Domain of applicability of Value Analysis approach in the pre-selection of resources

António Pires
School of Engineering – Polytechnic of Porto
Dep. of Mechanical Engineering
4200-072, Porto
Portugal
ant@isep.ipp.pt

Goran Putnik
University of Minho
Dep. of Production and Systems
4810-058, Guimarães
Portugal
putnikgd@dps.uminho.pt

Paulo Ávila
School of Engineering – Polytechnic of Porto
Dep. of Mechanical Engineering
4200-072, Porto
Portugal
psa@isep.ipp.pt

Abstract

For the project of an Agile/Virtual Enterprise (A/V E) the resources selection is a key factor. The output of the selection process should be prepared to guarantee quality, efficiency and cost-attractiveness, in order to ensure the agility and integrability of the A/V E. Despite the potential of Value Analysis (VA), none of the resources selection models found in the literature incorporates the VA integration. The main objective is to quantify the selection process performance with VA integrated into the pre-selection of resources in accordance with the developed model. The paper presents through the simulation results analysis, some of the benefits of VA application: greater applicability domain for candidate resources and number of tasks; and reduction of the selection time.

Keywords

value analysis, agile/virtual enterprises, resources selection, resources pre-selection, domain of applicability.

1. Introduction

It was the work of Drucker (1990) which gave rise to the concept of virtual enterprise associated with the concept of creating dynamic networks of companies. Nowadays, virtual enterprise is an important paradigm in an agile environment (Kaihara and Fujii, 2007). There is a lot of work done in the context of virtual enterprises (e.g. Macedo, Abreu and Camarinha-Matos, 2010, Eschenbacher, Seifert and Thoben, 2011, Romero and Molina 2011) but the resources selection problem remains a critical issue, namely the integrability of the resources in the configuration process of A/V E.

Our concept of A/V E is based on a hierarchical multi-level process, which aims to satisfy the basic properties of a virtual enterprise, namely integrability, distributivity, agility and virtuality (Putnik , 2000; Putnik, Cunha, Sousa and Ávila, 2005). Our model of A/V E involves the creation of a temporary network of various physical organizations (or resources) with the intent of developing and producing one or more products/services, in the desired quantities and quality, in response to the market request. In our model, the problem consists of selecting a system of resources (partners) with enough value to ensure the integrability of the resources systems which minimizes the total production time and/or cost (processing and transport) for the elaboration of a single product, independent of quantity, for which there are several candidate resources to process.

Several methods (e.g. AHP, game theory, linear/goal/multi-objective programming, Fuzzy, etc) were proposed to overcame the problem, but does not exist a consensus about this question. The pre-selection phase is not approached formally in the current models using these methods, but

2183-3060/2014/0101-012

integrated into the final selection. The incorporation of VA contributes with additional support for the A/V E configuration process. These factors are related to the nature of partners, trust, integrity, dynamic reconfiguration and organizational integration of A/V E. VA is a well known structured method to increase value and support the selection of the most valuable solution (Romano, Formentini, Bandera and Tomasella*,* 2010). Throughout recent decades, VA has proven able to reduce costs and ensure quality, while also contributing to the improvement of decision-making and other important organizational tasks. It is our belief that the application of VA into the paradigms of A/V E will bring the same contributions to A /V E performance as it has so far done in conventional systems (Pires, Putnik and Ávila*,* 2007; Pires *et al,* 2010; Ávila *et al*, 2010; Pires, 2011). The development and optimization of A/V E involve additional issues than those traditionally taken into consideration in conventional companies.

The main objective of this paper is to quantify the applicability domain of the VA integration model. With the proposed and simulated model, the results validate that the VA integration brings quality and quantity benefits to the process of resources selection, demonstrating the benefits of VA integration, namely a greater applicability domain;

2. Resources pre-selection model with VA

We intend to improve the resources selection by applying VA to this initial process of resources pre-selection while also taking into consideration its implications within the final selection of resources systems. One of the most important performance measures in the area of resources selection is the time expended in the process. It is fundamental to apply tools that are able to quickly and efficiently pre-select the resources. The pre-selection of resources enables planners to perform the final selection in a more systematic fashion and in accordance with the characteristics and specificities of each A/V E project. VA is important for improving both speed and reliability in pre-selection.

