Editorial

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Today launching new product development (NPD) projects, managing technical and technological issues or coordinating people and resources are amongst the greatest challenges for companies. Projects have to deliver successful products on time and to budget minimising industrial risks, while building up long term links across their design chains and supply chains and meeting their companies' strategic goals. Many NPD projects deviate from their initial goals as user needs change, unexpected problems occur and unexpected internal or external constraints become apparent. Some NPD projects are stopped all together due to internal problems during development, but for others unexpected changes in their supply chains can be a major factor.

Since early 80s there has been a growing awareness of the interdependence between NPD projects and their supply chains throughout the entire life cycle process through academic studies such as the Harvard automotive study (Clark, 1989) or the International Motor Vehicle Programme launched by MIT (Womack et al., 1991), which compared the Japanese and Western automotive industries. Early involvement of partners in a product development project is now recognised as a success factor, see LaBahn and Krapfel (2000) and Bidault et al.(1998).

This special issue addresses the particular connection between the product and its supply chain, by looking at the supply chain implication of design decisions and the behaviour of design processes arising from characteristics of their supply chains. To deliver a successful product the partners in the supply chain need to collaborate closely. By making a conscious effort to design the supply chain and rules and protocols for collaboration, managers can ensure better chances for a successful project. The couplings between product development and supply chain design and deployment is typically looked at from the point of view of a particular company, the Focal Company (FC). Supply chain research tends to focus on maximising the benefit for the customer.

Typically only a part of the solution is in the hands of the focal company, while other aspects are created by partners, who can improve the product concepts, influence the product architecture and suggest more reliable or more current technologies. Based on the product development project model by Ulrich and Eppinger (2003), Figure 1 shows a framework, which considers in parallel the product development process and the design and deployment of its supplier chain or more generally the network of partners. This global framework called Co-Evolution of Products and Network of PartnerS (CEPS) (see Zolghadri et al., 2009) underlines the need for a systematic evaluation of the consequences of decisions made in product development on the supply chain design and deployment and *vice versa*.

The framework also highlights that not all partners have the same influence on the product. Supply chain partners can be divided into four classes which are discussed later on according to the time they come into a project and the input they provide: *risk and revenue sharing* partners, *design* partners, *manufacturing* partners, and *parts sellers.* The doted lines before or after each class of partner indicate the possible limits of their contributions.

