DISCUSSION ON REQUIREMENTS FOR AGILE VIRTUAL ENTERPRISES RECONFIGURABILITY DYNAMICS: THE EXAMPLE OF THE AUTOMOTIVE INDUSTRY

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Product life cycles tend to shorten, time to market also, and even the global networked structures, corresponding to the recent approaches of the Extended, Virtual and Agile Enterprise (Agile/Virtual Enterprise model – A/VE) tend to last shorter and shorter time. The ability of dynamic reconfigurability is a requirement that the enterprises corresponding to this A/VE model must satisfy to assure a permanent alignment with the market. A/VE can have as many instantiations as required either by product changes or as a requirement of quality and competitiveness improvement. In the paper we discuss the need and the dynamics of the A/VE reconfiguration, using as support example the automotive industry supply chain.

1. INTRODUCTION

During the first half of the nineties, several criteria for competitiveness have emerged, and include requirements such as responsiveness, high flexibility, quality, constrained by environmental concerns. The goal of the enterprise was to fulfill the customer requirements, but, traditionally, using the limited set of resources available within the walls of the organisation.

As during the nineties, the present requirements for competitiveness remain, and the goal of the enterprise is still to fulfil the customer wishes. According to (Yusuf *et al*, 1999), a successful company must acquire the capability to achieve and explore the competitive advantage in synergy, i.e., using the best resources available to an organisation, which requires a shift from “self-centred close-enterprises” to dynamic reconfigurable global networked structures, corresponding to the recent approaches of the Extended Enterprise, the Virtual Enterprise and the Agile Enterprise (in the further text we will address the Agile/Virtual Enterprise model, A/VE).

Today’s competitive pressures have forced companies to abandon the traditional approach of product development and manufacturing, conceived as a series of fairly discrete steps. Business and product life cycles tend to shorten, and A/VE tend to last shorter time. Besides the shorter times, A/VE address dynamic reconfigurations; an A/VE can have as many instantiations as required either by product changes or as a requirement of quality and competitiveness improvement.

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Reconfiguration in A/V E can happen mainly from three reasons: (1) Reconfiguration during an A/V E life cycle is a consequence of the product redesign (a new instantiation of the A/V E is to be considered) in the business / product life cycle, to keep the A/V E aligned with the market requirements; (2) Reconfiguration as a consequence of the nature of the particular product life cycle phase (evolutionary phases); and (3) Reconfiguration can happen also as a consequence of the evaluation of the performance of the resources during one instantiation of the A/V E, or voluntarily by the participating resources, generating another instantiation, due to the substitution of resources.

In the paper we discuss this context of high reconfigurability dynamics in the Agile/Virtual Enterprise model, based on the analysis of the automotive industry.

2. AGILE / VIRTUAL ENTERPRISE MODEL

According to several definitions (just to mention, Davidow and Malone, 1992; Browne, 1999; Putnik, 2000), virtual enterprises (VE) are defined as “agile” enterprises, i.e. as enterprises with integration and reconfiguration capability in useful time, integrated from independent enterprises, primitive or complex, with the aim of taking profit from a specific market opportunity. After the conclusion of that opportunity, the VE dissolves and a new VE is integrated, or it reconfigures itself in order to achieve the necessary competitiveness to respond to another market opportunity. For the independent, primitive or complex enterprises, or companies, candidates to integrate an A/V E, we will use the designation “*resource*”, in the sense that they represent the potential “resources” for integration.

The knowledge and physical resources associated to the development and production of most of today’s products often exceed what a single firm is able to accomplish. The new production enterprise is a network that shares experience, knowledge and capabilities. The organisational challenge of partitioning tasks among partners in the distributed manufacturing environment so that they fit and take advantage of the different competencies¹ in A/V E, integration of the same, coordination and reconfigurability in order to keep alignment with the market requirements can determine the success or failure of a project.

Face to the requirements of competitiveness of the present, enterprises are expected to present at least the following characteristics: (1) fast reconfigurability or adaptability: the ability of fast change face to the unpredictable changes in the environment, implying substitution of resources (a new A/V E instantiation), and (2) evolutionary capability: the ability to learn with history.

3. THE AGILE/VIRTUAL ENTERPRISE MODEL AND RECONFIGURABILITY DYNAMICS

Product life cycles tend to be shorten, as well as time to market, and thus virtual enterprises tend to last shorter time. The requirement of responsiveness to the market demands, also forces the product life cycle to suffer frequent redesigns, which implies the requirement for increased dynamics to the A/V E model. The Agile / Virtual Enterprises must present a high reconfigurability ability in order to assure a permanent alignment with such market requirements. By alignment, in this context, we mean the actions to be undertaken to gain synergy between business, (a

market opportunity), and the provision of the required product, with the required specifications, at the required time, with the lowest cost and with the best possible return. In the A/V E model, we are concerned with the alignment between business and the integration of resources in an A/V E, to answer to that market opportunity.

