Managing supplier involvement in new product development:
a portfolio approach

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Abstract

Supplier involvement in new product development projects has become an increasingly popular method for improving project effectiveness (product costs and quality) and project efficiency (development costs and time). One of the key issues in managing this involvement is determining which type of involvement a manufacturer should have with the various suppliers that may be engaged simultaneously in a development project. In this article, a Supplier Involvement Portfolio is introduced to distinguish four types of supplier involvement in development projects. Subsequently, suitable supplier–manufacturer interfaces for the four types of involvement are defined in terms of the direction of information flow, the communication media used, the amount of communication, the topics discussed and the functions involved. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Supplier interface; New product development; Supplier involvement portfolio

1. Introduction

1.1. Supplier involvement in product development

Many firms increasingly realise that supplier involvement in new product development can be beneficial with regard to the costs and quality of new products and the costs and time associated with their development. Consequently, more and more suppliers are becoming involved in their customers’ development projects. This involvement may range from giving minor design suggestions (e.g. to improve a component’s manufacturability) to being responsible for the complete development, design and engineering of a specific part or sub-assembly. In contrast with generally held belief, however, prior research has shown that supplier involvement in new product development may not always lead to improvements in project effectiveness (product costs and quality) and project efficiency (development costs and time) (Birou, 1994; Hartley, 1994; see Wynstra, 1998; pp. 53–55). Still, this does not imply that supplier involvement is a poor strategy; it emphasises that supplier involvement should be managed carefully.

Especially in the case of final products consisting of parts from many different suppliers, supplier involvement may increase the complexity of managing development projects. One of the key issues in such situations is to determine which type of involvement a manufacturer should have with the various suppliers that may be engaged simultaneously in a particular development project. Collaboration with suppliers in product development takes time, effort and money in terms of coordination and communication; not only for the supplier, but also for the manufacturer. Supplier involvement is not very useful if the same amount of time as has been saved in internal engineering hours is now spent on additional communication with suppliers. Differentiation
between several forms and phases of supplier involvement may help to set priorities so that the involvement of suppliers becomes more manageable and economical.

Another argument for differentiation is that suppliers of different parts and components contribute to a different extent to the development of the final product. Literature provides us with a variety of models or typologies that differentiate between different forms of supplier involvement on the basis of product characteristics (Clark, 1989; Lamming, 1993; Kamath and Liker, 1994; Bidault and Butler, 1995). Although valuable, these typologies have some shortcomings that make them less suitable for managing supplier involvement in single development projects. Two of these shortcomings are especially relevant for our discussion. First, the models are ‘static’ or inflexible in assuming that a supplier of a certain component should be involved in the same way in different development projects. For example, the models indicate that suppliers of assemblies (e.g. a complete dashboard for a car) should always be involved early in the development project. This argument, however, focuses more on the supplier’s potential contributions (‘suppliers of complex products possess greater capabilities’) than on the actual need for such contributions (design suggestions, etc.) from the point of view of the manufacturer. In some cases, the modification or innovation of the final product does not require changes in the major subsystems of the product, but only in a small component. Useful tools for distinguishing different supplier roles in development projects should, therefore, include a consideration of the need for supplier input in the specific project at hand.

Second, most existing typologies do not address in much detail the issue of how the involvement of the different suppliers can or should be managed. They only provide guidelines regarding the phases of supplier involvement within the course of a development project (e.g. from the Concept phase until the end vs. only in the Detail Engineering phase) and the extent of involvement (e.g. the supplier only receives functional specifications vs. almost complete blueprints). However, little if anything is said explicitly about the kind of communication and co-ordination taking place. It is therefore not entirely clear how this differentiation of supplier roles can help manufacturers to optimise their communication and coordination efforts.

In this paper, our objective is to address both shortcomings by introducing the Supplier Involvement Portfolio. This is a tool that distinguishes different types of supplier involvement in new product development. In addition, for each type of involvement accompanying guidelines for communication and project management issues are described. The tool as well as the guidelines have been developed on the basis of an extensive case study of a Dutch medical equipment manufacturer.

1.2. Case study and methodology

Philips Medical Systems (PMS) is a product division within the Professional Products and Systems group of Royal Philips Electronics, located in Best (Netherlands). Its diagnostic imaging systems incorporate advanced X-ray, magnetic resonance and ultrasound technologies. In recent years, cost-reduction efforts at PMS have increasingly led to discussions on what should remain the core competencies of the company and what should be outsourced. As a consequence, the involvement of suppliers in product development has become a key issue.