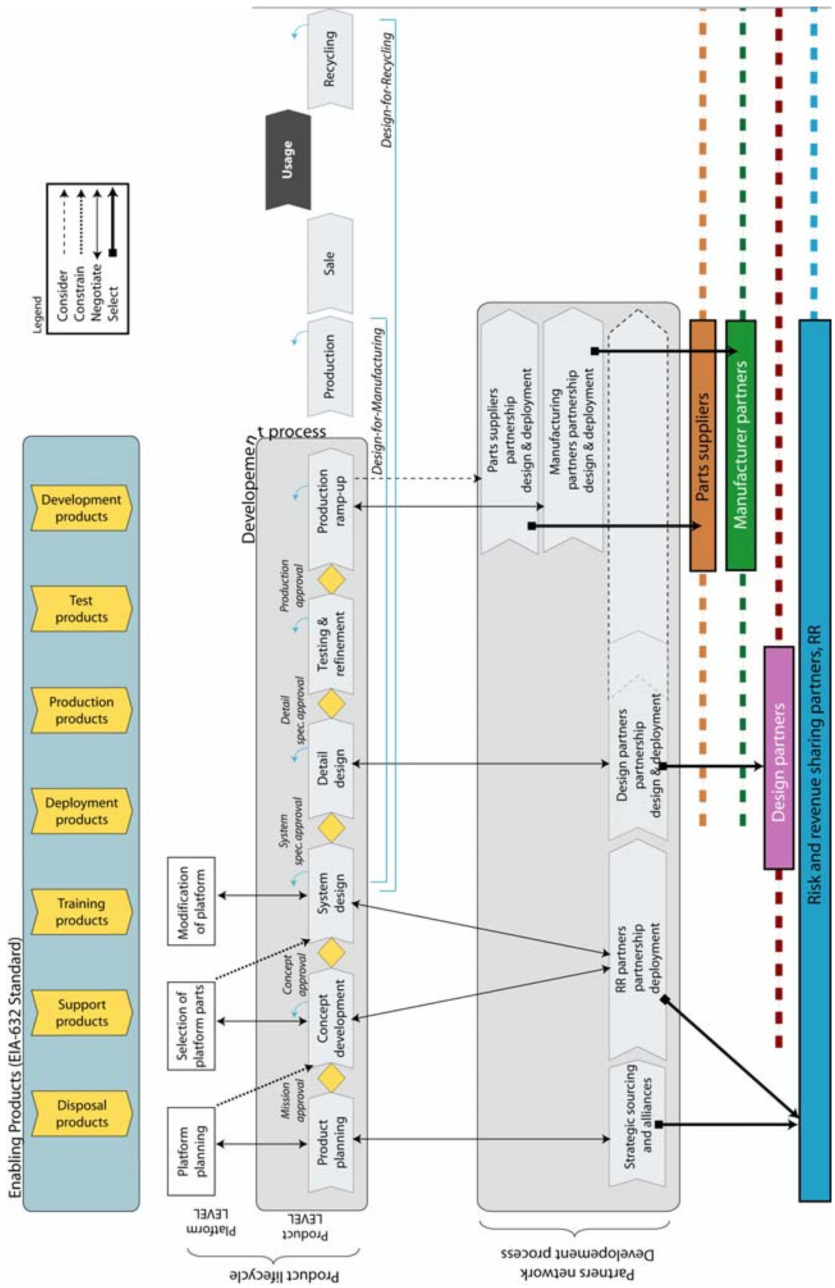
To complete the overall picture, enabling products (at the top of the Figure 1) are integrated into the model as suggested by the ANSI/EIA-632 standard (1998), which defines a systematic approach to engineer or reengineer a system and distinguishes between two classes of products, which are developed within a system engineering project: end products and enabling products. An enabling product is defined as an

> "Item that provides the means for a) getting an end product into service, b) keeping it in service, or c) ending its service. Enabling products are required to carry out process steps to "develop, produce, test, deploy, and support the end products; train the operators and maintenance staff of the end products; and retire or dispose of end products that are no longer viable for use." [ANSI/EIA-632 standard, (1998), p.47].

An end product is "the portion of a system that performs the operational functions and is delivered to an acquirer" [ANSI/EIA-632 standard, (1998), p.77].

The CEPS framework extends the product development model suggested by Ulrich and Eppinger (2003) into the product lifecycle to include production, sale, usage by customers and recycling. Designing products by taking these phases into account is of utmost criticality for the success of the project. Design-for-manufacturing or design-for-assembly address potential problems in the production phase already during the design of the product (see for instance Molloy et al., 1998). Suppliers can be involved in each of these phases including sale and recycling. In some industries, such as the automotive or aerospace industry, NPD projects cannot be launched and conducted anymore without considering the end-of-life phases and necessary steps such as disassembly or partial recycling of products (Ahn et al., 2005). Sustainability is becoming an increasingly important issue in product lifecycle management, and all partners in a supply chain now need to concern themselves to some extent with the end of life of a product. The scope of collaborations necessary to manufacture products is now larger than ever.

Figure 1 Co-evolution of products and network of partners (CEPS) framework (see online version for colours)



The very first activity of product development is *product planning*. Ulrich and Eppinger (2003, p.13) define this activity as follows "… it precedes to the project approval and launch of the actual product development process. This phase begins with corporate strategy and includes assessment of technology developments and market objectives". At the end of this phase the company has a number of alternative designs. This activity is carried out internally and under the responsibility of the focal company even if some strategic partners could help in the concepts definition. Once the fundamental concepts of the product are established the system-level design starts. Many official NPD projects only start at this point. Based on the selected concepts one or several system-level designs are developed representing possible solution approaches or configurations of modules to meet functional requirements. System-level design determines the modules which have to be designed and assembled in the final product and specifies the interfaces between modules. The clarification of these functional and technological interfaces is established through negotiations between different partners, sometimes in face-to-face meetings based on know-how within the company or in supplier companies or external inputs such as standards, see Baldwin and Clark (2004).

