Global Manufacturing Virtual Network and its Position in Manufacturing Systems

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Abstract:
Manufacturing system becomes increasingly complex in order to gain more competitive advantages in manufacturing globalisation. This paper seeks to gain a better understanding the practical and theoretical issues in collaborative manufacturing between companies in a value creation network. It proposes a conceptualisation for the Global Manufacturing Virtual Network (GMVN). It suggests that the GMVN – a new manufacturing architecture – has many distinguishing characteristics and is a promising example of the potential manufacturing configurations which could be based on a collaborative infrastructure and supporting ICT in order to address dramatic forthcoming changes in an increasingly fragmented market environment.

I. INTRODUCTION
One of the most identifiable trends in the fundamental changes that are currently transforming manufacturing industry is that the traditional, vertically-integrated value-chain is being replaced by collaborations between specialised independent companies. While some companies are pursuing subcontracting to allow them to concentrate on their customers and core competences, others are building their businesses by focusing on these same out-sourced tasks. Original equipment manufacturers (OEMs) are evolving into total solution providers, whilst contract electronics manufacturers (CEMs) are developing into electronics manufacturing service (EMS) providers. Collaborations between these two groups are resulting in global manufacturing virtual networks (GMVNs) that profoundly challenge existing business models and traditional concepts such as “manufacturing”, “service industry”, “supply chain”, and even “firm” or “enterprise”.

There are many unresolved questions in this new manufacturing transformation. This article seeks to explore the new phenomenon of inter-firm collaborations in the electronics industry and to understand in more detail the nature of virtual manufacturing networks and the issues that they raise. It proposes a conceptual framework for the GMVN, as a new platform for configuring manufacturing resources, and a common language that is relevant to different disciplines. It suggests that the GMVN represents a new type of manufacturing system which has distinguishing capabilities based on internet communication infrastructure and new models of collaboration. The GMVN is also recognised as an organisational foundation for future e-manufacturing.

II. RESEARCH ON GMN, ISA AND VO
In an era of globalisation, the nature and intensity of competition has been changed dramatically. Three inter-related concepts have been developed by researchers to describe the way companies are responding, or should respond, to this change; they are: the global manufacturing network (GMN), the international strategic alliance (ISA) and the virtual organisation (VO).

GMN research has its roots in the disciplines of production & operations management and manufacturing engineering. It seeks to extend traditional manufacturing system boundaries from the factory towards globally dispersed and coordinated factory networks. However, this research is still mainly focused within a single multinational corporation (Flaherty, 1986, 1996; Ferdows, 1989, 1997; Shi and Gregory, 1997, 1998). It is clear that the appropriate coordination of international manufacturing networks based on the strategic business unit (SBU) or product family can help multinational corporations compete globally. However, the weakness of this research is not only that it focuses on single corporations (or even smaller SBUs), but also that it does not address inter-firm collaboration or the impact of emerging technology on manufacturing systems.
The ISA, which does address inter-firm collaboration, has been advocated as a “logical and timely response to intense and rapid changes in economic activity, technology, and globalisation” (Doz and Hamel, 1998). It is implicit in this view that in the new competitive environment no company can compete in either domestic or global markets without partners. The ISA between manufacturing companies to form an international manufacturing network has become one of the most significant vehicles for pursuing global competitive advantage (Hinterhuber and Levin, 1994).

If strategic alliances were the dominating forms in the 1990s, how will these be influenced by increasing demands for more responsiveness and agility? “Just as the strategic alliance has become the popular phrase to describe the growing inter-organisation form of the 1990s, so does it seem probable that virtual corporation will fill that role in the first decade of the new millennium” (Faulkner, 1999). There is no commonly agreed definition of a virtual organisation (VO). People with different experiences or from different disciplines have used the term to mean different things (Travica, 1997, Palmer and Speier, 1997, Franke, 2002).

Similarly a few years ago “virtual manufacturing” was used to describe the use of virtual reality and its techniques in the area of manufacturing engineering (Banerjee, 1998). Most recently, however, the meaning of “virtual manufacturing” has been extended to signify inter-firm relationships used to form a temporary supply chain (Miscioscia, 2001).

