Linking Technology and New Product Development

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Abstract
This study explores the linkage between technology development and new product development (NPD). Literature suggests that there is a gap between technology development and product development. We develop a set of propositions through review of previous research and a case study from the semiconductor industry. We conclude that for successful integration of technologies into products, a formal technology integration process and technology portfolio management are highly recommended to prevent a misalignment between technology development and product development processes.

1. Introduction
For high-technology companies or companies that are dependent on technology, it is important to link technology development with product development processes for competitive advantage and organizational growth. Even in well-established organizations, product development under a technology development process for competitive advantage and organizational growth. The development process for competitive advantage and organizational growth.

Newer technologies may offer improved performance, but also can create a more challenging and risky product development process. Our findings show that technology integration is affected by both external forces and internal forces of the company. External forces could be defined as: available technologies outside of the company, technological strategies of competitors, and customers’ perceived value of new technologies. Internal forces could be defined as: technology capabilities of the company, technology selection and funding decisions within the company, existence of a separate technology integration unit, company goals, and organizational structure, cross-group collaboration and behavior for change.

2. Literature Review
Linking technology and product development processes efficiently leads to the development of superior products, which enables companies to stay competitive and to grow [1]. This can be achieved only by managing technology and product development appropriately. “New Product Development” has been researched extensively over the past two decades resulting in understanding of the criticality of doing it right. In the PDMA handbook, the definition of NPD is given as “the overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product”[2]. Considerable amount of research is done related to the factors leading to successful new product activity[3-6]. Some researchers suggest that the degree to which a firm is involved in new product activity depends on the extent and nature of its market focus [7-9]. Two behavioral components of market orientation are considered as customer and competitor orientation [10]. Daim et al. identified technology integration and disruptive technology capabilities as critical factors in successful product development [11]. A major part of the NPD research is focused on the frameworks used in the industry [12-21]. This group of literature supports the fact that NPD is influenced positively by adopting a well-defined development process with gates and metrics linked to business goals for decision making. The reason behind the need for a development process is the time constraint in New Product Development. New products need to be introduced to the market at a given time. In order to manage the scheduling and risk involved in new products, companies follow an NPD process they adopt.

“Technology Development” literature shows that in many cases, companies have their own research labs where the technologies are developed. However, technologies might come from many other sources such as; individual engineers, market research, universities, competitors, suppliers, etc. Usually, the aim of the research is exploring basic scientific assets [22]. Creating a separate technology unit that performs both basic and applied research for new technology development is a common approach. Although the scientists in these centers are free to utilize their creativity in selecting research topics, long-term funding for their projects eventually depends on the possible future commercial applications [23]. Since the funding decisions are highly linked to possible future commercial applications, the selection and evaluation of research projects become important. Research on technology evaluation methods includes frameworks,
quantitative and qualitative modeling. New technology selection, funding, and resource allocation are very critical strategic planning issues highlighted by managers at high technology companies [24]. A company can waste its competitive advantage by investing in wrong alternatives or investing too much in the right ones. It is getting more and more difficult to clarify the right technologies since both the number and complexity of technologies are increasing [25]. Pistorius and Utterback incorporated the interactions among technologies, strategies, R&D strategies and competition in their framework [26]. Other dimensions proposed for technology evaluation are market characteristics [27], market lifecycle and natures of technological innovations [28], and technological radicalness [29], just to name a few. Technology based companies rely on renewal of existing technological resources and development of new technologies to remain competitive and to maintain growth [30]. However, in today’s world it is getting highly difficult due to increasing complexity of technologies, convergence of technologies, plenty of technological options and higher technological development costs [31-33]. There are many technology and project selection methods that can be used to assist in the decision-making processes [34-36]. Based on literature these selection methods could be classified under three categories - economic [37-39], strategic [37-39], analytic [37, 40-46]. The decision to choose a quantitative or qualitative method applied to technology evaluation depends on the business objectives of the applying organization. For instance, quantitative methods are applied mostly for selecting or prioritizing research and development (R&D) projects or technologies [47, 48] and developing product-technology roadmaps [49, 50]. Qualitative methods for technology evaluation are mostly used for managing a strategic R&D portfolio [51-53]. Technology selection is a core technology management process which leads to making a choice among distinct alternatives. It suggests the gathering of information from various sources about the alternatives, and the evaluation of alternatives against each other based upon a set of criteria [54]. Using a mixture of qualitative and quantitative tools makes it difficult to define an optimum technology portfolio and this might lead to data surplus [55]. Therefore, technology portfolio managers often select their portfolio using a combination of expert judgment or scoring/weighting methods [56]. This group of literature supports the fact that technology selection, funding, and resource allocation decisions have major roles in the development of technologies. Moreover, being aware of the challenges and barriers and acting accordingly is very critical. Therefore, some challenges and barriers the organizations face are given in the “Linking Technology Development with NPD” literature [57-61]. According to Iansiti, system-focused organizations achieve matching technical concepts, product architecture and process characteristics successfully [62].

