A CONTRIBUTION FOR THE DEVELOPMENT OF NEW RESOURCES SELECTION MODELS FOR THE AGILE/VIRTUAL ENTERPRISES

Paulo Ávila
Polytechnic Institute of Porto, Portugal, psa@isep.ipp.pt
Goran D. Putnik
University of Minho, Portugal, putnikgd@dps.uminho.pt
Maria Manuela Cunha
Polytechnic Institute of Cávado and Ave, Portugal, mcunha@ipca.pt

Abstract

The process of resources systems selection, takes an important part in Agile / Virtual Enterprises (A/V E) integration because the efficient resources selection, or resources systems selection, running in useful time and cost and with efficient solution, is an important operation within the A/V E design phase and certainly will contribute for the flexibility of an A/V E within the phase of its reconfiguration. The resources systems selection is a difficult matter to solve in A/V E because: it can be of exponential complexity resolution; it can be a multi criteria problem; and because there are different types of A/V Es with different requirements that have originate the creation of a specific resources selection model for each one of them.

This kind of selection approach models will be reviewed from literature and analyzed its limitations and the consequent necessities of development new ones. At the first time we identified necessities that never were thought before, like performance measures for the selection model, and the necessities of identifying the sponsor for the selection process. We will see too that the models fit uniquely the requirements of a unique A/V E are rigid and not flexible enough to satisfy the requirements of another A/V E. These limitations that we highlight in this work are important to be considered in the development of new models and were simultaneously considered in the development of our selection model for the project of the BM_Virtual Enterprise.

Keywords:
Virtual Enterprise, Agile/Virtual Enterprise, Market of Resources, Resources selection, Partners selection, Selection algorithms, Broker, BM Virtual Enterprise

1 - INTRODUCTION

We have no doubts in our days for the majority of the enterprise that a selection process for any resource needs a structured proceeding that will permit the more adequate decisions. There are some

domains where the enterprises are inducted to practice a selection process, namely, about the suppliers' selection, decisions of integrated production systems, processing resources, computational resources and human resources. For all of them, in the context of the conventional enterprises, have been made studies and presented models for their selection, but for the A/V Es[1] are added new dimensions of complexity to solve the resources selection problem (Gupta, P. & Nagi, R. 1995). These new dimensions are related with the distributivity of the resources, the space of the potential candidate resources (enterprise and resources universe in the limit), the combinatorial problems of the selection and with the requirements of each A/V E that are different for each particular case. Additionally the A/V Es have appeared in the literature as organizational models with the capacity of satisfy the new market requirements and principally the requirements for rapid adaptation, i.e., *flexibility*, if the system is reactive, or *agility*, if the system is pro-active. We believe in this capacity but the A/V E needs means and resources that perform project tasks like the network, or configuration and with the high performance resources system reconfiguration.

In this work we will make a revision of the resources selection models, and their limitations and, consequently, we will justify the necessity to develop new resources selection models for the A/V Es, that in our case were in the origin of the development of a new resources selection model for the BM_Virtual Enterprise[2] project.

2 - RESOURCES SELECTION MODELS

The resources selection process for the A/V E depends from the selection model (phases and parameters) and its capacity to answer the A/V E requirements. It can be considered different phases (activities) in a selection model, like the resources search, the creation of a resources market or a focused market of resources, resources pre-selection, negotiation, resources system selection, contract celebration etc. During this chapter we will review different author's contributions for the selection process, principally for the resources pre-selection and resources system selection phases.

Minis (Minis, I. et al., 1996) developed a generative model to effectuate the partners pre-selection based on production process plans on higher detail levels (high-level process plans) for a product and with the partners process capacity joined with its performance. With this model it is possible to find out the potential partners that better fit to the process plan operations and then the partners are pre-selected and the feasibility of the product project is evaluated according to the partner's capacity. In this model the evaluation of the potential partners is achieved by the access to the resources information in a format defined by a resource model which permits to obtain more resource information about cost, time and quality production.

[1] We consider the enterprises whose concept is related with the distribution of competencies (services) that are integrated with the aim of develop a business.

[2] Project of Agile/Virtual Enterprises in developing at Minho University.

To select the resources system each system is evaluated, trough an explicit enumeration, in costs, quality and production time, considering the time and transportation costs proportional to the partner's localizations. The evaluation of the system, according to the multi-criterion performance, is defined by the author trough two possibilities, by linear combination of the different criterions with weights attributed by the selector, or specifying his preferences in natural language utilizing Fuzzy-AHP (an extension of the fuzzy in Analytic Hierarchy Process).

