36 AN ESTIMATION MODEL FOR BUSINESS BENEFITS IN HORIZONTAL COLLABORATIVE NETWORKS

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Nowadays, the advantages of virtual enterprises and collaborative networks are well known by scientists and professional communities. Despite the advantages, only a few networks continue running businesses after stopping the governmental subsides. One of the reasons is the lack of a model that evaluates the benefit from the firm's point of view. The objective of this work is to develop a model that estimates the business benefits in horizontal collaborative networks. We propose a method for evaluating the benefits for a firm to be enrolled in a collaborative network. This method can also be extended to the selection of partner. The approach is based on a combination of a product realisation graph and core competencies model.

1 INTRODUCTION

Several works have been carried out for the identification of the advantages of taking part in virtual enterprises and collaborative networks (Varamäki E. 2006). Many of them have focused more on the performance evolution than on the financial business aspects. The current estimation models then focus more on the End User performances and none of them really estimates the benefits from firms' point of view. This is even true in the case of horizontal (H) collaborative networks, for which this work is dedicated.

Aiming to build and to maintain Virtual Organisations (VO), we develop an estimation model for business benefits in horizontal collaborative networks. This paper gives first an overview of the current modelling techniques and proposes in a second step a new approach for estimating the benefits for a firm considering its involvement in a new opportunity for the H VO. The developed model is simple and can also be used for partners' selection during the set up of a new VO.

The benefit model might help in strengthening the mechanism of trust building among the organisations and in focusing on some common objectives.

2 MODELLING BUSINESS ACTIVITIES AND PERFORMANCE EVALUATION IN COLLABORATIVE NETWORKS

The previous developed models were focused on "Vertical networks" or "Hub and spoke networks" (Katzy, 2003). Few of them were oriented on "Horizontal networks" due to their complex dynamics. However, this kind of network exists and there is

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a need for benefit estimation model in order to estimate the best opportunity configuration based on cost optimisation.

In the literature, there are two orientations of research; one is focused on the management of a network and the other one is more oriented on how to set up the virtual enterprises through the breeding environment. In the first orientation, the developed models measure the past performance of the network, based on balanced scorecard. These works focus mainly on the End User (Bourgault et al. 2002)

Camarinha-Matos and Abreu (2005) build up a different model for the quantification of advantages in a horizontal network. This model is based on benefits that can be self benefit, received benefit or contributed benefit. This decomposition allows a better understanding of how the network runs and which firm is the most beneficiary. On the other side, it is quite hard to measure these different benefits due to information privacy.

The aim of the second orientation of research is to find a predictive method for evaluating the performance of different alternatives. Some authors have defined different modelling approaches for designing value chain in Virtual Enterprises. Kim et al. (2003) consider an approach that combines enterprises modelling and simulation modelling in "Hub and spoke networks". A similar approach can be found in a model based on SCOR approach where particular key performance indicators are proposed (Seifert and Eschenbaecher 2004). Confessore et al. (2006) develop a model for supporting the potential decision of getting new business opportunity. This model is based on competencies and activities. Even if this approach is interesting, it is not appropriate for H networks. In a H network, the core competencies are almost the same for all firms and the selection of different alternatives can not only be evaluated from this point of view. Despite that, the idea of core competencies will be used in our model. Chu X. et al. (2002) develops a model that permits to set up a preferential alternative; this model is based on Group Technology. The drawback of this method is the long audit time to determine what kind of component companies can produce. This approach is more oriented for assembly business and takes a lot of resources to estimate the advantages to set up a VE. Furthermore, the iterative process composed of a Product requirement Analysis, Product Function Design, Product Layout, Partner type Synthesis and partner Instance synthesis will be partly integrated in our model.

Wu and Sun (2002) have developed a different approach based on activity grouping to identify the core competencies needed to develop a new product. They identified two types of activities for grouping activities: key activities that require core competencies, and non-key activities that can be performed by all the members of a breeding environment.

In this review, we draw the conclusion that none of the developed models permit to estimate the benefits of being part of a horizontal collaborative networks in terms of financial optimisation.

3 PROPOSED MODEL FOR BUSINESS BENEFITS ESTIMATION

The proposed model is based on four different phases (see Figure 1). The first phase consists of the estimation of the opportunities that can be generated by the network; the second phase is the construction of product realisation graph for each opportunity and its related operations. The third part is the research of the best combination of firms to realize a customer's order. The last one is a summation of earnings for all members of the networks.

