DISTRIBUTED ENTERPRISES CONFIGURATION: ORDERS ALLOCATION WITHIN NETWORKS OF FIRMS

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Abstract: This paper describes a case study about an order allocation method for networks of firms. The method we present aims to calculate satisfying routes for each order, according to antagonist criteria such as resource occupation and knowledge acquisition. The order allocation procedure is first based on a product description (focusing on required activities and competencies), and second on the identification of the available competencies within networks of SMEs.

1. INTRODUCTION

This paper deals with "networks of firms", i.e. virtual industrial structures linked with horizontal agreements (unlike the "firm network" managed by a mainspring firm). Those networks are made of independent firms virtually linked together to achieve a goal. Different types of networks can be identified according to the nature of the relations that federate their members, for example (Poulin, 1994) : Purchasing network (economies of scale for purchases and supplies), Production network (joint production), New market oriented network (sharing new business services to increase turn over), (Quality certification network - sharing quality experts to obtain ISO 9000 certification), Data exchange standardization network (constructing and adopting common norms to exchange data), etc. These types of network are not mutually exclusive. For example, a group may correspond at the same time to a production network and a purchasing network.

Inside networks, co-ordination is not carried out through a hierarchical organization (as in the firm) or through price mechanism (as on the market), but through co-operation and interaction between firms within the network, and more exactly, by mutual adjustment and learning processes. In that context, our research specially addresses networks of SMEs. Network of SMEs are particular because the shareholder and the manager of a SME is often the same person. According to most studies, co-ordination is a relevant problem for network of SMEs, where each partner preserves its independence and often runs its own decision making processes among the network. Furthermore, different kinds of opportunism may appear among

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business networks of SMEs, such as only apparent co-operation (limited effort, lower quality goods, service below standard, ...), catch of an excessive share of joint profits (overvalued switching costs, overvaluation of the added value brought), excessive exploitation of a joint resource, or personal appropriation of the resources created in common or by others.

In that context, we propose a method to distribute customers orders among the partners of a network. This method aims to calculate satisfying routes for each order, so as to meet the customers needs in terms of cost, quality and delivery time (short-term performance criteria), and to promote learning processes and skills exchanges within the network (long-term performance criteria).

The problem consists in integrating those distinct kinds of criteria in a unique coherent decision aid procedure. Such an integration is based on the use of new concepts such as competence, technological map and competencies map. We first give definitions about those concepts (Section 2). We then illustrate through a case study the relevance of these concepts (Section 3) and we propose an order allocation procedure (Section 4).

2. DEFINITIONS

2.1 Technological map

The technological map of a product is made of (see Figure 1) :

1. A product attainment graph : this is the logical succession of activities to process the product. This graph includes parallelism, choices and anteriority constraints within activities. We note that at this stage the activities are generic : i.e. without any resource or actor allocation.
2. An activities/competencies table: it consists in a set of competencies list required for each activity.

We note that the activities/competencies table is built in conformity with a generic competency frame. This frame allows us to standardize the description of competencies among all actors. The authors are now working on the development of such an enterprise competencies frame. They base their research on the extension of normalized competency frames such as ROME³.

Figure 1 - Technological and competencies maps

2.2 Competencies map

Furthermore, for each partner of the network, a competencies map gives the list of competencies the partner possesses. This map also contains an expert level (between 0 and 4) and a learning policy for each competence.

The expert level refers to the following definition :

- level 0: no competence
- level 1: attentiveness
- level 2: ability to bring into play
- level 3: mastery
- level 4: expertise, ability to improve the activity execution.

The learning policy represents the fact that an actor decides to develop, maintain or even abandon a given competency. In the case of a development policy, different learning modes can be referred as learning by interacting (which requires a strong interaction among partners to transfer the competency from one to another) or learning by doing (the simple fact to do the activity several times allows to develop the competency). In the present paper, we are only interested in learning by doing.

The learning policy for the competency k is characterized by a weight (between 0 and 1) named α_k . Analytic Hierarchy Process (AHP) method can for example be used to find competencies weights (Saaty 1980).

