the practice of group composition and process management generally differs from proposed academic approaches in its reliance on more *ad hoc* methodologies. Based on the challenges unique to industry application, idealistic approaches proposed through academic research do not find widespread adoption. Additional resource limitations with respect to human capital, stringent deadlines and budgetary restrictions curb the ability of companies to implement optimally determined team composition and management structures. Adapting new management models and techniques requires large temporal and financial investments that increase in relation to the degree of change when compared to industry's current practices.

This paper is motivated by the results of 21 extensive interviews with team managers across multiple industries and varying scopes of product development. Building a synergistic environment encompassing industry and academia requires attention for theoretical propositions in combination with applicable practices. This work begins by interviewing product development managers across a variety of industries to gain insight on their current practices and the extent to which they implement state-of-the-art team development research. Section 2 presents the motivation behind and methodology used for the interview process. Next, interviewee responses are aggregated by identifying common trends in industry practice providing collective insight, while addressing the current literature on each respectively identified factor. In Section 3, the influential factors identified from the interviews are presented and the current state of the art of each frequently identified concept is explored. Then, in Section 4, we propose a conceptual management model to inform product development managers of efficient human resource allocation dependent upon project scope and complexity, while placing emphasis on flexibility and the simplicity for implementation within their firm's current process management method. This model is motivated by the interview responses, in combination with the current academic literature. Finally, the paper concludes with a discussion of potential efficacy of the proposed conceptual model and its implications on group performance and creativity and future directions in the context of NPD for complex products consisting of integrated components designed by multidisciplinary teams.

2. Team formation and management in industry

To identify influential components of team composition and management in industry, 21-h-long interviews of managers are conducted remotely across multiple industry segments and company sizes to avoid industry bias.

2.1 Interview structure

The interviews occurred between May and June 2020 and 9 of the 21 firms included are Fortune 500 companies. Interviews are performed one on one with individuals from senior management that oversee NPD teams. The structure of these interviews consists of two predominant objectives focusing on *team composition* and *team management*. No set questionnaire is strictly adhered to facilitate an open discussion; however, key questions that are covered in each interview are outlined in Table 1. All interview audio was recorded and notes were taken throughout each interview before they were manually summarized and aggregated using text editing software. Key concepts were extracted from the interviews and tabulated to determine trends. Each audio recording was reviewed to ensure

Investigation topic	Sample question	Motivation
Team composition	*What individual characteristics are considered when selecting individuals?*	To understand how technical competencies, personality traits, experience, congruency, etc. influence managerial decisions
	What level of redundancy with respect to ability is built into teams?	To determine how workloads are determined based on project requirements and complexities
	Who determines subteam formation?	To understand if teams are self-reliant on decomposing work or if management creates underlying team structure
	Is the process of composing teams highly structured or loosely organized?	To determine the level of management intervention when considering work procedures
Team management	*What management philosophy does your company adapt?*	To investigate if they use a set method such as stage gate or agile
	How frequently does your team meet to discuss or readjust development approach?	To determine the frequency of updates and corrective actions
	How is cross-disciplinary communication handled?	To determine the network of information flow, direct or mediated
	What managerial issues commonly arise throughout the development process?	To extract common issues and their resolutions

Table 1. Frequently asked interview questions

complete coverage of identified concepts. This loosely structured interview approach allows for storytelling and an open discussion as responses are obtained organically by exploring each interviewees' company culture.

The interviewees from the participating firms have an average of 10.5 years of experience in their current position of managing product development teams, with the maximum level of experience reaching approximately 30 years of experience. The industries, revenues and company sizes of each participant varied greatly, summarized in Table 2. Here, the revenue is rounded to the nearest $500m and the company size is rounded to the nearest 500 employees to maintain anonymity. The average team size ranges from two individuals, or dyads, up to teams consisting of 300 individuals all working on a shared development project and decomposed into subfunction teams.

2.2 Aggregated responses

Following the interviews, the responses are aggregated and frequently emerging trends are identified. In total, 18 out of 21 interviewees explicitly state that the process of composing teams follows a relatively unstructured process with significant influence on decisions coming from managerial experience. The described process generally begins with one or two individuals estimating the required human resources followed by a review of individual specialty and availability. When considering smaller organizations, resource availability becomes the driving component for selecting contributing individuals.

Selection of specific individuals comes from managerial experience when reviewing previous work and an individual's core competency. Each product component is generally assigned one individual to maintain a lean development approach with little redundancy in individual expertise with respect to the overall team. Large organizations developing products of greater complexity mention the ability to increase the specificity of individual expertise through subcomponent decomposition. These companies have much larger revenues and

Industry	Revenue ($ billion)	Company size	Average team size
Biotechnology	3.5	14,000	6
Chemical	15.5	47,500	20
Electronics	72.0	111,000	200
Electronics	0.1	100	22–25
Energy	21.0	95,000	20–25
Entertainment	33.0	25,500	2–8
Infrastructure	8.0	29,000	30
Infrastructure	4.5	N/A	Varies
Manufacturing	4.0	1,500	15–20
Manufacturing	14.5	57,000	6
Materials	16.5	17,000	Varies
Materials	2.5	10,000	20
Medical	31.0	100,000	10
Medical	20.5	80,500	50
Software development	69.5	223,000	2–7
Software development	136.5	114,000	Varies
Transportation	4.0	27,000	3–5
Transportation	156.0	190,000	300
Transportation	14.0	27,000	100
Transportation	24.5	25,000	12
Transportation	1.5	4,500	15–20