2.1. Review of the pre-selection phase in A/V E

An extensive literature review has demonstrated that the approaches to the global problem of resources selection in A/V E vary widely, according to Sluga and Butala (2001), Ko, Kim and Hwuang (2001), Chu et al (2002), Ávila (2004), Fischer, Jahn and Teich (2005), Huang, Wong and Wang (2004), Wu and Su (2005), Sha and Che (2005), Zeng, Li and Zhu (2006), Jarimo and Salo (2009). From the analysis of the existing models three main aspects can be pointed out:

1. The pre-selection phase is not formally approached in the current models but integrated into the final selection.

2. None of the analyzed models in the literature incorporate the value concept, suggesting that the value creation paradigm has yet to be considered, utilized, analyzed or incorporated into the selection of resources.

3. Also, most of the models fail to consider A/VE decision-making by way of a comparative analysis with conventional processes. References to this decision relate to the determination of the project accomplishment vis-à-vis the selected resources and eventual constraints of the model.

These are some of the main limitations of the existent models of resources selection and hence the importance of this work.

2.2. Demonstrator tool of the model

The main objective is to quantify the pre-selection performance with VA according to the developed model. We intend to demonstrate that VA integration brings quality and quantity benefits to the overall process of resources selection. In order to test this assumption, a demonstrator was defined and built. This should support a simulation of the pre-selection with and without VA and subsequent final selection. Certain conditions and restrictions on identifying and quantifying the domains of the model validation were accepted with the intention of being as comprehensive as possible. The MATLAB program was chosen as it adjusts to the desired objectives of our demonstrator.

3. Results and discussion

This chapter presents the results regarding the domain of applicability of the model for the final resources selection. These results were obtained from theoretical and simulation runs, as there is no application example in real virtual enterprise that includes this approach. The inputs data and their associated requisites were obtained from the data of a questionnaire in conventional enterprises (potential partners of an A/V E).

3.1. Results

Table 1 represents the partial results of the simulation plan for the initial number of candidate resources (Xc = 10) and for its final number (Xc = 50), whose value represents the limit of the processing capacity of the demonstrator. Between these limits multiples of 5 were considered for the number of candidate resources. For each Xc simulation runs were calculated since the number of tasks (n = 2) until this number reach the demonstrator processing capacity. Attending the results obtained three global considerations can be made:

1. In spite of the issues value and cost of the final resources systems are beyond the scope of this paper, it should be noted that the final systems selected with VA increases the final system value.

2. It is shown that the use of VA leads to lower selection times. An additional fundamental quantitative advantage is also achieved, i.e. effective and efficient pre-selection leading to faster selection, with obvious savings in time and associated cost reductions. This selection time, which involves other factors such as the time demands on resources and/or negotiation with resources, is vital to ensure the fast and efficient reconfiguration of an A/V E (Cunha and Putnik, 2006; Ávila, Putnik, Cunha and Pires*,* 2006).

3. As a consequence of the results for the processing time for selection an analysis of the applicability domain can be made, attending the number of tasks (n) and the number of candidate resources (Xc).

Table 1. Representation of simulation results.