For each partner and for each triplet (competence, activity, expert level), we define the number of “do” to reach the further expert level. This number of “do” refers to the number of times the activity must be processed within the firm before changing the expert level. For example, the partner M1 has got the competency C1 (buy), concerning the activity P(Purchasing) ; its expert level is 3, and M1 aims to reach level 4 after 4 orders:

Figure 2 - Competency attributes

3. CASE STUDY DEVELOPMENT

This case study is a simplified version of a real industrial case introduced below. Further to a modification in the purchasing policy of their main contractors and following cuts in the number of suppliers, seven subcontractors from the mechanical engineering industries set up, in 1995, a network named *Mécanergie*. The *Mécanergie* group federates a boilermaker, a sheet-metal worker and five mechanics firms. Here, the basic goal leading the firms to networking is commercial: each firm aims to increase its sales by reaching new customers. The network then recruits a

sales manager, the quest for clientele becomes national and is directed towards the manufacturing of components and subcomponents.

In our simplified model, we consider three actors among seven : two mechanics firms named M1 and M2, and the boilermaker named B3. It is noted that these three partners are complementary for few activities, and concurrent for others.

A main problem for this network is to dispatch fairly between the partners the activities to process orders, so that the customers needs could be met and the learning policy could be achieved. This network will first be analyzed according to its activities. These activities refer both to the technical work to process products and to the logistic operations like purchase of materials, planning, or delivery.

In the following section, we detail the instantiations of technological and competencies maps related to the case study.

Technological map

* Product attainment graph (see Figure 3):

For a better understanding of the case study, the product attainment graph has been simplified by grouping activities together. The following representation of the product attainment graph is conform to the IDEF3 formalism.

The activities needed to provide the required product are: purchase (P), machining (M), assembly (A), subcontracting control (SC), and delivery (D).

Figure 3 - Product realization graph

* Activities / competencies table:

The interviews carried out with the partners of the network of firms enable us to draw up the activities/ competencies table:

Activities		Required Competencies	
P	Purchase	buy negotiate approach customs	C1 C2 C3
SC	Subcontracting control	have technical know-how negotiate	C6 C2
M	Machining	machine dimension interpret design diagram	C9 C10 C11
A	Assembly	assemble	C12
D	Delivery	negotiate plan delivery	C2 C15

Competencies map

Thanks to several work meetings, the network partners can define the strategy of the network and the policy of competencies development. These decisions enable us to represent the competencies map as below:

M1	M2	B3
C1, P, 3, α_1 , 4 C2, P, 3, α_2 , 4 C3, P, 1, α_3 , 5	C1, P, 2, α_1 , 3 C2, P, 2, α_2 , 4 C3, P, 4, α_3	
C9, M, 4, α_9 C10, M, 2, α_{10} , 3 C11, M, 3, α_{11} , 4	C9, M, 3, α_9 , 5 C10, M, 4, α_{10} C11, M, 1, α_{11} , 2	
C15, D, 2, α_{15} C2, D, 3, α_2 , 6		C15, D, 4, α_{15} C2, D, 3, α_2 , 6
C2, SC, 4, α_2 C6, SC, 3, α_6 , 4	C2, SC, 3, α_2 , 4 C6, SC, 4, α_6	
	C12, A, 2, α_{12} , 5	C12, A, 4, α_{12}

4. ORDER ALLOCATION METHOD

4.1 The product/actor attainment graph

After designing the requested product technological map, the partners bid to carry out one or several activities. Each bid contains information relating to the due dates, forecasted cost, expected quality....

The association of the partners' bids and the product attainment graph enables us to build the product/actor attainment graph which represents all the possible routes of activities through the actors (the partners).

According to the actors mobilized for a given route, logistic or administrative additional activities can be generated, (typically transport and coordination activities). In the case study, if the machining and assembly activities are carried out by two distinct partners, transport and coordination activities will be generated. It is noted that those additional activities are not under scrutiny in this paper.

The product/actor attainment graph is presented below (see Figure 4).

In figure 4, we can easily notice that the actor M2 was not able to carry out both the Machining and the Assembly activities (M2 has not the capacity to carry out M and A). That is why this alternative does not appear in the product/actor attainment graph.

