Factors Affecting the Use of Outside, Intermittent Resources during NPD

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ABSTRACT

Information technology, globalization, and digital design have all contributed to the changing composition of new product development (NPD). These developments have led to a paradigm shift where continuous resources can be replaced by outsourced resources that are used intermittently throughout the entire innovation process. These resources can be plugged into the project at opportune times thereby lowering fixed costs and speeding commercialization. However, this intermittent use of resources requires appropriate management actions. This study reports on longitudinal, ethnographic case research performed over the span of the product development cycle of two projects. We look at multiple factors that can influence the effective coordination of outside, intermittent resources on the project. We explore critical characteristics of intermittent resources employed by new ventures, focusing on project management, the product development process, and the role of technology enablers such as IT collaboration. We find that technology's role in coordination of resources is less important than the robustness of interaction. Our qualitative study suggests that only when skilled project coordination is combined with precise communication can intermittent resources be effective. We conclude the article with the limitations and directions for further research.

1. INTRODUCTION

For the last thirty years, cross-functional resources have been seen to be at the core of efficient and effective new product development (NPD) [1,2,3]. Ideally, these teams would form at the very front-end of the process and remain intact until post mortems could be performed on the back-end of the project [4,5]. Design, engineering, manufacturing, marketing, and sales resources would contribute to the project in a continuous fashion, providing critical insight and expertise throughout the design process [6]. All team members would contribute within and outside of their normal routine and functional skill [7]. A prescribed benefit of this organizational arrangement is a cross-disciplinary understanding of design considerations earlier in the design process, eliminating costly downstream issues, a critical aspect of front-loading new product development [8].

A classic example of cross-functional resource deployment is the inclusion of manufacturing representatives during detailed engineering in order to reduce the complexity of manufacturing and assembly during and after launch. Firms have experimented with different organization types to find the optimum balance between effective teams and the resources required to run an efficient and effective NPD project. From matrix organizations to skunk works-like teams, firms have embraced the concept of cross-functionality with varying impact. For example, in their recent study of product development best practices, Barczak et al. [3] found that the best performing firms use multiple organizational processes relating to team effectiveness and cross-functional cooperation. Cross-functionality can lead to increased collaboration, which in turn can have positive effects on the project. These include achieving collective goals, and increased harmony among team members - leading to more successful projects [9,10,11]. Cooper's work also espouses the importance of teams [1,2,12]. Unfortunately, the idealized vision of co-located, harmonious teams collaborating collectively to achieve successful innovation is often challenged by global reality.

Current reality in NPD is characterized by globally distributed resources, knitted together by information and communication technology such as digital design, email, wikis, and instant messaging [13,14]. This is juxtaposed with tightening resources and increased competition. Given current global businesses and markets, and the dynamism of the innovation process in general, we posit that current

economics and the drive for ever higher efficiency and effectiveness have broadened the traditional cross-functional paradigm to include a model that favors distributed but selective — discontinuous or intermittent - use of resources to drive project progress [15]. Firms from the largest to the smallest are increasingly looking to distributed resources, often outside the corporation, to improve the innovation and commercialization process. Examples abound, from Apple's use of contract manufacturer Foxconn to Boeing's use of outside vendors in its development and manufacture of the new 787 airliner [16,17]. At the extreme, these outside resources can be used on an intermittent basis, moving past cross-functionality into a new paradigm that minimizes team interaction and selectively engages members only when needed for a specific task. The coordination - or project management - of these resources becomes an all-important issue [18]. In this research, we seek to understand the important project-level parameters of the adoption of distributed, intermittent resources and how these are best coordinated by a virtual project manager.

To study this phenomenon, we selected a sector of firms that, by their nature, are driven to pursue lean approaches to NPD. Lean innovation strives to reduce the use of resources and waste during the NPD process, akin to waste reduction in lean manufacturing. We focus our investigation on the world of early-stage ventures, those firms that are resource constrained both in human and financial capital, and do not have the luxury of ongoing revenue streams to cushion innovation failures [19]. These firms must successfully commercialize an innovation or expire. It can simply be too costly for many new ventures to deploy permanent, co-located employees that follow projects from beginning to end. New, resource constrained firms have to focus on low fixed costs, operating cash burn, and getting to market quickly in order to generate revenue. In order to accomplish more lean NPD, these firms often turn to outside individuals and resources to provide design, engineering, manufacturing, and sales support during NPD and launch efforts [20]. In this research, we explore how the entrepreneurial project manager within the new venture coordinates and controls these virtual, intermittent resources.

We contribute to literature by studying, at the project level, coordination of outside, intermittent resources. These new ventures seek to reduce expenditures and time-to-market. In order to accomplish this, we look at project coordination and control, communication and collaboration. We add to both theory and practice by noting the importance of communication precision, proactive interaction with resources, and collaborative design efforts via well-informed project coordinators. This study represents an initial attempt to understand virtual coordination in a real-world environment using qualitative case analysis. The coordination and control of internal and external resources are essential facets of innovation and new product development [21].

This paper is structured as follows: After developing a conceptual framework, we discuss our research methodology. Next, the case results are discussed. Lastly, management implications are discussed for deploying and coordinating lean innovation in both start-ups and established firms. We conclude the article with theoretical implications and directions for future research.

2. HISTORICAL AND THEORETICAL CONTEXT

2.1. The Evolution of the Organization of NPD Activities

Innovation development and commercialization is a dynamic process [15]. The process responds to changing needs in the marketplace (e.g., the adoption of quality function deployment [QFD] in the 1980s to better meet customer demands), competition (e.g., the rise of industrial design as a key product differentiator in the 1990s [22], or internal factors that require organizational design changes (e.g., the rise of the matrix organization in the 1970s and 1980's to more effectively utilize resources [23]).