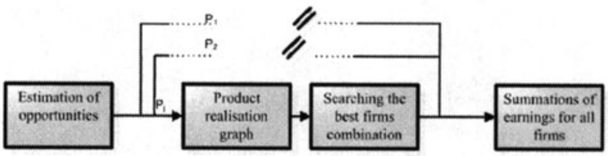

Figure 1: General model

3.1 Estimation of opportunities

There are three kinds of opportunities:

- Product introduction in new markets
- Increasing sales in actual markets for a given product
- Introduction of new product

These opportunities can be generated through the network which brings some advantages like the increase of renown, know-how, flexibility, production capacity and so on. For each opportunity, related to a product, we determine a production volume.

3.2 Product realisation graph

The product realisation graph is built for each opportunity. This graph is composed by activities, arcs and linguistic variables (Wu and Sun 2002). An arc represents the antecedence link between two activities. There are two different kinds of activities, the key activities and the non-key activities. A key activity is an activity that requires a core competency to be performed. A non-key activity is activity that doesn't require any core competency and that can be performed by every member of the considered network. To take into account the importance that two consecutive activities have to be performed by the same company, we introduce for each arc a linguistic variable. This latter can take one of the five values: {none, weak, medium, strong, absolute}. The weak term means that two consecutive activities can be easily performed by two different companies. The strong term mean that the link between the two activities is strong and it will be difficult to perform them by two different companies. The absolute mean that it will be impossible to perform the two activities by two different companies.

In order to reduce the complexity of the problem, we merge non-key activities to key activities. The merging mechanism is the following (see Figure 2):

1. First, we merge all non-key activities (represented by circles), which are at the beginning or at the end of the product realisation graph with the next, respectively following or previous, key activities (represented by ellipses).
2. In the second step, we merge all the remaining non-key activities. For merging activities, we use the value of the linguistic variable of each arc. We merge non-key activity which has the weakest link and so on.

We stop to merge activities when all the remaining activities are the key activities. This graph is called simplified product graph.

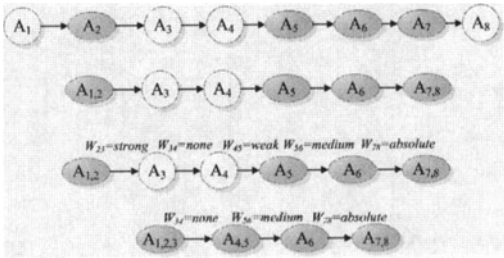

Figure 2: Product realisation graph

3.3 Searching the best firms combination

The third part of the model is the search of the best firms' combination to realize a customer's order. The Input for this part of the model is the Simplified Product Graph and the output will be the best alternative and its global cost (see Figure 3).

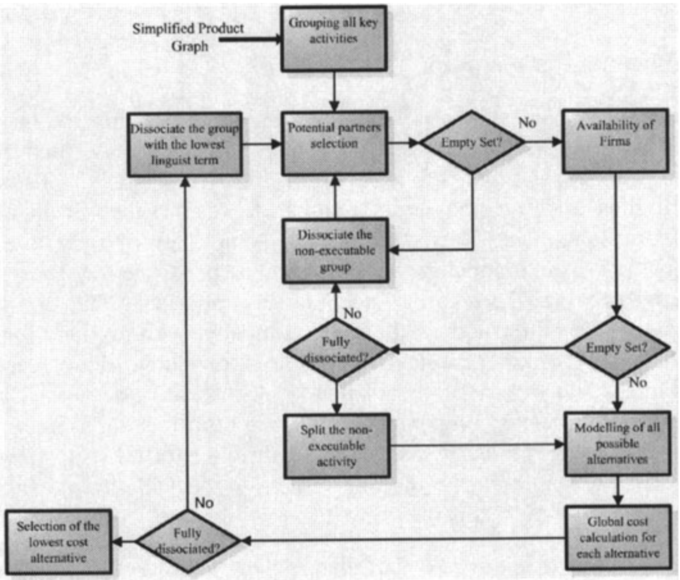

Figure 3: search of the best configuration

The first step consists of grouping all the activities together. This step means that all the activities will be performed by one firm. The second step is the potential partner selection based on core competencies of each firm. These core competencies have to match the competencies needed to perform an activity.

Among this set, we identify firms which have the availability to perform the activity or the group of activities. Among this sub set, we set all the possible alternatives to realise the product. For each alternative, we estimate the global cost of the full process. If during one of these previous steps an empty set is detected, the model dissociates the group of activities, which are unsolved. If there is still no solution when a model is totally dissociated, the unsolved activity is split in order to perform this activity in two different companies. Once we have obtained the global costs of alternatives, the model dissociates the group of activities with the lowest linguist term. This iterative procedure stops once we obtain the simplified product graph. Among all alternatives, we consider the best alternative as the alternative with lowest global cost. The calculation of the global price is the sum of the prices of realization of the activities or groups of activities and some additional costs which depend on the network.