The portfolio and the different supplier interfaces discussed in this paper result from ‘design oriented’ research (Van Aken, 1999). They are empirically validated by reviewing existing supplier relationships in product development at PMS and by analysing potential improvements by implementing relationships as suggested by our approach. The research was carried out in the period 1995–1998, involving interviews with purchasers, engineers and supplier representatives. Furthermore, two researchers have been stationed at the company for a considerable period of time, enabling first-hand observation of and participation in department and project meetings and discussions. In addition, project documentation was reviewed (for triangulation purposes), and workshops were organised in which the ideas were tested and refined in collaboration with PMS representatives.

1.3. Disposition

In Section 2, the Supplier Involvement Portfolio is introduced. However, before describing the tool itself, first the problems associated with its development are analysed. Section 3 deals with the process of ‘filling’ the Supplier Involvement Portfolio by discussing the steps required to position product–supplier combinations in this matrix. The actual deployment of the portfolio is the topic of Section 4. Applying the logic of Media Richness Theory, guidelines regarding efficient and effective communication behaviour are described for each type of involvement. In addition, examples from PMS are used to illustrate the various types of involvement. Finally, Section 5 concludes the article by discussing its limitations and providing some suggestions for future research.

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1 Obviously, literature provides various typologies that refer to the supplier’s participation in the customer’s product development as one of the aspects in supplier–manufacturer collaboration. Given their general character, these typologies suffer even more from the shortcomings discussed here than the current typologies that specifically deal with supplier involvement in new product development.
2. Developing the supplier involvement portfolio

2.1. Initial model

The development of the Supplier Involvement Portfolio was induced by a development project at PMS in 1992–1995 — the L’ARC C/N project — in which external suppliers had been given greater responsibilities for engineering activities and the delivery of prototypes. A close examination of this and three other (primarily internal) development projects revealed that the L’ARC C/N project suffered from considerable development time overruns (more than the projects in which prototypes had been made by PMS internal workshop). With respect to other aspects, however, the L’ARC C/N project did not perform badly: in terms of development budget, it had a relatively small (8%) overrun, and with regard to the cost-price of the new product, the project even resulted in a 12% reduction against the original budget.

Further analysis of the L’ARC C/N and other projects in which outside parties were involved indicated that these suffered from a lack of common understanding between the purchasing and development departments. There was a lack of understanding with regard to each other’s tasks and responsibilities, and — even more important — there was a lack of agreement and understanding with regard to the possible roles of suppliers in product development (Sie, 1996). In order to contribute to solving these problems, a procedure was developed for distinguishing different supplier roles in the product development process.

Initially, inspired by the example of Océ (a Dutch manufacturer of office equipment; Wynstra, 1998, pp. 47,48), the application of the regular purchasing portfolio (Kraljic, 1983; Van Weele, 1994) was tested for planning supplier involvement in an ongoing development project. According to this approach, suppliers of Strategic Items are involved early, in the Concept phase of a development project. In the Engineering phase, suppliers of Leverage and Bottleneck Items become involved. Involvement of Non-critical (Routine) Items does not start until the final stages of the development project. The portfolio was tested by comparing (1) how suppliers would be involved in the process if priorities were set as suggested by the portfolio with (2) the ideal situation inferred from interviews with purchasers and engineers on how it should have been done. This resulted in two major findings (Wynstra and Sie, 1996):

1. it did not result in the right priorities regarding the timing of supplier involvement in a development project; and
2. the phase and extent of supplier involvement were not directly coupled with each other — early involvement did not automatically imply a greater role for the supplier.

Hence, it was necessary to introduce another criterion (than logistical risks or financial importance) for differentiating between phases of supplier involvement. From the interviews with purchasing and engineering representatives, this criterion appeared to be development risk. Subsequently, a new model was developed: the Supplier Involvement Portfolio.

2.2. The Supplier Involvement Portfolio

The aim of the Supplier Involvement Portfolio is to provide support for setting priorities with regard to the involvement of suppliers in a new product development project so that it can be carried out with an optimal amount of ‘management capacity’ (time and money spent on communication, co-ordination, etc.) while making optimal use of suppliers’ expertise. This portfolio distinguishes four types of supplier involvement on the basis of two variables: (1) the degree of responsibility for product development that is contracted out to the supplier and (2) the development risk (see Fig. 1).

