MODELLING DECISION AND DATA DEPENDENCIES IN ENGINEER-TO-ORDER PROJECT MANAGEMENT

Marc Zolghadri[1], Claudia Eckert[2] and Rahi Rasoulifar[1]

[1]IMS-Labs Bordeaux, CNRS 5238, Talence, 33405, France
[2]Design Group, The Open University, Milton Keynes, MK7 6AA, UK

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1 INTRODUCTION

Dependency modelling has become a useful tool for understanding and managing product development processes. Traditionally models addressed primarily information dependency in process models and product connectivity in product models. Approaches such as Domain Mapping Matrices (DMM) bring heterogeneous aspects together in single integrated models. However the scope of these models has primarily been static relationships in a project, a product or a sub-system within one company. This paper reports on research to extend connectivity modelling to the temporal dependency of decisions across supply chains.

Engineer-to-order (ETO) refers to all those product development and manufacturing projects originating from customer requests that cannot be satisfied by company's standard offer. If the company, which will be referred to as the focal company, can not cover the request, from catalogue products, option packages or as changes to options, they have to launch a new project, where they need to look for contributions from know and unknown partners. Many engineering change projects also fall into this category, however in those cases companies typically draw on existing supply chains.

Such ETO-projects cover the whole development and manufacturing process and the focal company's supply chain partners might contribute to all phases. This necessitates frequent communication with partners to reduce technical uncertainties or solve problems regarding the design or manufacturing of components. Beside these technical issues, other questions (such as definition, timing and synchronisation of actions between partners) arise in the management of the ETO-project. ETO relationships are usually considered as isolated projects, but the focal company might have several of these projects to deal with at any one time, therefore they have to plan resources carefully across projects and coordinate the management of these activities.

In this article, we propose a framework to manage ETO projects including basically three levels of collaboration: technical, mono-project and multi-project. The framework looks at information exchange between partners forming a part of a supply chain. This framework is being developed in the CONVERGE project based on four industrial cases with companies at different places of supply chains. CONVERGE is a 30-months European project of the Seventh Framework Programme (2009-2013). It has been launched in June 2009 and involves 10 academic and industrial partners. It addresses the exchange of tactical and strategic information in non-hierarchical supply chains in the electronics industry. The industrial partners are two French, one German and one Greek electronic companies. Two are Small and Medium Enterprises, while the others are worldwide companies with partners from all continents. To identify the requirements for an information exchange tool for the electronic industry in general and the project partners in particular, the GRAI (Graphs with Results and Actions Inter-related) modelling framework (Vallespir et al. 2002) and CEN (1995) were chosen as the basic modelling tools. The GRAI method was developed in the 1980s at Bordeaux University and applied successfully to manufacturing processes over the last 25 years. Business process modelling techniques became common in mid-90s mainly for business process re-engineering. They allow analysts to obtain a realistic model of intertwined activities. GRAI particular focus lies on modelling the control system in business processes, as it maps decisions points on strategic, tactical and operations level and the information flows between them. It is based on the assumption that decisions will be reviewed at regular intervals varying with the scope of the decision. The top level GRAI model expresses the periodicity of these decisions, mapped onto the functional group that takes them and the time it takes for the decision to be updated. Used together, these models express existing dependencies between decisions made in various nodes of the supply chain. The CONVERGE modelling framework makes use of these techniques.

2 MODELLING TECHNIQUES

The CONVERGE framework looks at modelling information exchanges during the development and manufacturing phases (see Figure 1). As GRAI had traditionally been developed for manufacturing processes, which have a far more predictable decision making process, the CONVERGE projects needs to expand the GRAI approach to involve development processes, where most significant decisions are make for the future manufacturing of a product or decisions which impact on products in production. The CONVERGE framework includes two complementary views: a process view and an enterprise function view. The process view models the project steps showing how activities are linked based on typical information exchanges between the focal company, its customers and various suppliers. The enterprise function view is adapted from GRAI definition of function (see Girard, 2004).

Hereafter we will describe the CONVERGE framework shown in Figure 1. The development and manufacturing processes are shown at the bottom of the Figure 1 by two big arrows. At the right side of the figure, the management system of the manufacturing phase is modelled using the traditional GRAI grid called here GRAI-manufacturing grid. The grid captures the formal decisions made in various functions units of a firm, such as planning, resource management, and quality. This is the time when decisions are signed off or reviewed and therefore officially get logged, rather then when a team makes an informal decision. The GRAI grid captures the hierarchy of decision-making in firms by representing decision levels (strategic, tactical and operational for instance) by rows. Columns model functional groups in the organisation (purchasing, human resource management, etc.). A cell of the grid is called a decision centre. A decision centre models all decisions with similar time scales made by a given function of the firm, which belong to a same decision level requiring the same control mechanisms. For example this might be the case of all the decisions approved at a design review meeting, or at a board meeting discussing strategy development.

The central part of the grid represents the functions pertinent to the context of the study and their associated goals. The columns at both sides of the GRAI grid model exchanges with suppliers and customers. This model is built in a series of meetings, by somebody with GRAI training, involving major decision makers of the firm. Among various kinds of decision dependency, that one considered in CONVERGE project is the *information-based dependency*. Decision centres are connected together due to their hierarchy or by information link. The information link (simple arrow) shows how a decision D needs some information inputs generated by another decision C. The hierarchy is modelled as decision frame (double-lined arrows in the grids or between them). A decision frame is a description of a set of items that constrain the degrees of freedom of decisional activities and represent the flow of decisions up ad down a hierarchy. These decisions can be made within an organisation or across its supply chain (see the left side schema in Figure 2). For example major company periodically review their list of referred suppliers, whether the focus company is included or not clearly affects its decisions on all levels. Once completed, the gird expresses the decision-making hierarchy of all of the functions during the manufacturing phase. This is a master model of decision processes. This approach relies on the expertise of the model builder in extracting decision-making mechanisms.

