Next Generation Manufacturing Systems and the Virtual Enterprise

David Romero¹, Ricardo J. Rabelo², Mauricio Hincapie¹, Arturo Molina¹

¹CIDYT - ITESM Campus Monterrey & Ciudad de México, México
david.romero.diaz@gmail.com, maurhin@gmail.com, armolina@itesm.mx
²GSIGMA - DAS - Federal University of Santa Catarina, Florianopolis, Brazil
rabelo@das.usfc.br

Abstract: Next Generation Manufacturing Systems (NGMS) will support the Next Generation Manufacturing Enterprises (NGMEs). Adaptive distributed manufacturing systems seem to be a promising solution for NGMEs to provide increased levels of flexibility, reconfigurability and intelligence to respond to the highly dynamic market demands. Virtual Enterprises (VEs) are expected to be the dominant manufacturing enterprise model in the 21st Century. VEs promise new possibilities where a manufacturing system is not know in advance and has to be structured, optimized and implement from scratch to produce e.g. one-of-a-kind products. VEs can approach each industrial project with tailored manufacturing systems represented by a temporary integration of processes capabilities and resources capacities from multiple enterprises in order to meet or exceed the quality-, time- and cost-frame requirements of the customer. VE paradigm represents the future of the NGMEs, and can be also used to provide industrial services in a collaborative way to evolve from physical products to the notion of extended products.

Keywords: Next Generation Manufacturing Systems, Next Generation Manufacturing Enterprises, Virtual Enterprise

1. INTRODUCTION

“The virtual enterprise paradigm is gaining a growing importance in manufacturing as an instrument to help enterprises face the challenges of fast evolving market conditions” (Camarinha-Matos, 2002). Information and Communication Technologies (ICTs) have been the enabling factor in the reconstruction of traditional industrial paradigms towards the next level of integration in manufacturing enterprises: cell level > shop-floor level > intra-enterprise level > inter-enterprise level [the Virtual Enterprise] (Camarinha-Matos & Afsarmanesh, 2005). Furthermore, the concept of product has evolved from the physical product to the notion of the extended product as result of a competitive global marketplace where manufacturers have to package their products with additional services to make their products more attractive to the customer. In this sense, Next Generation Products [extended products] should represent high quality, affordable, fast and customized solutions for the customer, including service provision capabilities such as: real-time diagnostics, maintenance, security, traceability, self-direction, entertainment, convince, responsiveness, reproducibility, etc. Additionally, these products have to be environmentally friendly, which implies that they have to be made of degradable materials, produced with low environmental impact and designed for recycling (Myers, 2006).

All these trends drive the requirements and developments for the Next Generation Manufacturing Systems (NGMS) towards six grand challenges that imply (1) achieving concurrency in all operations in order to reduce products time-to-market at the same time that products lifecycle tend to shrink [Lean Enterprise]; (2) integrating human and technological resources to enhance workforce performance in order to operate as a customer-responsive enterprise and continuously improve management of product variety, product complexity and product manufacturing processes as a source of competitive advantage; (3) instantaneously transforming information gathered from a vast array of diverse sources into useful knowledge for supporting effective decisions-making by humans and machines across the product lifecycle. This is based-on real-time information flows that enable enterprise capabilities for concurrent manufacturing [Totally Connected Enterprise]; (4) reducing production waste [resources conservation] and products environmental impact [substitution of hazardous substances and materials] to “near zero” in order to become an environment-friendly and sustainable manufacturing enterprise; (5) reconfiguring manufacturing enterprises [VE creation] rapidly in response to changing needs and opportunities in order to become a flexible enterprise with adaptable, integrated processes and systems readily reconfigurable; and (6) developing innovative manufacturing processes and products with a focus on decreasing dimensional scale [miniaturization] in order to design and manufacture new materials and components that will enable the manufacture of innovative, customized, waste-free products (NRC, 1998; IMS, 2000; IMTI, 2000; IPTS, 2003).