There are at least three main reasons why virtual organisations and – specifically virtual manufacturing organisations – are thought to be emerging. The first is market change (Kotler, 1999); as customers’ demands become more diverse and fragmented, companies are finding it better to offer a more integrated, solution-based service rather simply selling a product. Many companies are similarly finding it advantageous to move from being traditional manufacturers to become system integrators integrators (Ross, 1998; Fuchs, 2000; Grady, 1994; East, 1994). The second reason is partly a consequence of the first reason. As some companies have started to pursue integrated solutions for their customers and as they have begun to outsource non-core manufacturing business, other companies, providing specialised manufacturing services as their own core competence, have been able to emerge to fill the gap between the system integrators and the raw material and/or functional module providers (Miscioscia, 2001; Serant, 2000; Ojo, 2001). The third reasons lies in the substantial opportunities arising from new information and communication technologies (ICT). These opportunities not only help smaller newcomers to access markets which were formerly the preserve of global corporations but also provide benefits for the global corporations themselves by allowing them to restructure their operations. The transparency of the value chain, which ICT can provide, allows companies to reposition themselves in the chain and dynamically collaborate with companies to optimise their business position.

Table 1 reviews key characteristics of research on GMNs, ISAs, and VOs, and highlights their differences. There are many overlaps between the concepts the ISA and the VO e.g. a contractual collaboration and a long-term virtual business network can describe the same relationship as in the case of some OEMs and their CMS providers. If ISAs represent one end of the spectrum of collaboration, VOs represent the other where collaboration is at arm’s-length.

**III. The Emergence of GMVNs**

Manufacturing outsourcing is an emerging trend, especially in the electronics industry. It is driven by: strategic focus on core competencies; pursuit of higher value positioning within the supply chain, pressure to improve return on assets; and desire to provide total solutions to targeted customers. System integrators, OEMs and major contractors are all becoming players on the new battle ground for manufacturing and are attracting wide interest. This is in turn stimulating developments in the key field of supply chain management (SCM).

The research community has largely neglected a very important phenomenon, which is gradually becoming increasingly important for all manufacturing industry and which has been caused by the re-configuration brought about by system integrators. This phenomenon is the emergence of professional manufacturing service providers- especially the contract electronics manufactures (CEMs) or electronic manufacturing service (EMS) providers in electronics and telecommunications sectors.
Together the emerging roles of OEMs and CEMs are re-structuring the electronics manufacturing industry. Most of the traditional vertically-integrated companies such as IBM, Motorola, Marconi, Philips, Sony, and Hitachi are being re-configured as they focus more on total customer solutions, R&D, ICT and marketing and as they increasingly outsource their manufacturing. Outsourcing of manufacturing by OEMs is fostering the growth of a new group of contract electronics manufacturers (CEMs) and allowing them to extend the scope of manufacturing service they provide to OEMs to the extent that they are often referred to as electronic manufacturing service (EMS) providers rather than simply CEMs. These CEMs/EMS providers include some key global players such as Solectron, Flextronics, Celestica, and SCI Systems, but there are more than three thousand local CEMs as well. CEMs or EMS providers typically start from a relatively narrow slice of manufacturing activity, such as in printed-circuit board (PCB) assembly (“board stuffing”) or manufacturing engineering development, but then move on to become involved in a wider range of activities throughout the manufacturing value chain. Miscioscia (2001) reports “EMS providers are working to offer a complete cradle-to-grave manufacturing solution”, whilst Labowitz and White (2001) say CEMs can promise to an OEM “you bring us an idea, we’ll manufacturing the entire product and ship it directly to your customer”. They may even develop beyond that to encompass after-sales service.

Traditional relationships between vertically-integrated manufacturers, component suppliers and distributors have been largely broken and new networks between OEMs, CEMs, component suppliers and distributors are emerging. These networks are, however, very complex and subject to dynamic change.

OEMs and CEMs are in effect creating virtual enterprises, typically led by OEMs. The OEMs gain both flexibility and concentration of key resources. Competition especially from new-comers like Cisco and Dell, which have neither manufacturing experience nor the associated resource “burden” is forcing a sharper strategic focus and demanding the creation of higher value and responsiveness throughout the supply chain. As a result OEMs cannot afford to keep comprehensive manufacturing resources waiting for potential customer orders. The risk in holding manufacturing assets is lower for CEM/EMS providers than OEMs, since they can offer their capacity to a wide range of OEMs.