3. Methodology

Even in well-established organizations, product development under a technologically changing environment many times results in failure [62-65]. Many organizations’ focus is to understand customer needs and use available technologies in a way that they can bring new products and services to the market to meet those needs. Huang and Mak claim that the failure of a chosen technology is often a result of poor management and unsuccessful change process [66]. There is a need for careful assessment of possible problems in business, technology, and market context before introducing a technology into an organization [67, 68]. Technology integration is the approach that companies use to choose and refine the technologies engaged in a new product, process, or service [62]. It is a set of knowledge-building activities that include exploring possible technologies, evaluating and selecting technologies, adopting technologies, and turning research ideas into successful products [22]. The major gap we see in the literature is that there is no satisfying answer for how to effectively link the technology development and new product development processes. At different levels, companies are already managing their processes and technologies; however, the approaches can be random and chaotic. It is very desirable to have a common view and vocabulary of what is being attempted and how it will be achieved. The major challenge is to create explicit and systematic technology transfer processes [69, 70]. We believe a structured framework can guide companies to consistently achieve technology integration success. Therefore, the main objective of our study is to better understand what is needed for successful technology integration and later, develop a set of requirements for technology integration framework. Case study is one of several ways of doing social science research. As Eisenhardt points out, case studies can be used to accomplish various purposes such as; providing description, testing theory, generating theory, etc. [71]. There are many reasons that led us to choose the case study approach. First of all, case studies are appropriate when conducting exploratory research on complex social phenomenon in real life contexts [71-73]. They are the preferred strategy when “how” and “why” questions are being asked, and when the investigator has little control over events. In our case; the main question we are asking is “how is technology integration performed in large organizations?”. Secondly, case studies allow researchers to observe formal as well as informal processes within an organization and to collect a wide range of data [74]. Third, R&D managers have been found to be positive about case studies and they
tend to support the case study research [75]. In choosing the case-study methodology, as mentioned in the literature, it is very important to develop theoretical propositions to guide data collection and analysis [72]. Lack of a research focus can create a surplus of data [71]. In conducting case study approach, multiple source of evidence were used such as: existing documentation, interviews, and direct observation. We conducted in-depth qualitative interviews with twenty Intel Corporation employees who had been working at Intel Corporation more than 7 years. We collected the interviews and observations from July 2007 through January 2008. All individuals are drawn from a snowball sample of Intel Corporation employees. The individuals we interviewed hold key organizational positions such as; technology architects and planners, platform planners, ingredient planners, program and project managers, and team members. Individuals participated in as many as 2 interviews, and the interviews ranged from 45-60 minutes. Interviews were designed to explore questions; Is technology and product planning done together or separately? Is there a communication channel between technology and product people, if so how does it work? Does just one organization own technology development or are there multiple organizations defining technologies in parallel? Who decides which technologies and products will be developed and how? When do new technologies integrate to new products and how that process is managed? etc.

4. Case Analysis

Intel had been the pioneering computer memory chips manufacturer in the 1970s. Recently they divided the operations into five groups: Digital Enterprise, Digital Home, Mobility, Digital Health, and Channel Platforms [76, 77]. At an early stage, Intel Corporation built its organization around manufacturing and to utilize manufacturing facilities, processes and equipment for the research necessary to advance its products. By 2004, Intel Corporation employed over 6,000 employees in R&D, with a budget of over $4 billion. Most of these resources were dedicated to the Technology and Manufacturing Group (TMG). Its task was to develop fabrication processes for Intel Corporation’s next generation silicon processors and chips. Today, along with industry-leading microprocessor technology, Intel Corporation delivers platform technology solutions that combine processor, chipset, and software. Technologies are developed throughout the entire Intel Corporation. However, the main technology developer is still the Corporate Technology Group (CTG). CTG labs are responsible for basic research. They work on technologies that take between 4-10 years to develop. The labs have a precise role to work with industry partners and other players to resolve standards issues and promote collaboration on future computing platforms. Each CTG lab has an informal line reporting relationship to a business group in which its technologies could progress. This structure was intended to create strong links between the two organizations and ease technology transfer into the business unit’s R&D groups [78]. In addition, each business unit has dedicated R&D resources focused on their next generation products, typically due to ship in 1-3 years [78]. Of the business units, the majority of technology developments come out of Digital Architecture Planning (DAP) which is under the Digital Enterprise Group. The research that is done at DAP is applied research and they work on technologies that could be delivered in 1-3 years.

