LINKING SITES OF KNOWING IN NEW PRODUCT DEVELOPMENT AND SUPPLY CHAIN MANAGEMENT FOR EFFECTIVE PROBLEM-SOLVING DURING DEVELOPMENT

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ABSTRACT:

Development of new products to a large extend is an act of problem-solving and decision-making. Previous research has examined how problem-solving during development improves as diversity in input increases. Traditionally, this question has been investigated where product development intersects with marketing and the manufacturing domain. As the horizon in research and practice expands and the entire supply chain is viewed as the central unit of competition, rather than the single firm, we consider the intersections between the supply chain domain and product development as important channels for problem solving. In this study, we concentrate on the connection between five development phases and the order fulfillment process. Our focus is specifically on domain specific knowledge which is exchanged as sub-processes connect. Sub-processes in development and the supply chain domain are viewed as sites of knowing. As episodes of practices occur and sites of knowing connect through exchanges, a network is formed that integrates knowledge so that it can be applied for problem-solving during development and during order fulfillment. We argue that the intensity of knowledge exchanges plays an important role for a new product's success. Specifically, we operationalize exchange intensity via a combination of early involvement, communication mode and network connectedness and suggest that the effectiveness of the level of exchange intensity, as an antecedent of product success, is situational and depends on the newness of the product idea. Based on four categories of product ideas, we develop a model of strategic fit, which is intended to aid managerial decision making, before and during development, on how to connect development and order fulfillment. Further, we develop six testable hypothesis that match different patterns of connections as well as levels of exchange intensities with newness of product ideas. We will test these hypotheses with a logistic regression model which uses product success as its independent variable. The survey instrument has been developed and tested by supply chain and new product development professionals.

1. INTRODUCTION

A significant amount of prior research has recognized the importance of the nexus between *New Product Development* (NPD) and *Supply Chain Management* (SCM) (Srivastava, Shervany and Fahey, 1999; Krishnan and Ulrich, 2001; Hult and Swan, 2003, Rungtusanatham and Forza, 2005; Simchi-Levi, Simchi-Levi, Kaminski, 2008). To a significant extent, the importance of the linkages between NPD and SCM hinges on them being enablers for problem solving during product development. Their joint problem solving can support many objectives during product development including (1) configuration of the delivery system for a new product, (2) optimization of product design and (3) alignment of product characteristics with supply chains (Krishnan and Ulrich, 2001; Thaler, 2003; Simchi-Levi, Kaminsky, Simchi-Levi, 2008; Primus and Stavrulaki, 2012). Accordingly, the consequences of their successful joint problem-solving are development outcomes with a better product and a better delivery system. Moreover, better problem-solving performance can translate into implementation of solutions with greater speed (Atuahene-Gima, 2003). Although connecting NPD and SCM can improve problem solving and thus can have a positive impact on productivity and the duration of the development activity, it may also increase project complexity and conflict as more people are involved and more processes need to be integrated early on the development cycle. In this paper we explore this tradeoff and aim to identify the appropriate level of connections between NPD and SCM that will allow for effective and efficient problem solving. Our focus is specifically on domain specific knowledge which is exchanged as sub-processes connect during problem solving.

Since problem-solving strongly relates to practice, we adopt processual perspectives of NPD and SCM. Thus, the unit of analysis of our work is at the level of sub-processes, which we view as *sites of knowing* as described by Nicolini (2010). By focusing on knowledge-sharing and creation between specific sub-processes both the NPD and SCM domains we aim to contribute in a unique way to the understanding of interdependencies between development and supply chains that impact on success with new products. Specifically, our central research question asks "what are the key linkages between NPD and SCM and how can their knowledge-sharing and creation benefit problem-solving to ultimately improve product success?"