3.1 Evolution of Product Life Cycle and A/V E Life Cycle

Global competition throughout the last two decades has strengthened the significance of a company's ability to introduce new products, while responding to increasingly dynamic markets with customers rapidly changing needs demands for shorten the time required to design, develop and manufacture, as well as for cost reduction and quality. In the past a product could exist without great changes or adaptations; today, besides the shorter life cycle, it suffers several adaptations in order to be competitive, i.e., aligned with the market, as shown in Figure 1.

If the product is to be developed and produced by an A/V E, for each product version the A/V E can suffer changes (reconfiguration), besides the reconfigurations that can happen within each product version. Even during one instantiation of the A/V E life cycle, the partnership can suffer from multiple changes to assure the permanent alignment with the market, as mentioned in section 1.

Figure 1 – Evolution of product life cycle

3.2 Subcontracting and A/V E Reconfiguration Dynamics

Coase (1937) observed that the distinguishing mark of a firm is the suppression on the price mechanism. Resource allocation in the market is normally driven by prices, but within the firm, functions are done through decisions and commands of management. Activities are collected in a firm when transaction costs incurred in using the price mechanism exceed the cost of organising those activities through direct managerial controls, otherwise activities could be outsourced.

Outsourcing also allows firms to concentrate on their core competencies, and increasing flexibility in the face of unknown economic or market conditions.

The services (/products /operations) to be outsourced can be *basic services* or *complex services* (products /operations), as represented in Figure 2.

Basic services are task specific and do not require detailed contracts or specifications, are usually of fixed and short duration, and support lower-level organisational tasks; examples are: payroll services, word processing, CAD drawing

services, testing /measuring services, cleaning services, maintenance services.

Complex services require detailed and complex contracts, detailed specifications, are usually of long duration, involve high costs and risks; its selection is time consuming and costly, as well as negotiation, monitoring and enforcement; examples include: product development, software development and turnkey manufacturing services.

Figure 2 – Product processes and corresponding Basic and Complex Services

As *complex services* outsourcing is complex, time consuming and risky, it is expected that complex service providers do not change much, that is, the partnership at higher levels of the process tree are expected to be lasting (less dynamics), while for the provision of *basic services* there exist a bigger pool of potential providers and hence partnerships are weaker. Reconfiguration dynamics for *basic services* outsourcing is higher than for *complex services*.

A possible instantiation of an A/V E to produce P could involve outsourcing of parts P1 and P2 to resources R1 and R2, as represented in Figure 3 (*complex services outsourcing*), or could involve outsourcing primitive parts (*basic services outsourcing*), to resources providers able to supply complex services (Figure 3) or only basic services (Figure 4).

4. RECONFIGURABILITY DYNAMICS IN THE AUTOMOTIVE INDUSTRY

In this section we will briefly observe reconfigurability in one of the most relevant industrial sectors –the USA automotive industry supply chain and the networks of subcontracts created around it.

4.1 Trends in the U.S. Automobile Industry

The automobile industry has evolved from a handful of large vertically integrated firms serving primarily domestic markets (the Big Three² in the United States, Toyota and Honda in Japan, Volkswagen and Mercedes-Benz in Germany) to a weaving /interlocking multi-tiered industry involving thousands of global suppliers.

According to a report prepared by the Research Triangle Institute (1999), the trends in the auto industry have elevated the relevance of interoperability. In an attempt to protect market share from imports, the U.S. auto industry began, in the seventies, to implement a number of practices, including outsourcing, to improve the industry's productivity and competitiveness. These practices resulted in significantly

reduced lead times and have narrowed the productivity gap between the U.S. industry and its competitors. During the nineties, manufacturing companies, particularly large original equipment manufacturers (OEMs), focused on reducing internal costs by shifting non-core functions outside of their organisation.

In a context of time-based competition and high performance, the A/V E model seems to be the one assuring enterprise integration and strategic alignment.

Figure 3 – Outsourcing Basic and Complex Services

Figure 4 – Outsourcing Basic Services

4.2 The U.S. Automobile Supply Chain

The automotive supply chain is complex. The U.S. automotive supply chain consists of four primary elements: original equipment manufacturers (OEMs), first-tier suppliers, subtier suppliers and infrastructure suppliers, as represented in Figure 5, organized in networks to form the supply chain, as represented in Figure 6.