Ávila (Ávila, P., 1998) created a resources system selection model for the selection of processing resources for machining processes to be integrated in an A/V E. This model contains two phases, the pre-selection of the processing resources, previously designated only by resources selection, and the resources system selection. In the pre-selection having as requirements a detailed process plan until the operation elements[1] level, the machines, specified by its manufacturing process capacity, namely the functional, geometric and technologic capacity, are pre-selected for the processes that fit inside its capacity limits. In the resources system selection, using an algorithm of complete enumeration, are considered, separately, in the evaluation of the resources system, the total production time, the total production cost (both including the transportation) and the total quality of the resources system.

Wu (Wu, N. Et al., 1999) developed a model supported in two phases, the pre-selection and the resources system selection, which author designate by preliminary selection and by final selection respectively according to figure 1

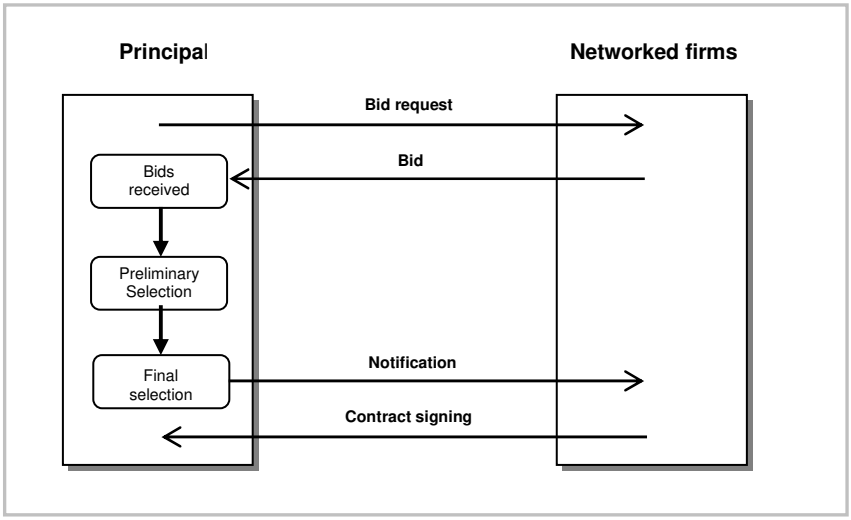

Figure 1 – Generic model of the Selection Process (Wu, N. et al., 1999).

It is assumed that all the candidates for each task are networked. Thus, the pre-selection phase is initiated by the diffusion of bid request into the network for all tasks, to which the interested candidates send a bid. In this model the pre-selection requirements are the capacity to execute the

[1] Operation element is an operation component carried out without having change of the cutting tool, the working surface, and/or the machining parameters (Wang, H. & Li, H., 1991).

task and the time compatibility due the precedence constrain between the tasks. The first requirement is satisfied only by the candidate proposal (bid), i.e., it is accepted without any kind of verification that he can satisfy the proposal. The second one is verified by human decision, which based on the received information (initial and conclusion dates from the candidate proposals) for all tasks, checks the time compatibility between the tasks and pre-select the candidates that feet inside.

In the resources system selection the model of (Wu, N. et al., 1999) only considers the total production costs minimization (tasks processing costs plus transportation cost estimated). To perform the selection of the best system he formulated the problem using integer programming and due the computational complexity he transformed it into the graph-theoretical formulation to apply a short path algorithm between two nodes of the graph.

Inserted in a project of the creation of one software platform for internet/intranet (project/model designated by WeBid), with the purpose of the involvement of the potential partners since the development of the client's product (Huang, G. & Mak, K., 2000), present a selection model based in two phases already referred but with different designations. In this model the task plan is associated to the BOM (Bill of Materials) of the product and for each material/component are specified their requirements and released an extended inquiry to the potential suppliers to define their capacities. By the answers obtained, that match the tasks requirements, the pre-selection phase is concluded.

The next phase contemplates the resources selection through the quantification of four types of indexes (satisfaction index, flexibility index, risk index and confidence index) associated to the inquiry items. To effectuate the global evaluation of each potential partner an arithmetic average is calculated for each one of the indexes and after that a weighed average, that involves the four indices, is calculated.