For many firms, the post-World-War II development paradigm consisted of functional organizations, which grouped skill sets together to work on specific stages of NPD (e.g., mechanical engineering groups). From a purely functional standpoint, it was an effective way for organizations to build functional expertise. However, this organizational structure, with its silos, was not performing very well with respect to processes that ran across the silos. This is especially true for processes in which downstream performance is dependent on upstream decisions. For example, poorly executed detailed design can have a direct negative impact on manufacturability. Once the product is released to production-ramp, either costly changes to a poor design need to be made, or the manufacturing process becomes more involved and inefficient. In other words, to achieve a high quality outcome often required rework of tasks already completed, which resulted in cost and schedule overruns. Takeuchi and Nonaka [7] noted these problems with functional, sequential development in their seminal publication on new product development. A case study of these issues was General Motors (GM) experience in the

1980s and 1990s. It suffered severe problems with their midsize GM10 (Chevrolet Lumina, Buick Regal, Cutlass Supreme, etc.) automobile line as a result of poorly thought-out designs that were costly to assemble, averaging a loss of nearly $2,000 per vehicle [24].

In the 1980s, with the rise of Japanese companies in electronic consumer goods and automobiles, firms began to reexamine corporate structures more broadly, and more specifically their development processes. What followed was the implementation of the now classic cross-functional organization where different groups were applied to projects concurrently [7]. This increases communication and collaboration among team members, and allows downstream resources to communicate with upstream efforts in real-time.

Collaboration is defined as a process in which two or more individuals or units work together, have mutual understanding, shared resources, and achieve collective goals [25],[26],[9]. Kahn [9] indicates that collaboration rather than simply interaction is a primary factor in NPD success. Cross-functional teams are at the heart of that collaboration. Sosa et al. [27] found that, when teams involved talked to each other as they began to see or anticipate unexpected problems, they were able to mitigate them before the product testing phase of the project, resulting in considerable time and cost savings.

A famous example of co-located cross-functional teams in the 1990's was the Boeing 777 project [28]. Driven by digital design, the Boeing 777 was a widely analyzed project that was heralded as an unmitigated success for the development process, organization, and project outcomes. Co-located multifunctional individuals can readily communicate, especially if in close proximity [29]. This ideal of collocated and continuous collaboration would be located in the temporal, continuous area shown in Figure 1.

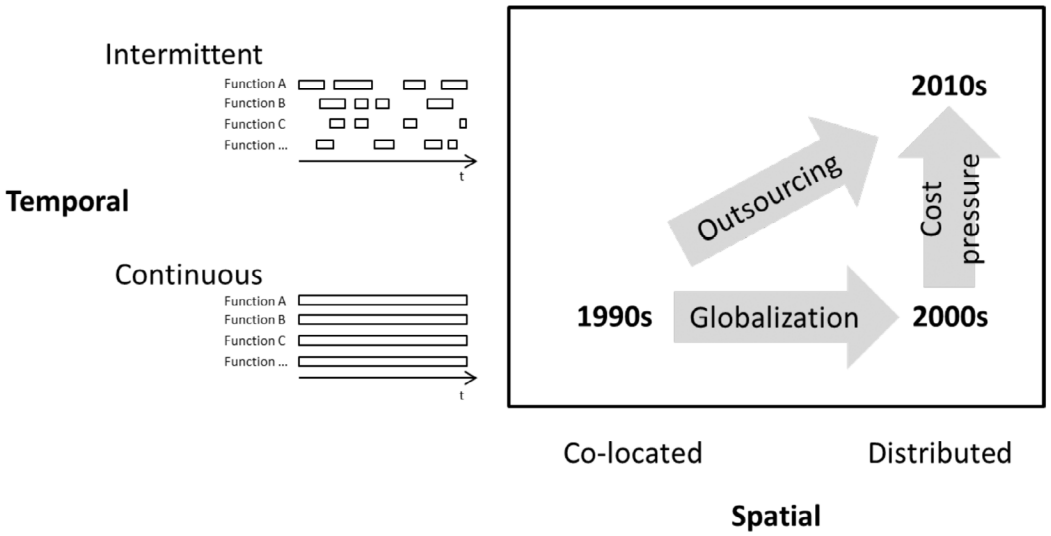

Figure 1. Dimensions of Cross-functional Collaborations.

In the two decades that have passed since initial development of the original 777, multiple factors have arisen that have caused firms to seek alternate development structures and processes. A major factor in this change has been globalization and the associated increase in competition. The rise of Asia as a manufacturing center, and low cost labor and parts, has shifted how firms design and manufacture products. As a recent example of this change, compare how Boeing's approach to developing the 787 differed from the one for the 777 [17]. For the 787, major structural fairings, subsystems, and components were sourced worldwide, to be integrated at final assembly. Seventeen major subassemblies from over ten countries are joined at the final assembly point [30]. Similarly, automobiles, computers, smart phones, and industrial equipment are designed, sourced, and assembled in a distributed manner. While post mortems on the 787 project are still being written, it is clear that many organizations have migrated away from the idealized co-located and often internal cross-functional organization toward a more distributed form, often involving partners and resources outside the firm boundary (representing a shift to the lower right in Fig. 1).

Although not an automatic complement to the shift from co-located to distributed work

arrangements (after all, it is possible that all members of a distributed team works for the same firm), distributed work more likely occurs in outsourced settings. Economists have discussed for centuries the question of what determines the existence of a firm boundary between two adjacent activities. Two main theoretical constructs trying to explain this phenomenon are transaction cost economics and resource-based view. The theory of transaction cost economics (TCE) refers to classic make-versus-buy decisions and is based on transaction theory, where firm decisions are based on the relative cost of options ranging from labor to the cost of manufacturing [31,32,33].

