

Managing Supplier Integration into Product Development: A Literature Review and Conceptual Model

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Abstract

This paper presents a critical literature review concerning the effects of involving suppliers in product development, the critical processes underlying the management of this involvement and the potential driving and enabling factors for managing supplier involvement in product development. Together they constitute the building blocks for a 'input-throughput-output' model that helps in understanding the crucial elements of how to manage supplier involvement in product development. This model draws on our previous work in this area, but focuses more clearly on the 'inputs' and 'outputs' of managing supplier involvement.

Introduction to managing supplier integration in product development

Literature on product innovation has been pervasively trying to distil the key ingredients for company success. Many of the internal and external actors that are involved in product development - and the interfaces between them - have been subjects of research. Especially the interface between R&D on the one side and marketing and customers on the other side has been investigated (Souder and Chakrabarti 1978; Souder 1988; Griffin and Hauser 1996; Sherman et al. 2000). Compared to this body of literature, the role of suppliers in contributing to company success via product development has been addressed only in a limited way. Also the specific management role of the purchasing function regarding supplier involvement from the customer side has attracted relatively little attention. The attention for this topic, however, has been on the rise.

Involving suppliers in product development has namely been argued to contribute to reduced development time, reduced development and product costs and improved product quality. However, the results of supplier involvement seem to be mixed (Birou 1994; Hartley et al. 1997b). For example, involving suppliers early does not always lead to acceleration of project cycle time (Eisenhardt and Tabrizi 1995). Some authors conclude that, apparently, the way supplier involvement is managed in the product development process is important in explaining the success of this supplier involvement (Ragatz et al. 1997; Wynstra 1998). Both in product innovation and in supplier involvement literature, increasingly thoughts are adopted from contingency theory to address the topic (e.g. Souder et al. 1998). Contingency theory tries to understand and explain phenomena and organisational issues from a situational point of view. The theory argues that companies face different environments and have organisational characteristics with a unique history that require differentiated management approaches and organisational structures. Although many alternative views exist, the basic assertion of this research strand is that there is no one organisation or management approach that leads to success. Companies need to adapt themselves to the most relevant aspects of the environments they are operating in. Applied to supplier integration in product development, this implies that the way that suppliers should be involved in product development requires an analysis of the situational factors and the critical processes to be managed. It is this contingency approach that could be valuable for understanding that there is no one way to look at product development and collaboration processes.

Objective

Objective of this paper is to develop a contingency-based model for designing and managing processes related to purchasing and supplier involvement in product development. For this model we need to gain insight into:

- (1) the effects of involving suppliers in product development and their measurement
- (2) the relevant product development and sourcing processes,
- (3) the relevant factors that drive the need for a particular form of supplier involvement and
- (4) the relevant factors affecting the ability of an organisation's purchasing function to orchestrate or carry out a particular role in these processes.

The input for this analysis is a literature review¹. The output will be a synthesis of relevant processes for managing supplier involvement in product development, combined with a set of situational and enabling factors for successful supplier involvement. We will refer to this synthesis as the framework for 'integrated product development and sourcing'.

We argue that in order to be successful, the involvement of suppliers needs to be embedded in the wider context of bringing a purchasing perspective to the development process. Such a perspective looks at the availability and suitability of external resources (i.e. the knowledge and skills of suppliers) for integration in the development process under conditions of timely availability, and appropriate or optimal costs and quality of the input items (parts, materials etc.) embodying those resources. This integration of purchasing and product development processes and considerations is what we mean by Integrated Product Development and Sourcing (IPDS) (Wynstra et al. 2001).

An Input-Throughput-Output model for Integrated Product Development and Sourcing

Based on various literature contributions and original research, our previous work has found that managing supplier involvement in product development has both long and short term effects (Wynstra 1998). Hence, managing supplier involvement encompasses a broader scope of activities, independent of a specific project, which are carried out at different organisational levels in the organisation. Our model should therefore delineate the critical processes required to manage supplier involvement at the strategic and at the project level.

Furthermore, as stated earlier, this model should provide insight in the factors that drive the need for a specific form of individual or sets of activities. Finally, it is assumed that the ability of a company to carry out activities in the framework is dependent on a number of factors.

The model will be structured according to an input-throughput-output logic. The factors affecting the need for and ability of an organisation to perform Integrated Product Development and Sourcing processes will be seen as inputs, and the processes themselves as throughput. The (desired) effects of these processes will be treated as the output.

The remainder of this paper consists of four sections. This includes the main body of the paper, consisting of three parts, respectively dealing with the throughput, output and input variables of our model. The last section of the paper is devoted to discussion and conclusions.

Throughput: the processes of integrated product development and sourcing

As a starting point for our discussion of the basic processes involved in managing supplier involvement, we use the model developed by Wynstra et al. (1999, 2000, 2001).

¹ Where we refer to our own previous research, this consisted of 21 case studies in two European countries (the Netherlands and Sweden) and across a number of different industries, including the telecommunication equipment sector, truck manufacturing, medical equipment sector, food packaging, plastic components production and power plant construction

This model distinguishes four management areas for managing the processes directly and indirectly related to supplier involvement in product development. Each management area consists of a specific set of activities:

Development Management: establishing the general policies and guidelines for supplier involvement in product development, and the technological areas in which to collaborate;

Supplier Interface Management: building an infrastructure or network of suppliers that can contribute to product development processes;

Project Management: managing the involvement of suppliers in specific development projects;

4. Product Management: helping to define actual product specifications within a specific development project.

Within each management area the following activities are proposed (see Table 1).

Table 1 Integrated framework for purchasing involvement in product development (Wynstra et al. 1999)

Areas	Activity
Development Management	Determining which technologies to keep/develop in house
	Formulating policies for the involvement of suppliers
	Formulating policies for purchasing related activities for internal departments
	Communicating policies and procedures internally and externally
Supplier Interface Management	Monitoring supplier markets for technological developments
	Pre-selecting suppliers for product development collaboration
	Motivating suppliers to build up/maintain specific knowledge or develop products
	Exploiting technological capabilities of suppliers
	Evaluating suppliers' development performance
Project Management	<i>Planning:</i>
	Determining specific development-or-buy solutions
	Selecting suppliers for involvement in the development project
	Determining the extent of supplier involvement
	Determining the moment of supplier involvement
	<i>Execution:</i>
	Co-ordinating development activities between suppliers and buyer
	Co-ordinating development activities between different first tier suppliers
	Co-ordinating development activities between first and second tier suppliers
	Ordering and chasing prototypes
Product Management	<i>Extending activities:</i>
	Providing information on new products and technologies developed or in market
	Suggesting alternative suppliers, products and technologies resulting in higher quality
	<i>Restrictive activities:</i>
	Evaluating product designs in terms of parts logistics, quality and costs
Promoting standardisation and simplification of designs and parts	

An important observation is that these management areas differ in time horizon and in the level of the organisation they are carried out. In other words, managing supplier involvement in a specific project requires management of other parallel processes. The first two areas use a more long-term horizon of preparing and developing a supply base in selected technological areas, while the remaining two management areas are more short-term focused, within the context of a specific project and specific supplier involvement.