		Without VA Integration					With VA Integration				
Xc	**n**	**k**	**t (sec.)**	**Final System**	**System Value**	**System Cost**	**k**	**t (sec.)**	**Final System**	**System Value**	**System Cost**
10	2	5	2	$r_{1,6}; r_{2,6}$	12.1350	13,9251	1	0	$r_{1,10}; r_{2,8}$	12.7519	19,8246
	3	5	1	$r_{1,5}; \mathbf{r_{2,6}}^*; r_{3,1}$	16.4943	19,1898	2	0	$r_{1,4}; r_{2,3}; r_{3,4}$	18.6295	30,5601
	4	6	8	$r_{1,7}; r_{2,7}; r_{3,5}; r_{4,1}$	22.2609	27,0634	3	1	$r_{1,9}; r_{2,7}; r_{3,3}; r_{4,2}$	25.3598	34,5625
	5	6	20	$r_{1,9}; r_{2,1}; r_{3,3}; r_{4,9}; r_{5,2}$	31.6199	28,2987	2	0	$r_{1,9}; r_{2,1}; r_{3,10}; r_{4,5}; r_{5,2}$	32.4921	38,5775
	6	6	176	$r_{1,7}; r_{2,10}; r_{3,6}; r_{4,9}; r_{5,4}; r_{6,9}$	36.9933	38,7640	3	4	$r_{1,7}; r_{2,10}; r_{3,3}; r_{4,4}; r_{5,7}; r_{6,9}$	38.3859	55,0109
	7	5	317	$r_{1,4}; r_{2,10}; r_{3,7}; r_{4,10}; \mathbf{r_{5,2}}^*; r_{6,6}; r_{7,2}$	43.7109	58,0794	2	0	$r_{1,1}; r_{2,10}; r_{3,1}; r_{4,8}; r_{5,6}; r_{6,6}; r_{7,2}$	44.8024	69,0215
	8	5	1025	$r_{1,4}; r_{2,8}; r_{3,2}; r_{4,9}; r_{5,4}; r_{6,6}; r_{7,1}; r_{8,5}$	49.2712	59,3443	3	25	$r_{1,4}; r_{2,8}; r_{3,2}; r_{4,3}; r_{5,6}; r_{6,8}; r_{7,2}; r_{8,1}$	50.3605	71,2312
	9	5	1119	$r_{1,10}; r_{2,1}; r_{3,2}; r_{4,7}; r_{5,7}; r_{6,6}; r_{7,2}; r_{8,8}; r_{9,7}$	56.8881	63,0147	2	2	$r_{1,10}; r_{2,1}; r_{3,8}; r_{4,1}; r_{5,7}; r_{6,9}; r_{7,2}; r_{8,2}; r_{9,7}$	59.6264	77,2620
	10	5	6092	$r_{1,4}; r_{2,6}; r_{3,9}; r_{4,5}; r_{5,7}; r_{6,10}; r_{7,1}; r_{8,6}; r_{9,8}; r_{10,2}$	60.3909	76,1906	1	0	$r_{1,10}; r_{2,8}; r_{3,9}; r_{4,9}; r_{5,7}; r_{6,8}; r_{7,2}; r_{8,3}; r_{9,6}; r_{10,4}$	64.7071	120,8015
	11*	5	7210	$r_{1,3}; r_{2,9}; r_{3,5}; r_{4,9}; r_{5,10}; r_{6,5}; r_{7,1}; r_{8,6}; r_{9,9}; r_{10,2}; r_{11,2}$	66.1357	93,8064	1	0	$r_{1,10}; r_{2,8}; r_{3,9}; r_{4,9}; r_{5,7}; r_{6,8}; r_{7,2}; r_{8,3}; r_{9,6}; r_{10,4}; r_{11,3}$	71.9824	138,3182
	12**										
………											
50	2	31	69	$r_{1,33}; r_{2,42}$	11.3186	4,5580	14	**5**	$r_{1,39}; r_{2,8}$	12.6339	10,2946
	3*	28	7262	$r_{1,15}; r_{2,41}; r_{3,11}$	18.9158	14,8912	19	1590	$r_{1,1}; r_{2,48}; r_{3,23}$	18.9379	15,1168
	4**										

Legend: Xc: Nº of candidate resources; **n:** Nº of tasks; **k:** Nº of resources pre-selected; **t:** Simulation time; **Final System:** System of selected resources**;** $\mathbf{r_{ij}}$**:** Resource *j* for task *i*; $\mathbf{r_{ij}}^*$: Resources that not obtained positive value in the 3 systems of level 2; * Exceed time limit; ** Exceed time limit without results.

3.2. Applicability domain for the VA model

As a consequence of the results for the processing time for selection, an analysis of the applicability domain can be made, attending the number of tasks (n) and the number of candidate resources (Xc). Figure 1 represents the model limits for the application without VA, demonstrating its importance. As the number of candidate resources (Xc), is increased, the number of tasks for which the demonstrator can make the final selection (valid n) decreases. For the maximum number Xc = 50, the demonstrator can only achieve an optimal solution for 3 tasks. For the minimum input Xc = 10, the demonstrator can obtain an optimized solution for 11 tasks (maximum task accomplished). The area below the line is identifies the domain of the model without VA.