The total cost of development and production for a firm can be viewed as the sum of production and transaction costs [32,34]. Lower production costs in the guise of reduced labor and tooling have been a primary driver in offshoring and outsourcing both in development and manufacturing for the last twenty years. The other theoretical perspective is the resource-based view. Resource-based theory (RBT) suggests that firms have different resources (knowledge, assets, etc.) and that firm performance depends on those firm-specific resources and how they are used [35,36]. RBT is important in the transformation of location of resources during development because the firm decides what resources will be utilized, where they will be located, and what core competencies of the firm will be required. Distributed resources bridge these literatures, and combine to form a theoretical basis for our investigation.

Regardless of whether firms outsource development to third-party firms, or they manage offshore facilities and subsidiaries, collaboration and coordination among the teams remain essential. Jassawalla and Sashittal [37] analyzed the concept of collaboration in the context of NPD by comparing different cross-functional linkages in NPD processes. In their opinion, NPD processes are collaborative and not only integrative. They defined cross-functional collaboration as a type of cross-functional linkage, where participants in the team are characterized by high-levels of integration, transparency, mindfulness, and synergistic tendencies in their interaction. The shift to more distributed, and more often outsourced, NPD processes was accompanied by the rise of the Internet and the emergence of various digital communication tools that helped maintain frequent and rich communication despite the distance between collaboration partners.

In recent years, on top of the pressure to use less expensive resources halfway around the world, cost pressures have now resulted in companies searching for ways to use these resources for only the minimum amount of time required. We label this new form of new product development collaboration intermittent. The guiding idea is that these decentralized resources can be employed on the project when and where needed - in theory reducing man-hour expenditures. These intermittent resources may be an industrial designer located in Milan, a manufacturer located in Shenzhen, China, or a computer-aided-design (CAD) engineer located in Boston. This change is represented by a shift to the top right quadrant in Fig. 1. A typical setting in which this type of intermittent use of NPD resources can be observed is an all means-constrained enterprise, particularly start-ups. Similar to the shift from co-located to distributed work arrangements, the shift from continuous to intermittent work engagement has often been accompanied by outsourcing.

While the degree of intermittency can vary, for the purpose of this paper we consider *an NPD project using collaboration resources only intermittently as one that consists of resources that are temporally, geographically, organisationally and/or culturally dispersed, but yet have to act interdependently, often through technology, to achieve a common goal like a new product, service, system, or organisational process. The team members may differ generally in their kind, position, discipline, and competencies and their membership may be temporary according to the needs of the long- or middle-term project and its dynamic nature*.

2.2. Project Management, Coordination and Control in New Venture NPD

Many new ventures have responded to their dynamic environments by introducing virtual teams, in which members are geographically dispersed and coordinate their work mainly through electronic information and communication technologies. For new firms, this is often driven by the necessity to increase skills and resources available to the founding team, while keeping expenses low. Small firm size presents a significant challenge for the firm that needs to design and implement a new product that requires any level of engineering, manufacturing and launch [19].

Over the last ten years, international cooperation has not only taken place in production, but to an increasing degree in the field of product and service development. In the current atmosphere of increasing pressure to reduce costs and shortening time-to-market considerations, virtual offers the

potential to improve innovation performance [38]. This is particularly important to the new venture that is resource constrained in time, labour, and capital. Antoncic and Prodan [39] found that firms that actively develop alliances and networks aid in firms becoming more entrepreneurial, resulting in performance improvements.

New ventures experience similar project needs throughout the development process as large established firms, pointing to the importance of NPD practices and processes in these new firms [40,41,42]. The Project Management Institute (PMI) defines a project as a unique set of tasks with a beginning, an end, and a well-defined outcome [43]. An early-stage new venture is in essence a pure project, which starts with an entrepreneur's idea, obtains funding, follows agreed milestones during design and development, and ends through on-going operations, closure, or a liquidity event [44,19]. Ulrich and Eppinger [6], state: "new ventures or start-ups are among the most extreme examples of project organizations: every individual, regardless of function, is linked together by a single project - the growth of the new company and the creation of its product(s)." Marion et al. [45] noted the importance of heavyweight project managers in driving the NPD process in resource constrained new ventures.

Many view the entrepreneur as a coordinator [46,33], with the primary role of the entrepreneur centred on the coordination of resources, both within the firm and through inter-organizational contracts [47]. Brentani and Reid [48] coined the term project brokers for managing individuals that synthesize, share, and manage project information among distributed stakeholders in the process to increase efficiency and effectiveness of innovation. Bretani and Reid define project brokers as predominately senior managers who can shepherd projects. Project brokers are not project-level personnel, but the concept denotes an omnipotent authority over project parameters and coordination. For ground-level project management, brokering individuals provide direction and coordination of the team and project tasks. These virtual resources and organizations may interface with one another, but the primary modes of communication exist between the project leader and the virtual resources. For this project-level function, we define the term project coordinator (PC). In this research, we focus on the important activities and attributes of these individuals.

Ideally, firms and their project coordinator could select and integrate particular skills at optimal points in the development process. This plug-and-play aspect could reduce fixed team costs, and would allow management to direct with pin-point precision where skilled assets can be deployed with the greatest impact. For example, industrial designers may be tasked with several discrete functions during the project such as: 1) up-front ethnographic research, 2) developing several concepts that express the research findings, and 3) evaluating design progress during detailed design. This may reduce design man hours substantially versus having an industrial designer on the project full-time from beginning to end. For the project, design is still being performed, but in a more targeted, discrete fashion.