Figure 4 - Product / Actor attainment graph

4.2 Assignment Procedure

The satisfaction of the customers' needs is the first priority of the network. Then comes the second aim: developing competencies within the network. In order to take these choices into account, we propose a two-stages assignment procedure :

Stage 1: starting from the product/actor attainment graph, we determine the set of feasible solutions (acceptable) according to logistic and customer constraints such as capacity, cost, quality, delivery...

Stage 2: starting from the set of the acceptable solutions, we assign the activities to the actors according to the competencies strategy of the network.

Figure 5 - Two-stages order allocation procedure

The proposed assignment procedure expresses the strategic choice of the network, which consists in satisfying short-term objectives (customer satisfaction) while respecting the acquisition and the development of competencies in the long-term. Other strategies leading to hierarchical structuring of the decision criteria could be considered but they are not developed in this paper. We continue this discussion with the example.

4.2.1 Stage 1

To find the set of feasible solutions, multi-objective programming (MOP) (Weber and al. 1991, Cohon 1978) or conjunctive method can be used.

The multi-objective programming (MOP) is a mathematical program with a stack of objective functions instead of only one. A MOP model provides the decision maker with a set of non inferior solutions rather than a single optimal solution so as to analyze the impacts of different criteria on decision.

Conjunctive Method is used if acceptable levels are defined for criteria (for example, the cost must be less than 100 \$, due date before 3 months). Hence, an alternative which does not meet the minimal acceptable level for all criteria is rejected. So, the minimal acceptable levels are used to screen out unacceptable alternatives.

Thanks to these mathematical methods, we limit the study to a partition containing good alternatives. The best alternative is to be found in this partition.

In this paper, we consider that the first stage of the procedure was largely studied in the scientific literature since its modeling require traditional logistic constraints. For that reason, we will be particularly interested, in the following paragraph, in the second stage of assignment procedure.

4.2.2 Stage 2

We calculate, for each acceptable solution of the product/actor attainment graph, a global score which represents the usefulness of the order processing as far as learning policy is concerned. This global score is calculated as follows:

$$\sum \alpha_k * (\text{Expert level after processing the order})$$

required competencies to process the order

Indeed, we built a hierarchical structure of competencies and we applied the Group AHP method to determine the competencies weights. Group AHP allows the synthesis of individual preferences to form coherent group preferences. The competencies weights we obtained are summarized in the table below.

Competencies	Weights	Competencies	Weights	Competencies	Weights
C1	0.17	C6	0.10	C11	0.10
C2	0.12	C9	0.13	C12	0.19
C3	0.09	C10	0.04	C15	0.07

In our case study, alternative number 4 is the best one as mentioned below.

Alternatives	Couples (activity, actor)	Score
1	(P, M1), (SC, M1), (M, M1), (A, M2), (D, M1)	4.52
2	(P, M2), (SC, M1), (M, M1), (A, M2), (D, M1)	4.41
3	(P, M2), (SC, M2), (M, M2), (A,B3), (D, M1)	4.44
4	(P, M1), (SC, M1), (M, M1), (A,B3), (D,B3)	4.78
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The obtained scores enable us to classify the possible alternatives, and consequently to choose the best one. In other words, they permit to select the assignment of activities to the actors that satisfy logistic and customer needs and guarantee the best competencies development.

5. PERSPECTIVES

To extend this model, the authors are now taking into account new learning policies such as externalisation, abandon or skills sharing. Furthermore, different learning modes are to be integrated to the model, especially learning by interacting. (learning by interacting means exchanging knowledge and skills between agents acting together) (Lundvall, 1992). Indeed, some particular skills are tacit and not codified (Polanyi, 1967). These skills cannot be transmitted like information, and it usually takes time for agents to assimilate and to appropriate them. So we assume that networking enables firms to acquire these particular external skills that they could not get by economic intelligence processes.

The authors are also working on the integration of additional activities generated by the assignment of activities to actors such as subcontracting control or logistic synchronization.

6. NOTES

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² We call Network of Firms (NF) distributed industrial structures linked with horizontal agreements (unlike the "firm network" managed by a mainspring firm)

³ ROME : Répertoire Opérationnel des Métiers et de l'Emploi (used in France).

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