A slightly similar model is presented by Monczka et al. (2000), who propose a process model that distinguishes a supplier integration Strategic planning process and an Execution process. The strategic planning process consists of five steps:

- A. *Determining current and future needs*
 - step 1. Establish internal core competencies and capabilities
 - step 2. Establish current and future new product requirements
 - step 3. Identify current and future needs for external technologies and capabilities
- B. *Establishing a strategically aligned world-class supply base*
 - step 4a Select appropriate suppliers and build relationships
 - step 5a Align objectives and technology roadmaps
- C. *Establishing a bookshelf of viable technologies and suppliers*
 - step 4b Monitor supply market for emerging technologies
 - step 5b Continuously evaluate emerging technologies

For the supplier integration execution process that follows the strategic planning process, Monczka identifies another 5 steps that should result in successful supplier integration:

- D. *Determining the Supplier's role and setting targets*
 - step 1. Give suppliers an active role on the project team
 - step 2. Jointly establish clear metrics and targets
- E. *Information sharing and learning from experience*
 - step 3. Share information openly and extensively
 - step 4. Involve suppliers in decision-making and problem solving during design process.
 - step 5. monitor results and learn from experience

Let us briefly review the differences and similarities between the two models, starting with the central element: the managerial processes involved ('throughput'). Secondly, we will make some initial remarks on the links between these processes and the results ('output') and between these processes and their enabling and driving factors ('input').

Regarding the processes, the interesting aspect of both models is that they integrate both strategic and project dimensions of managing supplier involvement in product development. Monczka provides a conceptually attractive model regarding the sequential process logic of the activities in both the strategic planning and execution process. Wynstra does not explicitly address this aspect of 'sequence'. Another advantage of the Monczka model is that it is more 'concise'; it incorporates fewer steps or processes than the Wynstra model.

Based on these two considerations, we propose a revision of our original model:

- Rather than an aggregation into four different management areas, we propose two different main groups of activities: Long-Term Strategic/Tactical Processes and Short-Term Operational Processes.
The key difference between the different management areas is this strategic/operational difference. Initially, our argument for making a further distinction within this strategic processes between Development and Supplier Interface Management was that the first is more internally, policy oriented and the latter more externally focused. Similarly, the reason for distinguishing between Project and Product Management was that the first was more process oriented while the latter area had a clear technical focus. Increasingly we realise that conceptually, but also empirically, the similarities between the two 'strategic areas' and the two 'operational' areas are larger than the differences.
- Rather than using our original number of processes (more than 20), we consolidate these into 15 basic processes.
Especially in the area of Project and Product Management, it has become clear that several activities could be integrated as they essentially form one process (e.g. Promoting standardisation and Evaluating product designs can be combined into Evaluating Product Designs (in terms of cost and availability/delivery aspects)).
- Rather than just listing the activities, we structure them according to a basic sequence.
*However, both the set of strategic processes and the one for operational processes should be seen as continuous, repeating 'activity chains'.
For this sequence, we stay close to the logic of the Monczka model.*

This results in a revised model, as depicted in Figure 1.

Figure 1: Integrated Product Development and Sourcing – Strategic and Operational Processes



Focusing on the relation between the processes discussed so far and their outcomes, the framework of Wynstra does mention the required relationship between the processes and the success of supplier integration in product development. He distinguishes between short and more long-term effects of supplier involvement, but does not fully address the alignment with corporate strategy and objectives. Monczka emphasises this link to a larger extent but does not clearly place the strategic and project execution success in a conceptual model. Neither of the authors captures the link of supplier involvement and business success. This effect, of course, is very difficult to determine, since there are numerous other explanatory variables affecting business success.

Regarding the input factors, Monczka however has not yet provided a conceptual framework with regard to the enabling factors, although he discusses at two places in his book factors that could be labelled as enabling factors. For instance, he addresses the barriers to effective supplier integration, the absence of which could also be framed as enabling factors for successful integration. Furthermore, we do not have clear understanding if and how supplier

involvement approaches should be differentiated dependent on specific environmental characteristics. Wynstra does attempt to provide some insight in the factors that drive the need for and appropriate form of the activities (Wynstra et al., 2000). Furthermore, he proposes some factors that may better enable an organisation to carry out the activities in his framework.

Based on these observations, and additional literature, we will propose a number of additions for a total framework for integrated product development and sourcing processes, especially with regards to the output and input variables in the model.

Output: the (potential) effects of integrated product development and sourcing

In this section, the (potential) effects of supplier involvement in product development, reported in literature, will be discussed. The impact of supplier involvement ideally should be linked to company level performance measures such as profit or market share. However, we will see that this link is often not clear and many researchers choose to use other measures of success when discussing the impact of involving suppliers in product development.

Potential advantages of supplier involvement in product development

In literature, various authors report on the positive effects of involving suppliers in the product development process. These advantages mainly boil down to achieving a certain type of cost-reduction (development or product costs), a faster project completion time and improved product quality. Access to critical supplier technologies and leveraging supplier's knowledge on design are also frequently mentioned. An overview of the advantages mentioned by several authors is provided in Table 2, where we have categorised the various advantages.

What becomes clear from the frequently mentioned potential advantages is that they differ in the time horizon in which they can be reaped and the way they become visible for the company. Short-term advantages are characterised by a link to one or more specific projects, while long term advantages may not become apparent from a specific supplier involvement in a project. Some examples of the short term related performance results to which a supplier can contribute are: *lower development costs, lower manufacturing cost, increased product reliability, increased product quality, more innovative product technology and better design solutions.*

There are also some potential benefits that are not directly quantifiable and traceable to a specific project and, which are of a long-term nature. These advantages are important for the ability of the company to assure the availability of the right type of supplier contributions for future projects. One such a long-term benefit may be that, even though supplier involvement has not lead f.e. to immediate efficiency improvements for that particular project, both the customer and the supplier have learned more about each other and their collaboration, which would possibly make future collaborations more efficient and effective (Van Echtelt and Wynstra, 2000).

In addition, the relationship with a particular supplier can provide the customer permanent, long-term access to supplier technologies or other specialist knowledge (supplier's suppliers) that increases the innovative capability of the customer. Other potential long-term effects are the long-term alignment of technological strategies and possibilities to influence future technological investments (in equipment, knowledge etc.).

