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THE NEED FOR A TOOL TO EXCHANGE INFORMATION IN NON-HIERARCHICAL NETWORK OF THE ELECTRTONIC INDUSTRY: AN EUROPEAN PROJECT

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1. Introduction

Very few electronic products are produced by one manufacturer directly for the end consumer. Most modern electronics products are no longer simple circuits designed to carry out one function and one function only, rather they are programmed and integrated with the rest of the product, requiring input from software engineers and system engineers and a close interaction with engineers in customer companies.
A complex supply chain is involved even in the provision of simple components, providing the raw materials, the design, manufacturing and assembly and often the programming of the components in different companies. In these supply chains very large companies producing fundamental components, such as standard processors, come together with often very small and very specialised companies. The electronics industry is a major supplier to many other industry sectors, such as defence, automotive or consumer goods. Other sectors contribute heavily to the design of electronics products, for example product design or mechanical design.
The efficiency and agility of the supply network is vital to the commercial success of any product. This is particularly critical for the European market, which is competing on value products, developed and produced to very high standards. To remain competitive companies need to collaborate trusting and supporting each other. In high tech markets there is now a general recognition, that companies need each other to work in a win-win situation, where all party can make a sustainable profit, rather then the more powerful companies trying to push maximise their profit. However, new ways of collaboration are still emerging. The traditional model of a purely hierarchical over the wall way of working, with formal process and modes of interaction is beginning to be outmoded, as it does not provide companies with the necessary agility. Companies are more and more trying to negotiate new paradigms of interactions, which move forward the relation to a non-hierarchical structure. A vital part of this is giving each other advanced warning of future changes or intensions, without risking that this information will be devolved to competitors. This requires sharing of information across a network of companies and not just passing information to the immediate contractual partner. In particular it is not enough to share operational day to day information, but also to share tactical and strategic information amongst the partner of the non-hierarchical network in a safe way.
The supply chain management (SCM) community has been concerned with the exchange of information across supply chains for a long time. To date, the main focus of research and tool development has been on data exchange systems of operational decision. Technical support for the exchange of data for synchronous and asynchronous decision making is provided in the form of stand-

alone tools (e.g. Customer Relationship Management (CRM), Enterprise Resource Planning (ERP) for accounting and financials, Supply Chain management (SCM) for supply chain, Production System Management for production management or integrated ones embedding a common set of functionalities/ modules). These systems have mainly been designed to exchange operational data and other information that can be represented in prescribed formats.

These systems do not cater specifically for the exchange tactical and strategic information. Traditionally this has often taken place in informal communication between people who knew each other.however as collaboration is widen this will not be sufficient, and new tools are required. To understand the requirements for such a tool it is critical to understand what it means to exchange tactical and strategic information in non-hierarchical networks. As people interpret information in different ways, a tools needs to both help people to recognise the significance of the information as having tactical and strategic importance, even if it is buried deeply in larger document. At the same time it needs to help save guard information against getting into the wrong hands.

This paper reports on the early stage of an EU framework 7 project, CONVERGE, which addresses these questions. Section 2 will discuss the context of this research introducing briefly the specific characteristics of the electronics industry and the challenges in exchanges information across company boundaries. Section 3 briefly discusses the methodology used in this paper before section 4 describes the context of the CONVERGE project and the approach it is taking to tackling these questions. Section 5 poses the fundamental research questions arising from it, before conclusions are drawn in section 6.

2. The context of the research

The CONVERGE project specifically addresses the electronics industry, which is linked to many other industry sectors as a second or third tier supplier. We therefore discuss the specific characteristics of the electronics industry and provide a short introduction to supply chain management and discuss the well-known challenges of communicating design information within an organisation, which need to be taken into consideration for communication across the supply chain.