The data presented in this paper come from a large number of interviews conducted at Intel Corporation from July 2007 to November 2007. The interview data is complemented with Intel Corporation internal archival documents and existing secondary literature. We employed an empirical approach and asked engineers and managers from product development and technology development for their perspectives on why and how Intel Corporation tries to link technology development with product development. Recently, seven technology initiatives have been created to group, fund, and manage the development of technologies. These seven initiatives are: manageability, virtualization, security, system on chip, I/O interconnect, memory, and power. Each initiative has a leader, architect, planner, manager, and sponsor. A program manager claimed: “This initiative structure enables the ownership of technologies and gives single point of contact”. Initiative structure also sets boundaries to technology ideas. If technologists want to get funding for their research, their technologies should belong to one of the seven initiatives. However, just belonging to an initiative is not enough to get funded. Each technology should have strong answers to: is there a value? – performance, reliability etc.; what is the differentiation?; would the ecosystem use this technology?; how much will it cost? (money, time); how much will be the payback?

Once technologies pass the initial screening of whether they are going to be funded or not, they still need to go through technology readiness levels and mature to be integrated into the platforms. CTG and DAP, each has their own ways of screening the technology readiness. However, based on the interviews it could be said that technology development pipelines followed by CTG and DAP have similar phases. One area that needs improvement is the connection between CTG and any business unit. They have some kind of technology portfolio approaches, but not a common one. Actually, what exists is a form of a repository. In that repository one can reach a list of technology projects, however since they are not grouped under
certain portfolios it is not convenient for someone looking for projects that are done or are being done in specific areas. Moreover, there is a need to connect different technology repositories. A technology manager explains: “There is no consistent inventory tool for all technologies. The closest thing is the Technology Readiness which is run under DAP. Technology Readiness is for developed technologies and still not all of the technologies go through it. For instance nothing that Software Solutions Group (SSG) does go into that inventory, they have their own spreadsheet. SSG doesn’t even go through any kind of technology readiness.” For some Intel Corporation people, not having a linkage between different inventories increases innovation and competition. On the other hand, for some Intel Corporation people it creates overlaps, redundancy, and even technology gaps. A principal engineer commented on the output of lacking a corporate wide technology projects inventory by giving examples from Technology Strategic Long Range Plan (TSLRP) that is run annually: “TSLRP is all about technology. It is an annual Intel Corporation-wide call for ideas on technology topics with breakthrough, disruptive potential for Intel Corporation. We only ask for abstract submission. Since there is not a company project database, some of the abstracts get killed by technology council at the first review. They are either projects that are already submitted - even started- and killed or there is existing work on them.” Structure and Efficiency Teams (SET) were created to look deeply into Intel Corporation’s cost structure and efficiency and to drive significant improvements to both. As a result of one of the SET suggestions, a Joint Pathfinding (JP) Group was created in January 2007. The aim of the Joint Pathfinding is to achieve 50% of central research projects run with and on behalf of business groups. The leader of JP explains it as: “Joint Pathfinding started in January 2007. We defined 6 specific projects where joint pathfinding is critical. 150 people from CTG and 150 people from product groups (almost 60 of them from DAP) were asked to participate in this pilot project. Now, we achieved 25% of CTG projects working with product people. Our goal is to achieve 30% of the overall CTG projects as joint projects and in addition to that 10-15% of the projects as business group projects. In the summer of 2007, we started interviewing each of the business groups and asked them what they want us to research. We are continuing the interviews. By the end of this summer, we also built a unified technology database among the CTG labs. This way we can keep track of all the technologies that are developed at different CTG labs.” Another comment on the unified database among CTG; “By having a unified technology database, we can keep track of all the technologies that are developed at different CTG labs; value proposition of technologies, who is doing the work, what is the budget for the technology project, and what readiness level they are at.” Another area that needs improvement is the collaboration between CTG and other business units. Senior level meetings happen between CTG and different business units quarterly. The aim of these meetings is to create a communication channel between the two and be aware which technologies they are working on. However, a principal engineer describes those meetings as: “5 on 5 meetings between CTG and business units take place more in a status update format. Each group talks about what they are working on and why it is important to the other group, instead of discussing which technologies they might work together or which technologies they can transfer to each other.” According to the principal engineer the major reason for lack of collaboration is little incentive for groups to work together, but more incentive to individuals championing their technologies. According to a product manager, technology developers do not want to lose their technology ownerships, they want to be acknowledged with the technology. Therefore it is very rare to see architect to architect handover. The principal engineer said: “Sometimes CTG people work on products, and sometimes DAP people work on long horizon technologies although they are not supposed to. No rigid borders are set.” The third area that needs improvement is the internal technology transfers and transfer decisions. A uniform structure doesn’t exist for connecting technology people with product people. It is mainly personal networks. Technology architects use their personal network to interact with either platform planners or architects. Same happens with the product people. A principal engineer explained: “Product people say it is my product. I don’t need to get any consultancy. If I like a technology I need to put into my product, I will take the risk.” Many technology and platform planners said that technology transfer depends a lot on whom they know. Therefore, one’s personal network and personal skills have a huge role on technology transfer from research to development. As observed by a program manager: “People are so busy with their own works. They don’t know what others are doing and they don’t look at implementation. Sometimes this causes big delays.” A principal engineer adds: “We don’t have a structure where one says we have this product, come and input your technology ideas. There is only POP (product opportunity proposal). But it is too late to have some kind of a forum! However, a consensus among architects and customers should be achieved first. Then, product people become aware of it.” A program manager and principal engineer noted: “The relationship between research and implementation is much better from the DAP perspective. Technology Readiness is helping to improve that relationship.” A product manager underlines the importance of
getting product people involved early in the process. According to him it is very productive. He also says that healthy two-way conversation is crucial for the success of platforms/products. At Intel Corporation, three type of readiness are needed; technology readiness, ingredient readiness, and platform readiness. To achieve the integration of the three, there is a need for a structure that is more than personal networks. Technology planners, ingredient planners, and platform planners use their own skills to overcome the chasm -“valley of death”- which exists in between technology development and product development. Mostly, they decide where and when technologies will integrate, which technologies will be selected, etc. Personal skills and judgments vary. Therefore, this creates another tricky area which is decision making inconsistency. A program manager explains: “A lot of times, it is hard to think of all aspects of the technology: manageability stack, hardware, expected usage, the impact it will create, what the competitors’ reaction will be, is the industry really ready, how much it will cost, etc. You have to win in performance before technology matters. Therefore, a judgment call takes place. It is more experience based; no risk assessment tools are used. Folks talk about things and use their judgment. Technology selection is still not easy...although what is expected for 2010 is known!”