A new type of manufacturing architecture, which we have called a Global Manufacturing Virtual Network (GMVN), is emerging from this scenario. The GMVN extends the concept of the GMN beyond the firm boundary with the term virtual carrying all its connotations of latency, impermanence and dependence on ICT. In a GMVN a lead company does need to maintain internal manufacturing resources to satisfy unpredictable market demand. Rather it depends upon a co-operative resource pool – a virtual network – and then constructs an actual supply network to deliver a customer required solution once it identifies a customer or receives a contract. The GMVN is thus based not on resource ownership but on resource leverage and collaboration.

In the electronics industry, OEMs and CEMs/EMS are already coordinating their specialised resources in this way. The OEMs and CEMs/EMSs each play an equally important role in GMVN, although CEMs are easily overlooked since OEMs are more visible through their brands and are closer to the final consumers.

Although it may not be part of their strategic plan, CEMs/EMS have the potential to develop their own brand names and so transform into OEMs. Conceptually each player in a GMVN has a similar opportunity to identify business opportunities and integrate the virtual network to deliver a solution to a particular customer. Because each one has its own core competence in the network, each could function as part of the many potential chains that could be organised from the collaborative resource pool. The virtual chain, therefore, can be organised to provide responsiveness, high flexibility and efficiency. This type of manufacturing system fundamentally changes the concept of system flexibility; it achieves real market agility and ability to deploy capacity and technology around the globe by externalising flexibility (beyond the firm), by reducing complexity (within the firm), and by accessing the most appropriate resources for a given opportunity.

IV. DEVELOPMENT OF CONCEPTUAL FRAMEWORK

A research field cannot be developed until there is a framework and an accepted core of theoretical ideas (Teece, et al, 1992). When a multinational corporation integrates its globally dispersed factories into a
globally coordinated factory network, it usually not only links its own manufacturing resources together but also integrates its supply networks worldwide. It is obvious that inter-firm global supply networks are more challenging to manufacturing managers because of their recent emergence and their complexity. However, a company which can manage a GMVN effectively will be in a much stronger competitive position. Moving from a GMN to a GMVN, will entail many changes, but the fundamental change is that the manufacturing system now crosses the firm’s boundary and into a complex inter-firm relationship. The change in paradigm from GMN to GMVN can provide manufacturing managers with a broader range of options to organise manufacturing resources more effectively and efficiently. A generic three-dimensional strategic environment for manufacturing system design is developed in Figure 1 (A).

Four key decisions areas must be addressed in order to design and operate a manufacturing system:

- **Manufacturing Internationalisation** – The manufacturing system is no longer a single site factory. Decisions must be made concerning geographic expansion or repositioning. In the process a company must consider its international expansion plans in the context of its history and must explicitly address issues of cross-cultural integration.

- **Value and Supply Chains** – The Manufacturing system and its tasks must be defined along the supply/demand chain or value-creation network by configuration (defining the manufacturing activities required in the value chain), position (that part of the value chain to be directly controlled by a company) and optimisation (selection of partners, grouping and disposition of activities for internal and external manufacturing resources, systems etc) to achieve higher value and competitive advantage.

- **Strategic Alliances** – A spectrum of potential collaboration modes, including intra-firm coordination and inter-firm co-operation, has to be evaluated. In inter-firm collaborations, there is a wide span of choices from strategic alliances (for longer term commitment) through virtual communities to arm’s-length trading relationships (for more flexibility).

- **Synthesis Process** – The above three dimensions cannot be considered independently in the current global competitive environment. It is essential to synthesise them into an integrated manufacturing system supported by a systematic strategy process and the most appropriate technology (including the cyber platform).

Thus according to our preliminary understanding of industrial requirements and manufacturing research, a GMVN can be considered as a synthesis of views along three basic dimensions in Figure 1 (B):

- **Global disposition and the evolution of manufacturing internationalisation** are represented on the manufacturing internationalisation dimension, “G”;

- **Value-creation oriented manufacturing activities and positioning** are represented on the value and supply chains dimension, “M”;

- **Collaborations with other companies to formulate a strategic alliance or temporary virtual supply-chain** are represented by the strategic alliance dimension, “V”

These three dimensions must be integrated by a synthesis process “N”, which must include network strategy process, communication platform and operational mechanisms. Figure 1 (B) illustrates that the GMVN represents a relatively small part of this three dimensional space; other manufacturing systems are appropriate in other positions.