2.1 Electronic Industry

The electronics industry is a highly heterogeneous industry sector, which supplies any other industry sectors. Therefore it is difficult to exactly define the scope of the electronics industry. It is frequently considered in conjunctions of the Information and Communication Technology (ICT) industry. As the electronic industry supplies industry sectors, such as automotive or aerospace, the distinction to these sectors can be hard to draw. The global electronics market has been estimated at $2 trillion each year. Semiconductors alone account for $275 billion revenue worldwide, with annual pre-recision growth forecast of between 6 per cent and 8 per cent (source: BIS, 2008). The European electronics industry has a total value of € 35,69 bn per annum.

The electronic industry is a fast developing market segment with strong global competition and rapidly changing production structures. Rapidly advancing technology leads to frequent product changes and short production runs.

Wildemann (2004) observed two major developments for automotive industry, where electronics companies tend to be second or third tier suppliers, which are reflected across other industry sectors:

- Consolidation of supplier base: as the markets is consolidating car companies are merging and wide ranging product platforms are introduced, the number of suppliers has been reduced by over 50 % in the last 10 years.
- Outsourcing of component development to supply chain: Increased partnerships in product development has let to greater involvement of suppliers in production as well as added value activities. This shifts the risks of product development from OEMs to suppliers, but increases dependencies moving the networks from hierarchical to non-hierarchical to avoid problems in product integration.

Companies in the electronic industry seem particularly confronted with problem in supply chain design, management and integration. The added value of electronic components (i.e. transistors, CPU) is increasing as OEMs of different application segments concentrate increasingly on assembling parts into the end product. Due to the implementation of identical electronic components (i.e. FPGA, micro-controllers, computer processor units) in products of different application segments (i.e. automobile, computer, information and communication, consumer industry, industrial products, government, etc.) electronic suppliers are simultaneously linked to multiple partners with fairly separate self-contained supply chains.

Some electronics products are changing very rapidly and have a short shelf life, for example in consumer electronics. In the automotive and aerospace industry changes are frequent during development, but new products are only developed when major new developments are required. Once a product is in production it can remain in production for many years, and spares might be required for many more. To enable suppliers to respond to quickly changing requirements, but also to support products in production it critical that also strategic and tactical information is exchanged efficiently. For example a supplier would like to know, whether the OEM is planning to persist with a particular technology, when they are considering updating their production machinery. On a tactical level information exchange is also of high importance to guarantee good co-operations, reducing cost and increasing quality (e.g. during the development process of products).

2.2 Supply chain management

Supply chain management (SCM) and other similar terms, such as value chain management and network sourcing management have become subjects of increasing interest in recent years to both the academic and industrial communities (Christopher, 1992; Lamming, 1996; Saunders, 1995). There is a large amount of research on supply chains, decision making and information exchange (e.g. Croom (2000) and Chen (2004)). See Table 1 for a summary. However, this research is fragmented originating from a number of very diverse research communities, who have traditionally ignored the fundamental questions of their adjacent fields. For example decision making is addressed by the management community, the organisational research community, cognitive science, mathematical decision making, research on computer support and the application domain in which the decisions are being made.

Table 1. Classification of supply chain research according to the level of analysis and elements of exchange

		Element of exchange			
		Assets	**Information**	**Knowledge**	**Relationships**
Level of analysis	**Customer/ Supplier Pairs**	Transaction cost Facilities location	Information Technology Support Interplant planning and logistical integration (EDI)	Collaborative design Guest engineer	Outsourcing/ subcontracting Trust/Power/ Commitment
	Chain	Quick Response, ECR, etc. Reverse supply chain management	Industrial dynamic approach Modelling the information flow	Supply chain councils	Scenarios good for supply chain management
	Network	Supply network sourcing Transport logistics	Information Technology support EDI	Suppliers meetings	Partnership sourcing Lean supply

The supply chain community has traditionally concentrated on the production of products and the logistic and resource issues associated with this. However, as products are designed by suppliers or co-designed with suppliers, supply chain management is becoming an important part of design chain management and understanding design processes is becoming a vital part of supply chain management. While many companies have established networks of suppliers, that they draw on for generations of products the network of suppliers is beginning to be seen the result of a design process in its own right, which occurs in parallel with the design of the product. Figure provides a more detailed view of this interaction, details can be found in Zolghadri and Eckert (in press).