In spite of the fact that Huang's selection model presents a more flexible concept, i.e. that has potential to adapt more easily to the requirements of each client (A/V E), it, in fact, only makes an evaluation of the total quality of the resources system. By not considering the transportation parameters (e.g., costs and time) the model leaves unsolved the resources system selection as the whole, and finish by evaluation and selection of the candidates task by task[1].

The model of (Sluga, A. & Butala, P., 2001) presents a selection process in which we identify three principal phases, pre-selection, resources system selection and the negotiation. Similarity to the (Wu, N. et al., 1999) model, the pre-selection begins with the diffusion of bid request on the net for different tasks. In the case when the bid contents of the two models are identical, Sluga and Butala increase in the bid by new requirements associated to the bonus and penalties related with execution term and of the proposal control like the validity and the proposal state (valid, expired, signed, confirmed and eliminated). The model considers as pre-selection requirements the capacity of the resource to execute the task and time/dates compatibility between tasks. This last one is verified by a branch-and-bound algorithm, developed in constraint logic Programming.

[1] What we call independent selection method.

The same algorithm is used for the resources system selection that better optimizes the less production time or cost, without considering the time and cost of transport. The model only confines to consider the some total of data received in the proposals. However if the mediator don't find solutions that satisfy his requirements he begins the negotiation phase. The mediator relaxes constraints and the process turns to the beginning.

The Ko (Ko, C. et al., 2001) focused his model only on resources system selection phase, i.e., it is assumed that the resources satisfy the pre-selection requirements, as referred by the authors, the quality levels and required technology. At the same time it is possible to inquire for which tasks or parts each potential partner has the capacity (see figure 2).

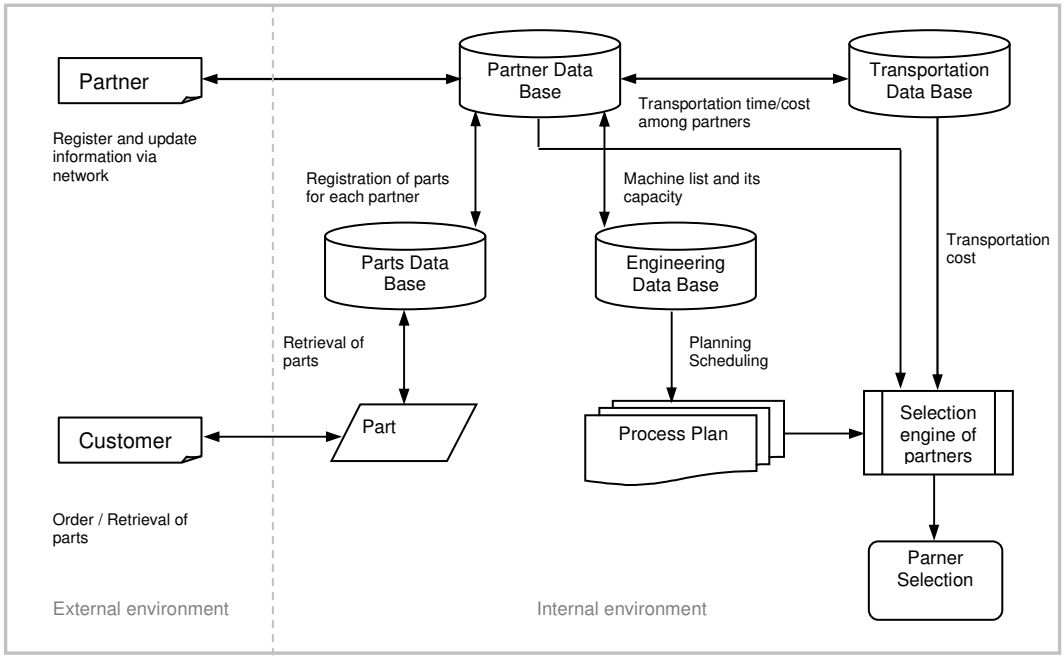

Figure 2 – Conceptual diagram for the external partner selection via network (Ko, C. et al., 2001).

The model proposed by Ko et al. has as the goal to select the resources system that minimize the total production costs (operation plus transport) for a product with several process plan possibilities. The authors formulate mathematically the model by integer programming assuming as known the times and the operation costs for each process plan, the production capacity of each candidate, the demand of the product and the transportation costs among the candidates. However, the model doesn't consider time/dates compatibility among the tasks, considering them always feasible at any time, and only penalise them with superior costs when the charge exceeds the candidate capacity. As it is difficult to obtain the optimal solution mathematically for big selection problems, the authors proposed heuristic algorithms based in the tabu search algorithm of (Glover, F., 1993) to obtain a possible good resources system solution.