Based on prior definitions in literature, our representation of supply chain management sub-processes consists of (1) orders processing, (2) production planning, (3) procurement, (4) warehousing & logistics, (5) production, and (6) distribution (Thaler, 2003; Hult and Swan, 2003). In the product development domain, we concentrate on the five sub-processes of (1) product design, (2) process design, (3) sourcing, (4) prototyping, testing & refinement, as well as (5) launch & ramp-up (Hult and Swan, 2003; Ulrich and Eppinger, 2011). Viewing these 11 sub-processes as *sites of knowing*, and the notion of a site implies that knowing (1) is created and shared as episodes of domain specific practices occur, (2) can be described in spatial and temporal terms, and (3) is observable and can be harvested, because a site serves as a clearing (Nicolini, 2010). We include customers and suppliers as important sites, because their knowing can increase problem-solving performance. For example, customers and suppliers can enhance product design (Von Hippel, 1986; Petersen et al, 2005) or improve forecasting and demand management (Ernst, 2002; Thaler, 2003). The key to managerial decision-making about linkages between the 11 sub-processes is to establish sufficient connections at the right places. However, managers don't want to 'overdose' on connections, because it will (1) consume resources that don't add any benefits, (2) increase complexity and the potential for conflict and (3) delay the time-to-market (Uzzi, 1997; Hansen, 1999). To that end we postulate that managerial decision-making about the appropriate level of intensity can be guided by the degree of newness of the product. This is because novelty represents a situational factor that determines the problem-solving load during the development of the product and its delivery system.

2. INTENSITY OF EXCHANGES OF KNOWLEDGE AND DATA BETWEEN DEVELOPMENT AND ORDER FULFILLMENT

When teams participate in problem-solving during development and introduction of new products they need to create, harvest, share and apply technical and organizational knowledge across functions and domains (Wheelwright and Clark, 1992). However, an increase in involvement does not categorically lead to an increase in product success. Findings by Hansen (1999) at the intra-firm level and Uzzi (1997) at the inter-firm level of analysis suggest that there are trade-off's as operational success sometimes requires a reduction of operational intensity, in particular as complexity decreases. A key reason for this may be that individuals and groups who are tightly linked and involved in intense exchanges experience more conflict situations and difficulty in finding consensus in decision-making processes, which results in a negative impact on productivity. Another reason might be that collaborative communication modes are associated with a high degree of interaction frequency, and therefore absorb a higher amount of resource time (Kahn and Mentzer, 1998). In summary, an exchange intensity that is too high may cause the development project to become unproductive and delayed without any additional gains to be realized. Because different levels of intensity may appropriate in different cases, we need to define and operationalize intensity of knowledge exchanges between development and the supply chain in a way that captures the temporal as well as the structural components of the overall development network. In this study, we define it through three components: communication mode, temporal overlap and connectedness.

2.1 Communication mode

Kahn and Metzner (1998) provide a useful definition for communication modes: interaction, collaboration and a composite mode. Interaction relies on face-to-face meetings, memoranda, telephone conferencing and the exchange of standard documents. Collaboration, on the other hand, is based on shared goals, processes and resources. Shared resources create important boundary objects, which can be an important factor in knowledge transfers (Carlile, 2002). Collaborative groups would view themselves as highly interdependent, whilst interacting groups would be described as independent. Thus, a collaborative mode implies the highest exchange intensity for knowledge, while interaction represents the lowest intensity within the spectrum of communication modes. The composite mode represents a moderate middle ground between collaboration and interaction. In the empirical part of their study, Kahn and Mentzer (1998) established two constructs for interaction and collaboration modes, respectively. Both constructs were developed and tested to measure the communication and integration between Marketing, Manufacturing and R&D departments and its impact on performance. We apply their constructs and the factors in our tests to describe the anchors of our scale for the communication mode.