Table 2. Industries interviewed

company sizes allowing for increased coverage of unique project components. Additionally, it is found that increasing the number of individuals working on a specific component is done to facilitate a knowledge transfer between senior and junior employees, an approach explicitly mentioned by two interviewees. Assigning individuals to project components requires an initial product decomposition along the lines of predicted project requirements before the allocation of individuals occurs. Effectively decomposing project attributes into manageable components transpires upfront and iteratively changes as new information is discovered throughout the design process. The act of mapping complexity of the assigned role to each individual is a product of individual competency and efficiency. To assist with managerial experience, three interviewees highlight the use of quantifiable performance metrics generated from previous projects; however, this method is not standardized and varied between firms. Furthermore, two interviewees spoke to current initiatives within their organizations to develop more robust systems of individual allocation, however the details of which were not provided. Five interviewees also make specific mention of following the Tuckman's model for group formation (Tuckman, 1965).

With respect to project management, 19 interviewees explicitly state that they follow a structured process such as stage gate (Cooper, 1990), waterfall (Royce, 1987) or a V-model (Forsberg and Mooz, 1991), whereas approximately 9 interviewees mention a recent transition to an agile development model (Beck *et al.*, 2001). Structured processes allow for repeatability between developments, however they have been criticized as being too linear, too inflexible and too planned to handle innovative and dynamic projects (Cooper, 2014), whereas agile developments have been embraced in software development because of its inherent flexibility. The original presentation of these processes dates back to 20 or more years, underscoring the rigidity of adaptation in the industry. While continually using a "tried and true" methodology is not necessarily an indication of resistance to adapting new techniques, this highlights the limited perceived performance improvements of academic approaches when applied in a real-world setting. Recent advances in agile development processes allow for the application of agile beyond software development (Ciric *et al.*, 2018; Cooper and Sommer, 2016), however these practices are not mentioned by interviewees.

Complementing the structured management approaches, 17 interviewees emphasize the importance of strong group cohesion and direction. When queried about factors that contribute to successful developments, a sense of shared understanding amongst the teams is continually highlighted as one of the most prominent success criteria. In a similar vein, a misaligned focus is also mentioned by 16 interviewees as a primary issue in product development teams. This makes individualistic focus with little understanding of the overall group objectives the number one driver for poor group performance.

Overall, it was found that composition of teams and selection of individuals for specific projects is generally loosely structured and relies heavily on managerial experience. Only three firms mention a method used for team composition that incorporates qualifiable metrics. On the contrary, 19 firms explicitly mentioned that they follow highly structured management processes throughout the development of a project consisting of strict adherence to time-dependent project milestones and reviews. These components of team composition and management are further discussed in the following sections with relation to current academic research before being synergistically combined to support the development of the proposed conceptual management support model.

3. Relating to academic research

With the interview responses as a guide, this section explores current state of the art in academic research related to team composition and management structures. Though not meant to be exhaustive, this work primarily focuses on research from *management sciences*, *organizational behavior* and *design engineering* literature.

3.1 Team composition

As mentioned with respect to team composition, 18 interviewees emphasize that individual allocation does not follow a highly structured process and is primarily conducted using the experience of the product manager. Two exemplar factors are considered, human resource availability and individual competency, with the former taking precedence. Eighteen interviewees state that when an NPD is proposed, they first consider how to allocate their available human resources based on individual competency, previous work experience and each individuals' currently allotted work in relation to the predicted decomposition of the required tasks.

Auxiliary factors, those mentioned with less frequency and following an interviewee's initial responses, also play a role in management decisions such as personality characteristics, which was only mentioned explicitly by four interviewees, or team congruency, which was only mentioned explicitly by five interviewees. These factors were considered secondary as intrateam conflicts are said to be addressed following initial team composition and with support of strong management these conflicts are generally quickly resolved. While this result is decidedly intuitive, it highlights the first disconnect between academic research and industry application. Numerous research methods propose optimal team formation approaches, however their implementation proves difficult because of the realistic constraints found in the industry environment (Alberola *et al.*, 2013; Dorn and Dustdar, 2010; Liemhetcharat and Veloso, 2012; Olatunde *et al.*, 2017; Zhang and Zhang, 2013). One of the primary limitations as it pertains to industry application is the expectation of accurately assessing individual competency, experience and efficiency and how these functions map to the predicted project requirements of a new development effort. The fuzzy front end of product development is substantially less defined than those used in optimal team formation approaches found in the literature. Effectively quantifying individual performance metrics creates an additional level of separation between realistic and idealized application. Multiple interviewees mention the drive for more granular performance metrics; however, these are met with resistance from individuals within human resources as they create a potentially harmful and needlessly competitive working environment.

Additional factors less frequently mentioned by the interviewees with respect to team composition are mentorship, matching senior with junior engineers (aka apprenticeship) and trust, ensuring individuals respect each other's abilities. Mentorship and trust were each only explicitly mentioned by two interviewees. Based on the frequency of responses from the interviewees, the following review focuses on the two primarily identified factors: *resource allocation* and *individual competency*.