3.3.1 Realisation costs of the activities and groups of activities

The cost of realisation of an activity is firm and volume dependent.

$$\mathrm{TRP}(\mathrm{alt}_y) = \mathrm{tr}\left(\mathbf{Pr}\cdot(\mathbf{A}^y)^T\right)$$

$$= \mathrm{tr}\left(\begin{bmatrix} \mathrm{Pr}_{F1A1} & \mathrm{Pr}_{F1A2} & \cdots & \mathrm{Pr}_{F1Aa} \\ \mathrm{Pr}_{F2A1} & \mathrm{Pr}_{F2A2} & \cdots & \mathrm{Pr}_{F2Aa} \\ \cdots & \cdots & \cdots & \cdots \\ \mathrm{Pr}_{FnA1} & \mathrm{Pr}_{FnA2} & \cdots & \mathrm{Pr}_{F_nAa} \end{bmatrix} \cdot \begin{bmatrix} A^y{}_{F1A1} & A^y{}_{F1A2} & \cdots & A^y{}_{F1Aa} \\ A^y{}_{F2A1} & A^y{}_{F2A2} & \cdots & A^y{}_{F2Aa} \\ \cdots & \cdots & \cdots & \cdots \\ A^y{}_{FnA1} & A^y{}_{FnA2} & \cdots & A^y{}_{FnAa} \end{bmatrix}^T\right) \quad (1)$$

Where:

TRP	Total realisation price for the alternative y alt_y	$\mathbf{A}^y$	Matrix of distribution activities among partners
Pr	Matrix of realisation prices	tr	Trace of a matrix
n	number of partners	a	number of activity groups

The matrix $\mathbf{A}^y$ is a repartition of the activities among partners. The value of a component normally is 0 or 1, but if an activity is split among partners, the component $A^y{}_{FxAz}$ can be of any value between 0 and 1.The only condition is that the sum of a column is equal to one.

3.3.2 Additional costs

The additional costs are the transport costs, administrative costs and knowledge transfer costs. The transport costs are dependent of the two partners involved; we assume that is time constant. The administrative costs depend on the trust between the two partners enrolled; this parameter can change with the evolution of the network. The knowledge transfer costs depend on the stage of activities, and we assume that these costs do not depend on the partner involved. All of these parameters are represented by some matrices in the aim of computation resolution (Piot 2007).

$$
\begin{aligned}
AC(alt_y) &= tr\left(\mathbf{TpC}\cdot(\mathbf{T}^y)^T\right)+\left(\overrightarrow{KC}\cdot\vec{t}\right)+\alpha\cdot tr\left(\mathbf{Trust}\cdot(\mathbf{T}^y)^T\right)\\
&= tr\left(\begin{bmatrix} 0 & TpC_{F1F2} & \dots & TpC_{F1Fn}\\ Sym. & 0 & \dots & TpC_{F1Fn}\\ Sym. & Sym. & \dots & \dots\\ Sym. & Sym. & Sym. & 0\end{bmatrix}\cdot\begin{bmatrix} T^y{}_{F1F1} & T^y{}_{F1F2} & \dots & T^y{}_{F1Fn}\\ T^y{}_{F2F1} & T^y{}_{F2F2} & \dots & T^y{}_{F2Fn}\\ \dots & \dots & \dots & \dots\\ T^y{}_{FnF1} & T^y{}_{FnF2} & \dots & T^y{}_{FnFn}\end{bmatrix}^T\right)\\
&+\left((KC(A_1A_2);KC(A_2A_3);\dots;KC(A_{a-1}A_a))\cdot(t(A_1A_2);t(A_2A_3);\dots;t(A_{a-1}A_a))\right)^T \qquad (2)\\
&+\alpha\cdot tr\left(\begin{bmatrix} 0 & Trust_{F1F2} & \dots & Trust_{F1Fn}\\ Trust_{F2F1} & 0 & \dots & Trust_{F2Fn}\\ \dots & \dots & \dots & \dots\\ Trust_{FnF1} & Trust_{FnF2} & \dots & 0\end{bmatrix}\cdot\begin{bmatrix} T^y{}_{F1F1} & T^y{}_{F1F2} & \dots & T^y{}_{F1Fn}\\ T^y{}_{F2F1} & T^y{}_{F2F2} & \dots & T^y{}_{F2Fn}\\ \dots & \dots & \dots & \dots\\ T^y{}_{FnF1} & T^y{}_{FnF2} & \dots & T^y{}_{FnFn}\end{bmatrix}^T\right)
\end{aligned}
$$

where:

- AC Additional costs
- **TpC** Transport costs
- **T** Matrix of interaction between partners
- $\overrightarrow{KC}$ Vector of knowledge transfer costs
- $\vec{t}$ Vector of activities separation
- α Value of the average administrative cost for an invoice
- **Trust** Matrix of trust among partners

The interaction matrix changes for each alternative. The range of variation of a component $T^y{}_{FxFy}$ is between 0 and (a-1). Each component of the trust matrix varies between 0 and 1.