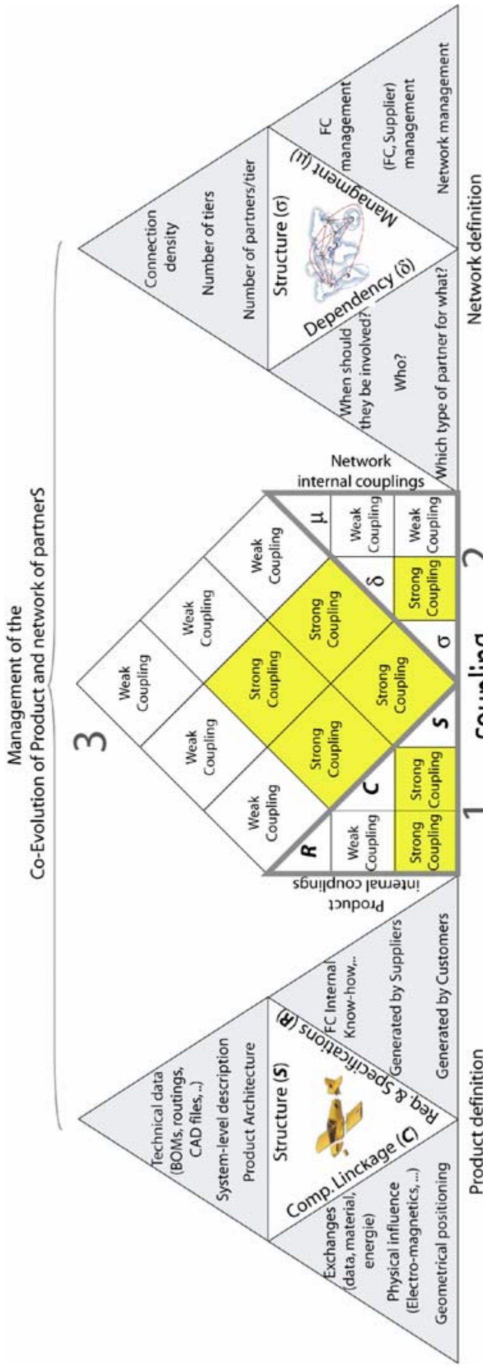
Concept development and system-level design is often carried out collaboratively with risk and revenue partners. These partners are identified as a result of strategic sourcing and alliances activity. Their collaboration continues beyond individual projects. These alliances are defined by corporate business strategies conducted by top management who plans, negotiates and sometimes signs long-term collaboration contracts with a very small number of partners typically as a result of successful past collaboration. According to resource dependency theory these partners are most critical to a company (Emerson, 1962), because the company relies on them for a definition of the business context and goals, the market structure, technology competence, positioning against competitors and specific know-how linked trends in product design. Risk and revenue sharing partnerships are long term and rarely change. The terms of collaboration are defined explicitly or sometimes implicitly relying on personal relationships between managers.

At the end of the system-level designs phase, it needs to be decided whether a component is designed or made internally or if it is brought in. The *design partners* participate in the design of modules and need to take the manufacturing of the products into consideration. These partners can affect product features deeply through their knowledge and technologies. They often make suggestions that lead to significant improvements to the product. These partners are clearly critical for success of an NPD project and therefore must be selected carefully.

Finally, once all designed modules are integrated and tested by physical or numerical prototyping, production ramp-up can begin. In the production phase, *manufacturing partners* and *parts suppliers* are involved. The impact of these partners has been studied for several decades, because it affects the success of the supply chain fundamentally.