Generally speaking, the manufacturing phase exchanges between suppliers and customers concern issues such as delivery delays, quality of components, changes due to particular properties of the manufacturing process, etc. These exchanges are typically well structured and can be formal (supported by different kind of documents) but can (rarely) be informal (for instance face-to-face discussions or conference calls). The GRAI-manufacturing grid was therefore developed for these repeatable modifications with known uncertainties in manufacturing processes. However, among the four CONVERG companies only one company is solely focused on the manufacturing phase, whereas the others are also involved in the product development phase.

The development phase, shown at the bottom left hand side of Figure 1 consists of design and preparation for production. Both activities involve iterations around user needs and specific manufacturing requirements. This process is modelled using the Business Process Modelling Notation, noted BPMN (2009) concentrating, as in the manufacturing phase, on formal and informal exchanges in the focal company and between the focal company and its suppliers and customers. The development management system is modelled by the ETO-Grids (see in the middle left hand side of Figure 1). This is an extension of the traditional GRAI concepts focusing on project management. Two types of models were developed: mono and multi-project grids.

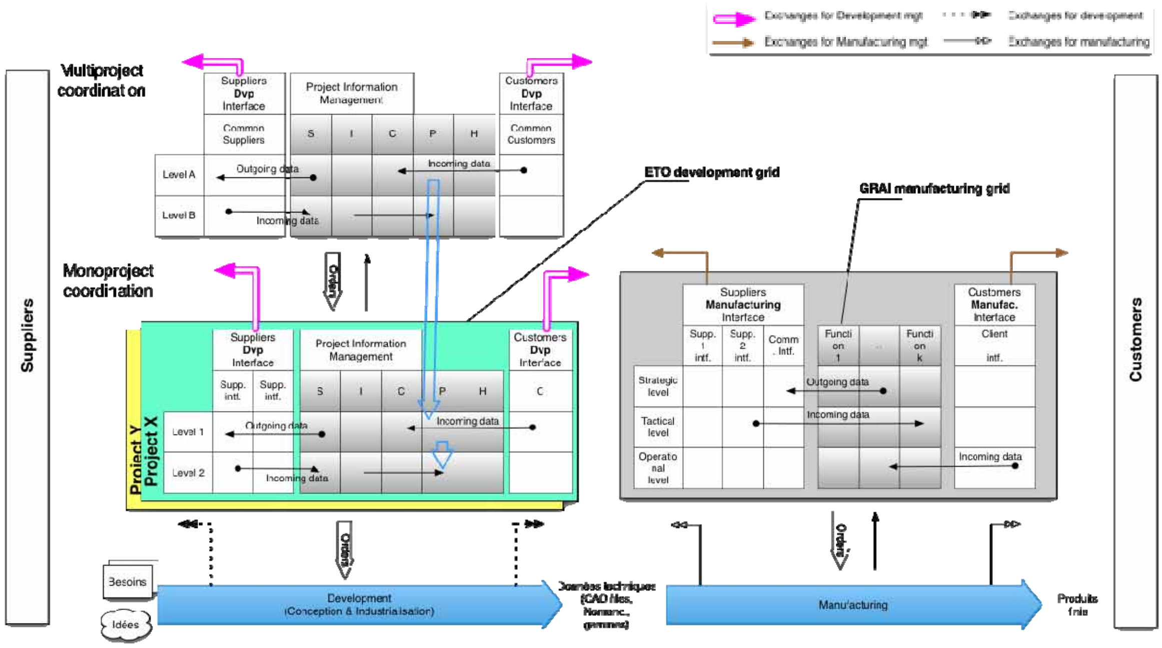

Figure 1. The global ETO project management framework

Single projects are modelled by these project-oriented ETO-grids, which allow analysts to map decision-making processes and workflows. The decision-making processes are organised by decision levels reflecting various monitoring levels of projects. Decision levels are identified based on two criteria *duration* and *milestones*. The duration refers to the longest duration of all activities considered at that decision level (phase, task, operation, etc.) performed in the project. As such, the modelled management decisions cover the overall dynamics of activities. Milestones refer to evaluation points that are carried out either jointly with the customer or for internal purposes in the focal company. The highest-level decisions are made concerning the development plan. Such contracts contain also the milestones on which deliverables are provided by the company and are approved by the customer. A list of formalised steps such as Kick-Off Meeting, Letter of Intent, Technical Documents Preparation, etc. can be found at this level. Other decision levels are modelled in lower levels based on the shorter duration and more localised targets, see right picture in Figure 2. Even if theoretically, several decision levels may be identified in this analysis, for the CONVERGE industrial cases, up to two lower-level decision making levels have so far been identified. These lower levels describe decisions made for development revised according to internal milestones (shorter than milestones signed with the customer).