2.2 Temporal overlap

We propose to measure the overlap between upstream (product development) and downstream (supply chain) activities through timing of the involvement, determined by when and how many elements of the order fulfillment process connect to phases of new product development. An earlier involvement, expressed in a high temporal overlap index, implies higher exchange intensity of knowledge, while a low temporal overlap index represents low exchange intensities within the spectrum of temporal connections. Our scale is based on Pisano's (1996) work who measures involvement of subsequent phases in the development process with a temporal overlap index. The overlap index is high (1 or 100%) when two phases start at the same time. It is at its lowest (0 or 0%) when two phases do not overlap in time.

2.3 Connectedness

Connectedness is a common term in (social) network analysis (Barabasi, 2003). It can refer to a single node in the network, or to the sum of nodes. In our case, the nodes represent the five development phases which may be connected to sub-processes of the order fulfillment process, customers and suppliers. An aggregate measure of how connected the two domains are is the ratio of actual connections and possible connections. This ratio will yield a density value which can be compared across samples with different numbers of nodes.

In our empirical study, we will measure exchange intensity as an aggregate measure of communication mode, temporal overlap and connectedness. Intense exchanges take place, for instance, when those involved in development activities are highly connected, exchanges are bidirectional, start early and a collaborative communication mode facilitates joint problem-solving.

We have already noted above that the impact of high levels of involvement on problem-solving decreases with decreasing complexity. Sethi et al (2001) emphasize that more involvement from other domains during NPD does not lead to higher levels of product success, if problems are already well understood. Managers and researchers alike may therefore be interested in what determines the appropriateness of higher or lower levels of exchange intensity. In the following section, we develop an argument that one answer to this question lies in the characteristics of the problems and solutions that shape the idea for a new product.

3. A BASIS OF MANAGERIAL CHOICE ON HOW TO CONNECT DEVELOPMENT AND ORDER FULFILLMENT – NEWNESS OF PROBLEMS AND SOLUTIONS

In 1994, Hamel and Prahalad argued that "competing for the future" means to be ready to transform unarticulated needs into fresh solutions. In the same spirit, Wind and Mahajan (1997) propose that the value of an opportunity with a new product depends largely on the newness of the idea. They suggest that an idea (for a new product) is composed of a problem and its solution and propose to categorize each component according to its newness. The result is a 2x2 matrix with four quadrants as shown in Figure 1. Wind and Mahajan (1997) argue that the focus in the 1990's was mainly on creating ideas which offered existing solutions to existing problems, whilst the biggest opportunities in the future, but also the greatest market risk, reside in new solutions for unmet needs (Figure 1).

In other words, and specific to our context, newness of product ideas is a two-sided coin: on one hand it can drive product success, but on the other it may introduce greater difficulty and uncertainty into development and supply chain (Crawford and Di Bennedetto, 2008; p.42). Thus, Wind and Mahajan's (1997) work provides a nice framework, which allows us to relate attributes of a product idea to the transformation process as an act of problem solving. However, in their framework the definition of newness, and in particular the aspect of to whom an idea is new or known, is vague. Garcia and Calantone (2002) propose a concept that explains this better. They note that in empirical NPD research, different levels of newness are most commonly measured in terms of *innovativeness*.