This intermittent use of resources, however, is counter to the findings that team performance increases with close co-location [29] and early involvement of other internal functions as well external partners such as suppliers and customers [49]. This suggests that project management (i.e., the coordination and control of resources) is a critical component of successful NPD outcomes. This role falls to the project coordinator. Meredith and Mantel [50] noted important parameters of a successful project manager. These include the ability to acquire adequate resources, the breadth of communication and collaboration, the type of communication, and the quality of communication. Experience and interpersonal skills are considered essential. Understanding the critical characteristics of the project coordinator and ultimate success of the project are essential to understanding the benefits and pitfalls of using intermittent resources during NPD.

In addition, the use of the Internet in general, and IT tools in particular, has risen with the increase of distributed and increasingly intermittent work, which suggests that IT tools can play a critical role for high NPD performance. More specifically, recent research suggests that the use of IT tools can foster collaboration, albeit moderated by product complexity and task interdependency [51]. With this paper, we would like to drill even deeper into this question and investigate how exactly a project coordinator's use of IT tools affects project performance. Thus, we posit the following research question:

Given that the coordination of only intermittently used resources is more challenging compared to continuously employed resources, what are project management mechanisms and forms of IT tool use that can avoid the otherwise predicted project performance deterioration?

3. RESEARCH METHODOLOGY

3.1. Research Design

In this study, we aim to understand how intermittent resources are coordinated and controlled, and what factors in project management contribute to improved performance in these settings.

Recognizing that virtual intermittent resource deployment occurs at the project level, it can only be made visible by unpacking product development projects by studying them at the level of the engineer and designer. Other studies following the same logic have unearthed formerly unseen relationships between advanced CAD tool use and unanticipated inter-phase workload shifts [52]. In order to encompass the entire product creation process, we include all activities from concept development to product launch. This aligns with the boundaries that other researchers have drawn around the NPD process, although they vary in how finely they segment the individual process steps (e.g., five phases in Ulrich and Eppinger [6], or three phases in Brown [53], Cooper [12] or Marion and Simpson [54].

For project performance measurement, we focus on three typical project-level performance measures: quality, time, and cost [55,56]. We break down these dimensions into more measurable variables such as adherence to predetermined performance, time, and cost targets. We then complement those dimensions with higher-level financial objectives (such as reaching market and earning revenue, which represent key milestones in new ventures).

While the increase of virtual intermittent resource deployment suggests that there are ways to make these rather fragile systems work, there are also plenty of opportunities for project coordinators to get it wrong. For example, ill-structured hand-offs can lead to incomplete information transmission causing expensive rework later. Consequently, we will search for actions and attributes of the project coordinator that mitigate these challenges of intermittent resource deployment for high project performance. More specifically, project coordinators can influence project performance through various control mechanisms.

We include three separate control mechanisms in our study: outcome control, process control, and clan control. Following Turner and Makhika [57], we apply the following definitions: outcome controls primarily focus on the "result that a set of tasks produces"; process controls are "mechanisms that specify the appropriate behaviors and processes in which employees must be engaged"; and clan control "relies upon a socialization process to effectively eliminate goal incongruence between individuals" [57]. As in Rijsdijk and van den Ende [58], we consider all three mechanisms simultaneously.

Finally, as the advancement of electronic communication and the associated fall of communication costs have enabled some of the intermittent use of resources in the first place, it is reasonable to ask whether the use of more, or more modern, tools has an impact on project performance. Thus, we investigate how the project coordinator's use of electronic communication tools affects project performance in an intermittent resources setting.

3.2. Case Selection and Data Collection

With the objective of this in-depth field study to explore how the use of outside, virtual intermittent resources in the NPD process within the space of small, new ventures can be managed, we identified two instances of a product development project that were very similar in terms of complexity of product, number of external resources employed members, and degree of intermittency of resource employment. However, one instance was a project failure, whereas the other was a success. We investigated the reasons for these different outcomes by comparing and contrasting project coordination and control.

Cases were selected deliberately by type of project (multi-part consumer product with embedded electronics and software, SAIC code 3873) to reflect typical entrepreneurial ventures. The case methodology presented here is consistent with the objectives of qualitative research [59,60], and follows closely other qualitative works including Karjalainen and Snelders [61], Brockman et al. [62], and Mabert, et al. [63] that utilize in-depth small sample size case research to develop new product development insights [19]. Our qualitative research included independent factors or variables such as project coordinator specifics, communication, collaboration, and specific outcome measures such as development cost and timing.

To reduce potential sources of bias, multiple data sources were used (interviews, review of internal documents, emails, project wiki posts, etc.) in order to minimize interpretive problems. In-depth investigation and data collection were performed over a multi-year period. The research was conducted

in parallel with the projects, embedding the principle investigator (PI) within the development team as a participant observer. Sub-contractors were engaged in the research to capture marginal performers and aspects of events through correspondence and review of communications (email, etc.). These methods are consistent with in-depth, ethnographic qualitative research.

An ethnographic approach is the most viable research method, given its attributes of helping to understand human behavior and practices within a natural setting [64]. This type of research has grown rapidly in the last decade, and has influenced a variety of research areas including law, education, media, sciences, design, and management [65]. The engineering technology and communication methods used to develop the projects were consistent among both firms and time periods (computer-aided-design [CAD] methods, communication methods, etc.) [66].

3.3. Project Characteristics

The project characteristics are shown below in

Table 1. Sample Project Characteristics.

