A Flexibility Reference Model to Achieve Leagility in Virtual Organizations

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Abstract. The paper proposes a Flexibility Requirements Model and a Factory Templates Framework to support the dynamic Virtual Organization decision-makers in order to reach effective response to the emergent business opportunities ensuring profitability. Through the construction and analysis of the flexibility requirements model, the network managers can achieve and conceive better strategies to model and breed new dynamic VOs. This paper also presents the leagility concept as a new paradigm fit to equip the network management with a hybrid approach that better tackle the performance challenges imposed by the new and competitive business environments.

Keywords: Flexibility, Leagility, Virtual Organizations.

1 Introduction

Flexibility is an increasingly popular concept in modern times. Frequently, analysts assume that flexibility is essential to accommodate changes in the operating environment. Overall manufacturing systems that are flexible can use flexibility as an adaptive response to unpredictable events. Therefore, flexibility has been seen as the main answer for survival in markets characterized by frequent volume changes and evolutions in the technological requirements of products.

Building a definition of flexibility is not yet a straightforward process since definitions are distorted by particular management situations or specific problems. For the matter of this paper, Upton's definition is used [1]:

"Flexibility is the ability to change or react with little penalty in time, effort, cost or performance."

Most companies work on stable product categories produced in high volumes but, at the same time, they must deal with frequent product modifications and short product life-cycles. These constraints force the manufacturers to continuously evaluate their ability to change their manufacturing systems and the cost consequences related to those changes. This represents a complex issue in dynamic manufacturing contexts, such as the automotive, semiconductor, consumer electronics and high technological markets because the products are affected by frequent changes in volumes and technologies.

In fact, the customization of system flexibility provides economic advantages in terms of competitiveness, but, on the other hand, tuning the flexibility on the production problem reduces some of the safety margins, introduces investment costs and, in some cases, it can jeopardize the profitability of the firm.

Due to these constraints, a larger number of organizations increasingly confide in a brand new concept: Virtual Organizations (VO). A VO aggregates a group of distinct organizations that share resources and skills to achieve specific objectives and goals, but not necessarily limited just to one business alliance, and may have a regional or global focus.

In this context, the VOs can support the design and the production activities in order to improve the responsiveness and flexibility to meet the market demands. This derives from the ability to achieve a high degree of flexibility through different factories that can provide different processes, technologies and specific equipment specifically suited to reach the desirable "flexibility element" in each client order, or demand.

Alongside the concept of flexibility, in recent years another hybrid concept, leagility, has not been fully exploited in the context of supply chains and collaborative networked organizations.

In recent years, the concepts of "lean" and "agile" have aroused great interest in the research of supply chain management. The two paradigms that support this philosophy are presented as follows [2]:

- Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule.
- Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace.

Recent researchers have advanced the idea that lean and agile systems coexist through the development of a theory of "leagile" manufacturing applied within a manufacturing system or supply chain. A leagile system has characteristics of both lean and agile systems, acting together in order to exploit market opportunities in a cost-efficient manner [3].

This paper addresses the use of the "leagile" philosophy within the context of dynamic Virtual Organizations coupled with the flexibility needs to motivate the decision-makers to improve the inter-organizational processes performance, thus assuring that the major goals behind the collaborative network formation are fulfilled.

Chapter two presents the flexibility concept in order to formalize the requirements model. The following chapter explains the leagile philosophy and its applicability in the context of dynamic Virtual Organizations. Chapter four addresses the definition of the VO and how the concepts of flexibility and leagility fit with the virtual organization management. Chapter five presents the Flexibility reference model proposed in the work and chapter six describe the technological approach for addressing the flexibility through the Factory Templates Framework. Finally, chapter seven presents final remarks and conclusions.

2 Flexibility Definition

A dominant feature in the academic literature is the use of taxonomies for flexibility, which classify different types of manufacturing flexibility elements. Table 1 presents a list of categories in order to typify the basic flexible categories relevant to dynamic Virtual Organizations.

These categories are useful in that they provide general "types" that can be used to distinguish one form or element of flexibility from another. This flexibility taxonomy is an important step to provide a better understanding of the overall flexibility concept.

Table 1. Categories for Flexibility.