The distinction of short- and long-term effects of supplier involvement provides some feeling regarding the differences in timing when these effects become apparent. Still, it may sometimes be arbitrary whether an effect is short-term or long-term; some of our presented examples of long-term effects may actually occur directly in connection with a project. The effect of involving suppliers could, therefore, also be analysed in terms of:

- 1) their strategic impact in terms of the company's way of doing business; for example increased access to supplier's technology can change the way future projects define their product offering for their target markets; or

- 2) their operational impact in terms of the execution success of a specific project in terms of Quality, Cost, Project Cycle Time etc.
We choose to combine the strategic/long-term and the operational/short-term dimension.

Table 2 Potential advantages for supplier involvement in product development

Nature of advantage		Potential advantages	Mentioned by
Strategic/ long term	Effectiveness	Innovation and technology related advantages	
		Increased efficiency and effectiveness of future project-collaboration	Dyer and Ouchi (1993)
		Better access to technological resources and knowledge	Ragatz et al. (1997), Bruce et al. (1995), Bonaccorsi (1997)
		Long-term alignment of technological strategies	Bonaccorsi (1992)
		Possibilities to influence future technological 'investments'	Wynstra (1998)
Operational/ short term	Efficiency	Time -to market related advantages	
		Lead-time reduction	Clark (1989), Kamath & Liker (1994), Hartley & Zirger (1997), Wasti & Liker (1997), Gupta & Souder (1998), Ragatz et al. (1997), Dröge et al. (1999), Bonaccorsi & Lipparini (1994), Bruce et al. (1995)
		Development Cost related advantages	
		Reduced development costs (improved resource utilisation)	Clark (1989), Bonaccorsi & Lipparini (1994), Dowlatshahi (1998), Birou & Fawcett (1994), Hartley et al. (1997a and 1997b) Wasti & Liker (1997)
	Reduced transaction costs	Dyer and Ouchi (1993)	
	Effectiveness	Product Cost related advantages	
		Provide suggestions on alternative materials increasing product quality/functionality and lowering costs	Dowlatshahi (1998)
		Reduced manufacturing costs	Dyer and Ouchi (1993), Kamath & Liker (1994) Mendez & Pearson (1994)
		Product quality related advantages	
		Development of better performing designs/improved product performance/Reduction quality problems	Clark (1989), Kamath & Liker (1994), Ragatz et al. (1997), Bonaccorsi & Lipparini (1994) Mendez & Pearson (1994), Wasti & Liker (1997)

When looking carefully at the type of advantages mentioned – especially the operational ones – one can observe that the contribution of suppliers can improve both the *effectiveness* of product development outcome and at the same time the *efficiency* of the product development process. The effectiveness dimension of the supplier contribution is related to how well does the supplier perform compared to desired product outcome (such as product reliability and quality, better performing designs). The efficiency dimension says something about how good a supplier is at using as few resources in the shortest time possible to achieve the desired contribution in the development project. Efficiency is related to development costs and the required time for the supplier to carry out its development tasks.

**Input: the driving and enabling factors
for Integrated Product Development and Sourcing**

Given our stated desire to build a contingency-based model, the addition of driving and enabling factors to the integrated product development and sourcing model may provide a valuable conceptualisation of when to choose and how to carry out particular processes in the framework.

Driving factors for Integrated product development and sourcing processes

Driving factors can be defined as those antecedent conditions in the environment internal and external to the company working with suppliers that drive a company towards a specific form and extent of integrated product development and sourcing processes.

In literature, driving factors have been addressed before. For example, various authors have investigated several aspects of the environments in which companies act and their impact on organisational structure and strategy (Burns and Stalker 1961; Lawrence and Lorsch 1967; Eisenhardt & Tabrizi 1995). The way companies adapt themselves is an issue we will leave aside for the moment. The relevance for the discussion here is that the organisation for involvement of suppliers can be driven by factors *internal* or *external* to the firm.

Literature on product development and supplier involvement provides different indications that such, potential driving factors may exist on three different levels of analysis: the business unit level, the project level and the level of the individual supplier relation (Van Echtelt and Wynstra 2000). In Table 3, an overview is given of these potential driving factors and the specific dependent variables as suggested by previous research.

Table 3 Potential Driving Factors

<i>Study</i>	<i>Potential driving factors</i>	<i>dependent variable</i>	<i>Level of analysis</i>
Eisenhardt & Tabrizi (1995)	Industry Market Uncertainty. Predictability of projects/ uncertainty surrounding a project	the effectiveness of experiential vs. compression strategies	Business unit
Fine (1998)	Industry clockspeed differences	The effectiveness of outsourcing	Business unit
Birou & Fawcett (1994)	Competitive conditions in customer markets	The role of supplier participation	Business unit
Wynstra et al. (2000)	R&D dependence	Need for purchasing involvement activities	Business unit/ company
Wynstra et al. (2000)	Supplier dependence	Need for purchasing involvement activities	Business unit/ company
Wynstra et al. (2000)	Company size	Need for purchasing involvement activities	Business Unit/ company
Wynstra et al. (2000)	Production complexity	Need for purchasing involvement activities	Business Unit
Griffin and Page (1996)	Product newness to the market and to the firm	Project performance measures	Project
Tatikonda & Rosenthal (2000)	Technology novelty	Project execution outcomes	Project
Tatikonda & Rosenthal (2000)	Project complexity	Project execution outcomes	Project
Wasti & Liker (1997)	Technological uncertainty of the component	degree of supplier involvement	Supplier relation
Wasti & Liker (1997)	Supplier market competition	degree of supplier involvement	Supplier relation
Wynstra and Ten Pierick (2000)	Development Risk Extent of involvement	Differentiation of management of supplier roles in product development	Supplier relation

Driving factors at the business unit level

Literature provides at least 6 potential driving factors potentially affecting the need and specific form of the IPDS-processes at the level of the business unit: 1) *Market and technological uncertainty*, 2) *Degree of Competition in Customer Markets*, 3) *R&D dependence*, 4) *Supplier dependence* 5) *Company size*, 6) *production complexity*
All these factors have in common that they are linked to either the company or business unit level depending on which level defines the relevant scope of industry best.

1) *Market and technological uncertainty (clockspeed)*

Eisenhardt and Tabrizi (1995) found evidence for two different segments of the global computer market, exhibiting different levels of technological and market uncertainty, that early supplier involvement had different effects on the time-to-market dimension. One of their conclusions was that suppliers should be involved earlier in projects aimed at more mature and predictable environments. They define "technological uncertainty" as the degree to which companies are facing changing technologies and "Market uncertainty" as the maturity and stability of the customer market. Fine (1998 and 2000) also addresses, to some extent, the phenomena of market and technological uncertainty. He discusses the dynamics of evolving industry structures and how individual companies should learn how to position themselves in different types of industries. Using the term *clockspeed*, he characterises the role of competition, innovation and the market in shaping the product and organisational life cycle. In some industries, these life cycles occur at a faster pace than in others and are either in the direction of vertical integration or horizontal specialisation.