In order to achieve the 21st Century manufacturing enterprise characteristics such as: adaptability, connectivity, flexibility, reconfigurability and responsiveness will be required to face NGMS challenges. This paper focuses on the VE paradigm as a promising enterprise model that allows “the rapid, inexpensive and robust assembly of geographically distributed but electronically-linked modular manufacturing units into a ‘virtual factory’, and the configuration or reconfiguration of cost-efficient/flexible/responsive manufacturing systems through collaborative and distributive design, resource and production planning and scheduling to manufacture high value-added products” (1*PROMS, 2006).
2. THE VIRTUAL ENTERPRISE

A virtual enterprise (VE) is short-term and dynamic coalition of enterprises tailored to respond to a single collaboration [business] opportunity and dissolve once their mission/goal has been accomplished, and whose cooperation is supported by computer networks. VEs are able to [rapidly] integrate skills or core-competencies and resources from different strategic partners required to meet or exceed the quality, time and cost frames expected by the customer (Camarinha-Matos & Afsarmanesh, 2006). VEs are [dynamically] formed according the needs and opportunities of the market and remain operational as long as these opportunities persist, suggesting a number of benefits/advantages such as: agility to rapidly react when a collaboration opportunity arises and to cope with the ever changing market conditions and customer needs; complementary roles to seek for synergies to explore new markets/products in multidisciplinary sectors and to achieve competitive advantages by excelling individual capabilities [focus on core-competencies]; achieving larger dimension to have more chances to compete with large companies by accomplishing critical [e.g. SMEs] mass and appear in the market with a large “visible” size; competitiveness to achieve cost-effectiveness and products uniqueness based-on the proper selection of cooperative organisations and division of subtasks among them; resources optimization to gather the “best of everything” and to share costs, risks, resources and core-competencies to provide world class solutions; and innovation to manufacture new products, offer new services and/or carried out new processes as result of knowledge and technological synergies (Browne & Zhang, 1999; Camarinha-Matos, 2002; Camarinha-Matos & Abreu, 2005; Camarinha-Matos & Afsarmanesh, 2006).

Furthermore, nowadays VEs show a growing number of manifestations in manufacturing and service provisioning. A virtual manufacturing enterprise (VME) can be defined as a short-term alliance of enterprises compromising different kinds of resources, [manufacturing] processes and knowledge needed for design, engineer and manufacture high quality and highly customized products for the customer (Jansson, 2005a). VMEs’ industrial projects include typically products that are complex and involve large manufacturing systems like: industrial plants, machine tools, ships, aircracts and buildings. Moreover, a virtual service enterprise (VSE) can be defined as temporary consortium of enterprises that come together to share knowledge and skills to fulfil different customer requests in after-sales services. VSEs main aim is to provide support to the customer in the maintenance of its machines and installations and to solve problems as immediately and as cost-effectively possible (Hartel et al., 2002; Jansson, 2005b). VSEs’ industrial services can be grouped as follow (Kalliokoski et al., 2003): (a) basic services - spare parts, consumables, maintenance and repair, installation and start-up, removals and re-installation, local support; (b) advanced services - project engineering, troubleshooting, inspections, performance guarantees, refurbishment, renewals, financing; and (c) knowledge services - process consultancy; training, remote operation, simulation, securing return on investment.

The VE model seems to better fit with the market dynamics and the variable duration of today’s business opportunities, including customers increasing expectations for integrated product-service configurations. Therefore, this short-term and goal-oriented collaborative network appears to be well-suited to become the reference model for the Next Generation Manufacturing Enterprises (NGMEs).

VEs represent a ‘new strategic logic’ where managers need to be good at mobilizing and managing processes and resources rather than owning them (Normann, 2001). VEs strategies concentrate on value creation for customers using “active collaboration” to provide low cost, high quality products and/or excellent service(s) in a flexible and more efficient manner as compared to a single enterprise trying to provide all them. VEs focus on flexibility and continue processes and resources re-configuration (Katzy & Obozinski, 1998) as a source of competitive advantage to create new (emergent) composite capabilities (Ermilova & Afsarmanesh, 2008) for satisfying a wide range of customers’ needs. VEs translate customers required priorities into specific performance requirements to choose the right strategic partners to assure that consortium capabilities are sufficient to accomplish them (see Figure 1). The intrinsic decentralization and distribution of capabilities involves not only tasks assignment over enterprises, but also inside them. This means having a more flexible and dynamic, inter-connected arrangement of manufacturing resources (like in Barata & Camarinha-Matos, 2003), computing resources (like in Pinheiro & Rabelo, 2005) and people (like in Dalsgaard et al, 1999).