Categories	Ability…
Product	*change the product been made*
Routing	*modify the production routes*
Operation	*change manufacturing operations and activities*
Mix	*change product mix*
Volume	*alter production volumes*
Expansion	*add new nodes to the network*
State	*adapt to state and governmental regulations*

Another important aspect behind the flexibility concept involves its characterization (see fig. 1). For each flexibility element, it is necessary to establish the time period or time horizon in which the general period during which the changes will occur is defined. Associated with each flexibility element there are also four characterization elements: range, resolution, mobility and uniformity.

- Range has to do with the ability to put into effect or accommodate an interval on the dimension of the change; it defines the interval domain of variation of the flexibility element.
- Resolution defines how close the alternatives within the range of a given dimension are. Resolution increases with the number of possible alternatives if they are uniformly distributed within the range.
- Mobility reports the ability to provide mobility within the dimension of the change.
- Uniformity evaluates some performance measures within the range and costly evaluate their different positions inside the range of variation.

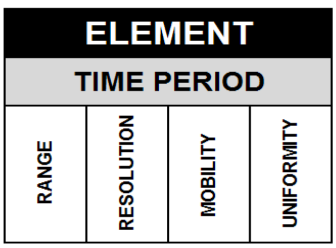

Fig. 1. Flexibility element characterization

Finally, the last feature associated with the flexibility concept is the definition of dimension. According to Terkaj [4], dimensions are general theoretical concepts that are embedded in the various forms of flexibility, which can be found in specific applications. For this reason, dimensions should not be measured, but should be treated as logical categories.

Table 2. Dimensions of Flexibility (adapted from [5]).

Dimensions	Definition
Capacity	The system can execute the same operations at a different scale
Functionality	The system can execute different operations (different features, different levels of precision, etc.)
Process	The system can obtain the same result in different ways
Production Planning	The system can change the order of execution or the DVO node assignment to obtain the same result

The above mentioned definition of flexibility is therefore intended to support the construction of the flexibility requirements model in the context of the dynamic Virtual Organizations.

3 Leagile Concept

Womack and Jones [6] have stated that a manufacturing system employing the lean paradigm strives to operate with optimum resources to obtain an optimum performance. He also indicated that there are five basic principles behind lean thinking:

(1) specify value by product;
(2) identify the value stream for each product;
(3) make value flow without interruptions;
(4) pull value from the manufacturer; and
(5) pursue perfection.

Thus, lean is a methodology to develop a value stream for all products that seek to eliminate waste in several forms, such as: overproduction, waiting time, over processing, transport, inventories, defects and rework, focusing on an operational level.

On other hand, the expression “agile manufacturing” stems from the Agile Manufacturing Enterprise Forum at Lehigh University [7]. According to Lengyel, agile manufacturing is the ability of an enterprise to survive in a competitive environment with continuous and unanticipated change, and to respond quickly to fast changing markets that are driven by the customers valuing the products and services [8].

An agile manufacturing organization is, therefore, an organization that has the ability to succeed and reconfigure itself in a dynamic and competitive environment. It acts proactively in order to be a step ahead of the market needs and requirements.

Concurrently with the definitions of lean and agile, the concept of leagile emerged more recently. It constitutes a system in which the advantages of leanness and agility are combined. This concept was first introduced by Katayama and Bennett in 1999 for the manufacturing supply chains [9]). According to these authors, the leagility occurs in a supply chain when lean and agile manufacturers co-exist in the same network.

Aligned with this philosophy, it is possible to distinguish between the lean and agile portions of the supply chain because the lean manufacturers will have a fixed level of inventory produced in advance, whereas the agile manufacturers would be able to produce for orders varying in demand and product mix.

The co-existence of these two approaches is possible in networked organizations due to the fact that the lean manufacturers are separated from the agile manufacturers in the chain by means of a separation point referred to in the literature as the "decoupling point", as shown in Fig. 2.