Since the degree of development responsibility contracted out to the supplier is strongly related to the difference in expertise (knowledge, know how and experience) between PMS and the supplier, it affects the phase of involvement. When a manufacturer decides to give a supplier a major responsibility for the development of a certain component in the new (final) product, it is useful that this supplier is contacted, ‘brought on-line’, in one of the early phases of the overall development project. Otherwise, the specifications of (the interfaces with) other parts of the final product may already have been fixed to such a large extent that the supplier’s degrees of freedom for developing his particular component may have been reduced considerably. As a result, the supplier’s expertise cannot be fully leveraged in the design of that component.

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Fig. 1. The Supplier Involvement Portfolio.
Development risk — the importance, newness and complexity of the (successful) development of the part concerned — gives an indication of the time and effort required developing a specific part. The more development efforts are needed, the earlier they should start.

Based on these variables, the four types of supplier involvement distinguished in the Supplier Involvement Portfolio are Strategic Development, Critical Development, Arm’s Length Development and Routine Development (see Fig. 1). Before describing these four types of involvement, we first discuss how the Supplier Involvement Portfolio can be ‘filled’. In this discussion, the two axes of the Supplier Involvement Portfolio are described in more detail.

3. Filling the supplier involvement portfolio

In order to find out which type of involvement is suitable, the value of the two variables for each specific supplier-component combination (i.e. the position on both axes of the portfolio or matrix) must be determined. The approach to be adopted when ‘filling’ the Supplier Involvement Portfolio is as follows:

1. determine the degree of responsibility that the supplier holds for the development;
2. position the supplier-component combination in the Supplier Involvement Portfolio; and
3. reflect on the distribution of the various supplier-component combinations across the portfolio, and — if necessary — re-position some of them.

Although it appears to be most logical to follow the steps in the sequence suggested here, steps 1a and 1b may actually be done in parallel or reverse order. Below, the three steps are considered in more detail.

3.1. Determining the vertical axis, the degree to which development is contracted out

A distinction is made between four levels at which the responsibility for the development of a building block (component) can be contracted out:

I. technical (or purchasing) specifications: on the basis of (full) technical specifications the supplier is given responsibility for setting up its production process and for the manufacturing itself;

II. detailed design: on the basis of a detailed design the supplier is given responsibility for setting up his production and assembly process and for ultimate production and assembly;

III. global design: on the basis of functional specifications and a global design of a building block the supplier is given responsibility for: the detailed design; construction and testing of a detailed design; and the setting up of production and assembly processes; and

IV. functional specifications: on the basis of the functional specifications of a building block the supplier is given responsibility for: the global design (concept and feasibility studies); the detailed design; testing of the (global and detailed) design of the building block; and setting up of production and assembly processes.

The approach to determine supplier responsibility for the development of a building block consists of several steps in itself. First, one needs to define each building block and determine, within the specific project, the ‘desired’ degree of development responsibility given to the supplier. Central questions for the degree to which development is to be contracted out are:

- Considering the firm’s core technological competencies, into how much detail should it go in developing specifications?
- Are there suppliers with more relevant product or production knowledge for this particular part than the manufacturer?
- Are there suppliers that can do the development work more efficiently than the manufacturer?
- To what extent does the manufacturer need development capacity (man-hours) of suppliers to meet the project targets?

Having defined the desired degree of supplier responsibility, one needs to identify suppliers that could be involved in the development of the building block. If there are no (known) suppliers, the definition of the building block or the desired degree of supplier responsibility for the development should be adapted so that there are suppliers that can do the development. Alternatively, suitable suppliers may be found through market research and/or by motivating suppliers to develop the knowledge and products the manufacturer needs.

3.2. Determining the horizontal axis, the development risk

The development risk for each building block — the horizontal axis — can be determined on the basis of a number of questions. In fact, based on interviews with development engineers at PMS, five questions seem crucial in determining the sequence in which building blocks need to be dealt with in the development process:

1. To what extent does this building block make an essential new contribution to the functionality of the overall system, as compared with previous systems?
2. To what extent does this building block determine the technical specifications and the design of other building blocks?
3. To what extent does the development or ordering time for (components from) this building block determine the throughput time of the entire development project at the manufacturer (‘is it on the critical path’)?
4. Deploying the Supplier Involvement Portfolio

Up to this point, the four types of supplier involvement distinguished in the Supplier Involvement Portfolio have not been discussed in much detail. Therefore, this section provides a more comprehensive description of the four types of involvement. This description also includes guidelines for efficient and effective communication behaviour in the situations concerned. However, as these guidelines are based on Media Richness Theory (Daft and Lengel, 1984,1986; Ten Pierick and Beije, 1998), it is useful to first introduce briefly the line of reasoning in this theory.