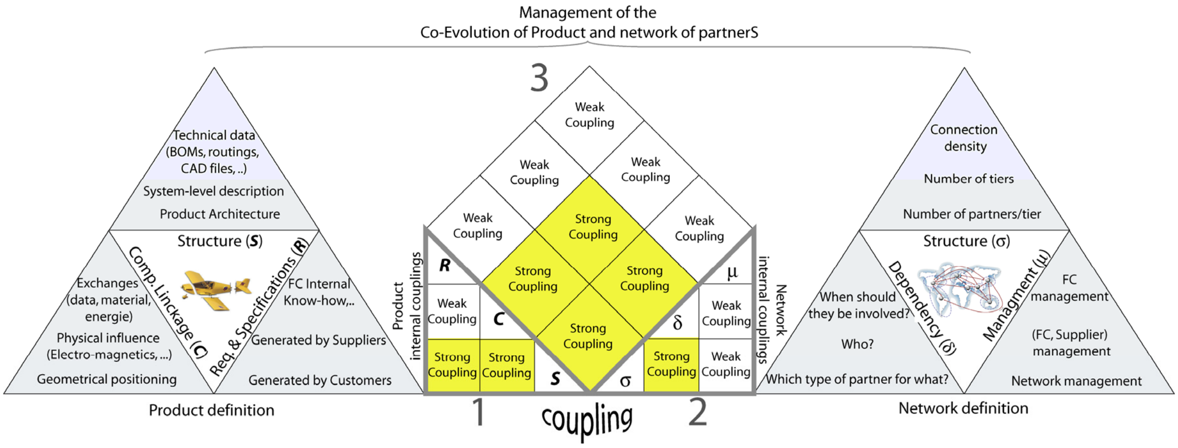

Figure 1. Co-evolution of Products and network of partners

2.3 Communication

Communication is often conceptualized as the exchange of data, information and knowledge. However, in the every day language of design the terms data and information, as well as information and knowledge are used fairly interchangeably for item of communication. This makes sense, as the same item can be data, information and knowledge at a different time and to different people. This is particularly critical in a supply chain context, as the same item of information or data, can be received by a large and heterogeneous group of people, who all will interpret the information in different ways according to their own context and knowledge.

Communication is a well recognised success factor of design processes, but is also often seen as a cause or manifestation of problems in design processes. Researchers like Bucciarelli (2002) or Henderson (1999) point out that even in co-located synchronously working teams understanding the intension and context of different team members can be problematic because of the influence of individual experiences and professional knowledge. Different groups use representations in different ways, have a slightly divergent understanding of key terms and would interpret ambiguous or incomplete information in different ways. These problems become worse with decreasing direct interaction different groups. A common understanding might be reached in a face to face meeting, which is hard to reach if the communication remains asynchronous or mediated through technology. This is becoming worse across company boundary, where different company cultures lead to different objectives and interpretation of terms. This is particularly an issue in the electronics industry, which supply other industry sectors and therefore operates across serious expertise boundaries. For example mechanical engineers in large automotive company need to work with electronically engineers in an electronic SMEs. Globalisation adds language and cultural problems.

3. The methodology of this paper

This paper is based on a literature study, case studies with three partner firms, and project meeting with partners, where research questions are discussed.

3.1 The CONVERGE project

CONVERGE is a European FP7 project funded by the Cooperation program, bringing 10 academic and industrial partners together. This program aims to improve the competitiveness of European industry and to transform it from a resource-intensive to a knowledge-intensive industry. The objective of CONVERGE is to reduce this gap by providing a framework and tools facilitating

exchanges of tactical and strategic Knowledge, Information and Data (KID) elements required for decision makings in non-hierarchical supply chains.
CONVERGE focused on the Electronic industry, is developing a decentralized decision support methodology covering product development and production planning. It consists of:

1) A reference model for inter-organizational decision making in supply chains;
2) A deployment method to adapt the reference model to specific supply chains and companies in the electronics industry;
3) Guidelines for supplier care and customer care;
4) A web-based portal facility, connectable to existing software tools, to support customer and supplier relations.