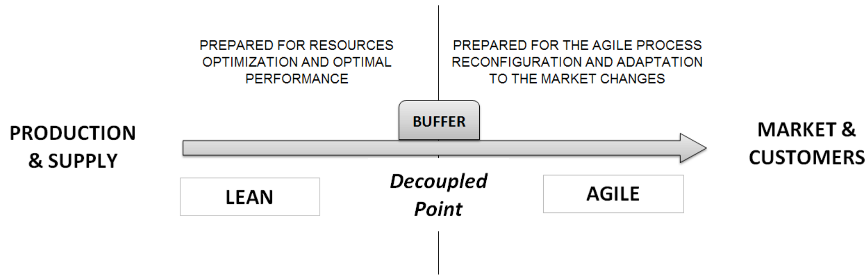

Fig. 2. Leagility in the manufacturing supply chain

This philosophy presents advantages in organizational terms. According to Van Assen [10], a decentralized organizational structure works best for agility because smaller, independent units can react to the environment more easily than a large, centralized structure. On the other hand, a lean organization performs better when there is a more stable environment and when steady material flow is created between the organization and the customers.

With this type of organization, the network is divided into a "back-end" part of the network that focuses on the production of physical products and/or services. And the "front-end" part of the network is aimed at the customer interface; it buys products from the back- end of the network, integrates them, and delivers them to the customers.

This organizational design thus seems ideally suited for a combination of the lean (production focused) and agile (customer focused) strategies, and it aligns with the vision of an agile network, thus being capable of dynamically reconfiguring itself as required to satisfy current market opportunities.

4 Dynamic Virtual Organizations

Today, it is increasingly common to see cases of collaboration among organizations that intend to integrate entities with similar or complementary competencies in order to design and / or produce new products and technological processes by sharing knowledge from their experience. Various forms of collaborative networks are applied in many areas and there are still various terminologies on this subject. In this context, Virtual Organizations (VO) aggregate a group of distinct organizations that share resources and skills to achieve specific objectives and goals. This is true when a group of organizations agree to adopt cooperation rules, common best practices, and mainly to share ICT infrastructures. Moreover, when a VO is established in a short-term to respond to an emerging market opportunity, during a short life-cycle, and dissolves when the goals are achieved, this is referred to as a dynamic Virtual Organization.

Nevertheless, this is really feasible whether it occurs within a VO Breeding Environment (figure 1). This means that the organizations and other supporting entities that adhered to a cooperation agreement based on medium- and long-term objectives, aim to increase their ability to form, design and implement temporary collaborations on the short-term, e.g., dynamic Virtual Organizations. The VBE concept is expressed in such forms as: industry cluster, industrial district, business ecosystems, inter-continental enterprise alliance, disaster rescue networks, virtual laboratory (e-science laboratory) and professional virtual community. Although the establishment of VBEs is increasing, there are still few such initiatives with proven experience and maturity [11].

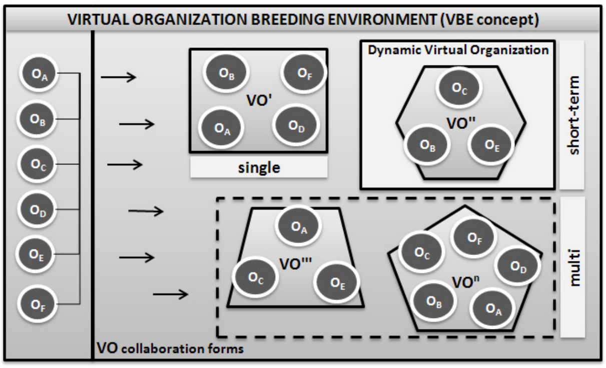

Fig. 3. VO Breeding Environment (VBE) – collaboration forms

The perspective of working together within the same extended infrastructure leads to the improvement of organizations' competitiveness. This can create high levels of synergy in terms of Business Strategy, New Product Development, Operations Management, among other concerns. Therefore, this makes it possible to select, agree and implement a dynamic VO as quickly as they can view market opportunities

So, it is suitable that improving solutions in order to bring agility and flexibility through collaborative networks be an important place in the support of strategies for competitiveness [12]. In this context, the application of the flexibility and leagile concepts in the VOs can be an excellent strategy to reach those challenges, bringing better overall performance. They search for process improvement and adaptation to the emergent market changes. Indeed, the VO's scenario appears to be suitable for the application of these concepts.

However, collaboration implicates agreement among participants. This concern must be treated appropriately in order to plan and solve problem situations involving trustworthiness, sharing of resources and knowledge, and strategic alignment.

5 Requirements Model for Flexibility

Due to the competitive environments characteristics where the VOs perform, it is imperious that a strategic approach be defined for the decision-makers in order to provide potential characteristics enhancement for the network performance.