2) *Degree of competition in Customer markets*

Another potential driving factor is the role of competition in the customer market in adoption of greater supplier participation in product development. Birou and Fawcett (1994) analysed the role of competitive dynamics in the customer markets in the adoption of supplier involvement practices. They conclude that global competitive forces sharpen the imperatives to compete on Time, Cost and Quality. Furthermore, they explain that U.S. companies, besieged by international competitors during the late eighties and nineties, have started to emulate Japanese supplier involvement practices. Therefore, they state that increased competition force new approaches to improve competitiveness with supplier involvement being one of those new approaches.

3) *R&D dependence*

The importance of product development, reflected in the relative level of research and development expenditure has been suggested by Wynstra et al. (2000) as an indicator for increased dependence on product development. Subsequently, this would make it likely that the company is more concerned with carefully managing the product development process and the possible involvement of suppliers in that process.

4) *Supplier dependence*

Another driving factor at the business unit level is the *overall dependence on suppliers* (Wynstra et al. 2000). This dependence is usually measured by the purchasing share in turnover (purchasing ratio). Higher purchasing ratio's would point to more dependence of supplier efforts in product development. Consequently, companies need to pay more attention to strategic and operational processes of the IPDS framework to manage these efforts.

5) *Company size*

Wynstra et al. (2000) has previously identified *company size* as a potential driving factor. Company size, measured by number of employees, is primarily an overall indicator of organisational complexity. The more complex the organisation, the more important it becomes, for example, to develop and communicate guidelines for supplier involvement.

6) *Production complexity*

The final environmental condition that drives the need for and a specific form of the processes, is the complexity of the production situation. Wynstra et al. (2000) suggests that environments with various types of assembly operations requires different emphasis on several processes than companies working in proces production environment. Assembly environments point to a more comprehensive approach to operational activities for integrated product development and sourcing processes.

The question remains whether this level of analysis provide sufficient clues for involving suppliers in specific projects. Some authors propose to really look at the project level to determine what driving and success factors can be identified.

Driving factors at the project level

Contributions by Griffin and Page (1996), Wheelwright and Clark (1992), Henderson and Clark (1990) and Luthardt and Mörchel (2000) all suggest that projects differ in terms of the underlying innovation and therefore require a differentiated management approach.

Furthermore, the contributions by Griffin and Page (1996) and Tatikonda and Rosenthal (2000) point out that project targets and their relative importance differ among projects with varying degrees of innovation. We can therefore assume that a differentiated management approach (and performance measurement) is required in order to assure the attainment of specific objectives according to project priorities. We argue, on the basis of these contributions, that *degree of innovation* and the *objective priority setting* in a project affect the need for specific forms of the IPDS processes.

(1) Degree of innovation

Wheelwright and Clark (1992) distinguish a project typology by focussing on technological aspects. They distinguish breakthrough projects, platform projects and derivative projects (besides advanced development and partnerships). This distinction is made to clarify both management's thinking about planning, staffing and guiding projects and to help developing aggregated project plans. since each of the project types requires a different level of resource commitment. Similarly, Henderson and Clark (1990) argue that projects differ based on their underlying type of innovation and as a result require different management forms. They distinguish projects that involve *radical, architectural, modular* or *incremental innovation*. They state that some types of innovation are hindered or facilitated by the existence or lack of certain communication channels and information filters. Certainly established firms can be handicapped to carry out radical or architectural innovation by a legacy of embedded and partially irrelevant architectural knowledge, embodied in these channels and filters.

We could argue then that projects with different innovation characteristics need other information filters, input and communication channels with suppliers, thereby increasing the need for specific forms of the operational processes of the IPDS framework.

Griffin and Page (1996) also assume that projects differ in terms of their innovation characteristics (strategy) and therefore need to be measured and managed in a different way. Important to note is that this framework takes into account the market and technology aspects by evaluating the degree of innovation for the market and the firm. In our view, therefore, the model by Griffin and Page (1996) provides a more balanced view towards innovation compared to the more technology focused contributions of Henderson and Clark (1990) and Wheelwright and Clark (1992). The latter contributions can, however, help in specifically describing the technological nature of innovation in terms of the type and depth of knowledge that are required for the project.

In terms of the implications for the need and specific form of the IPDS processes, we hypothesise that a high degree of project novelty (radical and architectural innovation) to the firm in all combinations of novelty to the market could point to an increased need for strategic processes. In these situations, an increased effort in technology scanning, supplier market analysis and targeting in advance of suppliers may be required in order to prepare their project involvement. A low to medium degree of innovation to the firm and medium degree to the market (incremental or modular) may drive the firm to emphasise scanning supplier markets for standard available supplier products and technologies.

Besides the relationship with strategic processes, we could argue that high degree of innovation necessitates choices regarding certain operational processes, for example, earlier involvement of specific suppliers, contributing an important technology to the project. Later involvement is required of those suppliers providing more standard components.

In terms of the specific form of the operational processes, high-innovation projects may need a more experiential, adaptive management process than the more predictable, low-innovation projects.

(2) Project objectives priority setting

At the project level of analysis, the priority setting of project objectives can be considered as a driving factor. The project typology proposed by Griffin & Page (1996) and the research by Tatikonda and Rosenthal (2000) provide this insight. In general, projects make trade-offs on performance dimensions which correspond with their interpretation of the target market needs. These trade-offs steer behaviour, project design and engineering choices. These trade-offs or, in other words, the priority setting of those performance dimensions is different for projects when the degree of innovation increases for both the firm and the market. For instance, in New-to-the-World projects based on radical innovation, product quality (functionality) may be the most important objective, while costs are of secondary importance. Although the various projects imply different project priorities, the likelihood of achieving them all at the same time has been questioned by Tatikonda and Rosenthal (2000). They found evidence that different degrees of task uncertainty will *not* have a moderating effect on the overall project execution success, but *instead* on the achievement of *individual performance objectives*. Task uncertainty originates from varying degrees of technology novelty and project complexity. They also found evidence for process technology novelty to have a negative association with the attainment of the time-to-market objective and the unit cost objective. Objective novelty makes a project more complex and has a negative impact on the unit cost objective.

Combining the insights of both contributions provides evidence that projects characterised by different degrees of innovation exhibit different levels of technology novelty and project complexity. If companies have difficulties in achieving certain individual performance indicators, given a certain degree of innovation, companies may manage supplier involvement in a different way. Companies may then emphasise those actions that are more in line with the degree of innovation of the project and the target market.

Driving factors at supplier relation level

Besides the analysis of driving factors at the business unit and project levels, some authors look at the level of the specific supplier relation; the level at which the component is developed.

For example, Wasti and Liker (1997) and Wynstra and Ten Pierick (2000) look at the specific co-development level, to study situational factors that influence management of specific supplier involvement cases. Following the literature review, we suggest the following driving factors: (1) *Component development complexity*, (2) *Component technological uncertainty*, (3) *Component contribution to the overall system functionality*, (4) *Novelty of the supplier relationship and its objectives*, (5) *Buyer-supplier clockspeed differences* and (6) *Supplier's competitive position*.