Consequently, VEs business models suggest a unique approach based-on “dynamic capabilities” for facing customers’ expectations and competition constrains based-on managing single or combined value disciplines and value propositions accordingly: (1) improve customer intimacy by focusing on delivering not what the market wants, but what specific customers want - value proposition - the best solution for the customer with all the support needed to get the maximum value from a product [e.g. an extended product]; (2) achieve operational excellence by reducing costs to manufacture and deliver reasonable quality products with the least difficulty or inconvenience - value proposition - low price and hassle-free service; and (3) foster product leadership through a very strong focus on innovation and time-to-market - value proposition - new and exceptional products and services (see Table 1) (Treacy & Wiersema, 1997).

In this context, the VE model seems to be capable of managing these value disciplines and value propositions configurations accordingly to each business opportunity characteristics thanks to its dynamic nature [short lifecycle: creation, operation, evolution and dissolution], strategic partners search & selection
process [e.g. competency-based and other criterions] and proper “VE management” incorporating all the activities, measures and operations needed to guide the inter-enterprise operational processes in order to achieve the target value discipline(s) objectives [or value propositions].

Table 1. Value Disciplines (VD) vs. Virtual Enterprise (VE)

<table>
<thead>
<tr>
<th>VD</th>
<th>Virtual Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Influence</td>
<td>• VE capabilities for handling products/services customization taking into account the customer preferences and specificities, and managing constrains with active collaboration.</td>
</tr>
<tr>
<td></td>
<td>• VE customers have better conditions to embed their particular, societal and environmental wishes into the products, for which a VE will be created.</td>
</tr>
<tr>
<td>Operational Excellence</td>
<td>• VE partners search &amp; selection based-on cost efficiency.</td>
</tr>
<tr>
<td></td>
<td>• VE partners rationalization and sharing of manufacturing and computing resources.</td>
</tr>
<tr>
<td></td>
<td>• VE partners share costs and risks associated with new product developments and their related activities.</td>
</tr>
<tr>
<td></td>
<td>• VE partners share a common basis of performance indicators, which force them to enhance their quality continuously as they are usually selected by means of benchmarking [VE partners search &amp; selection process].</td>
</tr>
<tr>
<td>Product Leadership</td>
<td>• Access to new knowledge in VE partners that may confront ideas and practices, and therefore induce/lead to innovation.</td>
</tr>
<tr>
<td></td>
<td>• VE customer involvement that may help to recognize new approaches to how innovative by allowing &quot;lead-users&quot; to co-design products/services to fit with their specific needs.</td>
</tr>
<tr>
<td></td>
<td>• VE potential enables launching the right product at the right time at right place.</td>
</tr>
</tbody>
</table>

3. NEXT GENERATION MANUFACTURING ENTERPRISE

Nowadays all manufacturing enterprises operate in everyday more demanding and dynamic markets with increased claim for product customisation, product variety and shorter delivery times with higher expectations of significantly improved delivery and [post-] service reliability. When these pressures are coupled with the inherent complexity of many manufacturing enterprises and their relatively stable supply, production, delivery and service networks, then the challenges and needs for the NGME arisen claiming for more dynamic network structures to serve the new market dynamic demands.

The IMS Project (2000) defines the Virtual Enterprise as “a globally distributed assembly of autonomous work units linked primarily by the goal of profitably serving specific customers and operating in an environment of abrupt and often unanticipated change”.

NGMEs will be characterized: (1) at enterprise level as organisations focusing on the customer, acknowledging its preferences and exploiting this knowledge for developing innovative products and services in such dynamic way that enterprises capability to adapt, promote change [innovate] and deal with customers emerging needs will create new sources of competitive advantage; (2) at product/service level as solution providers offering extended and tailored products to meet customers individual needs over by time, thanks to reconfigurable solutions [products and/or services] that can evolve to meet customers new requirements; (3) at environmental level as “conscious organisations” designing products for recycling, improving efficiency in production to reduce energy and materials wastes, and managing consumption to offer products and services just when the customer need them and only for the time they are needed; and (4) at relationship level as an organisation in close cooperation with its customers and suppliers, both integrated in the whole product lifecycle (Kidd, 2000).

Furthermore, recent trends in computing environments and engineering methodologies indicate that the future engineering infrastructures will be distributed and collaborative, where designers, process planners, manufacturers, customers, and other related domain personnel communicate and coordinate using Web technologies (Ostojic et al, 2007). Therefore, NGMEs will be supported by new ICT-infrastructures playing intermediary roles as the enablers of interoperations among manufacturing enterprises towards the rapid and adaptive design, production and delivery of highly customised products and/or services in collaborative engineering environments (Peñaranda et al, 2006; Pedrazzoli et al, 2007).