We didn't find more detailed resources selection models for A/V Es (or related) in literature but there are much more models that are not so detailed or explicit. To refer some, in (Spinoza, L. et al., 1997) the principal phases of the resources selection process are referred. In the case of (Ratchev, S. et al., 2000) for their pilot software tool for the product prototyping project and the resources system configuration, the authors refer to the selection process as one of the tool's modules presenting only its global functionalities. Concerning formalization of the selection process, (Biquing, H. et al., 1999) describe the selection model in the formal notation RAISE.

Another group of models that we didn't analyse here, maybe sub-models, because they approach only a part of the selection process, is related with the negotiation protocols applicable by intelligent agents.

3 - CLASSIFICATION AND EVALUATION OF THE RESOURCES SELECTION MODELS

To better synthesize what each resources model propose to answer we constructed the table 1 where are indicated the principal pre-selection and resources selection requirements, the types of resources pre-selected and if the model contemplates other phases like resources search and negotiation. Additionally we introduced two more criteria in the table, the performance of the model and the responsible for the selection. These two parameters are very important to characterise the model. The first one is important because it evaluates how much efficiently and effectively the model answers the A/V E solicitations. The second because characterise organisationally the model how the A/V E is related with the selection process, i.e., the selection is performed by the proper A/V E or it resorts to a third party to perform the process.

For the resources models classification, according to the criteria previously refereed, for this classification, to be not based only on yes/no (or do/do not) criteria value, we introduced one more criteria value, designated in the table legend by C (calculus/check) whose goal is to refer if the model has any mean of calculus or inquiry (intelligence) how the pre-selection requirements are satisfied. By other words, it serves to differentiate the information that is simply supplied by the resources, and accepted as true, from that information that suffer some kind of treatment or calculus. Concretely, the C inserted in the field of resources of transport means that it is made an estimation of the necessary information about them. In another cases it means that the model inquires the information from the resource's environment if the resource satisfies the requirements, and not simply accepting the resource's answer.

Table 1 – Resources models classification.

Legend: Y – Yes; N – No; C – Calculus/check		PRE-SELECTION							RESOURCES SYSTEM SELECTION					OTHERS PHASES		OTHERS CHARACTERISTICS	
		TYPES OF PRE-SELECTED RESOURCES		PRE-SELECTION REQUIREMENTS					SELECTION REQUIREMENTS					SEARCH (Strategy)	NEGOTIATION	MODEL PERFORMANCE	SELECTION SPONSOR
		PROCESSING RESOURCES	***TRANSPORT RESOURCES***	*Product specifications*	*PROJECT*	*PROCESS PANS*	*Production planning and scheduling*	*Others*	*Total number of participants resources*	*Total production time*	*Availability to the market*	*Total production Cost*	*Total quality of the resources system*				
SELECTION MODELS	(Minis, I., et al., 1996)	Y	N - C	Y	Y	Y - C	N	Y	N	Y	N	Y	Y	Data Base	N	N	N
	(Ávila, P., 1998)	Y	N - C	Y	Y	Y - C	N	Y	N	Y	N	Y	Y	Data Base	N	N	N
	(Wu, N. et al., 1999)	Y	N - C	Y	N	N	Y - C	N	N	N	N	Y	N	Net Diffusion	N	N	N
	(Huang, G. & Mak, K., 2000)	Y	N	Y	Y	Y	N	Y	N	N	N	N	Y	Announcement in a web platform	N	N	Third (Broker)
	(Sluga, A. & Butala, P., 2001)	Y	N	Y	N	N	Y - C	N	N	Y (without transport)	Y (without transport)	Y (without transport)	N	Net Diffusion	Y	N	N
	(Ko, C. et al., 2001)	Y	N - C	Y	Y	Y - C	N	Y	N	N	N	Y	N	Net Diffusion	N	N	N

Analysing the table 1, we observe the following main points:

1) None of the models is prepared to satisfy all the requirements for pre-selection and resources system selection, or the models don't consider them important;
2) None of the models resort to the pre-selection of transport resources and, consequently, their selection. At most, estimations for the necessary transport values are made;
3) About the negotiation, only one of the models admits its use but only refers this possibility without telling about the negotiation type;
4) Each of the models mention just one of the resources search strategies;
5) In neither case the models quantify its performance in terms of, e.g., time, cost and the quality of the resources system or effectiveness of the selection process itself;
6) Only one of the models resort to a exterior entity to perform the selection process without justifying the reasons, while the other models don't reference to whom compete the selection process, to the A/V E itself or to the third part.