3.1.1 Resource allocation. A core element for positioning individuals on a development project relies on the availability of individuals within the organization capable of supporting the estimated task requirements. From the academic literature, this approach relies on decomposing the project into predicted tasks while evaluating individual competencies and how they correlate to their respective tasks. This review focuses on the positioning of members on NPD teams from an individual managerial perspective as opposed to the extensive literature on human resource management systems from a company perspective (Boon *et al.*, 2019).

Unique to NPD processes, the specifics of each task are difficult to define at project initiation. Decomposing the predicted tasks required relates to the similarity between the new development and an organization's legacy products (Ball and Lewis, 2018a). Originally introduced by Steward (1981), the design structure matrix (DSM) decomposes product components and tasks based on the identification of dependencies. DSMs have been proposed to estimate product development time based on the probability of change and impact (Carrascosa *et al.*, 1998). Here, they present a model for analyzing different scenarios to evaluate task duration. Eppinger and Browning (2012) reviewed the applicability of DSMs including team-based and activity-based matrices, focusing on an organizational perspective (Browning, 2001, 2015). From the literature, a key component for the application of DSMs requires one to effectively predict the decomposition of required tasks to allow for individual allocation. In contrast to the literature, interviewees make no mention of the use of DSMs, or similar formal approaches, as means of requirement decomposition. The difficulty in effectively decomposing a new product based on predicted requirements greatly limits the applicability of these highly structured methods proposed by academic findings.

3.1.2 Individual competency. Based on the current state of the art in estimating ability, individual competency relies on multiple facets including personal attributes, project management, cognitive strategies, cognitive abilities, technical abilities and communication (Robinson *et al.*, 2005). Three primary approaches have been identified by Markus *et al.* (2005) including the educational approach, the psychological approach and the business approach. Additionally, individual competencies have been identified through surveying industry experts (Chen and Mohamed, 2008; Walsh and Linton, 2002) and engineering graduates (Male *et al.*, 2010), using a rubrics-based methodology (Pop-Iliev and Platanitis, 2008), assessing functional, processual and holistic shaping competencies (Sedelmaier and Landes, 2014) and the development of hierarchal competency models (Wells, 2008). Additional approaches have considered competency identification through automated topic discovery in combination with design performance (Ball *et al.*, 2020; Ball and Lewis, 2020). These efforts work to efficiently improve human resource management through a more comprehensive measure of individual ability.

From an industry perspective, the granular estimation of individual performance metrics is not generally performed in a structured method as only three of the interviewees make any mention of specifically quantifying individual ability and efficiency. One interviewee mentions that there was an internal push to create and monitor these detailed performance metrics, however that attempt led to significant push-back from human resources as it was found to create a competitive work environment that hurt the performance of the team. Additionally, two interviewees mention a current drive toward the development of an individual efficiency-based allocation system; however, these approaches were reported to be in their infancy. Based on the limitations of evaluating individuals based on their competencies, a tradeoff exists when implementing individual competency as a means of efficiently placing individuals while restricting the potential negative impacts of creating a toxic work environment. Limiting highly individualistic competency measures while maintaining the ability for effective individual placement is addressed in Section 4.1.

3.2 Team management

The second objective of the interviews is centered around team management. This work focuses on both individual factors and the implemented process. When speaking of team management from an individual perspective, the overwhelming consensus leading to successful teams is maintaining group coherence, as mentioned in 17 interviews. The development of a shared understanding by team leadership continually leads to more efficient teams and improved project outcomes. Additional factors, such as personality characteristics, were mentioned in four interviews, and incentive structures, were mentioned in two interviews. Based on the frequency of responses from the interviewees, the following review focuses on the *group coherence*, primarily shared understanding, and *process management*, in the form of a structured management process.

3.2.1 Group coherence. One of the most influential factors internal to an organization when performing NPD is the ability to build a collective understanding of the task (Bittner and Leimeister, 2014). Multiple studies have confirmed this phenomenon showing improved success of teams with a shared understanding (Ball *et al.*, 2020; Ball and Lewis, 2018b; Koutsikouri *et al.*, 2008; Langan-Fox *et al.*, 2004; Mathieu *et al.*, 2000; Mohammed *et al.*, 2010). Building a shared understanding within heterogenous product teams requires a top down approach of aligned objectives along with a bottom up realization of integrated project components (Austin *et al.*, 2007).

Dong *et al.* (2004) review design documentation and verbal communications of student design teams to compare performance and semantic coherence (Dong, 2005). They found positive correlations between semantic similarity and team performance, agreeing with previous studies (Ball *et al.*, 2020; Martin and Foltz, 2004). These studies however take a posteriori approach by reviewing previously completed projects and their respective documentations. Limitations remain as to how to foster a shared understanding throughout the development process. The realization of a shared understanding requires management to remain cognizant of individual differences such as personalities and individual motivations (Ball and Lewis, 2017; Chiu *et al.*, 2016; Peeters *et al.*, 2006; Reilly *et al.*, 2002; Van Vianen and De Dreu, 2001). To address the literature while supporting industry application, a conceptual managerial support model is proposed in this work that provides a visual representation of shared understanding allowing for management to effectively map project components to the overall development process.