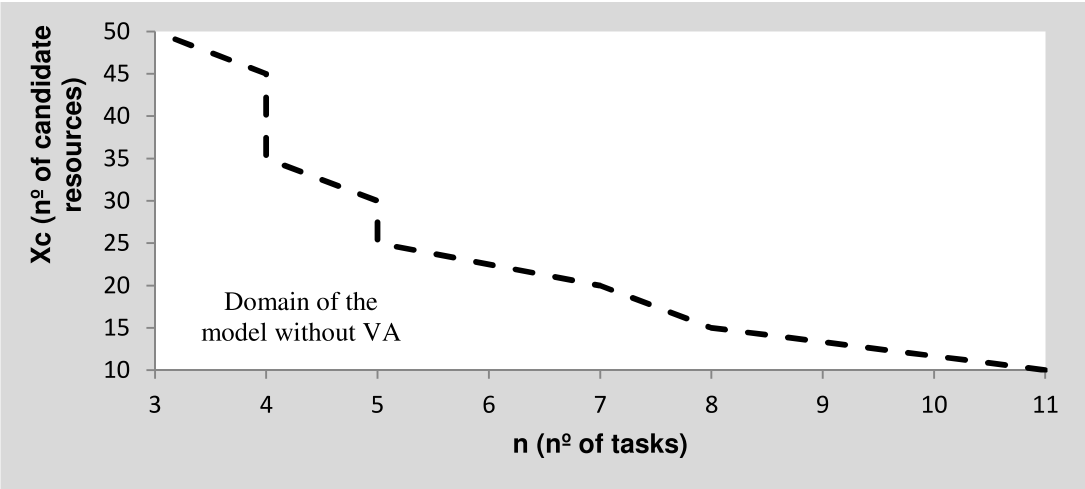

Figure 1. Model domain applicability without VA

It was, thus, decided to test what the limits of the model might be when the simulation is carried out only with VA. The results of previous simulations were analyzed as the number of tasks (n) expanded one by one to a previously determined quantity of candidate resources (Xc). A limit on the number of tasks (n = 25) was set. The main conclusion is the rise in the efficiency of the model with VA. The scope/domain of the model is superior to VA. Figure 2 illustrates the model's limits of application with VA. As the number of candidate resources (Xc) grows the number of tasks for which the demonstrator can perform a final selection (valid n) falls. For the maximum input Xc = 50, the demonstrator can obtain an optimal solution for 4 tasks. For the minimum input Xc = 10, the demonstrator obtains an optimized solution for 25 tasks (maximum task set).

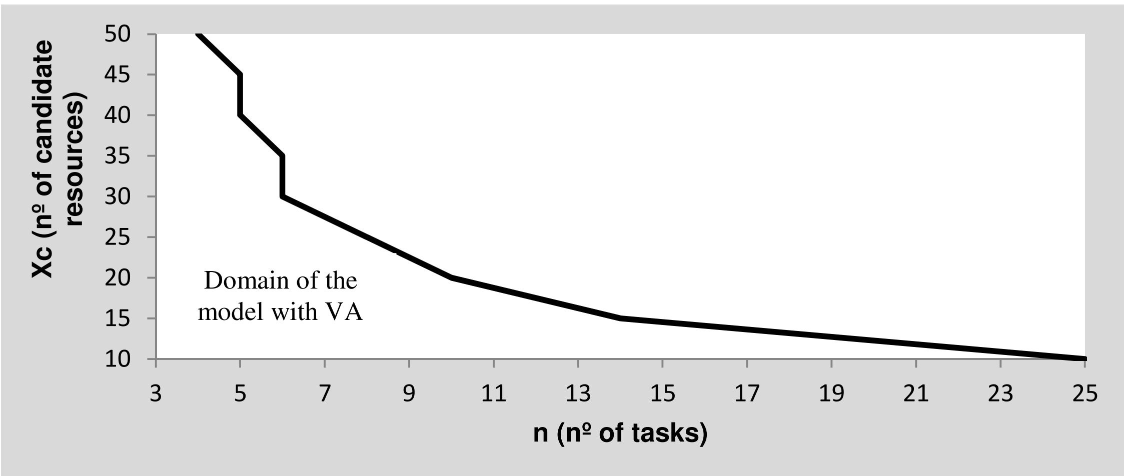

Figure 2. Model domain applicability with VA

Figure 3 represents the overall limits of the model in both situations, i.e. with and without VA, in order to simplify the comparison. As mentioned above, it can be concluded that the implementation of VA integration allows analyzing and performing a greater domain of tasks, validating our model's assumptions.