We will argue that 'development risk' is the term that links specific values of the situational factors to a specific form of Integrated Product Development and Sourcing processes. Therefore, we will first provide a clearer understanding of development risk as an overarching concept for categorising driving factors at the supplier relation level.

Development risk

The role of development risk in designing and managing a specific relationship with a supplier has been addressed by authors such as Bensaou (2000), Wasti and Liker (1997) and Wynstra and Ten Pierick (2000). Bensaou (2000) makes a distinction between product complexity and the maturity of the underlying product technology, assuming that relational requirements are different for products that vary for both variables. Wasti & Liker (1997) mention the importance of the technological uncertainty of the component in driving companies to involve suppliers earlier in the development process. Technological uncertainty consists of the complexity of the component (in terms of subsystem or not) and the degree of redesign since the last model. Wynstra and Ten Pierick (2000) suggest, in their attempt to provide guidelines for a differentiated approach how to manage different co-development relationships, *development risk* and *extent of involvement* as important driving factors. The development risk construct used by Wynstra and Ten Pierick (2000) encompasses both the sources of risk stemming from technical complexity and technological uncertainty. High degrees of these variables point out the need for information early in the project. Therefore,

the collaboration interface needs to be differentiated. We notice that, although authors like Bensaou and Wasti & Liker conceptualise and operationalise complexity and technological uncertainty in different ways, they seem to be related to a risk that could impact on a specific development collaboration.

Therefore, we argue that development risk provides a more direct link of some situational factors to the success of a specific involvement and relationship with a supplier. We can view development risk as a concept whose elements together provide a company with an understanding of *chance* and the *impact* of certain situations on the success of a particular project, if the appropriate form of processes is not in place. We will now specifically address the elements that contribute to development risk and discuss the implications for the need for and specific form of various processes in the IPDS framework.

(1) *Component development complexity*

Component development complexity can be viewed as the interdependence of tasks and the interfaces of the component with other functions or components. According to Hayes (1988) a systems level of complexity is dependent on the number of components and the type of interdependencies present in a product. The more interdependencies, the more complex the development will be in terms of specifying and designing the component, planning and co-ordination of tasks. The number of interdependencies and their nature determine the complexity of the task and the level of knowledge or skill needed for developing a component or a function. Thompson (1966) identifies pooled, sequential and reciprocal dependencies, which, if combined, will increase the systems or component complexity. At the component level, we can argue then that component development complexity consists of both a task and a technical complexity.

The relationship between component development complexity and development risk can be understood by introducing the notion that some of the knowledge and skills needed for developing a component are built through experience. The more novel a particular technology and component for a customer or supplier, the more uncertainty is present in the relationship regarding the way to design the product or specify the interfaces. In this case, technical complexity in combination with the level of experience constitutes a source of development risk. In situations of high component development complexity, it can be argued that especially operational processes of the IPDS framework need to be carried out in a different way than in low complexity situation. If the technical complexity is high, then earlier involvement of supplier may be required. Furthermore, the firm may be prompted to adopt other co-ordination mechanisms. For example, co-location can provide the best medium to discuss the technical and task interdependencies.

(2) *Technological uncertainty of a component*

A characteristic of uncertainty is that the direction and intensity of change are difficult to predict. Technological uncertainty related to a component is present where a possibility for changes in technical aspects, regarding product and production technologies exist and where the acceptance for these changes in various industries vary. Technological uncertainty is a concept that is interdependent with technical complexity. However, they are not the same. Building a ship or a house can be a complex project in terms of the number of tasks and the interdependencies between those tasks. At the same time, the underlying product and production technologies may be stable for a long time. However, products in the electronics industry (like CD/ DVD TVs, Printers) can be complex while at the same time the underlying technologies are unstable. Technological uncertainty of a component represents a development risk if for example there is a chance technological advancements of substitute components make components currently in use unattractive and the company is locked into a supplier's technology.

The degree of technological uncertainty surrounding a particular component affects the need for extra activities in both the set of strategic and operational processes in the IPDS framework. High uncertainty regarding the technical growth path could increase the need for extra search activities enabling the provision of information on viable alternative technologies and suppliers in projects. High uncertainty may require the targetting of more than one development partner to avoid being locked in a particular technology.

However, technological uncertainty does not provide the whole story of development risk. There are other factors that constitute a development risk and point to the need for more and specific forms of integrated product development and sourcing processes.

(3) *Contribution of the building block to the functionality of the overall system*

Whereas complexity and uncertainty tell us something about the chance aspect of development risk, the impact of the occurrence of a certain risk can also be an important driving factor. Wynstra and Ten Pierick (2000) identify the contribution of the building block to the functionality of the overall system as a source development risk. A component can be complex or subject to high technological change, if its importance to the overall functioning is not crucial then the impact of high complexity and high uncertainty may be moderated by a low contribution of this particular building block to the overall functioning of the system. If the contribution is significant, then the firm may need more resources to determine the right extent of involvement. Furthermore, the moment of supplier involvement may be early in order to closely monitor the development risks, given the large impact if a risk materialises.

The concept of development risk consists so far of elements that are related to technical aspects of the component. However, there may be additional elements of development risk, but then of a relational or different nature.

(4) *Relationship/Objective novelty*

At the level of the specific supplier relation, the way supplier involvement is prepared and organised may be dependent on the *novelty of the relationship* and the combination of *objectives novelty* for a supplier.

Starting a development relationship with a new supplier entails a period of understanding each other's questions and processes and requires mutually adaptations. The risk of involving a new supplier in a TTM driven project is high. Chances are that this specific development will cause a delay in overall planning. That is, if no proper attention is given to the unfamiliarity of the supplier with the customer's organisation and vice versa, a problematic collaboration can result.

Besides the novelty of the relationship, the novelty of the objectives (priority setting) or specific extent of involvement for the supplier could signal in advance to development problems. For example, Van Echtelt and Wynstra (2000) found some indications that the unfamiliarity of one or both of the parties to work with each other with a higher extent of involvement level constitutes a development risk in the project. This risk may relate to project cycle time or compromises on the achievement of certain individual objectives.

High relationship and objectives novelty could drive the need for more guidelines on how to prepare to work with new suppliers. Frequent contact with a supplier early on in the project may be required. Furthermore, more up-front analysis of how the develop-or-buy policy can be translated into the appropriate extent of involvement may be necessary.

(5) *Clockspeed differences*

In literature, another relevant driving factor can be found related to the differences of industry business and product life cycles. Although we have already introduced the concept of industry clockspeed at the business unit level, there are arguments for introducing *clockspeed* at the specific customer- supplier relation level. One of them is that the speed with which a supplier must develop new products can significantly differ from the time horizon of some of its customers. This speed can be attributed to the way that industry is structured and innovation drives competition.