Studying mutual influences of design and supply chain issues is not easy because of cause-effects loops or couplings, which are explained in the CEPS framework structure as shown in Figure 2. Products and network of partners are determined according to three 'dimensions' each and related in a matrix of couplings.

Figure 2 Couplings between product and network of partners (see online version for colours)



A product can be defined by three dimensions (left triangle of the Figure 2): its *structure* (S), its *components linkage* (C), and the *requirements and specifications* (R) to which it was generated. The structure of the product at an abstract level is defined by its fundamental architecture, which is determined during system-level design to describe modules and their interfaces. The detailed architecture is defined by technical data (bills-of-materials, routings, CAD-CAM files, etc.) which provide a complete description of the product at the end of the design process. The second dimension of product is related to its component linkages. Pimmler and Eppinger (1994) see spatial, information, energy and matter transfer as the basic components links. Physical influences were added by Zolghadri et al. (2007) as another class of product linkage, which may impact the product definition. Finally, the product is a response to customers requirements and technical specifications defined by the company and its partners, which put hard constraints on the product target structure, behaviours and functions (Gero,1990). These three dimensions of a product allow an analysis of the couplings with the supply side of the network definition.

The network of partners can also be regarded from three view points (right triangle of the Figure 2). The *structure* of the network, noted s, is defined by the number of tiers, the number of suppliers per tier and the density of the existing relationships between them. Partners will be involved in specific phases by bringing components, tools, resources, or know-how to the NPD project. The FC needs to select those partners who offer the right contributions at the right time. This is the second dimension of the network definition called *dependency* and noted d which defines the dependencies and precedences in partner involvement. To find this logical dependency between tasks, the following types of decisions need to be made: 'Which type of partner for what task?', 'Who are the potential partners?', 'How can the tasks be split between partners?', 'Who is selected?' and 'When and how should each partner be involved?'. Once, the network structure is defined and the dependencies between involved partners are established, the network needs to be managed. This is the *management* dimension, noted m, which addresses the running of the network as the product is designed and produced. It is a combination of three kinds of decisions which determine the dynamics of the network:

1 managing data, goods and financial links across all partners in the network
2 relationships between the FC and all its individual partner
3 the collaboration of internal departments and people.

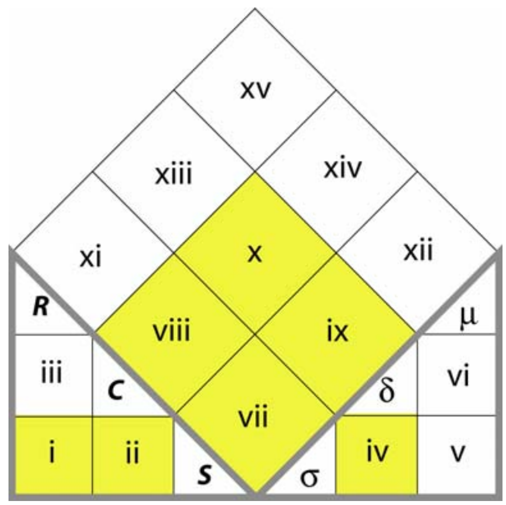
Based on this information the management can define the exact timing of operations.

These three-dimensional descriptions of products and networks show different couplings: product internal couplings (triangle 1 in the centre of the Figure 2), network internal couplings (triangle 2 in the centre of the Figure 2) and finally the couplings between the three dimensions of the product and the three dimensions of the network (square 3 in the middle of the Figure 2), which are at the heart of the CEPS network. The coupling links shown in this figure can be divided into strong and weak ones. A strong coupling between two dimensions means that a change in one of them if propagated will have fundamental consequences on the other. When the effects of changes remain limited or can be managed with localised corrective actions, the coupling is weak.

- Product internal couplings

  The requirements and technical specifications have a strong impact on the structure of the product (cell *i*). This is the basis of product design activities and the coupling is therefore strong. Another strong coupling (cell *ii*) exists between the structure and component linkage. The linkage is mainly a consequence of the structure of the product and the know-how and technologies the company possesses. However, as there is rarely direct relationship between the requirements and the component linkages of the product, this coupling is weak (cell *iii*).