4.1. Media Richness Theory

Media Richness Theory (MRT) suggests that (1) communication media vary in their information-carrying capacities, and (2) for efficient and effective communication to occur, communication behaviour should match information-processing requirements2. The first proposition is reflected in the continuum of information (or media) richness (Daft and Lengel, 1984); the second proposition is known as the matching hypothesis (Fulk and Boyd, 1991).

4.1.1. Information richness continuum

Based on the work of Bodensteiner (1970), Daft and Lengel (1984,1986) proposed that communication media could be placed along a continuum of information richness (see Fig. 2). They defined information or media richness as the capacity of a medium to overcome different frames of reference, clarify ambiguous issues or change understanding within a time interval. A medium’s richness is determined by a blend of four of its characteristics: (1) the capacity to provide (immediate) feedback; (2) the type(s) and number of cues and channels utilised; (3) the degree of personalisation; and (4) the variety of languages used.

According to these criteria, face-to-face is the richest medium, followed by telephone, addressed written documents (e.g. letters and memos), unaddressed written documents (e.g. bulletins and flyers) and, finally, numeric documents (e.g. quantitative computer output).

4.1.2. Matching hypothesis

Organisations are information-processing systems (Tushman and Nadler, 1978). They gather and interpret information in order to reduce uncertainty and equivocality (Galbraith, 1973; Weick, 1979). Uncertainty means absence of information (Daft and Lengel, 1986). It is “the difference between the amount of information required to perform the task and the amount of information already possessed” (Galbraith, 1973, p. 5). A typical response for organisations facing uncertainty is to increase the amount of information processing and communication (Daft and Lengel, 1984; Galbraith, 1973; Tushman and Nadler, 1978).

Equivocality means ambiguity. It is the extent to which information is unclear and suggests multiple and conflicting interpretations (Weick, 1979). While uncertainty is typically reduced by increasing the amount of information processing, equivocality reduction cannot be achieved by simply processing more information; it requires the processing of ‘rich’ information by the selection of ‘rich’ media (Daft and Lengel, 1984).

Drawing on the ideas of MRT, we continue to discuss guidelines for the relationships distinguished in the Supplier Involvement Portfolio. By way of introduction, it may be stated that (in general) equivocality is primarily associated with the degree of development responsibility

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2 The primary reason to select Media Richness Theory is that it goes beyond most other communication theories: it does not only explain communication behaviour, it also provides normative statements regarding the type of behaviour that is expected to be efficient and effective under particular circumstances (Fulk and Boyd, 1991).
held by the supplier. Uncertainty, on the other hand, may be caused by development risk (i.e. uncertainty primarily perceived by the manufacturer) and by the degree of supplier development responsibility (i.e. uncertainty primarily perceived by the supplier).

4.2. Strategic Development

Strategic Development is characterised by a high development risk and a high degree of supplier responsibility for the development. Using functional specifications as a starting point, the supplier is asked to prepare a ‘global design’ of the building block. It is for this reason that the supplier of the building block from the Strategic Management quadrant is the first to be involved in the manufacturer’s development project.

As the supplier is involved already in a conceptual stage, most information is imprecise and vague. This inevitably leads to a high level of equivocality. In addition, at this stage, the risks associated with the project are high for both parties. The manufacturer is confronted with a high development risk and therefore wants to be closely involved. The supplier perceives a high level of uncertainty because it does not know exactly what the manufacturer wants. As a result, especially at first, the collaboration needs to be close and interactive. That is, a lot of details (technical as well as commercial) have to be discussed and both parties have to check whether they understand each other correctly. Hence, regular verbal communication is necessary so that both parties can explain to each other what is desirable and what is possible. Furthermore, the two parties must discuss the problems and solutions that arise as a result of a lack of experience of working together. In addition, face-to-face contacts are also important for the exchange of knowledge and experience (Ten Pierick and Beije, 1998). Finally, as there are various kinds of information to be exchanged (e.g. technical, commercial and planning information) and because information exchange must not delay the development project, ‘rapid’ communication is needed. Communication lines should be short so that, for example, development engineers from both sides can communicate directly with each other.