3.2.2 Process management. As extracted from the interviews with senior management, 19 interviewees mentioned that NPD projects at each organization follow a structured management process. Four structures are identified: the stage-gate system (Cooper, 1990) with 16 mentions, Tuckman's team development model (Tuckman, 1965) with 5 mentions, V-Model (Forsberg and Mooz, 1991) with 2 mentions and a recent transition to the agile approach (Beck *et al.*, 2001) with 9 mentions.

The stage-gate system consists of initial ideation followed by multiple stages and gates, before a postimplementation review. Gate 1 is the initial screen when decisions are made to commit resources. Following this gate is the first stage, or preliminary assessment. This stage gathers information for marketing, design and technical aspects of the project. In Gate 2, the project is reevaluated and the decision is made to continue with product development. Stage 2 consists of further evaluating the market and technical requirements of the project. Gate 3 is the final gate before entering development. Following this gate, large financial investments are undertaken. Stage 3 consists of the actual development of the project including testing, marketing and operation planning. Gate 4 reviews the development process before entering Stage 4 where validation occurs. During Stage 4, the product is tested to ensure performance and pilot studies are performed to gauge customer reaction. Finally, the development enters Gate 5 where the decision is made to enter full production, which commences Stage 5, or commercialization. Following the stage-gate process, a postimplementation review is conducted, marking the end of the development process.

Tuckman's model focuses on the psychological development of teams, divided into four primary stages: Forming, Storming, Norming and Performing, followed by the Adjourning stage. During the Forming stage, groups are to understand what is expected of them based on the nature and boundaries of the task. Next, during the Storming stage, the team works through intragroup conflicts where individuals focus on an emotional response to the requirements of their tasks. The Performing stage is where shared understanding is emphasized and in-group consciousness is developed. It is at this stage that groups tend to become more cohesive and begin working as a functional unit. Finally, in the Adjourning stage, the group disbands and beings a process of self-evaluation.

The V-model allows for a visualized relation between system engineering and the project cycle (Forsberg and Mooz, 1991). The left side of the "Vee" represents the decomposition and definition of project activities, also known as the "waterfall." The right side of the "Vee" presents the integration and verification flow of project activities. In a project cycle, developments begin in the upper left where user needs are identified and finishes in the upper right, where a user-validated system is completed. Movement within the "Vee" structure provides a structured approach to the activities of the system engineer, addressing the technical aspects of the project and their relation to the sequence of project events.

The agile development process, originally introduced for software development, is centered around 12 main principles outlined in the agile manifesto (Beck *et al.*, 2001). The primary philosophy behind agile development is the ability to quickly and effectively deliver working solutions while responding to changing requirements at any point in the development process. Recent effort has been made to introduce agile and stage-gate hybrids while applying them to product development (Ciric *et al.*, 2018; Cooper, 2017; Cooper and Sommer, 2016). This novel approach has limited industry application and is not mentioned throughout the interviews.

Using the findings from the industry interviews and academic research, next we propose a model that addresses the frequently mentioned influential factors in team composition and management.

4. Comparing research to practice

Overall, it was found that the industry generally applies *ad hoc* methodologies when selecting individuals for NPD efforts and follows rigid process management when moving through the development process. Academic research has postulated methods of improving individual selection through competency decomposition and structured team member placement while continually making advancements in the efficiency of current process management techniques. A disconnect becomes apparent when viewing the applicability of academic methods in a company setting.

This work focuses on reducing the disconnect between industry and academia by presenting a conceptual, dynamic and easily adaptable management model. The primary component of an effective conceptual model increases the structure to individual placement, while limiting the granularity of individual descriptors that are found to increase intrateam conflicts. This conceptual model must also drive NPD efforts toward increased shared understanding to support overall collaboration of interdisciplinary teams. Finally, the proposed model must be able to coincide with commonly mentioned and highly structured process management approaches, allowing for a low cost attributed to implementation. Each frequently mentioned managerial considerations determined from the interviews and how they are addressed in the model is summarized in Table 3.

The following sections present a two-dimensional positioning map addressing these influential components. First, it supports structured individual placement. Next, it provides a visual representation of shared understanding. And finally, it remains easily adaptable to support the ease of implementation.

4.1 Aligning resources and complexity

One of the leading factors encouraging the application of academic research within an organization relies on a model's ability to adapt to dynamic changes, as developments are

Table 3.
Managerial considerations for team performance

Managerial considerations	Interview mentions	Addressed in model
Team composition		
Resource availability	18 (85.7%)	Visual understanding of individuals working on development
Individual competency	18 (85.7%)	Conceptual representation of where individuals are placed within project
Team management		
Shared understanding	17 (81.0%)	High-level understanding of positioning within project
Stage-gate system	16 (76.2%)	Ability for continued movement mapped to each stage gate
Tuckman's team development	5 (23.8%)	Alignment of stages to movement throughout the development process
V-model	2 (9.5%)	Adherence to cascading and verification functions
Agile	9 (42.9%)	Allowance for flexibility and dynamic changes

seldom a linear process, while maintaining a low cost of implementation. This paper proposes a two-dimensional positioning map relating product complexity to the interaction of contributing individuals to be used to conceptually model product management beginning at the project's inception and continuing to market (Figure 1).