Besides academic and software experts, the CONVERGE consortium involves four European Electronic companies. In order to identify the real requirements of the electronic industry in general but also those of CONVERGE, GRAI models was chosen to build enterprise decision models. The details of the CONVERGE methods and the GRAI methodology are explained in the following sections.

3.2 Case study of three partner firms

Studying the literature provided the background for understanding and thinking about the supply chain characteristics. The authors are working closely with three of the industrial partners in the project: a large French automotive first tier supplier, which is part of an international enterprise designing and producing electronic systems for the automotive industry such as lighting systems or, infotainment systems: a small French company specialised testing equipment as second or third tier aerospace supplier, and a German company which develops and manufactures customer specified electronic circuits using advanced interconnection technologies like thick film, PCB, Flip Chip assemblies as a second supplier for ceramic circuit boards to the automotive and defence industry.
11 interviews have been held during several months in different countries and the findings were shared in project meetings. From the interview preliminary process models and decision models have been developed, see below. The on-going field study is now reaching across the network to customers and suppliers to complete a picture of the information flow in and out of the companies.

3.3 Project meeting with partners

Results from the interviews have been reported back to all the project partners in regular meetings, in which the findings are being discussed and validated and the consequences for supporting the exchange of tactical and strategic information is assessed.

4. Towards understanding information exchange in the electronics industry

The CONVERGE methodology will be implemented in the first instance around the supply networks of the contributing companies. Each partner is seen as a focal company, i.e. the place of interest in the supply network. The pilot studies are considering a customer, the focal company and at least one 1st tier supplier (**Error! Reference source not found.**). This provides a wider view of the interconnectedness of different suppliers and customers. For example the automotive supplier might provide a part of a component that is used by several automotive companies, but sources its ceramic plates from the same sources as some of its competitors.
The CONVERGE project relies partly on a well-know enterprise modelling technique called GRAI (1985), which model decisions on different levels and time horizons in an organisation. These models are obtained by interviewing precisely identified staff (from operators to the CEO). One of the first models that can be obtained by applying the GRAI method is called the GRAI grid. It provides an abstract image of decision-makings processes within the firm.

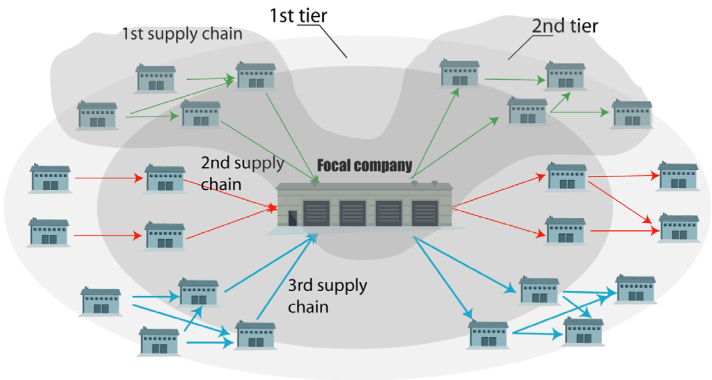

Figure 2. The network of partners, considered in CONVERGE

4.1 GRAI models

GRAI grid is a method and tool to capture decisions made by various functional groups of a firm (such as product development, planning, resource management, etc.). Simply by representing decision levels (strategic, tactical and operational for instance) by rows and functional groups in the organisation by columns, a master model of the decision system is obtained (see Figure 3). This blank form of the grid represents its core part and clarifies the conceptual limits of the studied sub-system in the firm. The studied sub-system refers here to those functions of the firm (executive tasks) that are to be modelled. The choice of these functions is based on the context of the study and its associated goals. Planning, resource management, quality are some examples of these functions. Two more columns are added to this grid. The internal data column is added at the right most side of the gird. It represents all the exchanged data is explicitly used for decisions made inside the studied sub-system. Necessary input and output data coming in or going out from this sub-system is represented in a column at the left side of the core grid. Every cell in this grid is called a decision centre. A decision centre describes all those decisions that are taken by a functional group.