Characteristics	Project A	Project B
Corporation Type	LLC	LLC
Number of founders	2	2
Equity Finance Type	Self-financed	Self-financed
Industry	Consumer Electronics	Consumer Electronics
Part Count	125	125
Full-time employees	2	2
Part-time employees	4	4
Used outsourced resources	Yes	Yes
Non, co-located resources used	Yes	Yes
Project Coordinator experience	3 years	15 years
Use of in-person meetings	No	Yes
Use of phone and video calls	No	Yes
Use of project wiki	Low	High
Reliance on email communication	High	Low

Projects A and B were conducted in the same new venture and had nearly identical scope; however, different project coordinators (PC) were tasked to manage the development projects. Project A was run before Project B. The project coordinator and most virtual resources were replaced after Project A ended and Project B was started. Project B was considered a complete reboot, clean-sheet approach to the project. Beyond initial specifications, almost no information was shared between the two projects.

The projects fell in the consumer electronics category, requiring mechanical, electrical, and software engineering as well as integration. These types of projects require industrial design, engineering, manufacturing, marketing and sales - and can be argued most resemble a traditional cross-functional project of some complexity. Given that these projects were so similar in their product specification, use of outside resources, and general NPD environment, we were able to distill what managerial actions caused a difference in outcomes.

4. RESULTS

Between the two projects, a PC was used to manage outside, virtual resources. The PC for project A (PC A) had three years of experience. Project B's project coordinator (PC B) was more senior, with 15 years of direct project management experience. While experience is shown to be an important variable in project management, our lens is focused on more nuanced variables in the successful coordination of outside intermittent resources. We first review the projects' use of intermittent resources.

4.1. Intermittent Resource Use

During the discovery phase, both project A and B used outside intermittent resources. Each of the projects used an outside industrial designer to develop conceptual sketches of the product. These designers were then engaged at various points in downstream phases. The designers produced color renderings, brochures, and packaging concepts and prototypes. At each point they were engaged, they

were given a discrete task list to work toward.

During the design phase, more outside resources were engaged to provide design and engineering services. For both projects, these included mechanical, electrical, software, sales, marketing, and prototype services. The use of these resources was similar in both projects, with the exception of sales, marketing and outsourced manufacturing.

In project B, sales and marketing input were not used, and the product team decided to do competitive analysis themselves, rather than outsourcing it. Lastly, project B brought the design input of the manufacturer into this phase. Project A did not do this. While they were selectively asked to review the design, the manufacturer was not a full-time participant in the project. They were asked to review a design, and give feedback on manufacturability and cost. PC B also remained active in the design process, directly participating in the development of concepts and engineering designs with the team, in ways that PC A did not. In many ways, this phase was a co-design effort of transactional collaboration.

For the commercialization phase, both projects sourced outside contract manufacturers. Interestingly, project B staffed a cross-functional virtual organization in their production ramp and commercialization efforts. This included an all-hands-on-deck approach to see through pre-production problems. In this phase, the virtual resources collaborated in a similar manner to a traditional cross-functional organization.

There is an important characteristic to note regarding the command and control of the resources. In all instances of project B, PC B acted as the information conduit among the team. Communication between the outside resources was virtually non-existent. Direct communication would flow between the resource and the PC, who would decide the next course of action. This would be followed by a project wiki post, and followed-up via a text or call. Because project A was halted before commercialization, data on this final phase does not exist for the project.

4.2. Project Outcomes

In terms of project outcomes, project A was a failure. None of the project goals was met. The project ran over budget and behind schedule, and the functionality of the product fell far below desired specifications. The founders were extremely upset with project progress, appearance, and functionality of the product. In fact, one of the founders was brought to tears based on one of the prototypes. The project was halted before the product could be commercialized. Project B was completed on time, but exceeded budgetary estimates because of unforeseen technical issues regarding system integration between software and hardware design that required additional engineering man hours.

The concepts for design engineering for project B were well received, and the project proceeded to be manufactured and commercialized. The product reached market in late 2012. As of this writing, the company is still selling the product. We were not able to gather data on sales or product margin.

4.3. Outcome Control

In terms of project outcome control, there was clear distinction between the Project A and B. Project B had clear goals and monitoring of team tasks. The Project Coordinator on Project B was very persistent and somewhat heavy-handed in terms of following-up on tasks, hours spent on tasks, and reviewing schedules with team members. This did not occur in Project A. For example, in the critical task of ensuring a printed circuit board design could fit into a housing and interface with control buttons, PC A was rather lax in following-up with the electrical engineer (who was located 1000 miles from the PC). Here is a sample of emails from PC A to the electrical engineer: *"Can you give me a call tonight? I'd like to know where the 'Project A' stands. I also sent you a sample of board / enclosure and I'd like to hear your thoughts. Thanks." Four days passed with no response, and a second email was sent to the electrical engineer: "Just checking in on the progress."*

From PC A's perspective, he was diligent in email requests for communication and technically is on top of the situation. However, there is a difference between a request for an update and proactively retrieving the required information. In unpacking this further, we see that PC A used email 30% more than PC B. Conversely, PC B used telephone communication 30% more.

As shown above, the emails lack a sense of urgency on the project. This is different from what was observed in Project B. PC B used telephone and instant messaging frequently, in some instances being unrelenting in seeking responses. This is one of the main reasons for the increased use of telephony. Often, PC B would post a project comment on the wiki and then wait for a response. If there was a lack

of response, PC B would troll indication of a logged on team member (a feature available on Google's electronic mail [gmail]). A chat would then ensue and, based on importance, a call might be scheduled. As example is this gmail chat between PC B and an industrial designer: *"Hi - can you talk this afternoon (by phone)? We need to wrap-up Project B. Thanks." The designer replied one minute later with: "good morning (to PC B)... yes - - anytime this afternoon - - it will be done today." PC B replied with the following response: "Great. I'm wondering if we can get a prototype of the packaging as well."*

There are several nuances in this brief chat. First, PC B waited until he saw the designer online early in the morning. As soon as the chat service indicated the designer's presence, PC B initiated communication. Lastly, this conversation was followed by a Skype call later in the day, where project issues, tasks, and delivery dates were reviewed in real-time with a video call.