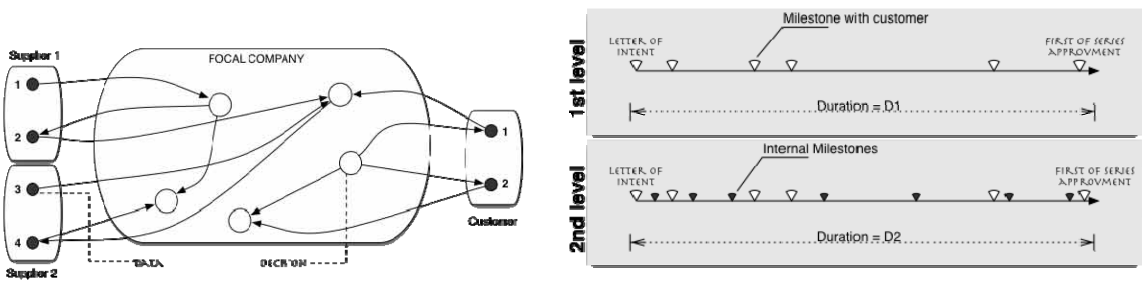

Figure 2. Dependencies between incoming/outgoing data and decision-making processes

If shared resources are used to perform projects, multi-projects coordination becomes necessary. These coordination decisions look at monitoring projects and available resources. Since parallel ETO-projects are not a priori synchronised, multi-project management decisions are made often periodically, as the organisation periodically reviews it activities on all levels. In this case, the ETO-multi-project management grid (at the top of Figure 1) contains decision layers identified based on the temporal periodicity.

3 THE CONVERGE METHODOLOGY

Combining these models show how ETO-projects are performed within companies. These models represent a map of dependencies between decisions and the exchanged information (left side of Figure 2) and the application of the CONVERGE modelling techniques should allow analysts and end users to set up new collaboration protocols because it would be possible to detect dependencies among decisions. The CONVERGE methodology contains four basic steps: AS IS modelling phase, AS IS situation assessment, and TO BE situation design, and TO BE implementation. The modelling techniques are applied first to the focal companies obtaining AS IS models. These models are then studied in order to find out possible improvements. Basically, mutual information dependencies among decisions are highlighted as well as those connections, which would improve collaboration among partners in terms of decision making or information exchange. Based on the focal company's needs the TO BE models propose collaboration protocols between the focal company and its partners. Finally the TO BE situation should be implemented by taking account of basic constraints of the firms.

4 INDUSTRIAL USE CASES

The authors are working closely with the industrial partners in the project. The example in Figure 3 is a simplified version of the ETO-grids for mono and multi-projects obtained from our case studies. This study was focused on an ETO-project developing an electronic device used in specific aircrafts. The project concerns 600 assembled products that should be delivered within 8 months. Tight milestones were set where the customer approves the preliminary development. In our use cases, each project is under the responsibility of a project manager who makes technical and/or management decisions and allocates resources to specific development activities. According to major decision makers of these firms the focus of the modelling should be put on the development phase because of the technical and management constraints. A series of interviews has been held within four focal companies in various fields, over several months, in average 4 meetings per company.