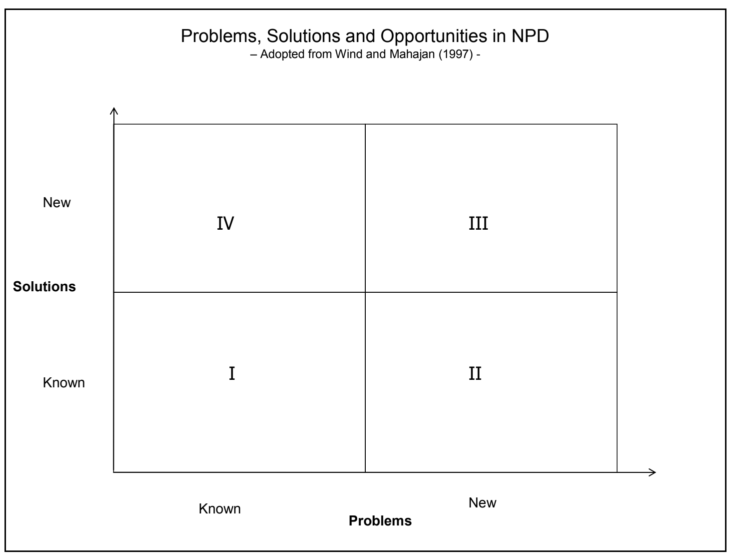

Figure 1: Newness of problems and solutions– adopted from Wind and Mahajan (1997)

Based on a review of innovativeness terminology in literature, they arrive at a classification of 3 degrees of innovativeness: *incremental*, *really new* and *radical*. Accordingly, the highest degree of newness corresponds to a radical innovation, whereas an incremental innovation rests at the opposite of the continuum. Really new innovations are located in the middle of the spectrum of the degree of newness. Garcia and Calantone (2002) argue that the degree of innovativeness or newness can be measured by determining what kinds of *discontinuities* are caused by a new product and who is affected by them. In terms of who is affected, discontinuities can be triggered on a macro-level or on a micro-level and both with respect to the market or to technology. We interpret the macro-level to represent the market, the demanders and the lead users, concerned with the new product. The micro-level, in our view, represents those who develop and deliver the new product. In consequence we equate the term macro-level discontinuity with a new problem, posed by the market, and a micro-level discontinuity with a new solution provided by the NPD collective and the supply chain. The notion of discontinuities also seems to be commensurable with the introduction of uncertainty and difficulty into the transformation process. For example, a radical innovation is expected to introduce a significant technological and market discontinuity that leads to uncertainty and difficulty, because it requires new solutions to new problems in terms of product design and business process design.

The matrix in Figure 1 and the notion of different degrees of newness of the problems and solutions associated with a new product can help explain varying levels of difficulties during development and product introduction. There are four different scenarios, two based on symmetries of newness and two more, based on asymmetries of newness. As discussed above, each scenario can be brought in line with a specific degree of innovativeness, and determined accordingly from the types of discontinuities a product idea generates. For products, which are based on known solutions for known problems (quadrant I) – for instance, when a simple product derivative is being developed – the level of difficulty during development is expected to be low. A product derivative is based on changes that refine or improve some product features without affecting the basic product idea (Kahn, 2005). For example, Sony built approximately 200 versions of walkmans on four basic platform products (Crawford and Di Benedetto, 2008). Some of Sony's derivatives distinguish themselves from others by very basic additional features, like sound enhancement switches. In terms of the idea framework introduced above, this is the most straightforward scenario. The people involved in development may largely draw from existing reservoirs of explicit, codified knowledge, data and processes for execution. In consequence, a high level of involvement of the order fulfillment process would only lead to unnecessarily high number of development hours, resulting in longer development times and higher development cost.

Furthermore, the existing order fulfillment process and associated strategies should be in a position already to generate the same level of customer satisfaction as it did with previous, similar products. Most of what and how much will be demanded should be known from experience with the derivative's predecessor(s). The key for a simple derivative is a quick time to market, to give customers the product update, when they expect it, or before competitors introduce a similar product. Light exchanges between the NPD domain and suppliers for the components involved in the update will generate the most productive and timely outcome. Therefore, in this instance, we expect low exchange intensity to yield the best overall product success, as suggested in hypothesis 1. Based on the notion that the majority of the connections associated with the demand and supply of the derivative are already connected to order fulfillment, the connection of the NPD domain to demanders and suppliers is expected to be mediated through the order fulfillment process in this case (Figure 2, quadrant I).