In terms of task management, although PC A and PC B both relied on a project wiki, where all members of the team were members of the project knowledge and information repository, PC B was more crisp in specifying tasks and following-up on them. An example is the use of short videos. PC A used screen capture videos to generally describe changes, then post the link to the project wiki. While these can be informative and visual, there is no mechanism to identify or track specific actions for the team. PC B however, specifically itemized each task (such as packaging design or modifications to CAD design) on the wiki and listed specifics on what needed to be accomplished in each area.

In this example, PC A used a short video to communicate task items, but nothing written to follow or track. In contrast, PC B has specific tasks that are also included in a task milestone spreadsheet posted on the home page of the wiki. The difference in the crispness of communication and task management is also apparent during important design communication. Here is an example from the project wiki on similar design issues from project A and B. In describing required design changes, PC A comments on the project wiki to the mechanical engineer: *"Yup, your [sic] right... How about designing some button extensions that we can SLA (a rapid prototype)? Looked a bit online for the button extensions and didn't see what we were looking for... Pic of holes looks good." In contrast, PC B notes that: "Yes, speaker should be under the mouth. Let's put small holes for speaker outlet there. Also, we need to include the post buttons in the Solidworks model. Regarding the wall thickness, if the overall size is smaller (and it is), I'm fine with 0.06."*

The communication of PC B is more authoritative, pointed, and descriptive. This allows the engineer to understand the communication clearly, and proceed with the tasks.

4.4. Process Control

For process control, neither PC A nor PC B followed detailed team procedures. This is typical of start-up environments [45,19]. While neither virtual team followed written procedures, there was some formality in how both teams approached communication.

Both projects employed a wiki space where files, blog comments, and postings were shared with team members. Only project B's coordinator defined a process and monitored that process. This process was based on a project wiki, where team members would post near-daily updates for review and comment. Continually, project B's coordinator would prod team members to use the wiki rather than email. This echoes the findings in Marion et al. [19], which noted that new venture teams approach the NPD process differently than large, established firms. They found that new ventures often run by milestone, rather than to defined processes and procedures. This is supported by other research, such as Brockman, et al. [62], who noted that NPD teams may obtain motivation at specific milestones - creating a strong atmosphere of commitment.

However, differences were found in how each PC approached these informal processes. PC B was very clear to team resources in declaring that all communication outside of phone or Skype calls were to be posted on the wiki. PC B stated: *"email traffic was reduced, as all back and forth communication on design would be done on the wiki, to ensure information is tracked."*

This informal procedure worked well for the team. In fact, project B had 50% more lines written on the project wiki than project A. In contrast, PC A relied more extensively on emails. In terms of team monitoring, because project B relied more on wiki postings, project progress and use of the tools could be more readily tracked. In fact, PC B regularly checked wiki logins to ensure participants were logging into the system and viewing updates.

4.5. Clan Control

In terms of clan control, project A and B results were mixed with differences in their approach. PC A did not develop a strong sense of unity among members, while PC B did. In investigating their differences in developing unity, it was found that PC B met in-person with several team members at various points in the project, while PC A did not. PC A relied solely on remote, virtual communication. As an example of this *ad hoc* meeting schedule during a critical design integration phase, PC B posted this on the project wiki: *"Need to meet to discuss terminals and slight change to buttons."* Several days later, both met for coffee to review the changes and CAD files in real-time, face-to-face.

PC A fostered a sense of belonging on the team, which was noted by some team members as his friendly and pleasant demeanor. However, this affable demeanor did not go hand-in-hand with a sense of community because many team members were frustrated over PC A's lack of experience. Project B's coordinator had nearly the opposite results. Project B's coordinator was a task driven person, who had high expectations for the contractors. The sense of belonging to the team was not a priority. Both PCs established good working relationships with the team members, and remained on good terms with the team after the project ended.

4.6. Communication and Collaboration

Communication and collaboration tools were used greatly by both projects and their team members. An overall table of communication-type usage is shown in Table 2.

Table 2. Communication characteristics.

Project Communication	Project A	Project B
Email	85%	55%
Telephone and video calls	15%	40%
In-person meetings	0%	5%
Wiki posting word count	788	1550

Project A and B both used wikis extensively, and the wikis were a main focal point of the project and process management, particularly in Project B. As mentioned previously, the project under PC B control used the project wiki 50% more. The predominant method of communication among all the projects was email, although, for the younger PC A, the volume of emails was substantially greater than that of the more experienced PC B. The wiki allowed highly transactional communication between the PC and outside resources.

A main difference between the two coordinators, besides the volume of emails and differences in wiki use, was the use of selective in-person meetings. PC B used these meetings at several points during critical design phases, with the hope of eliminating communication errors in important design elements. While design and engineering are currently globalized and virtual, Project B highlights that there still appears to be a benefit to in-person interaction, or at the very least, the use of video telephony. PC B used both to influence resolution of design issues.

5. DISCUSSION

Both projects in the study used some form of outside, intermittent resources during development. This included the use of industrial designers, and engineers tasked with detailed engineering design of components and assemblies. Both projects used rapid prototyping technologies, driven by their heavy use of digital design. In all cases, outsourced manufacturing firms provided input during production-ramp, with Project B interfacing manufacturing earlier in the design phase. Despite these many similarities, the two PCs did not approach the use of intermittent resources in the same fashion. We will now turn to a discussion of how to explain the performance implications.