The co-ordination mechanisms between decision centres within the studied sub-system are modelled through two main links: decision frameworks and informational links. A decision framework represent all those required inputs that a higher-level decision centre provides a lower-level decision centre. In the GRAI terminology, these elements are: objectives, decision variables, constraints, criteria, resources, performance indicators and data. The necessary data exchanged between two decision centres are modelled through an informational link.

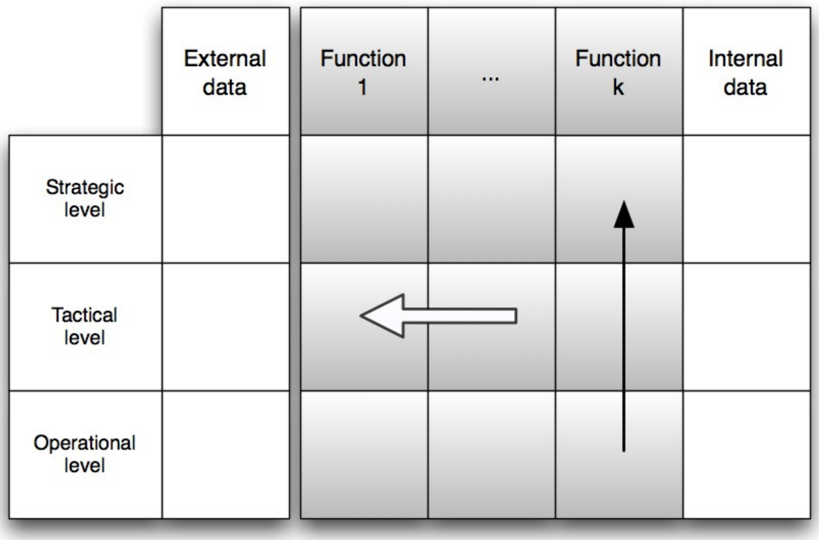

Figure 3. A blank GRAI grid

In the CONVERGE modelling framework, the main focus is placed on the collaboration among firms forming networks of partners. These networks are mainly made by one customer, a firm (the CONVERGE industrial partner) and its direct suppliers. In this case, the GRAI grids obtained for each company represents the way that it co-ordinate its activities internally. The collaboration among firms is modelled through exchanges and so through their interfaces. In order to model these interfaces clearly, the GRAI gird is extended by:

1. Adding an aggregated column called the Customer interface at the right side corresponding to a firm's interfaces towards clients, and
2. Adding an aggregated column called the Suppliers interface, formed by one column per supplier and one column containing all those KID elements that the focal company accepts to share with both suppliers. This column is called the common column. These columns model the interfaces towards suppliers, see Figure 4.

Incoming and outgoing sharable KID elements should be structured in each column.