We position the combination of factors leading to successful team developments from both a team composition and system realization perspective that can be positioned on the two-dimensional positioning map. This conceptual model is used to evaluate the current location of project components to support the identification of adjustments that can be made to improve the development process while adhering to current process management approaches. This model also facilitates a shared understanding within the group in the design process as product managers can assess where they stand with respect to product complexity and individual allocation to determine if they are located in an optimal position

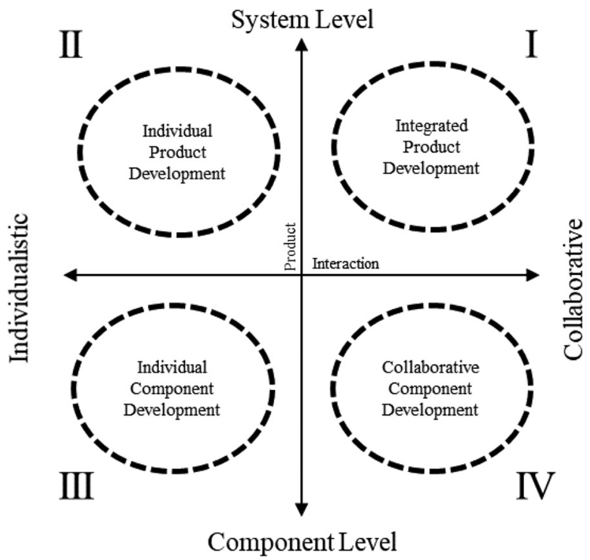


Figure 1.
Conceptual product complexity vs individual interaction positioning map

with respect to the factors that were recognized to lead to successful teams. This evaluation can be integrated into the commonly used stage-gate system and aligns with Tuckman's stages of team development. Additionally, components of agile are addressed through the ability to remain flexible and dynamic through iterative and accelerated developments. This conceptual model is not to replace managerial experience, but rather to support their decisions through a structured process.

Here, the vertical axis represents components of a *product* as their perceived complexity with the extremes ranging from singular components to entire system realization. Traveling between these two extremes requires an initial understanding of predicted product composition, extracted from a firm's previous developments of similar products based on the experience of management, marketing and designers. Structured decomposition of project attributes can be informed through the use of a DSM, as highlighted through academic literature; however, placing component complexity on a relative scale limits the requirements of detailed decomposition, a feature required for industry application in NPD. Throughout the product development process, this axis becomes more refined through iteration as the details of the true product composition are determined.

The horizontal axis represents the *interaction of individuals* involved in the product development ranging from a single contributor to the entire development team. Traveling between these two extremes allows for the creation of subteams as the collaboration of individuals increases. At the onset of a project proposal, individuals are positioned based on their perceived competencies and the mapping between ability and an aspect of a project's predicted requirements. This axis acts as a surrogate for cognitive capability and an initial understanding of each individual's general competencies is required to make effective initial placements. This approach aligns with the identified industry limitations on highly granular and quantifiable performance metrics that could lead to toxic work environments while still allowing for informed decisions of individual placement.

Each quadrant represents key development areas. As determined from interviews with industry professionals and the above review of the literature, system-level product developments must trend to the upper right quadrant throughout the development process to create successfully integrated products. The placement and subsequent movement of individuals is performed iteratively, corresponding to a firm's desired process management approach, examples of which are outlined in the following sections. In addition, the iterative movement of individuals aligns with an agile development as these moves respond to frequent changes in requirements.

Quadrant I – True integrated product development encompasses collaborative effort at the system level (Cagan and Vogel, 2020). Projects near completion must trend toward the upper right allowing for the inclusion of efforts from designers, engineers, sales and marketing. At this point the voices from all stakeholders must be considered.

Quadrant II – Throughout the product development process, processes may trend toward individualistic product development, however final project aspects should avoid this quadrant as this leads to disjointed product components leading to suboptimal final outcomes. This quadrant is designated as individual product development.

Quadrant III – At multiple phases in the development process, individuals are working on single components. Positioning the development in Quadrant III shall be completed near the project initiation, however as the project progresses, effort must be placed on transition to the upper right quadrant. This quadrant is designated as individual component development.

Quadrant IV – Similar to individual component development, Quadrant IV exists near the initial phases of the project timeline. Components that require additional considerations from multiple engineers because of increased complexity trend toward this quadrant.

Throughout the project's timeline, the positioning of individuals within the development process transitions was based on the current development phase. Based on the manager interviews and the standard baselines of formal NPD methods, in the following section multiple phases of the NPD process are explored and the suggested movement between quadrants is proposed, placing emphasis on key personnel from engineering, marketing and management. The goal is to help managers consider complexity, composition/decomposition and management of teams through different phases of system-level product development. The primary instances for evaluating the positioning of individuals throughout the development process are shown in Figure 2. First, this paper will align the conceptual positioning map with the stage-gate system as it was overwhelmingly identified by industry managers as their standard management process. Second, this work will consider the application of the positioning map within the V-model as this process was also mentioned as a common development process.