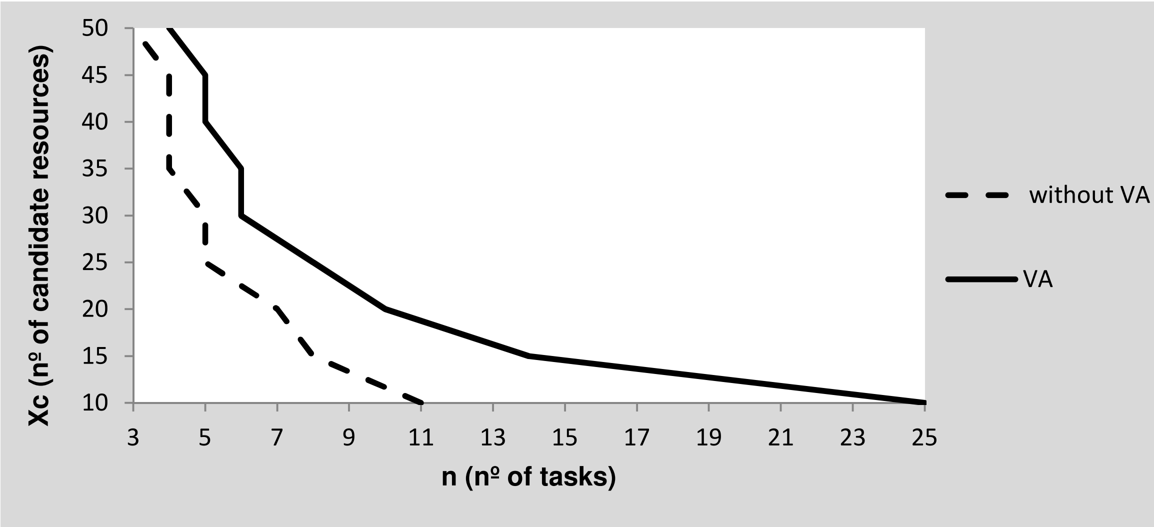

Figure 3. Overall model domain of applicability

4. Conclusions

This paper has analyzed the pre-selection phase of the existing resources selection models for A/V E, in order to identify their main limitations. The current literature fails to formally address the pre-selection phase, concentrating on analyzing and evaluating the final selection. Despite the potential of VA, none of the resource selection models incorporate the VA integration. So, our model constitutes an innovative approach towards greater sustainability in the configuration of virtual enterprises. In consequence, a model of VA integration in the pre-selection of resources was proposed. A demonstrator was built and simulations were performed to verify our assumptions.

The analysis of results demonstrated that the processing time of the final selection decreases with the VA integration model, which enables consequent time and cost reductions. This leads to a reduction in the analysis and selection decision time and the possibility of further refinement and search for additional information. This also facilitates the decision-making process engendering a greater degree of confidence in the candidate resources and indicates that an efficient pre-selection leads to better and faster final selection. Besides that, model domain of applicability with VA is larger than without VA. It means that the number of tasks and the dimension of the candidate resources that it is possible to analyze and evaluate are superior with VA.

As a final conclusion it can be said that for the entire process of A/V E configuration, especially in the pre-selection and consequent final selection of the resources system, VA delivers benefits. It results in a more systematic pre-selection procedure, with better performance in the resources selection process.

References

Ávila P., Putnik G., Cunha M. and Pires A., 2006. Broker and Market of Resources as Organizational Mechanisms for Sustainability of Resources Selection Processes in Agile/Virtual Enterprises. *Proceedings of SymOrg 2006 - X International Symposium*, Belgrade/Zlatibor, Serbia, 45-55.

Ávila, P., Costa, L., Bastos, J., Lopes, P. and Pires, A., 2010. Analysis of the Domain of Applicability of an Algorithm for a Resources System Selection Problem for Distributed/Agile/Virtual Enterprises Integration. *Sistemas y Tecnologías de Información, Actas de 5ª Conferencia Ibérica de Sistemas y Tecnologías de Información Vol.I*, 2010, Santiago de Compostela, 506-510.

Chen, Q., Chen, X. and Lee, W., 2007. Qualitative Search Algorithms for Partner Selection and Task Allocation in the Formulation of Virtual Enterprise. *International Journal of Computer Integrated Manufacturing*, 20 (2-3), 115-126.

Chu, X., *et al*., 2002. Partnership Synthesis for Virtual Enterprises, *International Journal of Advanced Manufacturing Technology*, 19, 384-391.