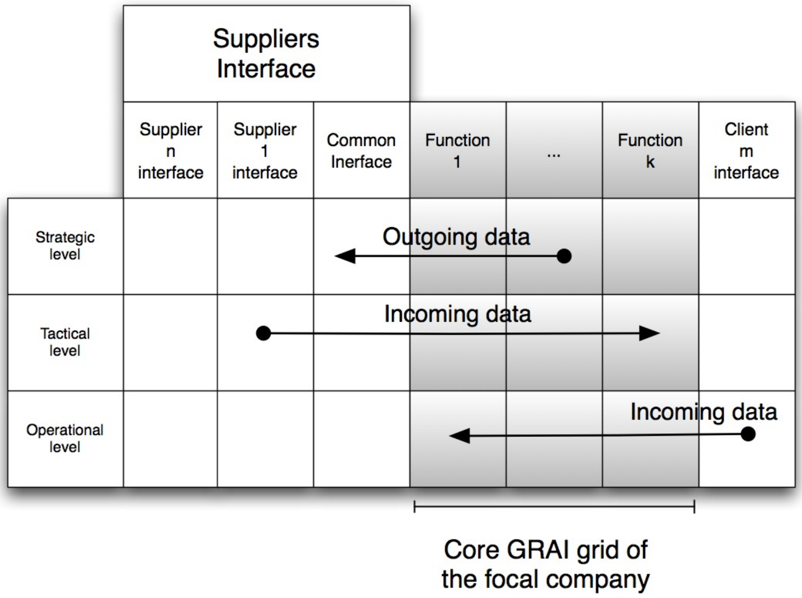

Figure 4. Extended GRAI grid integrating suppliers and customers

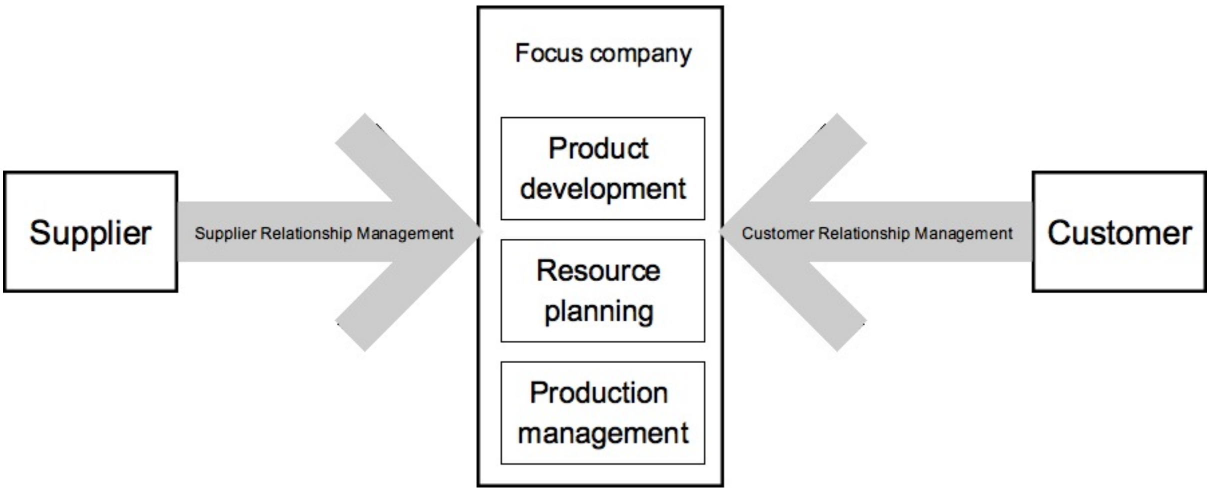

Figure 5. Interaction Scenarios

4.2 Interaction scenarios

The interviews with the partner companies have revealed that the exchange of tactical and strategic data centre around a number of interaction scenarios, see Figure 3. Product development featured particularly strongly in all the interviews. In particular as resource planning and production management is directly affected by decision made during product development. For example design decisions about future products affect whether product platforms will be continued and therefore seriously affect the volumes of production and thus both resource planning and production management.

5. The fundamental research questions

The overarching question that still remains is the key question of CONVERGE: how can the exchange of tactical and strategic information across a non-hierarchical supply chain be supported in the electronics industry? This is very pertinent as electronics companies typically have a very large range of different products and customers. For example the ceramic circuit board manufacturer interacts with over two hundred different customers and suppliers.
This raises several question questions:

5.1 What is tactical and strategic information in a supply chain context?

The CONVERGE project is employing the GRAI method, which is using a temporal classification of information into strategic, tactical and operational information. Managerial decisions can be classified in strategic, tactical and operational to indicate their time horizon and their level of importance. GRAI typically assumes that strategic decisions have a time horizon of up to 3 years, tactical information of up to 6 months and operational covering the day to day business. In order to understand the decision level, and to increase the effectiveness of decision analysis techniques, various ways of classifying decisions have been developed. For instance, Harrison (1975) distinguishes between two categories of decisions I and II. The category I decisions are repetitive and can be carried out through a known procedure, whereas the decisions of the second category require active problem solving to handle novel or unstructured problems. Finally McCarthy (2002) subdivides decisions based on their time horizon and level of importance, i.e. strategic, tactical and operational.
The division between tactical and strategic information could also be conceptualized in terms of the logical dependency of the decisions, whereby strategic decisions are deeply imbedded in following decisions; or by the focus of the decision with strategic decisions focusing on the what will be done and tactical decisions on how this is achieved.
The terminology of strategic and tactical decision making originates from a military area. Strategic decision making is defined by the Merriam-Webster Online Dictionary “as necessary to or important in the initiation, conduct, or completion of a strategic plan and of great importance within an integrated whole or to a planned effect, by contrast tactical is defined as (1): of or relating to small-scale actions serving a larger purpose (2) : made or carried out with only a limited or immediate end in view”. To put it another way strategic decisions are often concerned with the “what and the why” looking at the big picture. It requires the ability to recognize patterns and trends, establish priorities, anticipate issues, and predict outcomes. To some extend strategic plans involve the vision, the mission, the guiding principles and the goals for the business. By contrast tactical decisions are more short term and are concerned with how to achieve these goals.

5.2 What does non-hierarchical collaboration actually mean in the electronics industry?

The term hierarchy is used for several subtle different relationships: tree structures, pyramid relationships and inclusion relations to describe the structure of an object or construct. The hierarchy can lie in the structure of the thing itself or merely in the description that we are using for it. In the context of a supply chain a hierarchical view is a tree structure of relationships from the final product down to the component suppliers with the implication that contractual relationships and interactions occur only with the company above and the companies below in a pairwise fashion. However, it is not clear how far a non-hierarchical relationship reaches. Does it only mean increased vertical integration, i.e. a slightly wider interaction with customers' customers and suppliers' suppliers? Does is mean wider horizontal integration, i.e. sharing amongst the supplier to the same company? Or does it mean on opening of the entire network.

This is both a theoretical question about the configuration of supply chains, and a practical question for the collaborating companies. On the one hand more and more the suppliers in electronic industry take larger ownership of their components, as development is outsources across the supply chains. This forces a greater degree of collaboration across the entire network. This raises the question how much is the brokered through established chains or companies can interact directly. The information sharing, communication, and decision making in such non-hierarchical collaboration become extremely difficult. It necessitates a strong trust and alliance, as well as tools for interaction as it increases the number of potential links significantly.

5.3 How to model design decisions?

The nature of decisions in the design and development phases is completely different form those in the manufacturing phase. In manufacturing the activities are scheduled and the consequences are predictable. Moreover, manufacturing deals with a large amount of resources (human and machine) and materials and the degree of freedom for the decisions is quite limited. On the contrary, in development phase the design activities are complex and highly human based. A much smaller amount of non-human resources is engaged, and design decisions influence greatly the following steps in production. The GRAI method has proved its efficiency through many scientific study and industrial applications. However, the GRAI and other method such as SCOR (2009) do not cover the design and development phases, because of the whole different nature of decision parameters, such as time of efficiency. In the same direction, it is not clear how to categorize decisions into strategic, tactic and operational since the parameters for measuring the effect of decision is unknown.

5. Conclusion and discussion

To stay competitive the European electronics industry needs to learn to collaborate as effectively as possible across the entire network of suppliers. The traditional model of a rigidly hierarchical supply chain is beginning to change already, as companies are developing components and system together and share information more freely. This already works extremely well in isolated cases, but has not yet become the norm. To create a culture of open collaboration the needs and characteristics of the electronics industry needs to be better understood. As an industry section of highly intertwined supply chains, it is critical that companies can both be open with each other, while at the same time be sure that the security of their information is not compromised. The exchange of operational information is well supported already by existing computer tools; however the exchange of tactical and strategic information still occurs in an ad hoc way. The nature and challenges of the exchange of tactical and strategic information is still ill understood and no specific tools exist to date. The CONVERGE results including methods and tools fulfil a real industrial need.

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