4.2 Stage-gate system

4.2.1 Onset positioning. In the early phase of an NPD initiative, contributors are positioned based on the perceived complexity and predicted requirements of the project, while relating to the overall project goals and addressing the requirements for industry adaptation. This process heavily relies on managerial experience as the decomposition of required tasks and an understanding of individual ability is a fuzzy phenomenon. Product development subteams composed of a multidisciplinary group of engineers and designers are placed in Quadrant IV. Here, the engineering teams can further decompose their subsequent tasks before altering the positions of individual members. Marketing and sales are initially placed in Quadrant I ensuring a collaborative understanding of the overall product. This provides a top-level view into the customer requirements and how they integrate into the overall product. Early-stage positions are shown in Figure 3, aligning with Tuckman's Forming stage.

The early phase of development remains a highly collaborative effort. All members are initially placed by management near the right side of the position map ensuring the onset of a shared understanding of project requirements and goals. Engineering subsystem teams trend toward the component level of the product in an effort to decompose the required technical aspects of the development, whereas marketing subsystem teams trend toward the product level to ensure adherence to customer values. This phase of the design aligns with

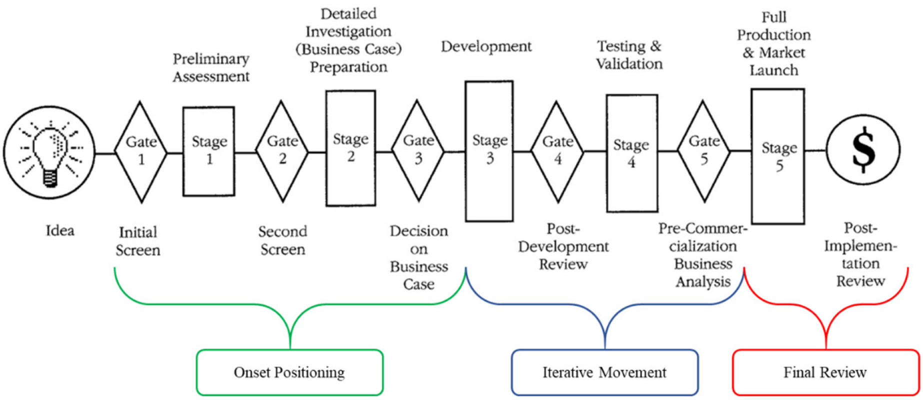


Figure 2. Primary evaluation instances related to the stage-gate system

Source: Cooper (1990)

Stages 1 and 2 of the stage-gate system. Before any large financial investments are allocated, the project manager is to consult with marketing, design and engineering to complete both initial and secondary screenings, ensuring that they have the resources available to complete the individual positioning.

Early positioning of members addresses the needs found within the industry interviews when relating to a relatively unstructured process of assigning individuals to specific roles. Here, product development managers can create a visual understanding of the initial team composition while maintaining a level of shared understanding. This process also touches on the limitations of optimal individual placement based on specific individual competencies recommended by the academic literature. General positioning supports the desire for a more structured process of team composition while adhering to the limitations of precise individual placement.

The onset positioning of members also allows for the development of the team dynamics, coinciding with Tuckman's Forming stage. Individuals placed in these initial positions relative to the overall project can begin developing interpersonal relationships among other members in their near proximity. As the development of the project continues and new information is discovered, individual roles are introduced and the process transitions into a development phase with iterative movements allowing for agility within the process. Onset positioning concludes at Gate 3 of the stage-gate process before entering the development stage where the next primary instance of individual positioning occurs.

4.2.2 Iterative movement. Following the initial positioning, individuals are allocated to locations specific to their required tasks. Marketing and sales remain at the system level, however they begin to trend toward individualistic roles to be mapped to specific project attributes. Engineering subteams are further decomposed based on project requirements and individual specialties. The movement of individuals is shown in Figure 4.

Engineers of a specific specialty are moved into Quadrant III where they perform tasks related to specific project components following a decomposition of project requirements. System engineers ensure product-level integration and act to connect discrete components