4 - REQUIREMENTS FOR A RESOURCES SELECTION MODEL

From the anterior models analysis and from the interpretation of what we believe how the A/V E contributes as a new organisational enterprise model, principal necessities inherent to the selection process are as follows:

- The model must be presented in structured and explicit form to be correctly and easily interpreted and implemented;
- At the same time the model should be flexible to answer any A/V E(s) requirement because during the product life cycle the requirements for a new resources system reconfiguration change over the time;
- The model should be quantifiable about its efficiency and effectiveness before performing the selection process, because there can exist restrictions that invalidate its applicability, e.g., the time available or cost limits;
- The model should refer and justify the responsible by the selection process, i.e., the A/V E itself in the person of the Principal[1] or to a third part like a Broker, which is refereed by some models for A/V Es, see (Ávila, P. Putnik, G. & Cunha, M., 2002). This last item is important to decide if the A/V E has itself the capacity (time knowledge, and tools) to perform the desired selection.

[1] Designation that we attribute to the responsible / manager of the A/V E.

5 CONCLUSION

In view of the present work we have no doubts that are necessary new resources selection models for the A/V Es, or to complete with more information and capacities (functionalities) the existed models. Based on the limitations existed in the analysed models, and because our A/V E project, like any other A/V E project, needs a selection model to perform the agile configuration and reconfiguration of the system, we have proposed a new model. This new model, whose part is presented in (Ávila, P., Putnik, G. & Cunha, M., 2003), is marked by new functionalities and structure that the selection model should perform in order to minimize the complexities/difficulties for the new A/V Es creation.

REFERENCES

Ávila P. (1998). A Contribution for Processing Resources Selections for VE/OPIM System Design, *MSc Thesis*, University of Minho, Braga, Portugal.

Ávila, P., Putnik, G., Cunha, M. (2003b). Activity-Based Model for the Resources Systems Selection for Agile/Virtual Enterprises Integration. *Proceedings of Group Technology/Cellular Manufacturing Symposium*, Columbus, Ohio, USA.

Biquing, H., Janowski, T., Yonghe, L. (1999). *Automating Partner Selection for a Virtual Organization*. United Nations University of Macau, report nº 165.

Glover, F. (1993). A User's Guide to Tabu Search. *Annals of Operations Research*, Vol. 41, p. 3-28

Gupta, P., Nagi, R. (1995). Flexible Optimization Framework for Partner Selection in Agile Manufacturing. *Proceedings of the 4th IE Research Conference*.

Huang, G. Q., Mak, K. L. (2000). WeBid: A Web-based Framework to Support early Supplier Involvement in New Product Development. *Robotics and Computer Integrated Manufacturing*, Vol. 16, p. 169-179.

Ko, C. S., Kim, T., Hwang, H. (2001). External Partner Selection Using Tabu Search Heuristics in Distributed Manufacturing*, International Journal of Production* Research, Vol. 39, No. 17, p. 3959-3974.

Minis, I., Herrmann, J. W., Lam, G. (1996). *A Generative Approach for Design Evaluation and Partner Selection for Agile Manufacturing*. Technical Report 96-81, Institute for Systems Research, University of Maryland.

Ratchev, S. M., Shiau, J., Valtchanov, G. (2000). *Distributed Environment for Manufacturing Capability Assessment in the Extended Enterprise*.

Sluga A., Butala P. (2001). Self-organization in Distributed Manufacturing System Based on Constraint Logic Programming. *Annals of CIRP*, Vol. 50, No. 1.

Spinosa L., Rabelo, R. Klen, A., Ferreira, A. (1997). An Oriented Decision Support System Model for Virtual Enterprise Coordination.

Wang, H.-P., Li, H.-K. (1991). *Computer - Aided Process Planning*, Elsevier.

Wu N., Mao N., Quian Y. (1999). An Approach to Partner Selection in Agile Manufacturing. *Journal of Intelligent Manufacturing*, Vol. 10, p. 519-529.