It can be argued that *differences in clockspeeds* of supplier and customer could pose a development risk in terms of obsolescence of components and systems validation problems, ultimately resulting in late market introduction and delivery problems. The synchronisation of planning and delivery and timely exchange of technical (roadmap) information will be critical then. Therefore, large differences in clockspeed between the industry(segment) of supplier and customer are likely to require extra resources and specific choices in both the strategic and operational processes. Presence or an expected change towards a supplier base with large clockspeed differences requires, for example, extra management attention to evaluation and

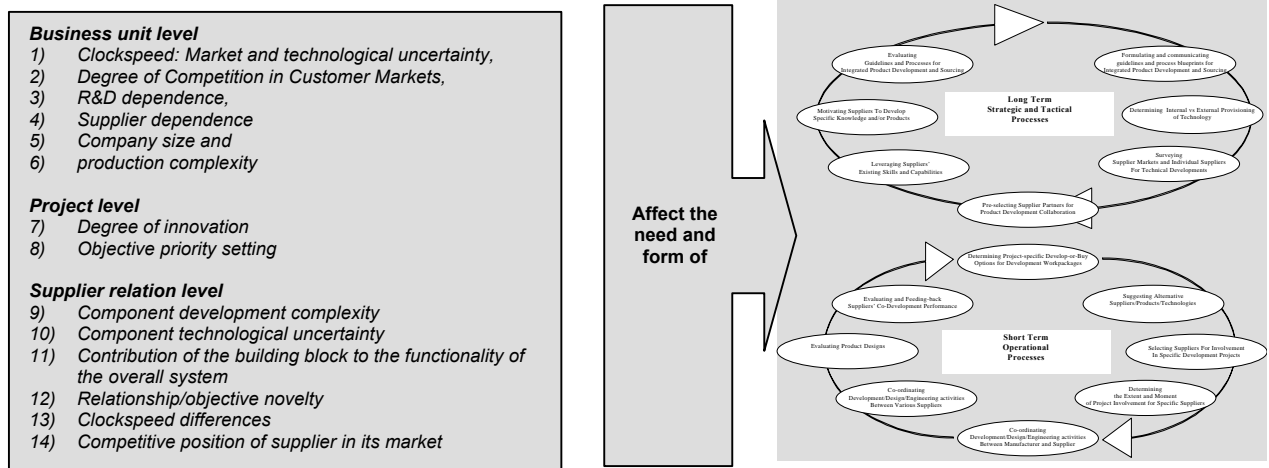
adjustment of guidelines regarding timely exchange of technical roadmap information and technical specifications for these type of suppliers. This requires the presence of specific operational co-ordination activities within projects. Furthermore, it is assumed that there is an increased need for fine-tuning and influencing technology roadmaps with suppliers active in industries with large clockspeed differences. To conclude, clockspeed differences between the industries of supplier and customer may be useful as a concept which can explain and point clearly to the need and specific form of several processes of the IPDS framework.

(6) *Competitive position of supplier in its market*

A final driving factor that can be considered important is the competitive position of the supplier in its market. A supplier that is a near monopolist in the market for a critical component can affect the short term ability of customer to achieve certain objectives (Time-to-market). In addition, the position of a supplier will also determine the degree to which the customer can influence the degree customisation and adaptation of the supplier technology roadmaps to their own. At the same time, the position of supplier in its market is relevant for long term supplier relationship risk management. If a supplier is losing out on its competitors and as a customer you are locked in, this supplier represents a development risk for future projects. Therefore, strategic processes are crucial here to make sure projects are able to involve this supplier successfully. For example, the development and sourcing of a component in a situation of a sole source would increase the need for more intense technology and supplier market scanning activities to find alternative sources or substitute products.

In the previous section, we have discussed a number of potential factors that drive the need for and the most appropriate form of the Integrated Product Development and Sourcing processes. Again, these contextual factors can be identified at three levels of analysis: Business Unit level, Project Level and Supplier Relation(component) level. We propose to further explore the impact of the following driving factors with specific activities of the IPDS framework (see Figure 2).

Figure 2: Impact of Driving Factors



We will now address the factors that enable an organisation to carry out specific activities if some situations call for a specific form.

Enabling Factors for Integrated Product Development and Sourcing processes

In this section, we discuss a set of factors or conditions, whose presence help a company to organise the required integrated product development and sourcing processes. An enabling factor can be understood as a factor improving the ability of a firm to organise the specific integrated product development and sourcing processes.

Past research has repeatedly proposed some factors that are thought to contribute to the successful execution of several processes that can be found in the IPDS-framework and which can be viewed as enabling factors. These enabling factors can be logically categorised as

factors that are present internal and external to the customer's organisation or in the specific relationship between customer and supplier.

Table 4 Potential Enabling factors

Potential Enabling variables for IPDS	Author
Internal enabling factors	
Internal organisation of the purchasing department and development team	Wynstra (2000), Burt & Soukup (1985)
Recording and exchange of information	Wynstra (2000)
Quality of human resources	Anklesaria & Burt (1987), Guy and Dale (1993) Atuahene-Gima (1995), Dobler & Burt (1996), Wynstra (2000)
External Enabling factors	
Supplier technical capabilities	Wasti & Liker (1997), Hartley & Zirger (1997), Birou and Fawcett (1994), Handfield et al. (1999)
Relationship enabling factors	
Past experience of collaborations	Wasti & Liker (1997), Farr & Fisher (1992)
Compatibility of Culture/operating style	Lorange (1988), Perlmutter and Heenan (1986), Whipple and Frankel (2000), Bruce et al. (1995)
Trust - Social Climate	Sako (1992), Gabarro (1987), Bensaou (2000)

Internal enabling factors

(1) The customer's internal purchasing and product development organisation

A frequently mentioned enabling factor for successful product development has been the customer's internal organisation. One of the instruments related to the internal organisation is the use of cross-functional teams (Gupta and Wilemon 1990; Imai et al. 1985; Brown and Eisenhardt 1995; Clark and Fujimoto 1991; Dröge et al. 2000).

Other literature has focused specifically on the integration of two functions, for example, the R&D-marketing interface (Souder and Chakrabarti 1978; Souder 1988; Griffin and Hauser 1996). Benefits are associated with short communication lines and early involvement of several players. This contributes to a faster and effective problem solving process.

Wynstra et al.(2000) argue that the presence of an internal organisation that is able to support the required communication and co-ordination in product development is critical for the successful execution of the product development processes. They specifically distinguish between the internal organisation of the *purchasing department* and of the *product development team* itself.