The design and production of an automobile require interaction and coordination among many functions and industry participants. The structure of an automobile consists of app. 15,000 parts and accessories that must be designed to be compatible.

The automotive industry structure is characterised by Morell and Phelps (2000) for the National Coalition for Advanced Manufacturing as follows:

1. There are only few OEMs and first tier suppliers often do business with a few of them;
2. Because of the OEMs interest in outsourcing complex components, the number of first tier suppliers is small;
3. First tier suppliers do relatively little business outside of the auto sector;
4. Moving to lower tiers, the total number of potential suppliers increases;
5. Lower tier suppliers nearly always have a large customer base than first tiers;
6. Also down the chain, automotive suppliers tend to also sell to other industrial sectors, thus decreasing their dependence on automotive business.

Items 1 to 3 demonstrate the low dynamics felt for complex services subcontracting, while items 4 to 6 reveal the potential for high reconfigurability

Cost pressure on the supply chain is strong. Many companies feel the need to aim for the position at the interface to the OEM, expecting that increasing power will enable them to shift cost pressure down to lower tier companies. Cost pressure will more and more be complemented by sharing risks between OEMs and 1st Tiers suppliers. The A/V E concept implies risk share for lower level tiers. Suppliers believe that consolidation of their industry is essential, by means of a concentration process around large 1st Tier suppliers, who will outsource specialised functions.

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graph LR; A[Infrastructure Suppliers] --> B[Original Equipment Manufacturers  
Highly concentrated  
"Big Three" (Chrysler, Ford and General Motors)]; A --> C[First Tier  
Hundreds of companies  
Some large and some small]; A --> D[Subtier  
Thousands of companies  
Mostly small];
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Infrastructure Suppliers

- Original Equipment Manufacturers**
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[illegible]

Ford's chairman, in an on-line magazine (Reid, 1998), refers the trend to supplier rationalisation: all OEMs were intending to reduce the number of suppliers at the interface; at the end of the 80s, Ford had more than 3,000 1st Tiers, and expected to have only 800 by the end of 1999, which does not mean that Ford no longer need the components supplied by the remaining suppliers, it means that they are simply pushing the responsibilities for managing these suppliers down the supply chain. The big challenge in the auto industry, consists on the reduction in the top of the supply chain to 30 to 50 mega suppliers per vehicle in 2010 (Tiemann *et al*, 2000), organised in three to five top suppliers per module; a vehicle will be composed by ten modules. By strengthening high processes subcontracts (complex services) it is expected an increased dynamics at lower level processes (basic services).

On the other side, the degree of outsourcing from OEMs is expected to grow in

this decade, from the actual 60-70% to 70-80% of vehicle value (Tiemann et al, 2000). Consequently, the cost and quality of a vehicle is a function of the productivity of a network of collaborating firms working in.

Regarding the reconfigurability, the reduction in the number of suppliers is already the reconfiguration process itself. From the other hand, less OEM's suppliers doesn't imply decreased reconfigurability dynamics, it only decreases the solution size (number of supplier integrated in the A/VE system). The reconfigurability dynamics remains, if not increases, due to the bigger solution space size, and, consequently, the complexity of searching for a supplier and for an adequate A/VE system structure would increase as well. The expectation of the higher degree of outsourcing also supports the expectation of the higher degree of the reconfigurability dynamics.

4.3 The influence of the product changes

A study of Research Triangle Institute (1999) refers that one OEM estimates as many as 453.000 exchanges of product data occur each year within the company and among the company and its suppliers. This figure could lead to the possibility of 453.000 different instantiations of the A/V E, or at least to the possibility of 453.000 evaluations of the A/V E performance, in order to determine the need of reconfiguration (it is important also to remark that this is not the only justification to reconfiguration, the performance during an instance could also determine the need to substitute resources). Those 453.000 annual instantiations would mean an interval of 50 seconds between alteration requests, supposing a continuous operating industry (24 hours per day), 260 days per year, or an interval of 17 seconds supposing a one turn operating industry (8 hours per day).

4.4 The reconfiguration time

It was not possible to find data concerning mean times of reconfiguration and integration processes, however, the idea of the frequency of reconfiguration requests, given the costs of evaluating the need to reconfigure the A/V E and given the complexity of the process of selection and integration, in many cases the reconfiguration is overtaken, with sacrifice of the A/V E performance, unless there exists an environment to support dynamic reconfiguration and integration.