Hypothesis #1: ***When developing incremental new products, based on known solutions for known problems, which equates to an incremental innovation, a low exchange intensity for knowledge and data between NPD, suppliers and order fulfillment will yield the best overall product success.***

Hypothesis #1a: ***For incremental products, the connection of the NPD domain to demanders and suppliers is expected to be mediated through the order fulfillment process.***

Whenever there are asymmetries in newness of problems and solutions such that an existing solution or technology is introduced into a new market place (quadrant II) or a new solution replaces an old technology for a known application in a population of existing customers (quadrant IV), more unknowns and difficulties will arise.

Examples for when an existing solution got introduced to solve a new problem (quadrant II) are LCD technology and ink-jet printing. LCD technology was originally used in wrist watches, then progressed to calculators and notebook computers, before it was used in large size flat screen TV's (Christensen and Raynor, 2003). Commercially available ink-jet technology was first introduced by Siemens for medical strip chart recorders (in hospitals) in the 1950's. In the 1980's Hewlett-Packard and Canon released the first mass-market inkjet printers, mostly for office printing and labeling. Today, high-resolution ink-jet technology has become better and more affordable. It is widely used to produce photo images, in commercial settings and in homes. In a scenario, where an existing solution gets introduced to solve a new problem, the order fulfillment process breaks into a new territory. Work processes (practices) will need to be invented or adjusted. The development domain, on the other hand, will most likely already have attained vital information about the new market place through its connection with market research (marketing). Specifically, external connectedness to lead users (von Hippel, 1986) is important, because they can contribute to accurate framing of the new problems and requirements. Further, lead users may already have done supplier searches and therefore have knowledge of viable sources for inputs/components. Thus, order fulfillment will receive important customer information via exchanges with the development domain (Figure 2, quadrant II), as suggested in hypothesis 2b.

When a new solution replaces an old technology for a known application in a population of existing customers (Quadrant IV), the scenario is similar to quadrant II. This was the case, for example, when disk drives were replaced by CD and DVD drives as storage devices in personal computers. The key difference to quadrant II is that the development domain will be looking for new solutions on the supplier side more than on the customer side. This is because new solutions are commonly driven by technology and will require supplier involvement. A certain level of connection to potential demanders of the product upgrade is also important. Since the product enters an existing market place, order fulfillment practices should already be highly acquainted with customers and most suppliers and, therefore can provide crucial knowledge to the development domain. The connection of the NPD domain to demanders would be mediated through the order fulfillment process in this case (Figure 2, quadrant IV), as suggested in hypothesis 2a.

Both scenarios with asymmetries in newness of problems and solutions lead to a moderate level of difficulty. Because only one of the two dimensions is known, there will be more unknowns and uncertainty than with an incremental innovation, but less than with a radical product. Overall, we expect a moderate level of exchange intensity to provide the best balance between productivity, development lead time and effective problem-solving, as suggested in hypothesis 2.

Hypothesis #2*:* ***When developing really new products, based on known solutions for new problems, or new solutions for known problems, which equates to a really new innovation, a moderate exchange intensity for knowledge and data between NPD and order fulfillment will yield the best overall product success.***

Hypothesis #2a*:* ***The connection of the NPD domain to demanders is expected to be mediated through the order fulfillment process, when the new product is based on new solutions for known problems.***

Hypothesis #2b*:* ***The connection of the NPD domain to suppliers is expected to be mediated through the order fulfillment process, when the new product is based on known solutions for new problems.***

Quadrant III represents a scenario when a product idea breaks new ground in both dimensions, problems and solutions. According to Hamel and Prahalad (1994, p.65) people in the 1970's were not able to articulate a desire for minivans and personal computers. In the same fashion, ten years ago, very few people could have described the problems and solutions that frame the idea for a smart phone. Yet, minivans and personal computers became realities in the 1980's, as much as smart phones have become an integral part of many peoples' daily lives today. In accordance with previous sections, we expect a product idea that provides a new solution to a new problem to lead to a high level of difficulties and unknowns. High uncertainty and difficulty will require the development domain and order fulfillment to connect earlier and engage in intense exchange of knowledge and data. Extensive input from selected lead users and suppliers will be needed to understand the problems and to develop solutions. They will need to contribute to problem-solving in both domains, development and order fulfillment (Figure 2, quadrant III). We expect a high exchange intensity to generate the best overall product success, as suggested in hypothesis 3.