When looked from the product perspective, there are other areas that need improvement. First of all, technology architects start working on the same thing 4-5 years ahead of platform architects. Therefore when the time comes for transition from technology to platforms, in some cases hands-off is faced. Technology people know a lot about the technology by the time platform people are involved, but they need to start working on a new technology. A product manager adds on to this by saying: “Sometimes technologies look good on paper, but not applicable to a specific platform. This happens because no business criteria were applied to the technology. Technology Readiness is not very efficient. Technologies don’t reach to a sufficient level of maturity soon enough to intercept the components. For example, for a CPU you need a mature technology 4-5 years ahead of product launch, where the whole Technology Readiness process is 2-3 years.” Similar to technologists who do not want to lose ownership of their technologies, sometimes product people do not want to integrate technologies that were not developed in their business units. This is called “Not Invented Here” (NIH). A product manager gives an example of this; There was this new memory power technology, which achieves 15% power reduction. The software solution group (SSG) didn’t want to use this technology since it was developed in another group and they were not the enablers. Another area where less attention has been given is the pipeline view of the technologies for the platforms. Platforms search for technologies which are mature and could be integrated in a timely manner. Therefore technology selection decisions are made mostly ad-hoc. Possible technologies that could be integrated to multiple generations of platforms are not explored ahead of time. With each platform, the planning of which technologies to integrate starts over. This creates a disconnection between planning of technologies and platforms. It is apparent that some improvements are needed in Technology Development (TD), Product Development (PD) and also in between them which we call the Technology Integration (TI). At TD, the problems could be grouped under lack of one common portfolio approach and lack of connection between technology developers’ inventories. At PD, the main problems are decision making inconsistencies and lack of pipeline view of technologies. At TI, the major problems arise as a result of missing two way structured visibility, or communication channel.