4.5 The Environment For The A/V E Dynamic Reconfiguration and Integration

To contribute to the reduction of search time in procurement and engineering, and to reduce transaction costs, OEMs have created *Covisint*, an electronic market to pool their purchasing power and to develop technology platforms to exploit networked technologies. Electronic markets like *Covisint* provide the environment to improve the A/V E reconfiguration. The concept of Market of Resources proposed by Cunha, Putnik and Ávila (2000) was conceived exactly as an organised environment with the objective to "boost" the dynamics as well as to support the high dynamics of the A/V E reconfiguration and integration. *Covisint* could be seen as a special case of the Market of Resources³.

5. CONCLUSIONS

Reconfiguration dynamics increase with the degree of process decomposition and depth of the processes. Partnerships for low level processes tend to be weaker and as such last less time than partnerships for the interface tiers (1st Tier), which are expected to be lasting. We have proposed the classification of services to subcontract in the A/V E model in *basic* and *complex services* and, based on the analysis of the U.S. automotive industry, concluded about a high reconfigurability dynamics for *basic services* subcontracting (low level processes and primitive processes) and an reduced dynamics for *complex services* (high level processes), as complex services outsourcing is complex, risky and time consuming.

It is expected that the reconfiguration dynamics will increase in the future. This hypothesis is supported also by the concept of the Market of Resources as an organised environment to support the Supply Chain, or A/VE high reconfiguration dynamics, which models (e.g. *Covisint*) are already implemented and in use.

6. REFERENCES

1. Browne, J., Zhang, J. (1999), "Extended and Virtual Enterprises", *International Journal of Agile Management Systems*, Number 1/1.
2. Coase, Ronald H. (1937), "The Nature of the Firm", *Economica*, vol 4 (Nov 1937), pp. 386-405.
3. *Covisint*, <http://www.covisint.com/>
4. Cunha, M. M.; Putnik, G. D.; Ávila, P. (2000), "Towards Focused Markets of Resources", in L. M. Camarinha-Matos & H. Afsarmanesh (Eds.) *Proceedings 4th IEEE/IFIP International Conference on Information Technology for Balanced Automation Systems in Manufacturing and Transportation*, Berlin, 27 to 29 September 2000.
5. Davidow, W. H., and Malone, M. S. (1992), "The Virtual Corporation: Structuring and Revitalizing the Corporation for the 21st Century", Ed. Harper-Collins Publications, New York, 1992.
6. Goldman S. L., Nagel R. N., Preiss K. (1995), *Agile competitors and virtual organizations*, Van Nostrand Reinhold.
7. Morell, J., Phelps, T. A., (2000), *A Review of Interoperability Issues In The Automotive Industry*, A White Paper produced by ERIM – Centre for Electronic Commerce for National Coalition for Advanced Manufacturing, [WWW document] URL: <http://www.ericm.org/cec/papers/> [2001, Aug].
8. National Coalition for Advanced Manufacturing (2001), *Exploiting E-Manufacturing: Interoperability of Software Systems Used by U.S. Manufacturers*, Washington, D. C.: NACFAM.
9. Putnik G. (2000), BM_Virtual Enterprise Architecture Reference Model, in A. Gunasekaran (Ed.) *Agile Manufacturing: 21st Century Manufacturing Strategy*, Elsevier Science Publ.
10. Reid, Charlie (1998), "Industry Watch: Big wheels keep on turnin' ", *Manufacturing Automation Interactive* [on-line] URL: <http://www.automayionmag.com/curr/> [2001, Aug, 15]
11. Research Triangle Institute (1999), *Interoperability Cost Analysis of the U.S. Automotive Supply Chain*, Manufacturing Engineering Laboratory of the National Institute of Standards and Technology
12. Sage, Lee (2001), "Power shift?" *A Profile of Tomorrow's Automotive Supplier*, Ernst & Young.
13. Tiemann, R., Scholz, J., Thies, C. (2000), "Future Trends in Technical and Strategic Relations among OEMs and Suppliers – Re-shaping the Automotive Industry", in *Proceedings of the FISITA World Automotive Congress 2000*, Seoul, Korea, 12-15 June.
15. Yusuff, Y. Y., Sarhadi, M., Gunasekaran, A. (1999), "Agile Manufacturing: The drivers, concepts and attributes", *Int. J. Production Economics*, No. 62, pp. 33-43.

¹ We describe the domain of competency of an organisation as the specific areas in which it has competitive problem solving capability, i.e., resources for efficient and effective problem solving.

² Ford, General Motors and Chrysler.

³ *Covisint* and the *Market of Resources* were developed independently.