> Hypothesis #3: ***For radical products, based on new solutions for new problems, a high exchange intensity for knowledge and data between NPD and order fulfillment will yield the best overall product success.***

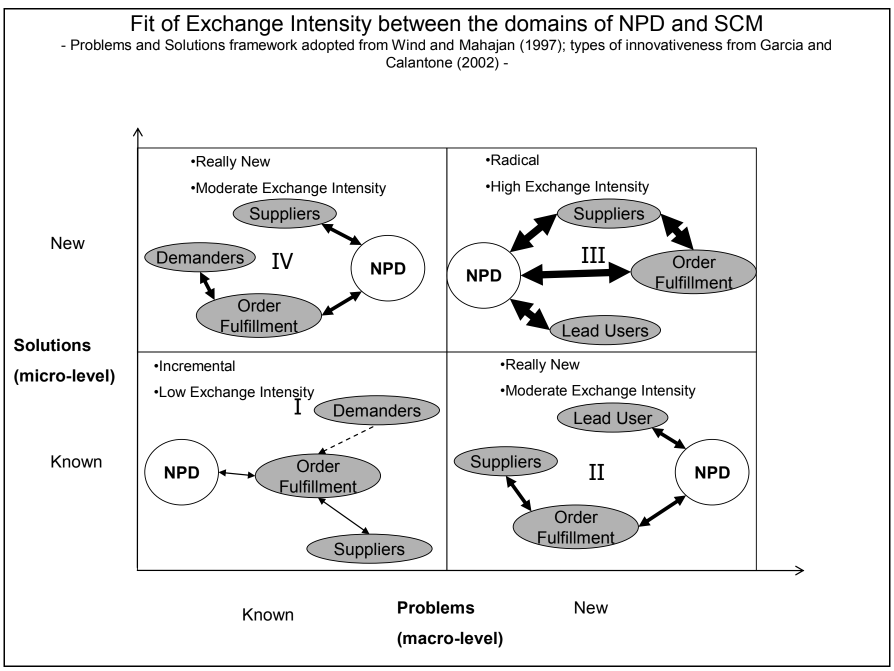

Figure 2: Fit of exchange intensity for knowledge and data between NPD and SCM

4. METHODS

We will test our hypotheses by identifying matches and mismatches with our alignment framework shown in Figure 2. Hypothesis 1 through 3 will be tested by comparing product success rates for matches and mismatches between exchange intensity and newness of the product idea. We will test the overall impact of matches and other independent variables with a logistic regression model. We will collect data from product development leaders in multiple industries.

Our dependent variable product success is dichotomous. Multiple product success measures have been used in new product development literature, ranging from productivity, expressed in person-hours, team effectiveness, over revenue figures, to time-to-market measures (Brown and Eisenhardt, 1995; Ernst, 2002). More recently, practitioners and academics have turned to return-based measures, like the internal rate of return (Kerzner, 2000) or the net-present-value (Ulrich and Eppinger, 2011) of a particular product. We will ask respondents whether a product has met, respectively exceeded or failed to meet the NPV targets set at time of launch.

We will control for market munificence and changes in product promotion through changes in spending on advertising. The score for the independent indicator variables that describe the newness of the product idea (NEWN1 and 2) will depend on the number of discontinuities caused by the product idea. The measures in the questionnaire are based on four measures of innovativeness and newness, commonly used in empirical NPD research (Garcia and Calantone, 2002): (1) new to market (Cooper, 1979; Cooper and De Brentani, 1991), (2) new to the technology community (Green, Gavin and Aiman-Smith, 1995), (3) new technology for the NPD teams (Green, Gavin and Aiman-Smith, 1995) and (4) new processes required (Cooper, 1979). We have chosen these four measures because, based on our discussion of the degrees of newness, they appropriately describe them within our context.