Hence, NGMEs will be driven by the application of information and communication technologies and the increasing demand for the efficiency in all operations in their networks. As such, the VE model is viewed as an enabling enterprise model for agile manufacturing and service provisioning, allowing appropriate competency levels for challenging the market pressures by integrating technological capabilities and human resources knowledge with effective collaborative managerial systems to improve the current manufacturing and service systems. All these systems supported by transparent, easy-to-use and affordable "plug-and-play" ICT infrastructures as the key pre-requisite for the effective implementation of advanced virtual enterprises (Rabelo & Gusmeroli, 2008).

4. NEXT GENERATION MANUFACTURING SYSTEMS

According to Shen & Norrie (1999), NGMS should satisfy the following fundamental requirements: (1) enterprise integration at intra- and inter-enterprise levels by integrating all systems within an enterprise and with the systems of its strategic partners to achieve the “totally connected enterprise”; (2) distributed organisation dealing with the management of materials, components, assemblies, manpower, equipment, information and financial flows in a geographically distributed environment; (3) heterogeneous environments with dissimilar software and hardware components interacting between diverse manufacturing and information systems; (4) interoperability between these software and hardware components [e.g. application-, information-, communication-, manufacturing-operating- systems] operating seamlessly, (5) open and dynamic structures with reconfiguration capabilities that allow adding and/or removing new systems/resources or modifying the existing ones in a system without stopping or reinitializing its operational functions; (6) cooperation among all stakeholders and potential new partners, including the customer, in the value network; (7) integration of humans with software and hardware applications [e.g. human-computer / man-machine] to achieve balanced manufacturing system with the correct mix of automated activities and human activities across the product lifecycle; (8) agility as the ability...
to adapt the manufacturing environment by means of rapidly reconfigure and interact with heterogeneous systems and partners (9) scalability to incorporate new systems/resources as they may be required; and (10) fault tolerance as the capability to detect, react and recover from system failures in order to minimize their impacts on the manufacturing environment.

As a result, NGMS will be distributed reconfigurable virtual factories [e.g. the Virtual Enterprise] in which autonomous and heterogeneous entities/agents [e.g. enterprises, humans, machines, information systems, control modules, etc.] are integrated and interoperate/interact to achieve agile, scalable and fault tolerant manufacturing systems.

NGMS will be developed and evolved based-on different distributed manufacturing system models such as: fractal-, bionic-, and holonic-manufacturing systems or hybrids of them (see Table 2), applying new concepts, methodologies and technologies with the aim of preparing the manufacturing enterprises to face the NGMS challenges.

Table 2. Distributed Manufacturing System Models (DMSM)

<table>
<thead>
<tr>
<th>Model</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fractal Manufacturing Systems (FrMS)</td>
<td>An open and dynamic manufacturing system consisting of self-organized, self-similar and self-optimized agents called fractals with the capacity to react and adapt quickly to the new environment changes, and whose goal can be achieved through cooperation, coordination and negotiation with other fractals by reorganizing the fractal system configuration to a more efficient and effective one. FrMS are flexible, fault-tolerant, and self-reconfigurable manufacturing systems (Ryu &amp; Jung, 2003).</td>
</tr>
<tr>
<td>Bionic Manufacturing Systems (BMS)</td>
<td>An open, autonomous, cooperative and adaptive manufacturing system consisting of a set of agents called holons forming self-division or aggregation, in order to adapt and react to the requirements imposed by the environment (Sousa et al., 1999).</td>
</tr>
<tr>
<td>Holonic Manufacturing Systems (HMS)</td>
<td>A highly decentralized manufacturing system consisting of autonomous and cooperating agents called holons [product, resource, order and staff holons] that respect some flexible control rules for forming a holarchy to provide the flexibility and adaptability of hierarchical control for reacting to changes and disturbances agiley, and the performance stability, predictability and global optimization of hierarchical control to guarantee the manufacturing system performance (Huang et al., 2002).</td>
</tr>
<tr>
<td>FRABIHO Manufacturing System</td>
<td>A hybrid manufacturing system articulated on the basis of a set of premises, which give to it holonic, bionic and fractal attributes from autonomous and collaborative cells [agents] that are governed by a holarchy (Marcos et al., 2005).</td>
</tr>
</tbody>
</table>

Furthermore, nowadays these DMSM are typically applied individually without considering the advantages provided by the rest of them, but first efforts regarding the incorporation of the main advantages of HMS, BMS and FrMS models to create hybrid models such as FRABIHO [FRActal - Bionic - HOLonic] have been already carried out in order to propose new models that contain the most relevant properties of the previous models described (Marcos et al., 2005).