Figure 3 Identified couplings (see online version for colours)



- Network internal couplings

  The dependency definition of the network depends directly on the structure of the network (cell *iv*). For instance, the logical sequence of activities needs to consider the timing of contributions from 1st tier suppliers. The management of the network is influenced by the structure and the logical dimensions, the actual temporal sequence of activities is driven by the need to synchronise the flow of goods, data and resources. Therefore the coupling between the logical dimension and management dimension is weak (cell *vi*). The coupling between the structure and the management is weak because management decisions are strongly influenced by other issues such as resources availability, due dates and so on (cell *v*).

- Product and network couplings

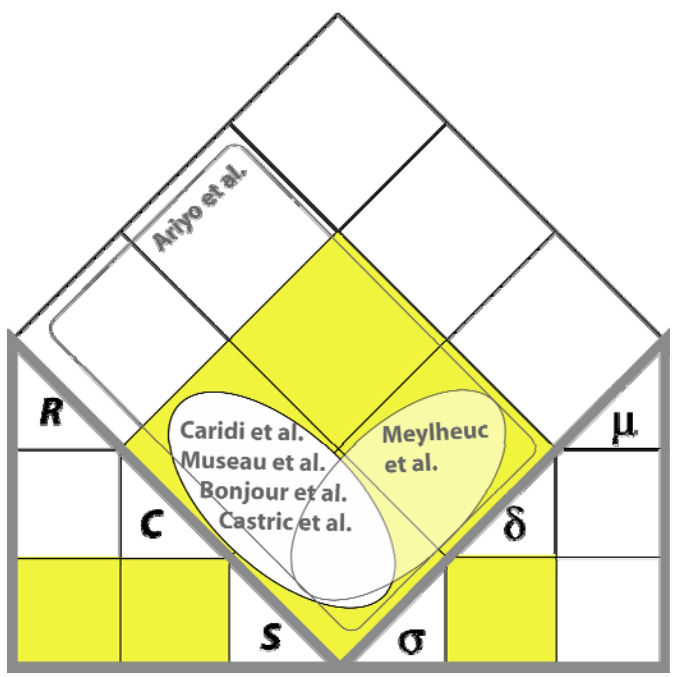
  The structure of the product has a strong impact on the structure and the network dependency. The network's structure is partly defined according to the supplied components and modules of the final product (cell *vii*). The dependency of the contributions of different partners is also defined by the product structure (cells *ix*). The system-level definition of the product, its modules and their interfaces set the basic network structure in terms of partners, partners per tier and the connection density (cell *viii*).

> The definition of the components of the product and their linkages set the dependency of the contributions of the partners and the need for collaboration in designing parts or more generally handling the interface between their components (cell *x*). Decisions made about the network's structure may put more or less hard constraints on the product or its modules, for example through the innovation capacity or manufacturing capability of the partners. If partners cannot provide required components or modules, the design itself might have to be changed. Therefore, there are strong couplings between the structure and the components linkage of the product and the structure of the network and its dependency links.

Requirements for the product have low-level influence on the network structure unless specific contributions of some suppliers are required by the customer (Intel inside for instance). More generally, the requirements are weakly coupled in three dimensions of the supplier network (cells *xi, xiii* and *xv*). The management dimension of the network is weakly coupled with the three dimensions of the product, because the management is mainly influenced by internal resources, partners and production goals (cells *xii, xiv* and *xv*).

According to this description of couplings decisions made in the product field rarely do not influence the network and the network characteristics can rarely be neglected in the design of the product. Decisions are affected by different couplings and the extent of the influence can vary. A coordinated management of product development and the design and deployment of the network is therefore necessary. The main goal of this special issue is to provide some contribution to the understanding of these couplings. Figure 4 shows the scope of various contributions of this special issue.