Exchange intensity will be measured through the overall communication mode (COMM), timing of involvement (INVOL) and density of the communication matrix (DENS). COMM will have the value 0 for no connection between two particular sites of knowing in NPD and order fulfillment. When there is/was a connection, COMM will be scaled from 1 for interaction to 5 for collaboration. The anchors of the scale in the survey will be described through validated items/factors, in accordance with Kahn and Mentzer's (1998) study.

The independent variable for alignment between exchange intensity and newness of product idea (ALIG3) is dichotomous. If the exchange intensity was matched with newness of product idea per figure 4, ALIG3 will have the value 1, otherwise 0.

Hypothesis 1a, 2a and 2b, relating to how customers and suppliers connect to the development activity will be assessed via the questionnaire for data points that generated matches per figure 4. This data serves to confirm our theoretical construct shown in figure 4. We don't expect any impact of differences between the connecting node on product success.

We are proposing the following equation to model hypothesis #1, #2 and #3 and the relationship between, independent variables, matches, control variables and the dependent variable:

$$NPV^* = b_0 + b_1 \times (NEWN1) + b_2 \times (NEWN2) + b_3 \times (ALIGN3) + b_4 \times (COMM) + b_5 \times (DENS) + b_6 \times (INVOLV) + b_7 \times (MUNI) + b_8 \times (ADV)$$

with NPV*= ln (NPV/(1-NPV)) and NPV representing the probability that the NPV target was met or exceeded in the post-launch review. The impact of each variable is expressed through b_i. Its value translates one unit increase of the variable into percentage change in odds to meet or exceed the NPV target post-launch as $e^{bi} - 1$.

5. DISCUSSION AND CONCLUSION

In this paper, we have argued that two key domains for product success in hyper-competitive markets, NPD and the SCM, are not only successive contributors but need to be linked through exchanges of knowledge during product development and introduction. This is because successful development and introduction of new products essentially depends on efficient and effective problem-solving in both domains.

Our central research question asks "what are the key linkages between product development and the supply chain domain and how can knowledge exchanges and creation between them affect product, development and supply chain to ultimately improve product success?" We argue based on existing literature that product success essentially depends on effective problem-solving in both domains, NPD and SCM. We thus identify 6 supply chain management sub-processes as a critical factor for product success. Supply chain processes and product development are viewed as end-to-end processes that involve customers and suppliers. We identify *sites of knowing* (Nicolini, 2010) as knowledge reservoirs for problem-solving and equate them to process phases, customer and supplier practices. *Sites of knowing* that are in need for knowledge to solve problems gain access to others via networks. The currency in their exchanges is knowledge. We discuss that NPD literature has identified several factors that determine how knowledge can be exchanged most efficiently. We suggest that the intensity of exchanges (operationalized via the three components of communication mode, temporal overlap and connectedness) is a situational variable and thus needs to be adapted based on the newness of the idea. Therefore our conceptual framework, summarized in Figure 2, suggests that radially new products require high levels of exchange intensity, really new products require medium levels of exchange intensity, whereas incremental new products require low levels of exchange intensity. Figure 2 also shows that the architecture of the connections between NPD, SCM, suppliers and customers also depends on the newness of product ideas.

We will test our hypotheses with a logistic regression model. All quantitative data will be collected in retrospect. We will also collect ethnographic evidence in selected cases.

Practitioners will benefit from our work in two ways: One, we will share our aggregate data report with each participant for their organization's benchmarking activities. Two, the outcome of our data analysis will indicate the relationship between each component of exchange intensity, as well as newness on the odds of product success. Together with the indicator variables for alignment between exchange intensity and newness they produce a decision-making framework for managers who organize and plan for development.

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