Cunha, M. and Putnik, G., 2006. Identification of the Domain of Opportunities for a Market of Resources for Virtual Enterprise Integration. *International Journal of Production Research*, 44 (12), 2277-2298.

Drucker, P., 1990. The Emerging Theory of Manufacturing. *Harvard Business Review*, 94-102.

Eschenbacher, J., Seifert, M. and Thoben, K., 2011. Improving Distributed Innovation Processes in Virtual Organisations through the Evaluation of Collaboration Intensities. *Production Planning & Control,* 22 (5-6), 473-487.

Fischer, M., Jahn, H. and Teich, T., 2004. Optimizing the Selection of Partners in Production Networks. *Robotics and Computer-Integrated Manufacturing*, 20, 593-601.

Huang, X., Wong, Y. and Wang, J., 2004. A Two-Stage Manufacturing Partner Selection Framework for Virtual Enterprises. *International Journal of Computer Integrated Manufacturing*, 17 (4), 294-304.

Jarimo, T. and Salo, A., 2009. Multicriteria Partner Selection in Virtual Organizations with Transportation Costs and Other Network Interdependencies. *Transactions on Systems, Man and Cybernetics*, TSMCC 2009, 124-129.

Kaihara, T. and Fujii, S., 2007. Game Theoretic Enterprise Management in Industrial Collaborative Networks with Multi-agents Systems. *International Journal of Production Research*, 46 (15), 1297-1313.

Ko, C., Kim, T. and Hwang H., 2001. External Partner Selection using Tabu Search Heuristics in Distributed Manufacturing. *International Journal of Production Research*, 39 (17), 3959-3974.

Macedo, P., Abreu, A., and Camarinha-Matos, L., 2010. A Method to Analyse the Alignment of Core Values in Collaborative Networked Organisations*, Production Planning & Control,* 21 (2), 145-159.

Pires, A., Putnik, G. and Ávila, P., 2007. The Potentialities of the Application of Value Analysis. *Proceedings of the 24th International Manufacturing Conference,* 2007. Waterford, Ireland, 745-751.

Pires, A., Putnik, G. and Ávila, P., 2010. An Analysis about the Resources Selection Process in Agile/Virtual Enterprises. *In:* Putnik, G. and Paulo Ávila, P., eds. *Business Sustainability I, Management, Technology and Learning for Individuals, Organisations and Society in Turbulent Environments*, U.Minho and I.S.E.P., 196-202.

Pires A., 2011. Integração de Análise do Valor no Processo de Configuração de Empresas Ágeis/Virtuais. PhD Thesis. Minho University.

Putnik, G., 2000. BM_Virtual Enterprise Architecture Reference Model, *In*: Gunasekaran A., ed. *Agile Manufacturing: 21st Century Manufacturing Strategy*, Elsevier Science Publishers, 73-93.

Putnik, G., Cunha, M., Sousa, R., Ávila, P., 2005. BM_Virtual Enterprise: A Model for Dynamics and Virtuality, *In:* Putnik, G. and Cunha, M., eds. *Virtual Enterprise Integration: Technological and Organizational Perspectives*. Hershey: IDEA Group Publishing, 124-143.

Romero, D. and Molina, A., 2011. Collaborative Networked Organizations and Customer Communities: Value Co-creation and Co-innovation in the Networking Area. *Production Planning & Control,* 22 (5-6), 447-472.

Romano, P., Formentini, M., Bandera, C. and Tomasella, M., 2010. Value Analysis as a Decision Support Tool in Cruise Ship Design. *International Journal of Production Research*, 48 (23), 6939-6958.

Sha, D. and Che, Z., 2005. Virtual Integration with a Multi-Criteria Partner Selection Model for the Multi-echelon Manufacturing System. *International Journal of Advanced Manufacturing Technology*, 25, 793-802.

Sluga, A. and Butala, P., 2001. Self-Organization in Distributed Manufacturing System based on Constraint Logic Programming. *Annals of the CIRP*, 50 (1), 323-326.

Wu, N. and Su, P., 2005. Selection of Partners in Virtual Enterprise Paradigm. *Robotics and Computer-Integrated Manufacturing*, 21, 119-131.

Zeng, Z., Li, Y. and Zhu, W., 2006. Partner Selection with a Due Date Constraint in Virtual Enterprises. *Applied Mathematics and Computation*, 175, 1353-1365.