5.1. Control and Resource Coordination

In looking more deeply at project management and the project coordinator, project coordinators need to focus on project control. Managing to milestones and providing teams with goals and feedback is important. This echoes the findings of Marion et al. [19] who noted the importance of milestone management for ultimate project success. While lacking a defined process, project B did have some

process control with the use of wikis, messaging, and phone call follow-up that can be considered an *ad hoc*, but not written procedure. Another factor influencing outcomes was the environment fostered by the project coordinator. The unsuccessful project A had less clan control than project B. While enjoying a friendly environment, team members on project A were often frustrated by the PC's lack of experience and direction from the project coordinator. Managers and project coordinators would be well-served to focus on enabling an environment that is focused on goals and targets, while ensuring openness and trust.

An interesting observation was that although intermittent resources were used, ultimately these teams started to resemble cross-functional teams when needed or when the project was in extremis (during resolution of design or manufacturing issues delay production and sales, for example). This was particularly true of project B. Both of these projects had mechatronic elements with embedded software, with increased complexity and engineering needs versus simple consumer products or minor software applications.

In these situations, although the team was cross-functional, the intermittent resources remained primarily focused on their tasks at hand. Inter-task communication and collaboration occurred when a design or manufacturing issue occurred, not by proactive planning or happenstance. In general, the intensity of intermittent resources used increased dramatically as the project neared commercialization, becoming nearly continuous when needed.

Conversely, because these resources are utilized only when absolutely needed, there is a potential loss of planning input early in the process. As Thomke and Fujimoto [8] noted around the importance of front-loading, each of these projects was noticeably light in up-front research involvement. When not monitored, this has the potential to lead to back-loading [52].

For the new venture, managers and project coordinators should consider bolstering intermittent resources up-front in the discovery phase, rather than waiting for input only when it is critical. What is clear is the importance of the role that the PC plays in coordination and control of communication. In project B, the PC acted as the conduit and synthesis for all information. While design input was logged into a team system, resources did not act until instructed by the PC to do so. This can reduce the potential for outside resources to go off on their own, billing a large number of hours for little total project gain, a phenomenon that was symptomatic of project A.

5.2. Communication Precision

Lastly, in terms of digital design and IT, it is clear that these tools were used, but the way in which they were used is as important for intermittent resource use effectiveness. Interestingly, there was a generational difference in communication. The older PC B spoke more by phone; the younger PC A emailed substantially more. The older team members preferred the directness of phone or video calls.

In reviewing emails and wiki posts, it was also noted that older members were more clear and concise in directions to resources. The more pointed communication of design issues of project B's coordinator versus the less authoritative, more ambiguous post for project A's coordinator is an example of the need for communication to be direct and precise, and to eliminate areas of potential vagueness in today's collaborative IT environment.

From reviewing emails and posts, it appears it is the fidelity of communication, rather than type of tool, that is impactful to outcomes. For managers, it is important, as they grow tied to ever more complex digital design and IT packages, that the quality of communication is not overshadowed by the ease and capability of new tools. A pointed, direct instruction is much more impactful than an ambiguous suggestion.

Overall, as answers to our research question of the role of project management mechanisms and forms of IT tool use for the effectiveness of intermittent resource use, our case analysis suggests the following:

(i) While in both projects the use of intermittent resources was prevalent, the actual form of engagement varied substantially across the two cases. The type of intermittent use was similar (engineers, designers, prototyping, and manufacturing). What differed across projects was timing, intensity, and quality of engagement. Our small sample does not allow establishing a conclusive answer to which form is best for product development performance for any project, but our analysis fleshes out that intermittent resource use requires thoughtful and clear project management and coordination.

(ii) Our cases suggest that the skills of the project coordinator are also reflected in the way in which IT tools are used. This is important as it suggests to simply answer the question whether or not an IT tool is used is insufficient to understand how its use affects project performance.

5.3. Knowledge Management and IT Precision

This insight goes beyond advice on how project coordinators should use existing IT tools. It points to the requirements of future digital design and communication tools. In product development projects, both quantitative and qualitative data is generated. Existing digital tools, such as CAD or product lifecycle management (PLM) systems tend to focus on ensuring accuracy and completeness. They can do that only for explicit, mostly quantitative data. However, especially at the beginning (user research) and the end of the process (market launch), substantial tacit knowledge is generated [67] that exists at best in qualitative form.

In addition, throughout the process, data is transferred between parties, which often require a reinterpretation. For all of these tasks, direct and frequent communication channels are often the best mechanisms to minimize the loss in translation. In recent years, wikis and blogs have emerged as digital versions of face-to-face conversations. These tools have two significant advantages: first, they allow a distributed team to have a focused discussion on an issue; and second, the tools keep a record of the discussion. Both aspects make these tools particularly useful for the coordination of intermittent resource use. While there was a clear difference between the PCs' experience and approach to project management, there are differences in their approach to and use of this communication technology. Deconstructing further, PC B used precise communication with a sense of urgency and supplemented these communications with in-person meetings rather than relying solely on electronic communication. Further, when new media tools such as wikis were used, the directness of communication appears correlated to successful knowledge transfer of design input.

In this research, from a project-level, functional standpoint, it appears that the use of new media tools like wikis are able to catalog and transmit casual information such as design directives. These are then input into high accuracy software such as CAD systems. However, there is currently disconnection between the two, signaling opportunity for convergence in the future. We argue that one of the main future tasks of IT solutions will be to bring closer together, perhaps even integrate, the digital tools that maintain data accuracy and completeness with those that allow in a conversational style various team members to understand the meaning of tacit knowledge and qualitative data in the project context (Figure 2). This stands to improve the efficiency and effectiveness of the PC and intermittent team members.