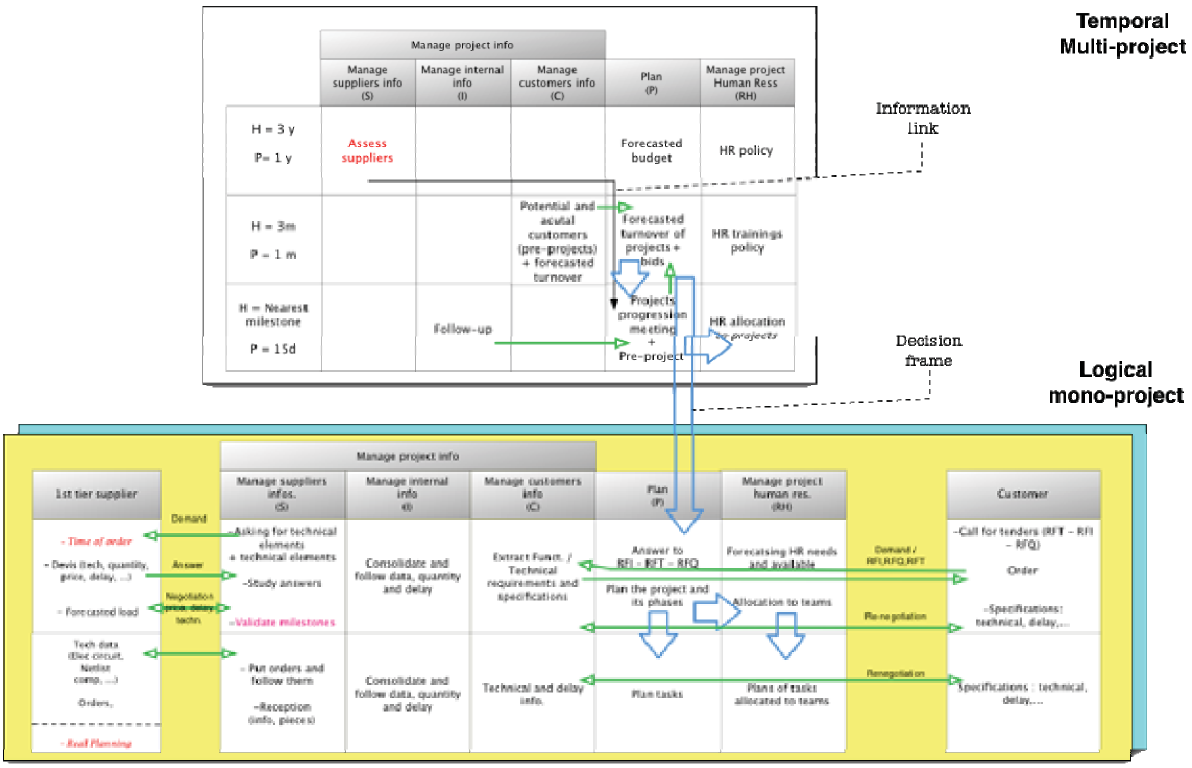

Figure 3. A simplified model French SME model of ETO-project management

A consolidated version of the ETO-grid model is now available. Hereafter, due to confidentiality reasons, a simplified version of this model is provided, see Figure 3. Some technical data is eliminated from the models to guarantee the privacy of companies. The process model of the ETO-project was performed using BPMN (2009), shown in Figure 4 for a part of these process models. During the analysis of these models potential improvements were identified.

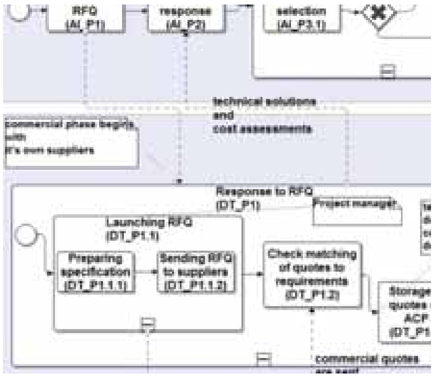

Figure 4. A part of a development process modeled by BPMN

5 CONCLUSIONS AND ONGOING WORKS

Clarifying dependencies among actors of a supply chain is a challenging task. The CONVERGE project aims to provide such mappings in order to foster better collaboration and higher efficiency. Decisions made within the focal company are greatly dependent on internal and external data, which could be formal and informal. Formal data is predominant in the manufacturing management while informal data exchanges within the supply chain are vital during the development phase.

The CONVERGE modelling framework and tools (ETO-grids and GRAI grids) are based on established business process and manufacturing models and informed by communication research. These tools are applied step by step to the real cases in order to refine them. Not all the models are already available. Ongoing project work packages will on validating the CONVERGE especially for ETO-grids which have to map the major dependencies within the supply chain. The modelling has come from a different tradition as the traditional DSM research, but further work will address the applicability of DSM and MDM analysis techniques to periodic decision-making.

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Contact: Marc Zolghadri
IMS-Labs Bordeaux
351 Cours de la Libération
PO Box, City: 33405 Talence Cedex
France
Phone: +33540002405
Fax: +33540006644
e-mail: marc.zolghadri@ims-bordeaux.fr

MANAGING COMPLEXITY
BY MODELLING DEPENDENCIES

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Marc Zolghadri[1], Claudia Eckert[2] and
Rahi Rasoulifar[1]
[1]IMS-Labs Bordeaux, CNRS 5238, France
[2]Design Group, The Open University, UK

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Index

- CONVERGE project
- Engineer-to-Order projects
- CONVERGE modeling framework
  - GRAI-Manufacturing
  - GRAI-project
- Industrial use-cases
- Conclusions and perspectives

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CONVERGE: “Collaborative Communication Driven Decision Management in Non-hierarchical Supply Chains of the Electronic Industry”

- Start: June 2009, End: November 2011 (30 months)
- Human resources: 288PM
- Funding: 1.8M€
- Partners: 10
- Countries: 5

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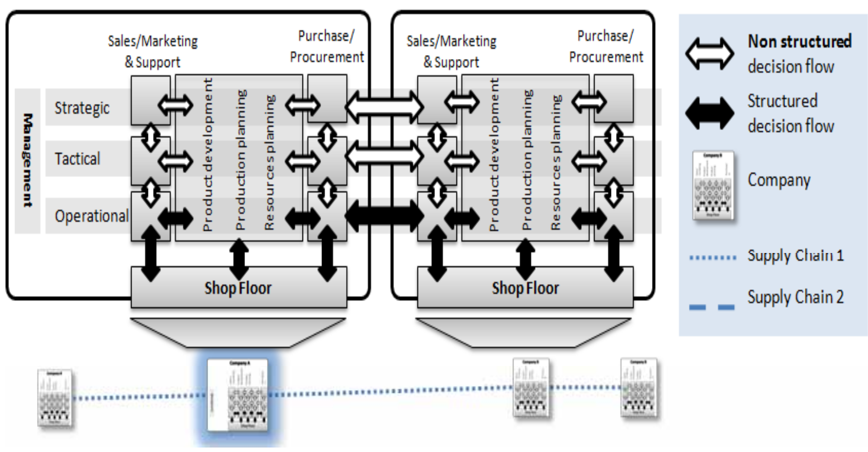
CONVERGE

- The goal: To improve decision-making efficiency in non-hierarchical supply chains by supporting strategic and tactical data exchanges.
- Focused Processes: Product dvp, Production planning, Res. planning