Figure 4 The scope of contributions (see online version for colours)



In their paper 'The impact of NPD projects on supply chain complexity: an empirical research', Caridi, Pero and Sianesi look at understanding the effects of innovations in NPD projects on the complexity of supply chains. Through an empirical study of 16 companies, the authors measure innovation of NPD projects according to product and process dimensions. The complexity of the supply chain is characterised through the configuration, coordination and collaboration necessary to make the projects work. The authors argue that the complexity of the supply chain increases when product/process innovativeness increases, but is more sensitive to the product innovation than process innovation. The introduction of an innovation changes the network structure by introducing new logistic actors.

By focusing on micro-products, the second paper 'A product-model supporting coupling's management during microproduct design' by Museau, De Grave, Masclet and Paris, highlights one of the most critical issues in NPD projects – collaboration during the system-level and detail-level design of the product, when the specific technical properties of the product are defined. Micro products require specific modelling, as they exhibit different behaviour due to their size. The paper defines the basis of a support system to facilitate collaboration between actors belonging to various fields (such as electronic or mechanical engineering) and in particular those who understand the specific characteristics of micro systems. This is expressed in a product-model described by seven elements modelled by a UML class diagram: design requirements, functions, physical principles, and couplings, manufacturing processes, geometrical representations and materials. This model is then applied to micro electro-mechanical system which is an RF switch.

Designing new products or adapting existing products to the needs of a new market or customer generates changes that could be propagated to other components and therefore to other partners of the NPD project. Ariyo, Clarkson and Eckert study the nature of change propagation. The article gives an overview of change prediction tools, proposes change propagation patterns and defines future challenges in this field. Change handling strategies are subdivided into passive support, active support and procedural techniques. Passive support strategies are not aimed at reducing change propagation probabilities but at allowing an easier management of changes. Active strategies and procedural techniques try to limit change propagation. The authors then discuss existing mainly academic tools for identifying, modelling and predicting of changes. The ability to assess the effect of changes on the product and the processes by which the product is generated is the key to understanding engineering change. A case study shows the way different change patterns can contribute to and arise from product failure. These basic change propagation patterns are simple enough to be understood by practitioner and are powerful enough to model change propagation mechanisms in complex products. Such patterns could also be used to explain how changes can be propagated through the network of partners and their effects of its complexity as defined in Caridi's paper.

An industrial case study of design-for-manufacturing discussing injection moulding design is the subject of the fourth paper by Meylheuc and Goepp. The authors consider three main areas where design and manufacturing fundamentally influence each other: materials, shape of parts and the manufacturing processes. Transforming the traditional sequential design of a part and its mould, this paper presents an approach where the CAD models of the part and the mould are designed in parallel. The conformity of these models with each other is checked regularly taking their mutual influences and constraints into account. This approach is implemented in ProEngineer providing a web-based interface. This approach has been applied to a product provided by Delphi to a car manufacturer.

Bonjour, Dulmet, Deniaud, and Micaëlli take the issue into the wider business context by considering in their article the mutual influences between products and the organisation of the design teams. Their approach is based on a design structure matrix. After building a product-oriented DSM an organisational DSM is developed by two different approaches: a matrix based approach and a fuzzy method. Finally, a clustering algorithm is applied to the organisational matrix in order to identify design teams. The whole approach is applied to a case study of a gearbox.

The engine is one the most complex parts of a vehicle. It is composed of many mechanical parts with usually electronically control. All its parts are highly coupled requiring not only a precise definition of each interface but also a clear understanding of their dynamic behaviour. Due to the intertwined behaviours of parts, no single model can contain all of the parameters and variables of the engine. Design of experiments calibration is now used to analyse this behaviour allowing the final definition of an engine control module. The last paper of this special issue is directed at the final design phase. Castric, Cherfi, Boudaoud, and Schimmerling propose an improved method to calibrate engines' control parameters under special pollution constraints in the European countries. Basically, this final stage of engine design uses a test bed with static parameters (such as load of the vehicle) and the most optimised set of parameters found at this step could generate unsuspected air pollution in the real usage of the car. They develop a Bayesian approach to readjust the model by including the expert knowledge.

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