These future emerging hybrid models from different distributed manufacturing system models will cover the needs for the NGMS that have been defined by Christensen (1994):

1. disturbance handling providing better and faster recognition of and response to machine malfunctions, rush orders, unpredictable process yields, human errors, etc.;
2. human integration supporting better and more extensive use of human intelligence;
3. availability providing higher reliability and maintainability in the manufacturing systems despite system size and complexity;
4. flexibility supporting continuously changing product designs, product mixes, and small lot sizes; and
5. robustness maintaining the manufacturing system operability in the face of large and small malfunctions.

In terms of performance measurement, NGMS will require new indicators to assess their performance. Besides the traditional indicators used at operational level [e.g. % delayed orders, % defective work-pieces, # of machines disruptions, machines repair time, make-span, lead time, etc.], most of them from the SCOR model and at strategic level [e.g. related to suppliers, innovation, society, etc.], most of them based-on the Balanced Scorecard model, new performance indicators will be needed in order to cope with the ten requirements pointed out at the beginning of this paper. Examples of such new indicators comprise the level of cooperation among VE partners, of carbon emission in the manufacturing process, of global governance, of trust, of agility, among many others.

5. VE MODEL FACING THE NGMS CHALLENGES

As mentioned before, the 21st Century manufacturing enterprise should be agile/adaptable, connected, flexible, reconfigurable and responsive to face NGMS challenges.

Why the Virtual Enterprise as the NGME?

Because the VE model allows delivering/offering the right product/service at the right time and the right place by using the right strategic partners with the right competencies and resources. Therefore, VE creation process allows dealing with these issues thanks to a collaborative product development and production approach to handle this constant scenario of change.

How the VE model will face the NGMS challenges?

Challenge 1: Achieve concurrency in all operations. In order to achieve a more rapid production force to cope with shorter product development lifecycles, the VE model allows creating a collaborative manufacturing networked enterprise whose rough plan is designed to achieve as much as possible parallelism in all tasks related to the product development and production processes through information decentralization and cooperative work among the VE partners. The VE model is based-on a collaborative engineering environment enabling cooperation among engineering groups, supported by tools and methodologies that allow knowledge sharing and simultaneous engineering activities, regardless the machinery and staff location. These tools known as engineering software applications are based-on mathematical, simulation, modelling and knowledge models supporting the whole product lifecycle. Applications such as: Computer Integrated Manufacturing tools (CAx: CAD / CAE / CAM / CAPP), Knowledge-based Engineering Systems (KBES), Product Data Management...
tools (PDM), Engineering Decision Support Systems (EDSS) and Manufacturing Production & Scheduling Systems (MPSS) are examples of these engineering applications allowing the achievement of concurrent engineering. Additionally, these computational applications stand for the automatization of methodologies such as: QFD (Quality Function Deployment) enabling the transformation of customers’ requirements in product designs, FMEA (Failure Mode and Effect Analysis) detecting potential failures in a product or process before these occur, and DF (Design for eXcellence) providing specific guidelines for product development [e.g. assembling, designing, manufacturing, maintenance, recycling, etc.].

Challenge 2: Integrate human and technical resources to enhance workforce performance and customer satisfaction. The VE model nature aims to integrate human [skills, experience, knowledge, etc.] and technological [machinery, information systems] resources in order to meet or exceed the customer requirements. The “virtual” word of the ‘virtual enterprise’ term represents two possibilities: (1) to transcend organisational boundaries to build “virtual teams” with the most knowledgeable and skilled engineers regardless to their physical location, and (2) to integrate VE partners’ competencies to create knowledge and technological synergies that enhance the VE processes capabilities and resources capacities in respond to the customer demands [e.g. improve quality and delivery time for new products and/or services].