Regarding the organisation of the purchasing department, the first two important aspects are *the degree and principle of specialisation* of the individual buyers; f.e. when they are specialised in narrow product or technology areas, similar to their engineering counterparts, they probably can communicate better. Another important aspect is the *horizontal complexity* of the purchasing department; the number of different units or groups with specific tasks within a department. When a purchasing department consists of an operational unit and an initial unit, this may increase the overall ability of that department to perform initial, product development related tasks, such as supplier selection.

Regarding the organisation of the product development team there seem to be 3 important aspects: *structure, composition* and *location* (Wynstra et al. 2000). People can work in an *organisational structure*, where still a strong functional orientation exist of the department or at the other hand where a strong project orientation prevails.

The project's success can be negatively affected to the extent that the functional orientation will make purchasers act in the interest of the department and their departmental performance objectives. The *composition of product development teams* is important for the ability of functions to be informed about the project specific needs (information) or other activities. The effectiveness of a cross-functional representation of the Purchasing department or suppliers on the project team partly depends on the *physical location* of its members.

(2) *Recording and exchange of information*

Product development has been conceptualised by several authors as a information processing set of activities. They vary in content, frequency and also in means. Wynstra (2000) views that all purchasing involvement activities have a information component in them. This implies that, for example, in order to carry out technology or supplier market scanning the process could be facilitated by the use of access to databases or other means of information and communication.

(3) *Human resources*

This factor regards the ability of persons to play various roles in the NPD process. Prior research suggested buyer's attributes as enabling factors for a greater role in product development (Birou 1994). Atahuene Gima (1995) found, for instance, that *1. level of education*, *2. perceived confidence in the capabilities of organisational buyers* and *3. the risk taking propensity* enable a buyer to have a greater role early in development projects. Wynstra et al (2000) mention additional personal attributes such as *4. kind of previous experience* and *5. the degree of technical expertise*.

It is worthwhile to note that the execution of the processes in the IPDS framework is not restricted to buyer personnel only. Other organisational groups may be better equipped to lead the execution of specific processes.

External enabling factors

Factors that enable a successful execution of the activities of the framework are not only limited the company's internal environment. Outside the company, in particular at the level of suppliers or of supply networks, other factors support an organisation to carry out IPDS processes.

(1) *Supplier capabilities*

Literature provides some evidence that supplier capabilities are a prerequisite in order to have a earlier and or a more successful involvement in a project. Wasti and Liker (1999) indicate that the technical capabilities are a strong indicator for earlier supplier involvement. Zirger and Hartley (1997b) found a significant relationship between high technical capabilities and reduced project cycle time. Besides technical capabilities, Handfield et al. (1999) suggest a supplier must also have the organisation and processes to meet specific customer's targets. It is important to note that a technical capability in isolation will not be valuable, until it is viewed as compatible with the customer's need and the development situation at hand.

Relationship enabling factors

So far, we have specifically discussed the internal and external enabling factors for efficient and effective execution of integrated product development and sourcing activities.

However, the collaboration between customer and supplier is also supported by the way customer and supplier are able to work with each other, exchange resources etc.; in other words, collaboration is facilitated by a well-established relation. Factors that can neither be attributed to the supplier or the customer pertain to the:

(1) *Past experience of collaborations*

Wasti and Liker (1999), Bruce et al. (1995) and Dyer and Ouchi (1993) state that the length of the buyer-supplier relationship enables the supplier to gain knowledge of the buyer's organisation processes and objectives. This facilitates own product development planning and capability development.

(2) *Match in business model*

A company's business model is the fundamental way a company has chosen to operate in its business environment. The business model pertains to the business unit's main strategy (consumer/industrial customers), its supply chain position, the organisational design towards customers, the product development horizons and type of production/assembly (high or low production series, customisation or standardisation). It can be argued that a match on these aspects of both business models enables a company to better smoothe the processes to involve the supplier in product development projects.

(3) *Compatibility in company culture*

The role of culture in customer-supplier relationships has been addressed to some extent in previous research. Although, we do not discuss culture and all associated aspects at great length here, we can identify three elements that logically enhance the ability of customers and suppliers to collaborate successfully in projects. These elements are *Shared values* (Perlmutter and Heenan 1986), *Operational style* (Bruce et al. 1995; Whipple and Frankel 2000) and *Problem solving style* (Whipple and Frankel 2000).

A mismatch in either of the three elements of company culture between a supplier and customer in a context of product development collaboration, can cause an ineffective execution of the IPDS processes and possibly to less successful supplier involvement.

(4) *Trust*

The role of trust in customer supplier relationships has been quoted as a positive influence on the success of collaboration. There have been various definitions of trust and they identify more than one kind of trust. For example, Sako (1992) distinguishes between contractual, competence and goodwill trust. The definition by Gabarro (1987) distinguishes character and competence based trust. Character based trust examines qualitative characteristics of behavior inherent in partners' strategic philosophies and cultures; competence-based trust examines specific operating behaviors and day-to-day performance

This concludes our discussion of the input-throughput-output elements of our model. The model, and the different variables, are presented in Figure 2.

Discussion

In this paper, we have discussed a potential model for studying the managerial processes regarding the involvement of suppliers in product development; or in our words, Integrated Product Development and Sourcing (IPDS).

We have looked at the throughput (the managerial processes themselves), the input (the antecedents in terms of drivers and enablers) and the output (the intended effects) of IPDS. Regarding the processes, based on our own research and the model of Monczka et al. (2000) we propose a total of 15 key managerial processes, divided into two main areas: long-term, strategic and tactical processes on the one hand and short-term, operational processes on the other. According to our perspective, the key challenge of managing supplier involvement is to balance two types of processes. First, to assure that the relevant and expected contribution of the supplier for that project is achieved resulting in the desired project execution success. Secondly, assuring that the supply base is prepared for integration in future projects and in this way will support the competitive position of the firm in the long term, while minimising technology and supply risks.

Regarding the outputs or effects of IPDS, a distinction has been made between strategic/long-term versus operational/short-term effects. We have indicated that we deliberately opt for this double designation, since the time-horizon difference may not always be that evident: strategic effects may also (start to) occur on the short term. At this point we should also add that we see no exclusive link between the operational processes and the operational goals, and between the strategic processes and the strategic goals. We think there are strong 'cross-fertilisation' effects. Essentially, we think that also the way operational processes are carried out, has an effect on the long-term, strategic effects, and that also the way in which the strategic processes are managed has a bearing on the operational effects.

In terms of the inputs or antecedents of IPDS, we have a crucial distinction between factors that impact the need for IPDS activities ('drivers') and those factors that affect the ability of an organisation to perform those activities ('enablers').

Regarding the driving factors, a further classification has been made according to the level at which these may occur: business unit level, project level or supplier (component) level. In other words, we hypothesise (supported by previous research) that differences in the extent and the way in which IPDS activities are and should be carried out exist between firms or

business units, between different projects within the same firm, and between different suppliers within the same project.