One of the basic elements of this strategic approach requires the comprehensive use of the flexibility concept as a fundamental aspect behind the design of dynamic collaborative networks. Flexibility is an intrinsic value that must be present in the role of decision-makers of Dynamic VOs during the entire collaboration life-cycle.

Flexibility improvement is frequently among the top concerns of manufacturing managers and is growing in importance; nevertheless this concept is somehow diffuse and ambiguous. So, this work seeks to address this problem especially in the VOs context by structuring the flexibility concept through a requirements model. Figure 4 presents the flexibility requirements model matrix.

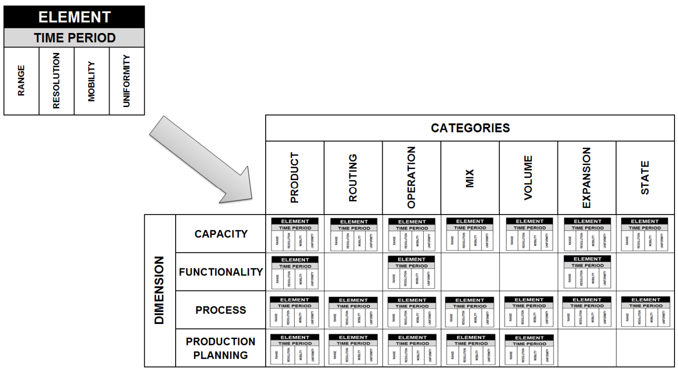

Fig. 4. Flexibility Requirements Model Matrix for Dynamic VOs

Using the concepts presented in Chapter two, it is proposed a matrix in which rows representing the dimension definitions, and in the columns the flexibility taxonomic categories. In the intersection of the rows and columns it is presented an abstract flexibility element that correlates the corresponding concepts from the dimension and flexibility categories where it is applicable for the dynamic VOs context.

Each of the abstract “flexibility element” is instantiated in a specific feature or ability that according to the decision-makers is relevant for the overall network performance.

At the same time the concept of leagility is convergent with primary motivations behind flexible dynamic VOs. Just as the VOs need these approaches to improve their performance also these concepts are fundamental to improve the competitiveness of organizations in VBE.

Another important aspect intended to address flexibility in dynamic VO’s is related with the way the productions systems architecture are organized in order to flexibility and how they are depend in ICT technologies. The present research work proposes a new approach based on a Factory Templates Framework intended to help dynamic VO’s stakeholders to conceive and implement adaptable and flexible VO’s.

6 Factory Templates Framework

In contrast to other complex products, production systems and especially factories require an overall system architecture that allows them for continuous adaptation to the needs of customised products, the economic environment and the objectives behind the dynamic VO's. Consequently, in manufacturing, as in all complex systems, knowledge represents the key to maximising manufacturing success and the dynamics of this socio-technical system. This knowledge, which implicitly exists within the skills of workers, technicians and engineers, must be captured and stored within intelligence management systems, as well as being stimulated to flow between knowledge sources and all who seek knowledge in order to improve their work and optimise their processes. This exchange of knowledge between the different company's repositories within the VO's, must be structured and organized in a global reference model recognized by all the actors in the manufacturing processes as a Factory Templates Framework.

This Factory Templates Framework allows in the dynamic VO's the structuring and management of documents, best practices, methods, techniques, processes and knowledge, as well as manage constraints, goals and requirements following a concurrent engineering approach. In order to be successful, during the planning phase, the factory designer/manager must take into account different factors and issues such as: business goals, production facilities, human roles, information and control systems, energy efficiency as well as environmental and social issues.

Moreover, FT should support the process planning of the production systems at short, medium and long term, sharing with all the stakeholders involved in order to answer: *Which* are the goals to be achieved, *How* it is supposed to be done, *Who* is involved, *What* are the dates of start and end of each process and finally the reasons *Why* it should be done according to plan stipulation (Factory Planning support).

Therefore, it is not only important to design and monitor processes evaluating their flexibility, but also study its performance, looking for new paths to achieve better results inspired in the company's expertise acquired in the past. In line with this, the Factory Template Framework should support users to find answers to their problems, help them to develop the adequate level of flexibility, looking for the reasons that are affecting the system, and also supporting its improvement. Thus, two important functionalities should also be taken into account when exploring the Factory Template approach: Continuous Improvement and Performance Targets Management.