Challenge 3: "Instantaneously" transform information gathered from a vast array of diverse sources into useful knowledge for making effective decisions. Nowadays, the workforce has been decentralized and demands for rapid, accurate and high quality information and communication tools to perform their tasks. Advances in information and communication technologies have made possible that modern manufacturing systems and virtual engineering teams overcome the geographical distances and manufacture and market collaboratively products and services on regional and global basis. From the manufacturing systems side, data formats such as: EDI, STEP and HTML/XML are widely used to exchange information in order to collaborate in different manufacturing and marketing activities. Most recently Web services approach has made possible the integration of more and more engineering applications enhancing the information sharing and collaborative work among humans, machines and information systems. From the staff side, basic tools like e-mail and chats or more advanced tools such as CSCWs (Computer Supported Cooperative Work) have enable the interaction between VE partners involved in the different stages of the product lifecycle. Finally, through the use of these communication tools and other tools like ontologies and translators has been possible to communicate and share almost transparently different kinds of information and knowledge used to support decision making by humans and machines.

Challenge 4: Reduce production waste and product environmental impact to "near zero". Environment-friendly production processes and products are becoming the new product differentiators for the conscious consumers and perhaps the new source of competitive advantage for the 21st Century manufacturing enterprises. In this sense, the VE model allows analysing different value networks [VE structures] during its creation process in order to minimize the use of materials, energy and wastes during its lifecycle. Furthermore, the possibility of designing products for recycling and producing/offering ad-hoc products and services allows the VE partners just consuming the minimal resources and energy required to produce the exact volume of products to satisfy the customer demands.

Challenge 5: Reconfigure manufacturing enterprises rapidly in response to changing needs and opportunities. The VE lifecycle aims to establish and dissolve quickly different short-term and dynamic coalitions of enterprises tailored to meet the market demands and access global business opportunities. Moreover, the VE model aims to continually assess its value network capabilities for a fast response to the customer needs and integrate and disintegrate strategic partners and their core-competencies [e.g. VE evolution] as required by the business opportunity requirements. Hence, the VE model provides basis for agility in turbulent market conditions.

Challenge 6: Develop innovative manufacturing processes and products with a focus on decreasing dimensional scale. New production processes and materials are emerging in order to meet the high expectations and constantly changing demands of customers. Most of these production processes are based-on collaborative models such as the VE model with the ability to create new products and innovative processes as result of sharing and combining ideas and practices that lead in occasions to innovations.

6. VE MODEL ACHIEVEMENTS vs. NGMS CHALLENGES

During the last decade different research communities have made a substantial progress in order to face the NGMS challenges. Table 3 intends to give a synthetic overview of how the VE model has contributed in the last years to achieve the challenges identified for the Visionary Manufacturing 2020.

Table 3. VE Model Achievements vs. NGMS Challenges

<table>
<thead>
<tr>
<th>VE Model Achievements vs. NGMS Challenges</th>
<th>VE Model Achievements vs. NGMS Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Business:</strong></td>
<td>• VE Collaborative Business Model (e.g. Walters, 2004):</td>
</tr>
<tr>
<td></td>
<td>o Managing processes and competencies that facilitate a rapid and flexible response to the market changes.</td>
</tr>
<tr>
<td></td>
<td>o Building new capabilities based-upon developing unique relationships with strategic partners.</td>
</tr>
<tr>
<td></td>
<td>o Managing resources rather than owning them.</td>
</tr>
<tr>
<td></td>
<td>• VE Collaborative Strategy Model (e.g. Camarinha-Matos &amp; Abreu, 2005):</td>
</tr>
<tr>
<td></td>
<td>o Agility to chance ‘market focus’ as opportunities emerge and/or market requirements change.</td>
</tr>
<tr>
<td></td>
<td>o Collaboration to share risks, resources, responsibilities, and rewards in e.g. new product developments.</td>
</tr>
<tr>
<td></td>
<td>o Flexibility to offer a broader range of products/services.</td>
</tr>
<tr>
<td></td>
<td>o Specialization to focus on core-competencies in order to remain lean and highly efficient in competitive markets.</td>
</tr>
</tbody>
</table>