In traditional manufacturing system design, especially at the factory decision level, the internationalisation, (G), and collaboration, (V), dimensions are rarely considered. Similarly the value/supply chain position (M axis) is simply represented by the “span of manufacturing process” (Hays and Wheelwright, 1984). Current research on manufacturing systems and operations management is still limited to two dimensional constructs – either on the GxV “plane” dealing with internationalisation and alliances or the GxM “plane” dealing with supply chain and internationalisation (Harland, et al, 1999). The synthesis process, N, in Figure 1 (B) has been largely neglected and this inhibits the development of comprehensive understanding of GMVN.

As they involve manufacturing systems, GMVN must be differentiated from generic virtual organisations. The latter could involve a pure broker subcontracting anything and everything. But manufacturing companies, especially global players, have to own some essential process-based
resources, such as technology, facilities, equipment, capacity, and even organisation. Future development is largely dependent upon resources and from this viewpoint the GMVN’s role is situated between ISAs and VOs. Therefore, the “virtual” character of GMVN’s must be understood in this unique context.

Figure 1 also provides an analytical tool to capture some key features of industrial transformations. Taking an evolutionary perspective of the electronics industry, it has been observed that, during its globalisation from the 1980s to the mid-1990s, many multinational companies extended their manufacturing systems worldwide but retained hierarchical control and vertical integration. However, after the mid-1990s, OEMs reduced the span of manufacturing process they controlled directly and used outsourcing and collaboration to develop a virtual manufacturing system with which to exploit global opportunities. This eventually helped both OEMs and EMS providers achieve more potential for growth in global new-technology markets. The three-dimension model (Figure 1) helps manufacturing managers to design the architectures and mechanisms of these new manufacturing networks, by making explicit those elements which must be integrated.

If ISAs and VOs are placed in a spectrum, as in Figure 2-A, the GMVN covers quite a wide span of this spectrum. The GMVN can combine the appropriate balance of the virtual organisation’s flexibility to capture business opportunities and the ISA’s ability to develop capabilities and relationships. Its fundamental characteristic is not a hierarchical organisation as in a global manufacturing network (GMN), i.e. an internal manufacturing system, which is vertically-integrated. It is instead an inter-firm network or a relationship. This however may be regarded be a static view of the GMVN’s architecture.

The dynamic view of GMVN as a network of collaboration between different companies, is much more interesting (Figure 2-B). It may be regarded as a pendulum moving between VOs and ISAs changing the relationships between as OEMs and CEMs. In other words the nature of relationships in a GMVN is not fixed; it changes in response to market requirements. A small specialist manufacturing service provider might spot an opportunity and “activate” a value chain from GMVN members. Over time experience with the project will enable players to develop their core competencies. If the project is successful and enduring it could become core business for some of these players. At this stage, the lead company’s concern is how best to manage this activity over the longer term; it may, for example set up more binding ties with its partners or alternatively it might internalise some of the activities, which were initially outsourced to GMVN partners. As each partners core competences develop, it is more able to identify/access new market opportunities, which may in turn be exploited by starting another GMVN. This dynamic model may help managers adopt a more evolutionary vision and avoid competence traps.

V. FURTHER RESEARCH ON GMVN

Although GMVNs have been observed in several industry sectors such as electronics, automotive and even aerospace, we still have a lot to learn in order to understand these virtual networks fully and to design and operate them successfully. Such understanding will only come from a close collaboration between academics and practicing managers.

From a research perspective, further detailed studies on GMVN should include three main strands:

- The GMVN’s environmental and industrial sectors: This will help clarify the main driving forces for the emergence of GMVN and identify for which other sectors GMVN would be an appropriate manufacturing system.
- The characteristics of the GMVN system: This will enable us to understand GMVN’s attributes in terms of its main building blocks, its architecture, its dynamics and its management processes. It will also help formulate a strategy and design process for developing an effective GMVN.
- The key new technology and infrastructures for building and operating GMVN: This includes the design and operational techniques for systems which will facilitate the establishment of a GMVN community together with the necessary ICT platforms and infrastructures.