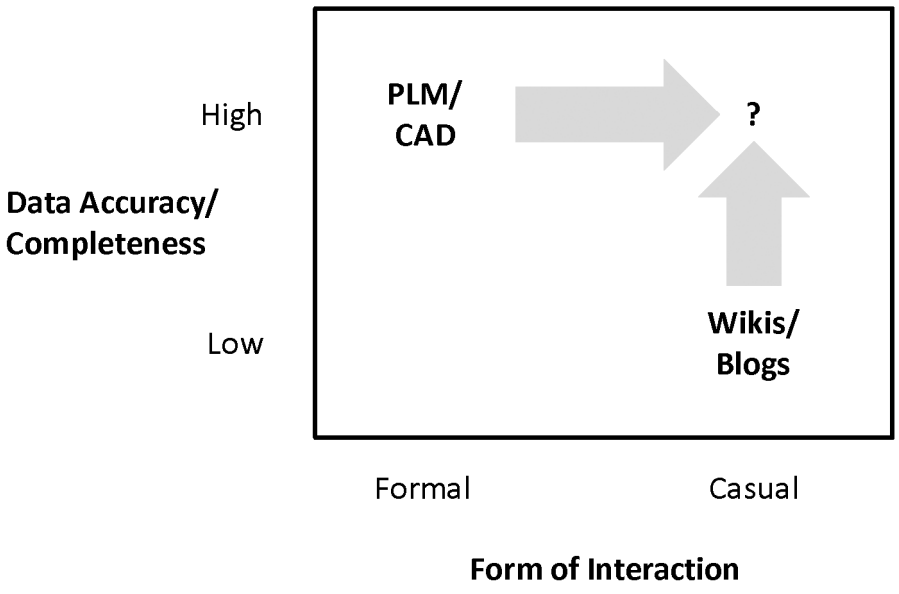

Figure 2: Future of digital design and communication tools.

6. LIMITATIONS AND FUTURE RESEARH GOALS

There are several limitations in this study we hope to address in future research. The first is sample size. While important, the observations from the case studies can only indicate insights into some of the mechanisms at work in teams consisting of intermittently deployed resources, not providing statistically relevant data over larger n samples.

Next, while we were deliberate in our selection criteria (multi-part, consumer products) in order to control for product complexity, future empirical studies should vary complexity and innovation type (incremental versus radical, etc.). In addition, another extension could be to look at the impact of intermittent resource involvement by international region. The firms in our study were headquartered in the Unites States; thus, it would be valuable to compare this sample versus new ventures in China and Europe where there may be differences in financial and human capital pressures.

Lastly, we are interested in looking at the long-term impact of lean development methods for new ventures, exploring the issue of truncating development steps to reach market faster. We would also like to investigate the potential of detrimental impact on ultimate product and firm performance.

To accomplish these tasks, we plan on undertaking a quantitative study in the U.S. and China to empirically investigate the parameters of intermittent resource use and management. A survey will be developed, tested, and deployed to company principles at new ventures, SMEs, and large corporations. We feel that comparing similarities and differences between firm size and age will lead to valuable insights for both theory and practice.

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APPENDICES

Appendix A1. Detailed project data.

Project Coordinator (PC)	Project A	Project B
Experience	3 years	15 years
Degree	BS Eng. Tech., MSTE	BSME, MSE, PhD IE
Gender	Male	Male
Projects Managed	10	100+
Start-up experience	3 years	10 years
Large firm experience	0 years	7 years
Tenure on team	6 months	6 months
Outcome Control		
Team goal monitoring	No	Yes
Cost monitoring	No	Yes
Clear cycle time goals	No	Yes
Process Control		
Detailed team procedures followed	No	No
PC specified processes	No	Yes
Team monitoring to process	No	Yes
Clan Control		
Developed a sense of unity	No	Yes
Fostered belonging to the team	Yes	No
Developed strong sense of community	Yes	No
PC on good terms with team	Yes	Yes
Communication and Collaboration		
Email used	Yes	Yes
Wikis used	Yes	Yes
CAD used	Yes	Yes
Phone used	Yes	Yes
In-person meetings	Yes	Yes
Teleconferences	Yes	Yes
Video calls	Yes	Yes

Intermittent Resource Use	Project A	Project B
Discovery Phase		
Industrial designer	Yes	Yes
Mechanical Engineer	No	No
Electrical Engineer	No	No
Software Engineer	No	No
Sales and Marketing Resource	No	No
Outside Prototyping Firm	No	No
Outsourced Manufacturing	No	No
Design Phase		
Industrial designer	No	Yes
Mechanical Engineer	Yes	Yes
Electrical Engineer	Yes	Yes
Software Engineer	Yes	Yes
Sales and Marketing Resource	Yes	No
Outside Prototyping Firm	Yes	Yes
Outsourced Manufacturing	No	Yes

Commercialization Phase		
Industrial designer	No	Yes
Mechanical Engineer	Yes	Yes
Electrical Engineer	Yes	Yes
Software Engineer	Yes	Yes
Sales and Marketing Resource	No	Yes
Outside Prototyping Firm	No	Yes
Outsourced Manufacturing	Yes	Yes
Project Outcomes		
Process Performance		
Project met planned schedule	No	Yes
Project was completed on time	No	Yes
Project stayed within cost estimates	No	No
Project as costly as expected	No	No
Actual costs adhered to expected costs	No	No
Product Concept Effectiveness		
Conformed to performance specifications	No	Yes
Met technical requirements	No	Yes
Product reached market	No	Yes
Satisfied customers	No	Yes
Currently still on sale	N/A	Yes
Financial Performance		
Achieved market share objectives	N/A	N/A
Achieved sales objectives	N/A	N/A