Moreover, using a feedback approach, the FT Framework is able to support the actual processes and activities performance analyses and assess their flexibility. Thus, the overall productions systems managers will be able to detect and visualize bottlenecks that affect negatively the whole VO's, and consequently, perform corrective actions in the specific low performance points in the network in order to improve the global performance. Done the corrective actions, it is essential that these new changes should be evaluated and the results confirmed, so they can be stored at Knowledge Repository and Best Practices databases.

With the Factory Templates approach it is expected that not only the dynamic VO's decision makers design their network processes faster, which are normally crucial and time expensive, but also improve the Virtual Organization overall flexibility and business goals alignment .

From the research work performed by this paper author's team, a new Factory Templates Framework was designed and currently its development and implementation phase is undergoing. From the performed work, the proposed Factory Templates framework is divided into 5 main modules:

- Workflow manager: composed of a workflow editor and engine, this module provides an intuitive interface that makes it easier for the Manufacturing Design to model approval based workflows. In this way, the WorkFlow Manager is responsible for the implementation of each process for each step of a VO life cycle stage, providing specific reports for each activity.
- FT Manager: this module is responsible for facilitating and assuring the correct creation of the overall product manufacturing process over the network, as well as deploying and controlling the life-cycle stages, guaranteeing that the planning sequence is accomplished. Once, the definition of the decoupling point for the leagile supply chain has been accepted as a potential competitive advantage, this will be crucial to overall VO manufacturing system planning support and execution.
- Performance Measurement: In this module, it is possible to measure all types of defined operational and logistic key performance indicators. By placing the evaluation results accessible to the rest of the network, this offers means to the decision makers in the VO's target low performance areas of the VO's and pursue improvement.
- Database Templates: this module is the Factory Template repository responsible for the storage of manufacturing process templates. In this repository it is not only stored the manufacturing processes and best practices implementations schemas.
- Best Practices Expert: this is the module responsible for the integration of the Factory Template with case based reasoning platform responsible for the search of the suitable Best Practices that best respond to the problem/solution that is being searched.

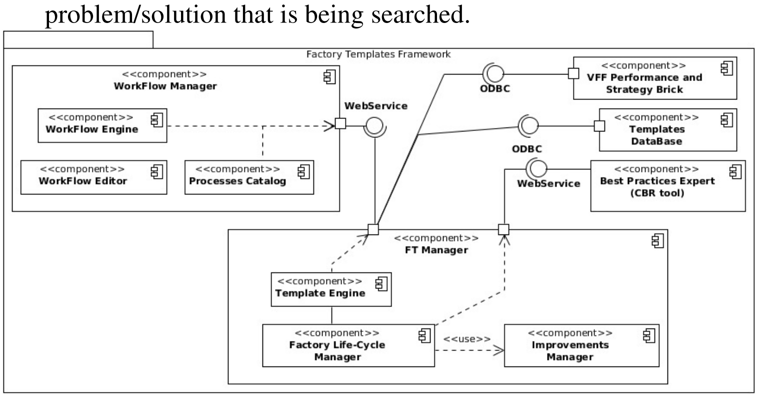

Fig. 5. Factory Template UML Diagram

In order to simplify and guarantee a flexible architecture, a WebServices and an Open Data Base Connectivity approaches were used in order to support the global communication of the Factory Template Framework with the whole VO's network. Figure 5 presents the Factory Templates Framework UML module diagram.

7 Conclusions

The ideas presented in this paper intend to support Dynamic VO decision-makers in their management activities, allowing the effective response to the emergent business opportunities. The construction and analysis of the flexibility requirements model empowers the network managers through methods and tools in order to better formulize the strategies which can accomplish the short-term agreements so fit to the dynamic VOs concept.

The leagility philosophy it would in the perspective of the author's present competitive advantages to meet the challenges imposed by the new business environment. It provides both the efficiency associated with the lean concept, and the agility and proactivity associated with the agile manufacturing concept.

By the definition of a Flexibility Reference Model and further by the implementation of a Factory Templates Framework, the research team believes that is possible to provide managers of VO's networks with a conceptual and technological framework fit to the demands and challenges posed by a post-globalized market.

The outcomes expected with this approach seek to increase the organizations capabilities to strategically analyze and configure future networks with the abilities to ensure greater competitiveness and profitability.

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