Figure 3 demonstrates these three strands of the research work and places them into three layers and six major research modules.
Manufacturing industry has been changed dramatically as brand-owning businesses have changed their business model towards providing individual client-based solutions rather than simply manufacturing and selling products. However, studies of international strategic alliances and virtual organisations, have paid little attention to the manufacturing networks that are emerging from this transformation, nor to the implications for the structure and operation of supporting communication systems. Understanding the nature of these new global manufacturing systems and the emerging electronic commercial and communication environment is fundamental to our appreciation of the implications of e-business for manufacturing worldwide.

In this paper, a specific class of manufacturing system – the GMVN or global manufacturing virtual network – has been identified and its characteristics and potential have been outlined. The potential of GMVNs to enhance a company’s ability to exploit competences has been introduced. The concept of the GMVN is especially important for manufacturing companies, when their business is shifting from product manufacturing to providing solutions; the electronics and telecommunication may lead in this development, but it is appropriate for engineering, automotive and aerospace sectors as well. Future work is proposed to understand GMVNs better at three levels (Figure 3) and to develop practical decision tools and strategy processes for GMVN formation and operation.

**Table 1. Review of the Characteristics of Three Organisation Types**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>GMNs</th>
<th>ISAs</th>
<th>VOs</th>
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<tbody>
<tr>
<td>Missions and Purposes</td>
<td>- opportunity and capability</td>
<td>- capability orientation</td>
<td>- business opportunity orientation</td>
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<td></td>
<td>- coordination + learning</td>
<td>- sustainability push</td>
<td>- responsiveness/agility pull</td>
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<td></td>
<td>- global expansion driven</td>
<td>- world and future driven</td>
<td>- niche/emerging market driven</td>
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<tr>
<td></td>
<td>- geographic dispersion</td>
<td>- co-option (collaborating)</td>
<td>- scanning and identification</td>
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<tr>
<td></td>
<td>- value-adding chain position</td>
<td>- co-specialisation (Core)</td>
<td>- brokering and integration</td>
</tr>
<tr>
<td></td>
<td>- operations coordination</td>
<td>- learning &amp; internalisation</td>
<td>- networking and positioning</td>
</tr>
<tr>
<td>Structures (Architectures)</td>
<td>- SBU and Int’l Mfg. strategy</td>
<td>- seriously strategic planning</td>
<td>- strategic fitness planning</td>
</tr>
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<td></td>
<td>- Product family and globally dispersed factory network</td>
<td>- stable and close relationship</td>
<td>- order or project based temporary relationship</td>
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<td></td>
<td>- owned by one company</td>
<td>- contractual collaboration</td>
<td>- dynamic re-configuration</td>
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<tr>
<td></td>
<td>- each factory is a node</td>
<td>- consortiums</td>
<td>- no equity collaboration</td>
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<tr>
<td></td>
<td>- location and dispersion</td>
<td>- joint ventures</td>
<td>- few stable partners</td>
</tr>
<tr>
<td></td>
<td>- integration and coordination</td>
<td>- equity collaboration</td>
<td>- ICT platform and teamwork</td>
</tr>
<tr>
<td>Operations (Dynamics)</td>
<td>- Dynamic Response Mechanism: opportunity identification and swift mobility</td>
<td>- longer term co-operations</td>
<td>- temporary co-operations</td>
</tr>
<tr>
<td></td>
<td>- Product Life Cycle (PLC) and Knowledge sharing and transfer</td>
<td>- longer term commitment</td>
<td>- shorter term business deal</td>
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<td></td>
<td>- Operational Mechanisms and ICT network daily co-ordination</td>
<td>- sharing strategic resources</td>
<td>- strategic competence fitness</td>
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<td></td>
<td>- Dynamic Capability Adaptation and Network Evolution: learning</td>
<td>- seeking synergy from co-op</td>
<td>- seeking function integration</td>
</tr>
<tr>
<td>Other Characteristics</td>
<td>Like self training, personal cultivation and individual capability development</td>
<td>- &quot;running-in&quot; and cultivation</td>
<td>- sharpen core competences</td>
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<tr>
<td></td>
<td></td>
<td>- adaptation and evolution</td>
<td>- fast engagement &amp; work</td>
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<td>- infl cultural synthesis</td>
<td>- responsiveness and flexible</td>
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<td>- cyber and global sourcing</td>
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**Figure 1. Manufacturing System Contexts and GMVN Position**
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