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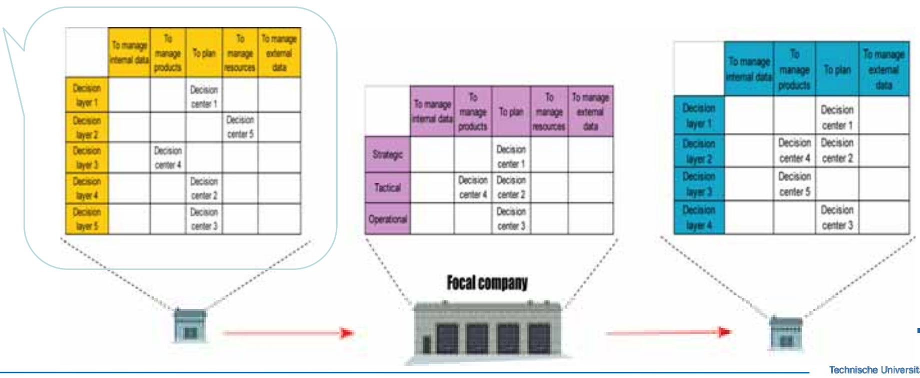
CONVERGE

- Waited Results:
  - A reference model *for collaboration in non-hierarchical networks, on management level. It will be based on the extended GRAI-approach to inter-organizational level.*
  - A deployment process *to apply the reference model at different usage levels (generic processes for all industry sectors, processes for the electronic industry, for particular networks and for particular companies).*
  - A prototype *based on existing IT-Tools extended and adapted to the new reference model.*

GRAI model



BY MODELLING DEPENDENCIES MANAGING COMPLEXITY

CONVERGE

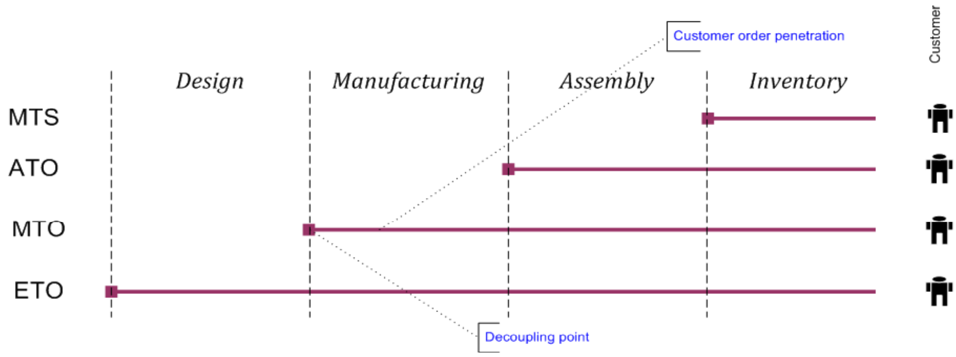
Our Roadmap:

- 1.Determine the fundamental structure to which the FC belongs.
- 2.Map basic decisions made within the FC. They consist of two kinds of decisions:
  - a.Internal decisions. They are indirectly connected to the partners’ activities.
  - b.Frontier decisions. Their inputs come from a partner and/or their outputs will be used by at least one partner.
- 3.Indentify as clearly as possible the dependencies between decisions modelled in the past step.
- 4.Analyze dependencies then search for an efficient support tool to help FC’s decision-makers in their daily tasks.
- 5.Design and produce that support.

Engineer-to-Order projects

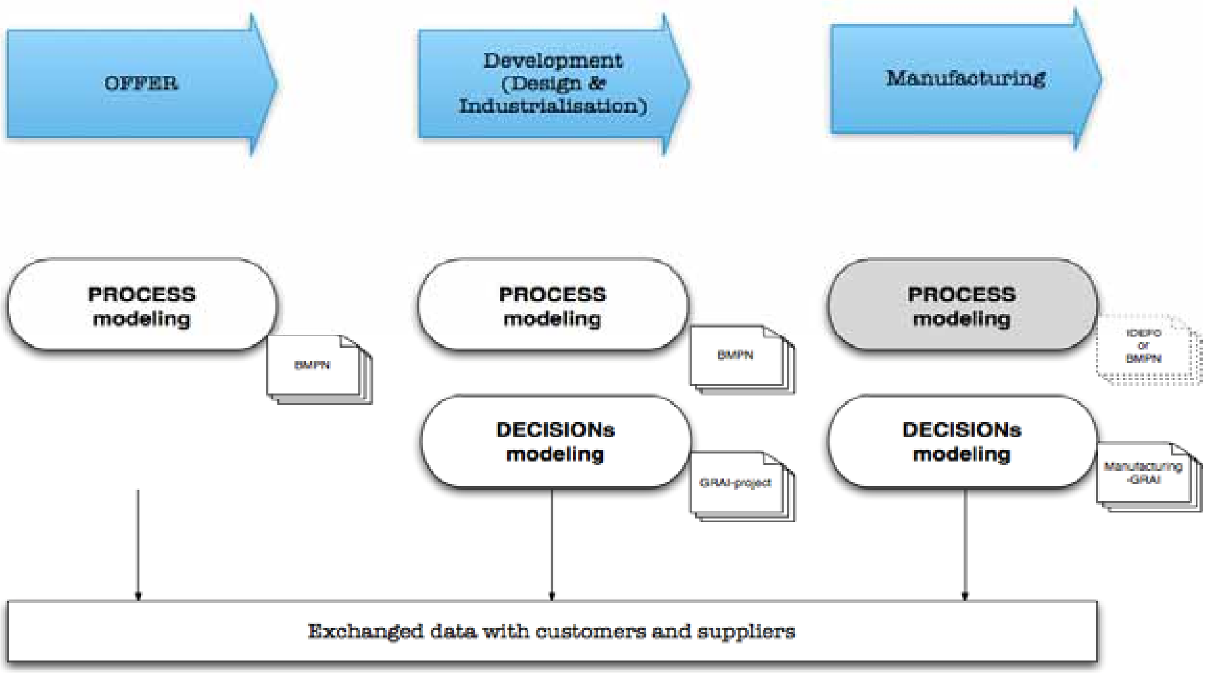
- (Slack et al, 2004):
- "low volume – high variety".
- In these systems, customized products should be delivered to the customer. This means that design activities will take place before any manufacturing. The product adaptation could represent high level design or small improvements.