| **Knowledge:**                           | • Knowledge about the VE lifecycle management processes: |
|                                          | o VE creation processes such as collaboration opportunities identification, brokerage, VE rough planning, partners search & selection, agreements negotiation, and contracts establishment (e.g. Camarinha-Matos et al, 2005; 2007). |
|                                          | o VE operation/evolution processes such as management, coordination and supervision (e.g. Ollus et al, 2007). |
Applications:
- Software for VE creation/operation processes simulation:
  - VE configuration simulation based-on user-defined criteria (e.g. Baldi et al, 2007) and work-allocation problem (Jarimo et al, 2005; 2006) to support partners & selection process.
  - VE rough planning simulation to support tasks planning, (re-)scheduling and optimization for the production/service plan (e.g. Heifeng & Yushun, 2003).
- Software for VE operation performance monitoring:
  - VE performance simulation to support decision-making (e.g. Hodík et al, 2007) and operational management (e.g. Hodík & Štach, 2008).

Communication (ICT):
- Data interchange standards:
  - EDI, STEP, HTML/XML (e.g. Panetto & Molina, 2008).
  - Reliable communication networks:
    - Pervasive computing, p2p networks, grid computing, multi-agent systems, etc. (e.g. Rabelo & Gusmeroli, 2008).

Knowledge:
- Knowledge about VE (potential) partners profiling:
  - A catalogue based-on a common enterprise profile model (e.g. Ermilova & Afsarmanesh, 2008).
- Knowledge about VE (potential) partners competencies:
  - A catalogue based-on a competency model to describe VE partners’ competencies as processes capabilities and resources capacities in order to get involved in business opportunities (e.g. Ermilova & Afsarmanesh, 2008).

Applications:
- Enterprise Applications Integration (EAI):
  - Integration of ERP, SCM, CRM, MES, SCADA, etc.
- Workflow Management Systems (WMS):
  - Business processes modelling and execution engines.
- Computer Supported Cooperative Work (CSCW):
  - Collaboration engineering environments/platforms (e.g. Peñaranda et al, 2006).
  - Collaborative virtual labs for manufacturing, design and training/education (e.g. Dragoi & Cotet, 2004).

Communication (ICT):
- Collaborative ICT-infrastructures:
  - ICT-infrastructures that support transparent, plug-and-play and standard communications as enablers of interoperability among VE partners (e.g. Rabelo & Gusmeroli, 2008).
- Human-Machine Interfaces (HMI):
  - Intelligent solutions providing control and visualisation interfaces between human-machine (e.g. Khalid, 1999).
  - Friendly User Interfaces:
    - Text displays, Graphical panels, Touch-screens.
7. CONCLUSIONS

This paper has presented a vision for the NGMS having the VE concept as a basis for it, giving rise to the NGME.

NGME imposes many changes in the way enterprises traditionally use to work. This involves more agility, environmental care, innovation, increasing influence of customers in the products’ design, higher levels of governance, clever usage of the shop-floor and computing resources, all this deeply helped by information and communication technologies and the Internet. In this sense, it is to be highlighted the importance of flexible and robust ICT-infrastructures and Web 2.0 services and tools.

Of extremely importance are the potentials that NGME can provide in terms of value added in many perspectives. In other words, NGME is a way to achieve customer, manufacturing and design excellence while processes and resources are used with the required efficiency and flexibility. The VE concept offers the necessary theoretical foundations for the NGME, providing not only reference models or approaches, but also sustainable business models. Actually, in the same way that CIM concepts (Computer-Integrated Manufacturing) provided the very basis for B2B and increasing of inter-enterprise collaboration, the VE concepts now demand better efficiency levels from the shop-floor and resources utilization.

As long as ICT evolves, human and cultural issues must be properly tackled. In fact, the NGME demands deep changes on the way managers and workers see a business, their suppliers and customers, their competitors and the available resources.

One of the key issues in the NGME is integration. Acting in dynamic and temporary strategic alliances such as the virtual enterprise will require integrating enterprises’ systems agilely and seamlessly. This necessity will need to overcome a number of interoperability problems at several levels, from the collaborative and B2B business processes level to the shop-floor level. In this scenario, collaboration, interoperability, innovation, agility and rational usage of natural resources should be a routine, and not an exception or option of work for the NGME.

ACKNOWLEDGEMENT

The research presented in this document is a contribution for the “Rapid Product Realization for Developing Markets Using Emerging Technologies” Research Chair, ITESM, Campus Monterrey, and for the “Technological Innovation” Research Chair, ITESM, Campus Ciudad de México.

REFERENCES