For PMS, the case of an Italian supplier of generator segments may illustrate these guidelines. This supplier — which had not been used before by PMS — had to develop a new building block on the basis of functional requirements. These requirements were faxed to Italy and clarified during several phone calls. After some months, the supplier sent a prototype to PMS. However, this prototype did not comply with PMS expectations. This led to the decision to drastically change the communication pattern: a series of face-to-face meetings was arranged — involving a number of people from several departments from both parties — to discuss the different requirements. In addition, other contacts (i.e. telephone, fax and e-mail) were intensified. Eventually, after another couple of months, the supplier delivered a prototype that met the requirements of PMS.

4.3. Critical Development

In the case of Critical Development the supplier involvement is characterised by a high development risk and a low degree of supplier development responsibility. Often, this involves possible interfaces, connecting pieces and transmission mechanisms, but also near-standard purchasing parts that determine to a large extent the ‘global design’ of other building blocks. Since these products determine the further progress of the development project, the manufacturer needs information from the supplier at an early stage. There is a need to obtain sufficient information about what is and what is not possible with regard to different solutions for technical problems so that choices can be made and the development of other building blocks may proceed.

In this situation, the manufacturer asks the supplier for concrete information. As a consequence, the level of equivocality is probably low and therefore ‘lean’ media can be used. The level of uncertainty — as perceived by the manufacturer — is high: the manufacturer lacks a lot of information. On the other hand, the supplier — as
information provider — does not perceive any uncertainty. As a result, the amount of communication is limited. Moreover, the topics of information ‘exchange’ mostly concern market information (e.g. the costs of different options) and technical details. Therefore, the functional disciplines typically involved in the communication are purchasing and development.

An illustration of the segment Critical Development is the product category of bearings. As bearings have a significant impact on the functionality of PMS systems (e.g. with regard to the speed of rotation), PMS requires information from the supplier at an early stage of the development of a new building block. However, PMS is usually able to specify exactly the kind of information it needs (e.g. questions like ‘Is it possible to meet these specifications?’). Therefore, most of the time, telephone and fax are used in the communication with suppliers. Moreover, it is probably clear that generally the initiative lies with PMS.

4.4. Arm’s Length Development

In the case of Arm’s-Length Development a large part of the development is contracted out to the supplier, but the development risk is considerably lower than it is in the case of Strategic Development. The difference with Strategic Development is that the development is contracted out in a more formal manner and the relationship is considerably less close. As in the situation of Strategic Development, the supplier receives rather ‘vague’ information. This implies a high level of equivocality and the necessity to use rich communication media. However, the need to exchange information is lower than in the situation of Strategic Development. That is, although the uncertainty is high for the supplier (because of the need to know exactly what the other party wants), the manufacturer experiences low levels of risk and uncertainty and therefore does not feel a strong urge to be closely involved. Hence, after the transfer of the functional specifications and the ‘global design’, the information ‘exchange’ takes place mainly upon the initiative of the supplier. Finally, the functional disciplines involved at the manufacturer’s site are mainly development (with respect to technical issues) and sometimes purchasing (for co-ordination purposes).

Drawing on the study at PMS, a case illustrating the quadrant of Arm’s-Length Development concerns a supplier of monitor ceiling carriers from Belgium. Based on a functional specification and having a prior model at its disposal, this supplier had to design and subsequently manufacture a new generation of monitor ceiling carriers. To facilitate this process, there have been some meetings. However, most of the information was transferred by means of media such as telephone, fax and mail. Moreover, the major part of the communication was initiated by the supplier.

4.5. Routine Development

Routine Development is characterised by low development risk and little or no responsibility for the development being held by the supplier. The manufacturer draws up technical or purchasing specifications, co-ordinates all changes and monitors to ensure that all prototypes are on time so that the construction and testing of the (system) prototypes are not delayed. Further, the relationship consists mainly of the two parties keeping each other up to date about any changes, costs and specifications.

In terms of equivocality and uncertainty, the communication requirements are minimal. As the information exchanged is concrete, there is no need to use rich media. Therefore, efficiency considerations lead to the selection of lean media such as fax, mail and e-mail. In addition, since the development risk is low and since both parties know what to expect from each other, there is no need to contact each other frequently. Moreover, to economise further on communication costs, both parties can appoint a contact person.

The case of Routine Development is illustrated by the traditional purchasing process at PMS (and most other organisations). In this process, purchasers typically order ‘new’ products by calling the supplier’s sales representative or by sending an order form (either by mail or fax) to the latter. Furthermore, the purchasing officer monitors prices, delivery times and changes in the product. Only on specific occasions are there additional contacts. However, there is usually at least one face-to-face meeting each year to ‘stay in touch’.