Slack N, Chambers S, Johnston R, (2004) Operations Management. 4th ed., Pearson, London



CONVERGE modeling framework

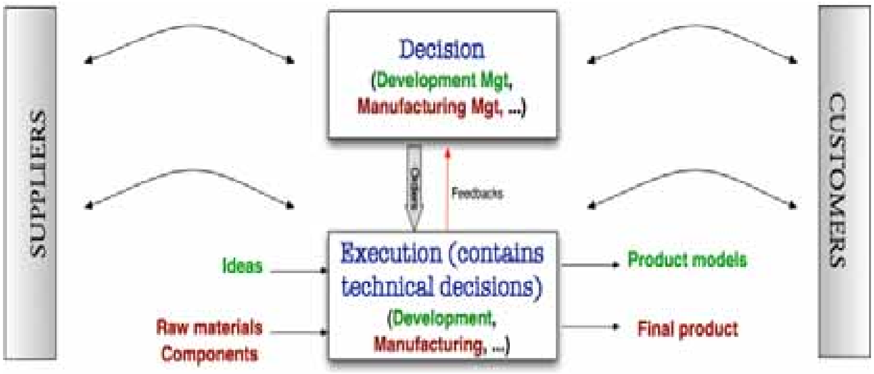
- Three majors phases of an ETO project: Offer, Development, Manufacturing



CONVERGE modeling framework

Simple decomposition of a system

- A Decision system: Makes decisions to manage the controlled system.
- An Execution system: Consists of all technical decisions and executions necessary for creating product models (design) and/or manufacturing.
- A firm exchanges with customers and suppliers.



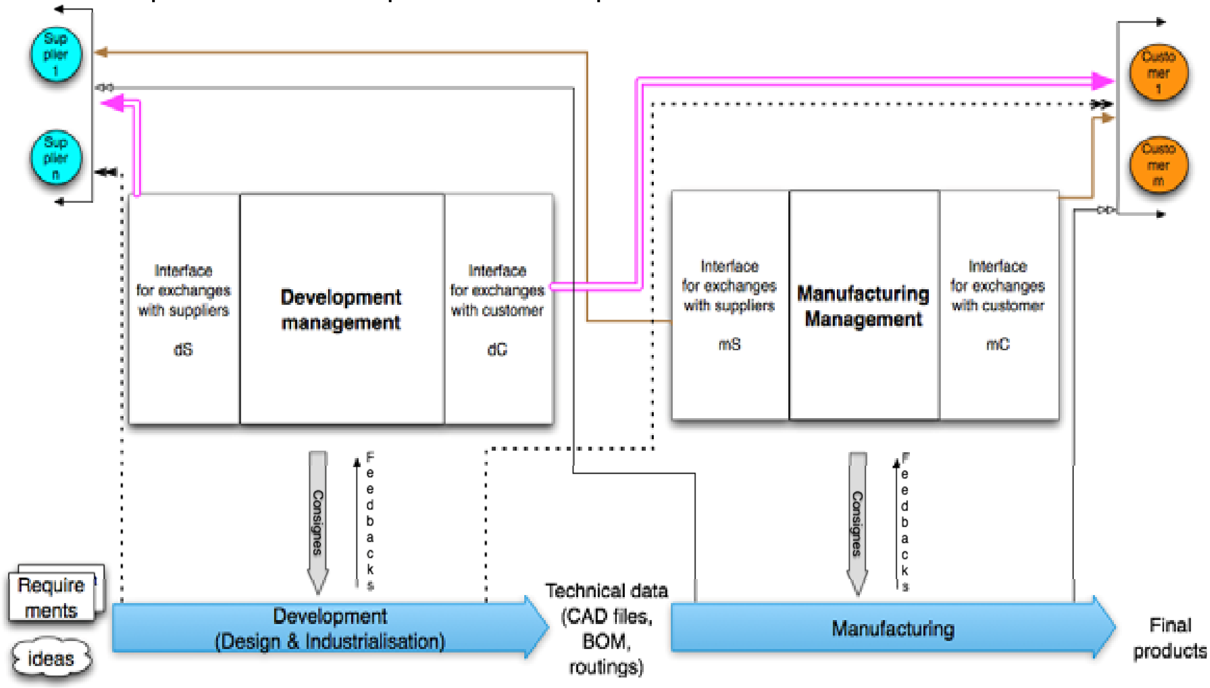
Exchanges between FC and its partners

- Management-based exchanges concern **ONLY** the management decisions:
  - synchronization of activities, resources,
  - description of rules, constraints,
  - ...
  - Examples: Customer order, Supplier catalogue, …

- Execution-based exchanges concern **ONLY** the executive activities:
  - goods transfer (raw materials, components, ...) Manufacturing
  - technical data of products Development
  - Examples: Customer technical requirements, Components specifications, ...