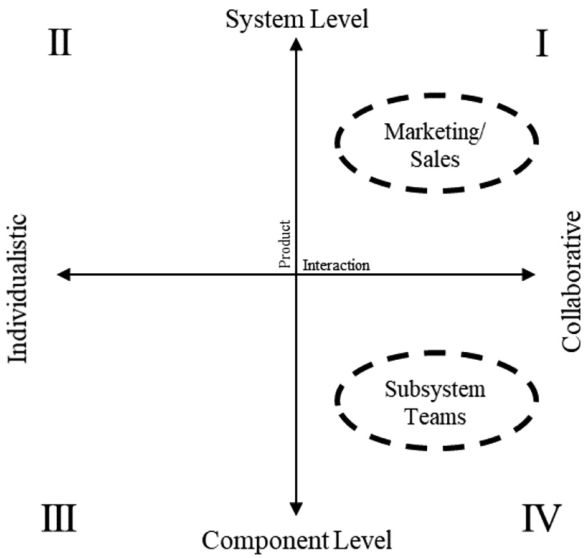


Figure 3. Individual placement at project onset

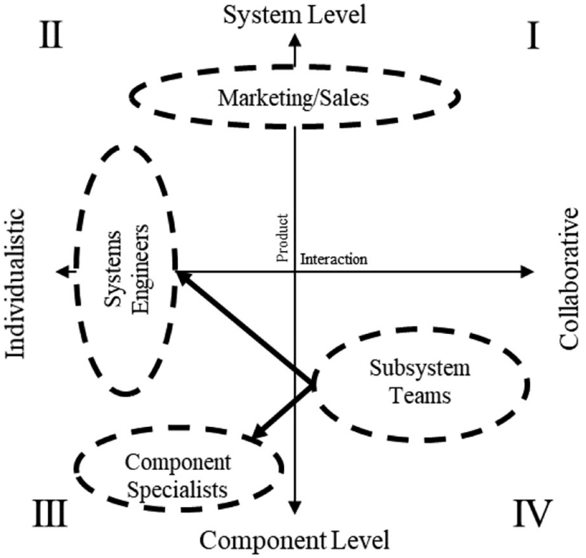


Figure 4.
Initial individual movements

and the entire system. It is at this point that individuals diverge into their respective roles while retaining an understanding of the bigger picture. In relation to group composition and process management, the initial moves align with Tuckman's Norming and Storming stages and Stage 3 of the stage-gate system. From the psychological standpoint of Tuckman's system, teams are focused on the characterization of their tasks and any intragroup conflicts. When conducting the managerial review of Phase 3, leading into Stage 3, individual activities can be identified and explicitly allocated.

As design is an iterative process, individuals are continually moved based on new and relevant information. As component design is completed, it is integrated into system-level considerations, trending toward the upper right, or fully integrated design. Continual movements align with Tuckman's Performing stages and Stages 3 and 4 of the stage-gate system. Managerial oversight ensures that moves are not made that reduce product integration resulting in disjointed efforts.

Iterative movements align with the identified industry need for greater structure in team composition. During iterations, individuals can be systematically included, removed or repositioned within team efforts based on the identified project needs and how they relate to the overall development effort. These moves also address the limitation of currently proposed methodologies in academia as specifically determined individual competencies are not required. Additionally, the practice of iterative movements aligns with the current drive toward incorporating agile developments. The flexible and dynamic positioning of members, as required of agile developments, can be properly informed and visualized in relation to the overall project goals.

Following Gate 5, the final primary instance of evaluating individual positions occurs in the form of a final review.

4.2.3 Final review. The final stages of managerial oversight focus on the adjourning stage of Tuckman's model and Stage 5 of the stage-gate system. Here, the project enters commercialization and the team reviews lessons learned. Individual placements are reviewed and the final product is assessed to ensure that an integrated product development process was followed. If issues arose during the development process, they can be traced back to their root cause albeit incorrect positioning or disconnected project attributes. Future development teams benefit from the previous understanding of how individual positioning impacted overall product performance and the impacts related to group coherence.

4.3 Relation to the V-model

Beyond the stage-gate system, two interviewees state that they currently develop products using the V-model (Forsberg and Mooz, 1991). The V-model is similar in nature to the stage-gate system, however it emphasizes the decomposition of the overall product into specific components. An example of the V-model for vehicle design is shown in Figure 5.

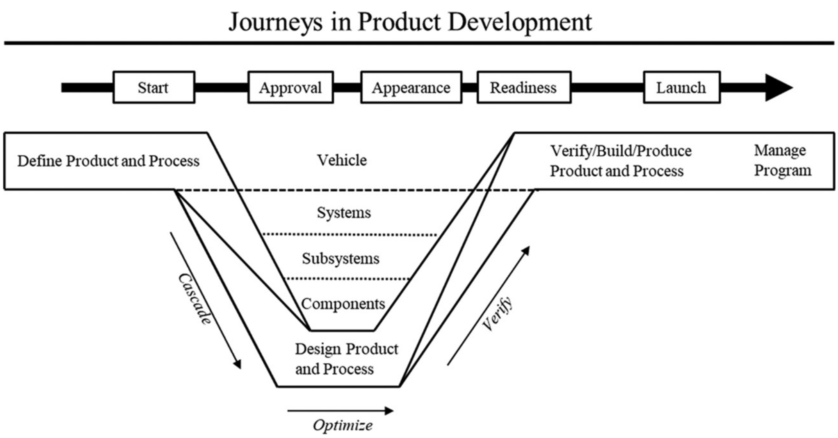
In relation to the proposed positioning map, cascading from the vehicle level to the component level represents a move along the vertical axis from the top to bottom. During this process, the product is decomposed into the specific components before they are optimized. When product managers are performing this decomposition, the placement of human resources becomes more individualistic as it trends toward Quadrant III.

Following the optimization of components, individual positions are to trend toward Quadrant I, aligning with the verification of component integration while maintaining a shared understanding of the overall product. Trending toward Quadrant I leads to an increase in the interaction of individuals as the product development trends toward the system level. Individuals, subsystem teams and system teams can be easily identified on the positioning map shown in Figure 6.

The location and movements of individuals remain within the areas identified as leading to successful developments as identified by the interviewees. This process creates a structured method of individual allocation while also fitting into the identified process management methods.