It should be noted that, per definition, the project and the supplier drivers mainly have an impact on the operational processes. The strategic processes are rather independent from specific projects and individual supplier relations, although their overall characteristics (i.e. of the full project portfolio and the entire supply base) obviously affect the strategic processes too.

Regarding the enabling factors, we have made a distinction between internal (factors internal to the buying firm), external (i.e. supplier characteristics) and relationship enablers. This is a different classification than the one for the driving factors. We could also propose a conceptualisation of enabling factors similar to the three levels identified for the driving factors, but in our opinion the distinction internal/external/relationship is more crucial. Also, it will be difficult to assign just one level to an enabler: for example, the way a product development team is organised may be both a project and supplier level enabler. However, it is possible to identify some basic relations between the two classifications. Internal enablers seem primarily present at the business unit and project level, whereas external and relationship enablers are most visible at the supplier relation level.

In reflection, we want to point out some notable aspects of our model and some issues for further research. Our model tries to provide an integrated conceptualisation of the managerial processes regarding the integration of product development and sourcing processes, looking both at antecedents, processes and outcomes. This 'integral' aspect has some potential advantages and disadvantages. On the upside, we think that such an integral model can add useful insights in an area where most research tends towards fragmentation through a focus on a limited area (e.g. the impact of purchasers' skills) without a clear conceptual model.

On the downside, in its aim for completeness, our approach may neglect some of the more detailed aspects of involving purchasing and suppliers in product development.

We will try to address these issues in the research that we intend to carry out using this model. First, we will develop a questionnaire to be used in a survey study among US and Dutch firms, in which we will try to identify the most significant variables in explaining strategic and operational 'success' of IPDS. We will carry out this survey in a two-step process. Our first questionnaire will be directed to purchasing and R&D managers, and will focus on the more strategic aspects of IPDS. Then, a follow-up questionnaire will be sent to development project managers in the same firms, focusing on the more project-related, operational aspects. In this way, we try to capture all aspects of our model, without the individual questionnaires becoming impossible to handle.

Another related, potentially negative aspect of our model may be its apparent 'mechanistic' or simplistic nature. Many people would argue that our approach is oversimplifying the issue.

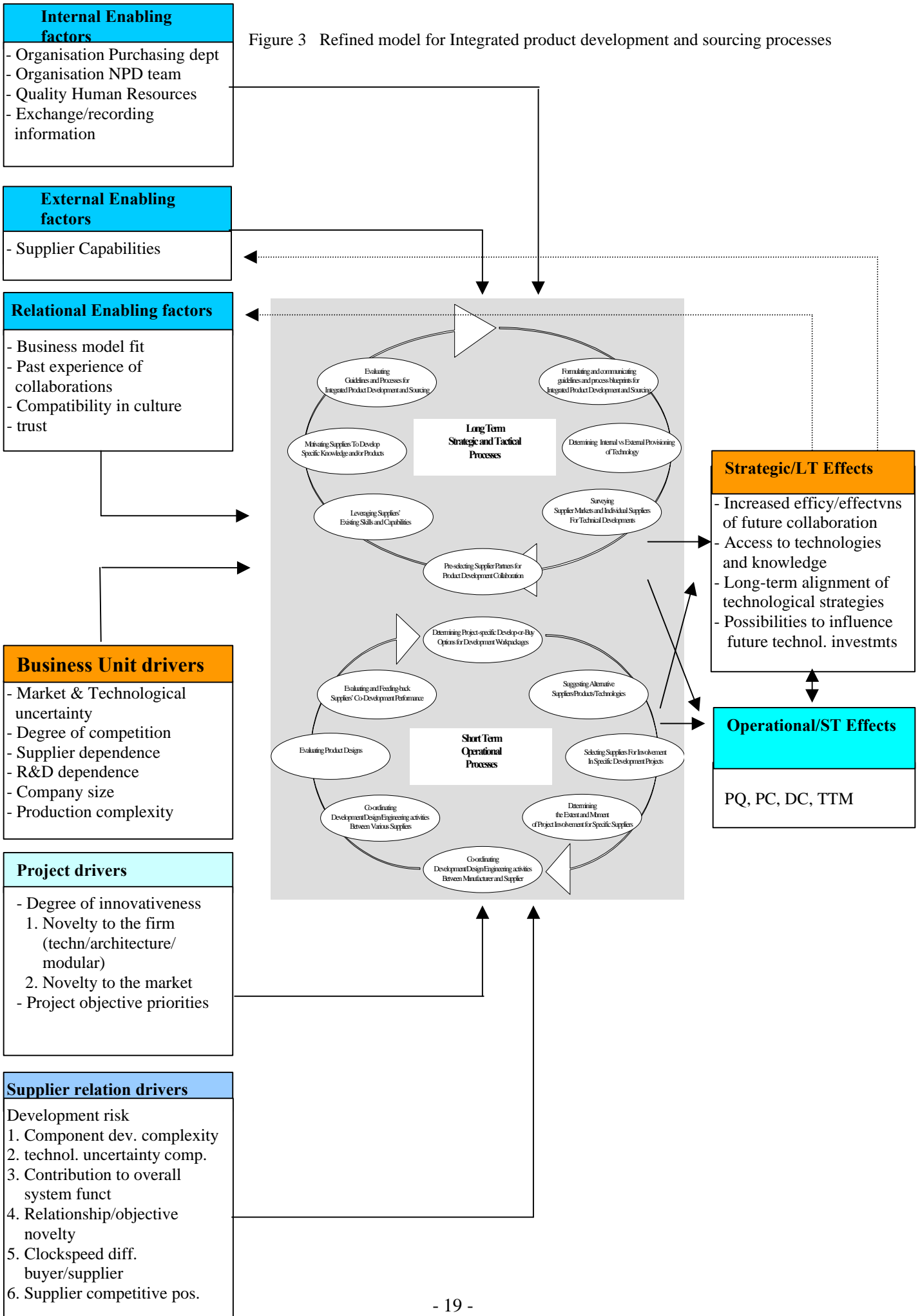
However, by using this structure we do not want to imply that the model is uni-directional; there are various feedback loops to consider. For example, positive strategic effects – increased supplier capabilities – may act as an enabling factor for the next project.

Another particular drawback, it may be argued, is that the model does not address the interactions between manufacturer and supplier. As Ford (1998, p. 4) argues: strategy in complex business markets is essentially an interactive process of 'coping, reacting to the actions of significant others'.

In that respect, we should however point out that our model is a model for managerial processes, and not for interorganisational processes. Still, even then it is useful to consider the impact of supplier behaviour on customer's actions and strategy, and therefore this will be one of the special points of attention in our more qualitative research supplementing our quantitative surveys.

Overall, the model should be seen as a conceptual framework, which can be used for studying specific aspects of integrated product development and sourcing with the use of varying methodologies.

Figure 3 Refined model for Integrated product development and sourcing processes



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