5. Discussion and Conclusions

Our research revealed that in the area of technology integration, there hasn’t been any theory developed or any cases reviewed or any solutions provided. Our observation confirms that there is a gap. Also the experts we interviewed say that it is required to have a framework to drive technology integration. For successful internal transfer of technologies three things are needed. These are processes, tools and infrastructure, and culture. Based on the literature review and interviews done at Intel Corporation, we developed a set of hypotheses for a technology integration process. The hypotheses are explained below;

Communication channel between technology and product people: In literature, communication is listed as one of the organizational barriers for technology integration. It is highly important to achieve interaction between technology and product people who have different mindsets. The right style of communication can help to decrease the time and money spent for technology development and internal technology transfer. The importance of communication between technology and product people are confirmed by experts at Intel Corporation. Therefore, we claim that existence of a communication channel between technology developers and product developers would improve technology integration.

Single point of contact for both technology and product people: For decision making and communicating between different units, it is important to know who is accountable for what. Single point contacts accelerate the decision making process and reduce the time to reach the right source for the subject matter. It also helps people to stay on track. Intel Corporation created initiatives to be able to group, fund, and manage the development of
technologies. However, the most important aspect of these initiatives is that it enables ownership of technologies and gives single point of contact. Both technology developers and product planners know who the leads are for those initiatives and they work with them. For the technology integration, knowing who to reach for specific technology/product issues and also for collaborating between product and technology development is said to be highly significant for solving the hand-off problem. Therefore, we claim that existence of a single point of contact both for technology developers and product developers would improve technology integration.

**Technology readiness:** As mentioned in the literature, technologies need to be available and mature enough to be integrated into products. Therefore, a process is required to measure the maturity level of technologies. Technology readiness should be able to demonstrate business value, usage models, market-ecosystem analysis, target roadmap intercepts, cost analysis, performance analysis, risk/reward estimation, and technology challenges. Also, the technology maturity levels should have the same meaning both to the technology side and the product side. At Intel Corporation, some cases show that technology readiness problems occur during the integration of technologies to products. The major problem raised by the experts is that sometimes technologies do not work at systems level. According to the experts, root cause is lack of understanding the maturity requirements of technologies for specific systems and technology maturity expectations should be well understood by both parts. Therefore, we claim that existence of a technology readiness process would improve technology integration.

**Technology portfolio:** The importance of R&D portfolio and its requirements are discussed in many studies. By having a technology portfolio approach, companies can keep track of all the technologies that are developed within their organization. The technology projects could be grouped under different portfolios and all necessary information about them could be available. Having a portfolio is efficient both for technology developers and technology customers. Access to technology projects can reduce overlap from technology developers’ side. On the other hand, it can ease the technology selection process of business units since they can easily search for technologies that would meet their needs. Therefore, we claim that existence of a technology portfolio system would improve technology integration.

**Consistent criteria and metrics:** Having the right criteria and metrics to support a consistent and effective decision making process is required. It can also provide homogeneous understanding and comparison bases for technology and product groups. Therefore, we claim that existence of consistent criteria and metrics would improve technology integration.

**Incentive structure that supports collaboration:** Incentive structure is a part of the organizational structure. The culture of the organization and the incentive systems create a collaborative environment. Almost in all interviews, experts mentioned the importance of early involvement of product people in the technology development. Some companies have little incentive for groups to work together, but more incentives to individuals. This might stifle the collaboration between different groups and, it needs to be considered for an effective technology integration process. Therefore, we claim that existence of an incentive structure which supports collaboration would improve technology integration.

**Consistent decision making:** In high tech organizations, decision making has a huge impact on the success of new product and technology development. Managers have to decide on many things such as; which technologies will be developed, how and when they will be integrated into products, whether technology projects will be funded or not, who will be involved in development and integration, when the products will be introduced, and which technologies will be in the products. Also, the technologies are not developed only in one area but in many different areas. Therefore, for the success of the products, technologies, and the company consistency in decision making is required. A set of decision making tools, processes, criteria and metrics can help organizations make decisions in a faster and more efficient manner. Therefore, we claim that existence of consistent decision making would improve technology integration.

**Long term strategy:** Both for technology planning and product planning, having long term strategies is very valuable. Understanding the market and ecosystem, and setting goals accordingly, or in other words having a strategy, supports the decision making process. It also helps companies to manage their resource allocations and respond fast in case of market or technological changes. Synchronizing long term strategy for technology development and product development could help companies to better link the technologies to their products. Therefore, we claim that existence of long term strategies both for technology planning and product planning would improve technology integration.

6. References