CONVERGE modeling framework

- Management of development and manufacturing
- Specific models required for these phases



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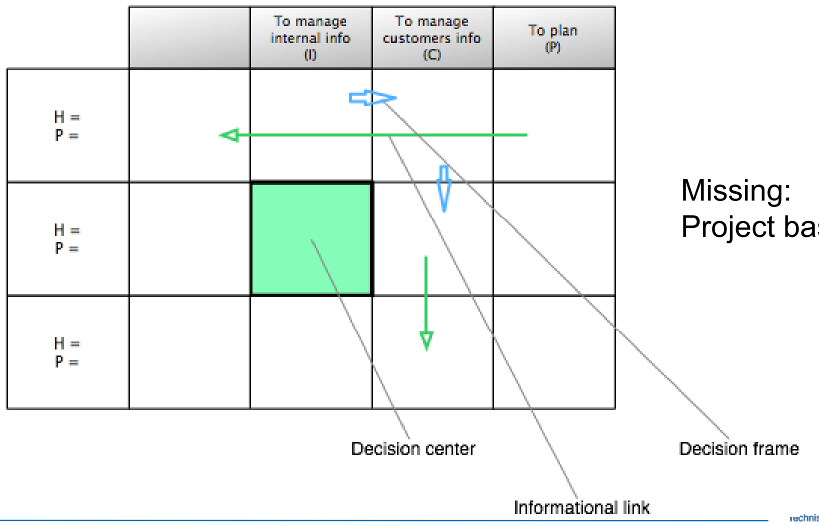
CONVERGE modeling framework: GRAI-Manufacturing

- Decisions:
  - Rows < > Decision levels
  - Columns < > Functions
  - “Periodic” decision-making
  - Applied basically in manufacturing, service, banks, hospital, …

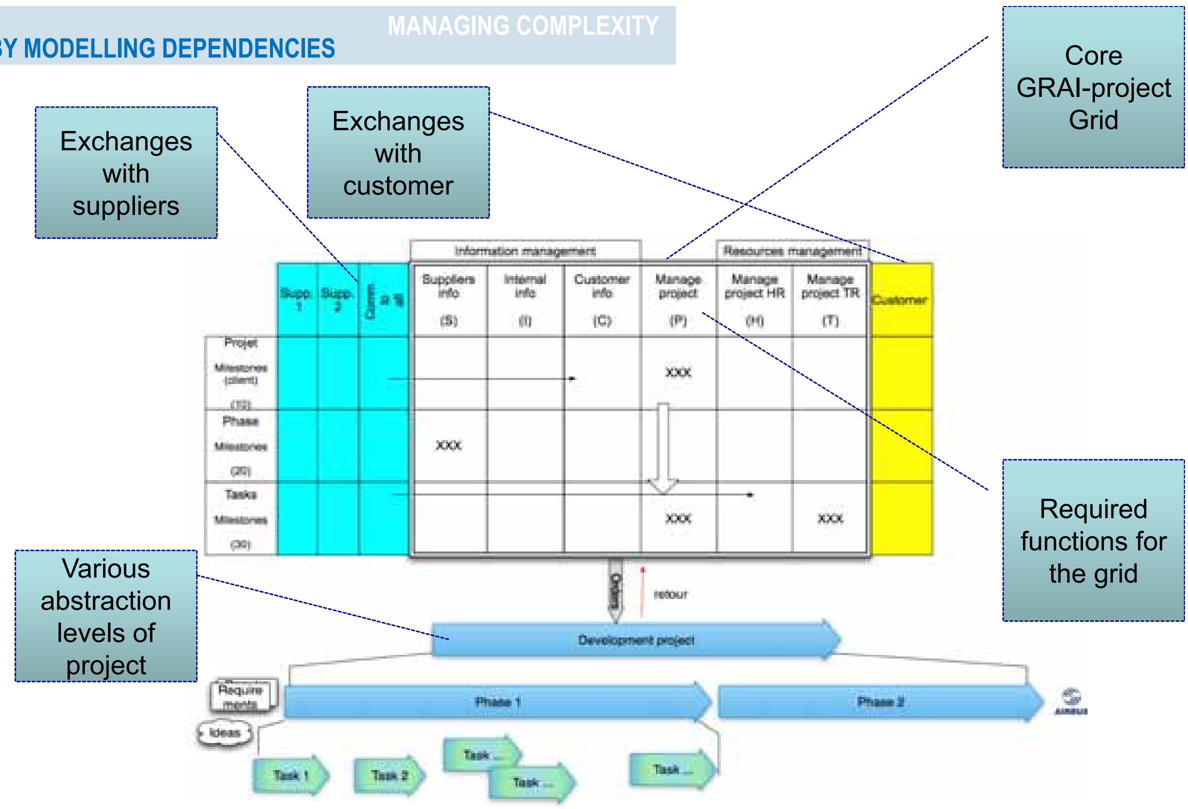


Missing:
Project based method

CONVERGE modeling framework: GRAI-Project

- Project:
  - Could be complex formed by a huge amount of activities executed by resources.
  - Could need to be managed according to several abstraction levels (phase, macro tasks, tasks, …).
  - Various functions are required to control a project (information management, resource management, planning, …).
  - The customer’s contract shows explicitly milestones.
  - Resources can be used by various projects.
  - Decisions are dependent on each other by exchanging data.