4 APPLICATION OF THE MODEL TO VIRTUAL SWISS MANUFACTURING NETWORK

The model is applied to the "Virtuelle Fabrik Nordwestschweiz-Mittelland" (Göckel M. 2001). The concept of this network was established by the 'Institut für Technologie-management' of the University of St-Gall. The network was built in 1997 and now is containing 19 firms (Fi, i=1...19) and 2 public institutes. The aim of this network is to create high-value product, which integrate the following competencies: design, engineering, manufacturing, assembly, control and commissioning. Most of the companies are manufacturers, some of them are in the engineering field and a few of them are consulting partners.

Few products have been developed up to now, namely a-turning assembly table, a dustbin, and some others. We have done an application of our model for the dustbin product (Litter Shark). The dustbins are developed by a partnership with some firms of the network. Without this partnership, none of the firm would have been involved in this opportunity. The requirement of the client is to have only one interlocutor. Actually, this product is one of the leader products developed by the network, and its worldwide commercialisation is bringing some new profits.

5 RESULTS

We apply our model to the dustbin product. The first step is to build the product realisation graph. To summarize the development only the simplified product graph will be displayed. It is composed of fives key activities, in order, design (A1), engineering (A2), sheet metal working (A3), painting (A4), and assembly (A5). The obtained simplified product graph is represented in figure 4.

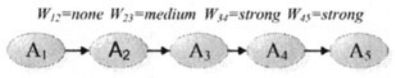

Figure 4 - Dustbin simplified product graph

The first iteration of the model evaluate that none of the firm can perform all the five activities. The second iteration, which is based on a graph composed by the activity A1 and a group G1 of the four remaining activities, evaluate that one alternative (alt1) is possible. The alternative alt1 enrol two firms, Quadesign Partner AG (F14) for the activity A_1 and Brüco Swiss AG (F_5) for the group G_1. The global costs of this alternative is estimated to be 71.7 kCHF (Table 2)

The third iteration, which is based on a graph composed by the activities A1, A2 and a group of activities G2 (A_3, A_4, A_5), evaluates four possible alternatives (Table 1 which gives the firms combinations for each alternative). In this case, there are no transport costs because there is no physical product between activities A_1, A_2 and G_2. The global costs of alternatives, estimated using equations 1 and 2 are shown in the Table 2.

Table 1 – Alternatives Table

		Alt_i			
Activity	Firm	2	3	4	5
A_1	F_{14}	1	1	1	1
A_2	F_2	1	0	0	0
	F_5	0	1	0	0
	F_6	0	0	1	0
	F_{11}	0	0	0	1
G_2	F_5	1	1	1	1

Table 2 - Global costs of all alternatives

Alternative	Global cost
Alt_1=Alt_3	**71.7** kCHF
Alt_2	**68.8** kCHF
Alt_4	**74** kCHF
Alt_5	**78.3** kCHF

The results of further iterations are not interesting enough to be displayed and the global costs of these alternatives are more expensive due to the knowledge transfer costs and the administrative costs. As we see, the alternatives alt_1 and alt_3 are the same, only two firms are involved.
The best alternative for the model is the alternative Alt_2, which involves the firms (F14, F2 and F5). If we compare the results to the reality only two firms (F_{14} and F_5) were involved in realizing the product. The reality matched the alternative Alt_1, which is the second best alternative for our model. The reasons might be that the network did not look for the optimal alternative; the additional costs were underestimated or personal reasons for the firm F_2. Furthermore this solution is still acceptable and we arrive with few resources to estimate the benefit for the firm to be part of one

network. The application and the result analysis have been approved and validated by the network. The model can be used without generating privacy or autonomy problems among the future network's participants.

6 CONCLUSION AND FUTURE WORK

An estimation model for business benefits in horizontal collaborative networks is presented and developed. As a conclusion, the selection can not be only based on core competencies. Other criteria are then considered as the global price or the availability. In the future, our goal will be to continue the development of the model by introducing the delays and the risks related to the alternatives. Further test for managing opportunities on the operation level could be done using the model.

7 ACKNOWLEDGEMENT

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