The guidelines for the different types of supplier involvement are summarised in Fig. 3. Wynstra (1998) discusses additional aspects of the different interfaces (e.g. the form of project organisation, the kind of agreement and evaluation).

5. Conclusion

The central argument of this paper has been that one of the critical elements in reaping the potential benefits of giving suppliers a greater involvement in product development is defining the appropriate form of involvement. If manufacturers do not distinguish between different types of supplier involvement, they may end up spending as much time on co-ordinating and managing supplier involvement as they save by giving suppliers more development and engineering responsibility. The Supplier Involvement Portfolio and the supplier interfaces it proposes do not only give indications of how to adjust co-ordination and management efforts to the potential benefits of involving a supplier early and extensively, but also provide detailed recommendations on the form and the intensity of communication with different suppliers, based on project-specific considerations. In that sense,
the paper fills an existing lack of such tools. In addition, as argued previously, existing models or typologies only distinguish (static) supplier ‘roles’ such as ‘proprietary parts supplier’, ‘black-box part supplier’ and ‘detail controlled parts supplier’ (Clark, 1989) or ‘mature’ and ‘child’ (Kamath and Liker, 1994). These typologies do not provide sufficient guidance for differentiating supplier involvement in an individual development project. The Supplier Involvement Portfolio distinguishes specific development situations rather than generalised supplier roles.

At this stage, we can only present the results of using the ideas described in this paper on the level of individual supplier relationships. We cannot yet compare different new product development projects with and without using the portfolio approach because no development project has been finished yet in which the portfolio has been deployed fully. Future research will investigate the impact the use of the portfolio has on project efficiency and effectiveness. Nevertheless, initial experiences show that the portfolio helps to improve supplier involvement in product development, by giving clear guidelines on how to manage different types of involvement.

Whilst the initial development of the portfolio and the interface guidelines was based on findings from the PMS case study, pilot applications at other companies also seem fruitful (see Mevissen, 1999). This indicates that the underlying factors for distinguishing different types of supplier involvement may indeed be generic. However, depending on the specific context, variations or extensions of the Supplier Involvement Portfolio may be

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### Fig. 3. Guidelines for the interfaces in the different collaboration relationships.

<table>
<thead>
<tr>
<th>Kind of Collaboration</th>
<th>Strategic Development</th>
<th>Critical Development</th>
<th>Arm’s-Length Development</th>
<th>Routine Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clone co-operation as ‘sparring partners’</td>
<td>Focus on obtaining information</td>
<td>Independent development by supplier</td>
<td>Informing each other about changes</td>
<td></td>
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<tr>
<td>Joint development</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Direction of Communication</th>
<th>‘Two-way traffic’</th>
<th>‘One-way traffic’ at manufacturer’s initiative</th>
<th>‘One-way traffic’ at supplier’s initiative</th>
<th>‘Two-way traffic’</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Communication Medium</th>
<th>Rich media such as face-to-face group meetings</th>
<th>Lean media such as telephone and fax meetings</th>
<th>Rich media such as face-to-face meetings</th>
<th>Lean media such as fax, mail and e-mail</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Amount of Communication</th>
<th>High</th>
<th>Medium</th>
<th>Medium</th>
<th>Low</th>
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</table>

<table>
<thead>
<tr>
<th>Functional Disciplines</th>
<th>Diverse</th>
<th>Purchasing/sales (and development)</th>
<th>Development (and purchasing/sales)</th>
<th>Purchasing/sales</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Content of Communication</th>
<th>Technical and commercial information</th>
<th>Market (and technical) information</th>
<th>Technical (and status) information</th>
<th>Status information</th>
</tr>
</thead>
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<tr>
<th>Communication Structure</th>
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3 Related to this point, it is useful to note that most existing models (see Section 1) assume that the extent of involvement and the phase of involvement are directly related: the more intensive the involvement, the earlier it should start (and vice versa). In our project management tool, on the other hand, the phase of involvement is the result of two aspects: (1) the extent of involvement (or degree of development responsibility) and (2) the degree of development risk. In other words, a high degree of involvement does not automatically lead to early involvement (and vice versa); this also depends on the degree of development risk.
necessary, such as a $3 \times 3$ matrix for a manufacturer dealing with very complex development projects (e.g. the development of a new aircraft).

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