  - GRAI-Project: Mono-project grids + Multi-project grid



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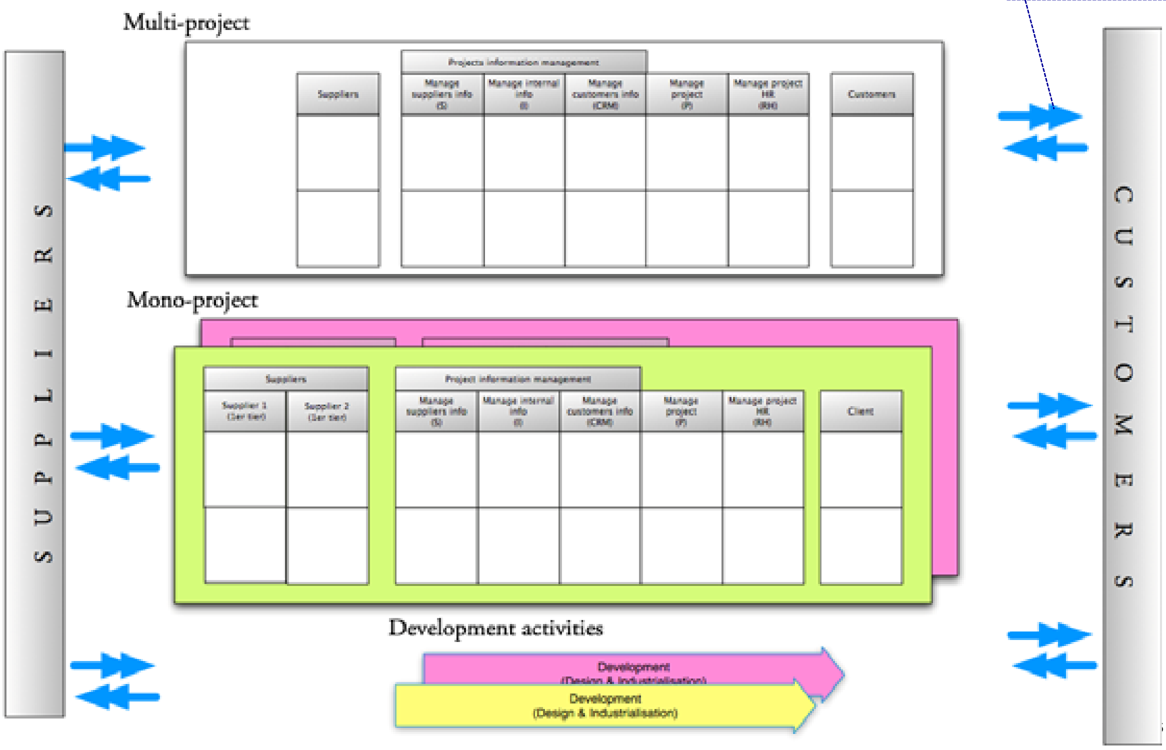
Three types of data exchanges



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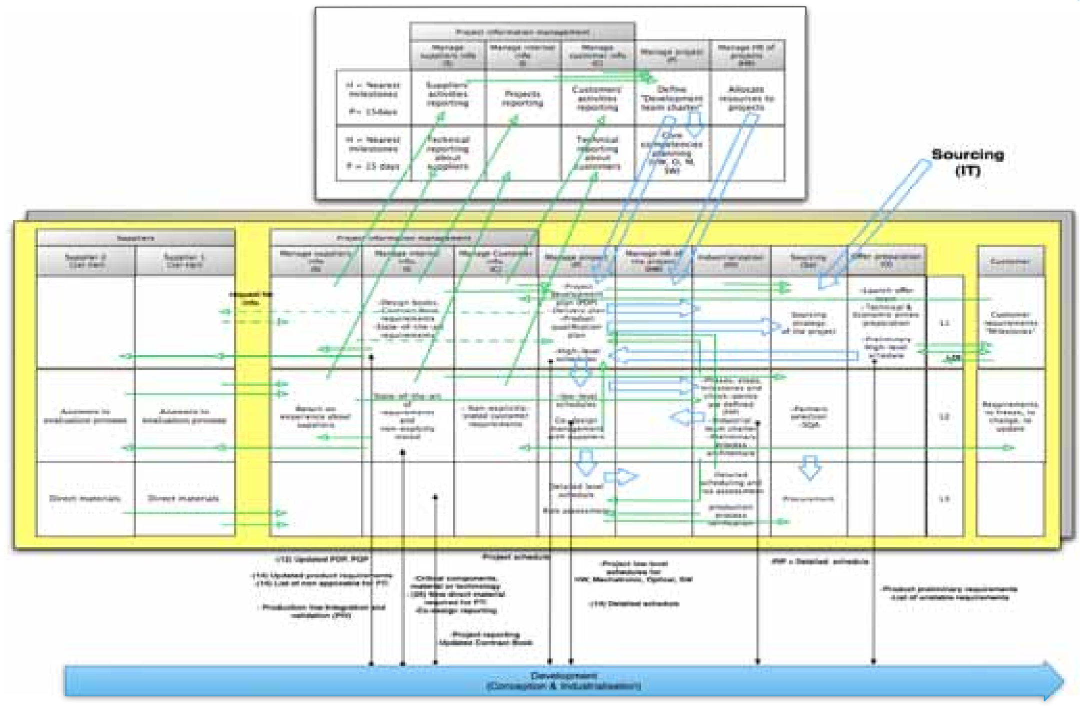

Conclusions and perspectives

- GRAI-Manufacturing and GRAI-Project allow to model the existing decisional dependency among actors of supply chains.
- Preliminary models are obtained. Models are understandable by final users.
- They should be improved to fit to the complexity of the reality.
- Exchanged formal data are collected. Informal data remain a big challenge of CONVERGE.
- The deployment processes are not totally understood yet.