5. Discussion

This paper presents a highly adaptable conceptual visualization of individual positioning correlating to the development phases found within the NPD process allowing for continued analysis and mapping of individuals throughout the entire design process. Following the



Source: Otto and Wood (2001)

Figure 5. V-model for product development applied to vehicle design

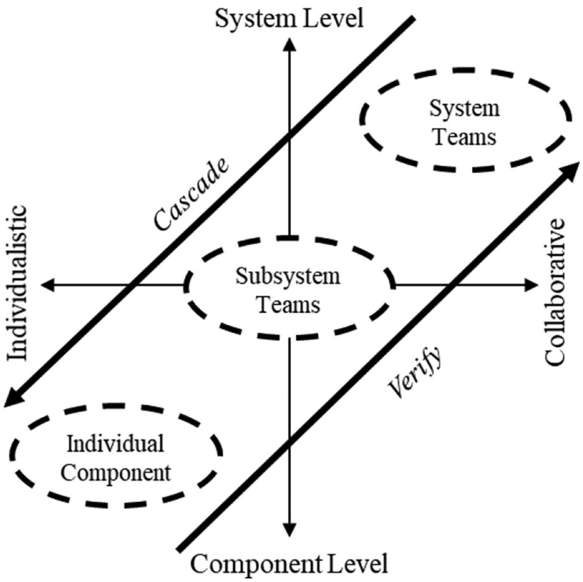


Figure 6.
Alignment of V-model to positioning map

flow across this diagram, individuals understand their dynamic responsibilities and how they correlate to the remaining design activities. From interviews with industry professionals, the influential factors leading to successful developments are addressed within the proposed two-dimensional positioning matrix, summarized in Table 4.

With respect to team composition the two primary factors, human resource availability and individual competencies are used to determine the initial positions. Based on a predicted decomposition of development tasks, individuals are to be placed where their efforts can be efficiently used. This addresses the limitation of industry application, as precise and detailed quantification of individual ability and project requirements is not necessary because each axis is relative to the overall team and product. Before entering Stage 3 of the development process, the availability of resources is addressed in combination with individual placement based on competency. Individuals are also informed on their position and role in the overall project, addressing the commonly identified issue of misaligned individual focus.

Considering process management, each move on the positioning map aligns with the highly cited stage-gate system and Tuckman's group development process while allowing for agile

Table 4.
Relation of success factors to model characteristics

Success factors	Model characteristic
Resource allocation	Visual understanding of individual utilization within project development process
Individual competency	Relative positioning to overall team and project based on project decomposition
Shared understanding	Visual understanding of individual position within team structure
Structured process	Seamless integration within stage-gate and V-model processes
Adaptable	Ability for dynamic and frequent changes to individual positioning and team requirements

considerations. Managerial oversight can use the visualization model to ensure that individuals are properly positioned depending on the respective stage. Moving between stages while adhering to proper positioning allows for continual assessment of group coherence ensuring the development process trends toward integrated product development.

The presentation of an adaptable and visual management model allows for the seamless integration into future product developments while allowing for individuals to understand their position within the project. A structured understanding of individual placement can also foster and encourage a more creative design environment as individuals can visually observe how their contributions are related to aspects within the overall system. Minor adjustments on the component level can generate unique solutions that can be traced to the top-level creative system design. Additionally, having a visual and structured understanding of where each individual contribution applies in the overall design can spur more guided creative solutions.

Finally, because of the high investment costs associated with significant process changes resulting from additional training, the simplicity and flexibility of this conceptual model allows for limited to no financial resource allocation. Incorporating this model into an organization's current process management practices requires little modification of their standard procedures while allowing for management to gain additional information into the development process. This factor addresses the limited applicability issue found between academic literature and industry behavior.

6. Closure

This work began with interviewing product development managers from a wide assortment of industry segments. Following these interviews, the identifiable primary factors leading to successful development processes were aggregated, paving way for the proposal of a conceptual management model designed to support product development managers throughout the NPD process. Considering industry requirements for usefulness and application, the proposed management model addresses the commonly found needs of industry. Additionally, the relatively unique requirements of NPD including increased team interaction required creativity in solutions, and overall structure is addressed.

Based on this work, product managers are recommended to continually address the positioning of members throughout the entire NPD process. In the early stages, individuals are to be placed to work on project components with explicit consideration toward the perceived complexity of tasks and individual competency. Throughout the development process, individuals' positions vary based on new information while continued emphasis is placed on maintaining a shared understanding.

This study presents an initial step toward the development of an industry supported NPD tool; however, there exists limitations within this work that must be addressed to further support its applicability. The primary limitation of this study stems from the moderately limited interviewee pool. Twenty-one interviewees were able to provide great insight into their managerial processes; however, this limited number is unable to capture all of the nuances that exist between industries. Unique defining parameters may be required for specific industries, which could be captured by a greater number of interviews, however the current state of this work allows for strong implications across a wide variety of industries. Additional interviewees and industry segments also create the potential to study international considerations and regional customs. Additionally, the use of an unstructured interview process was used to promote an open discussion, however the lack of structure reduces the ability to perform statistical analysis. Future studies have been considered to standardize the questionnaire and increase the breadth of the interviewees while also incorporating automated text processing methods including sentiment analysis, allowing for more statistically significant results. Also, as the interviews were conducted during a period where most employees were working remotely, a follow-up study has been considered for when working conditions return to a normal setting. Finally, the current state of this work is absent of a working case study. To further support the development of this model, an applicable case study should be performed.

Bridging the gap between theory and application within product development teams is a necessary step toward improved product development. Industrial settings require practical solutions that can be applied economically and efficiently within their organization. Theoretical reflections postulated by academia support improved team design, however to achieve true success, they must be applicable when considering product development.

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