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VIRTUAL TEAMING IN THE AGILE SUPPLY CHAIN

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This paper discusses the information flows in the supply chain, and identifies knowledge and expertise as "richer" more capable entities for its management than data or information. It briefly explores how the structure of the automotive supply chain is changing due to the pressures of increasing complexity and urgency. Then it highlights the inevitability of instability in the supply chain, through a discussion on turbulence. Agility is identified as a response for coping with this uncertainty. The tool identified for introducing agility in the supply chain is Virtual Teaming. It achieves this by forming collaborative supply chain partnerships, unconstrained by geography that can quickly apply knowledge and expertise as corrective and preventive mechanisms. A survey of the suppliers to a major automotive manufacturer has highlighted the need for this form of working.

A major function of the information flows in the supply chain is in providing control information. This function is threatened because the structure of the supply chain is changing due to the pressures of increasing complexity and urgency. Tiered supply chains can lead to an increasing possibility of disturbances in the material flow in the supply change, often initiated by frequent and unexpected changes in demand. These disturbances have been termed "turbulence", which can be classified in five categories, design, volume, mix, schedule and process [1]. A number of approaches such as concurrent engineering and late configuration [2] have been proposed to reduce turbulence. However these do not reduce the occurrence of some of the more advanced forms of dynamic behaviour [3]. It is proposed that what is needed is a context in which human knowledge and expertise can be brought to bear. The article examines the agility strategy for competitiveness in changing market conditions and particularly Goldman *et al.*'s [4] proposals for agile supply chains that exhibit high degrees of reward, enrichment and linkage amongst members: ideas that are congruent with needing to inject human knowledge and expertise. One of the barriers to direct human interaction in the supply chain is, however, the geographical separation of its members. Virtual teaming is proposed as the model and practice that can overcome this geographical barrier. A virtual team, composed of members of the supply chain and using advanced communications technology, can improve the flow of information and quickly dampen turbulence through the ability of members to behave as a team, sharing knowledge and expertise, regardless of location. However, building effective virtual teams requires an organisation to tackle several technology, process and people related factors [5], while Clegg *et al.* [6] warn that technology factors typically receive attention at the expense of non-technology factors, thus impeding the success of many IT-based processes. The article presents overview data from two research programs on virtual teaming in the automotive supply chain. The data shows recognition of the promise of virtual teaming, in terms of "better, faster, cheaper" benefits, but also revealed significant barriers to successful implementation in the non-technology, process and teaming areas.

Information and Expertise

The convergence of fundamental manufacturing trends, *increasing complexity* and *increasing urgency* is forecast to continue. The prime resources utilised to tackle this convergence are data and information. We can and do apply database systems, management information systems and increasingly, knowledge-based systems to help manufacturing cope. It has long been recognised that effective information flow is crucial for an efficient supply chain. The supply chain needs to transmit Value & Demand information up the chain and Cost & Supply information down the chain with sufficient detail and timeliness to avoid instability (see Figure 1). Instability can occur because of the variable time delays and multiple information paths that can exist. The success of a particular supply chain depends on its ability to intercept and respond to these two information flows, and the clarity and speed of the overall information flows control the health of the whole supply chain.

Insert Figure 1: Information Flow in the Value System

Adopting a control systems analogy, this information, if timely and sufficient, provides the feedforward and feedback necessary to maintain stability in the system. The model illustrated in Figure 1 is widely accepted, but what could provide better control than data or information? Figure 2 illustrates the relationship between data, information, knowledge and expertise. Data placed in context creates information, information analysed over a period of time generates knowledge and knowledge applied skilfully is expertise!

Insert Figure 2: The relationship between data and expertise

The potential for instability is inherent in the supply chain because of the variable delays and multiple feedback and feedforward loops that can occur. Since knowledge and expertise are richer, more robust entities than data or information, they may be able to provide better feedforward and feedback control than information. Expertise however is difficult to capture in a system, and is usually in short supply. This expertise needs to come from all the components of the supply chain.

Instability in the supply chain

Supply management must be able to cope with the effects of demand instability but, for manufacturing companies, good supplier performance by itself does not mean that the whole supply chain is being properly managed. Even when problems relating to material availability are completely overcome, manufacturing may become a source of disturbance in the supply chain [7]. The concept of turbulence proposed by Bhattacharya *et al* [8] is useful for identifying the usual contributors to the instability that can arise in a supply chain. Comparing production flow with fluid flow, and manufacturing constraints with a pipe, Bhattacharya *et al* show that in a rigid pipeline, variability and uncertainty of inputs - which in this case represent the demand - may cause "swirls, blockages and pileups". Here, the fluid flow struggles to adapt to the form of the pipe (Figure 2). Those disturbances in the production flow caused by frequent and unexpected changes in demand are called "turbulence". Bhattacharya *et al.* classify turbulence in five categories; design, volume, mix, schedule and process. Three of them will be used in the present analysis; design, volume and mix.

Design turbulence relates to disturbances caused in the production flow by changes in product design. This kind of turbulence is very likely to occur when manufactured products have short life cycles or go through numerous design changes within their life cycle. This is precisely the case in mass customised markets such as those the automotive industry is tending to [9].

Volume turbulence is a consequence of changes in total production volumes and usually occurs in the form of capacity constraints or materials shortage. Manufacturing has to work with very short planning horizons and consequently may be prone to volume turbulence. Because products in mass customised markets have short life cycles it is difficult to buffer variations in demand (even when they are expected) by building stocks. This is a particular problem in tiered supply chains as seen in major sectors like automotive and aerospace. An Original Equipment Manufacturer (OEM) may have problems in the supply chain due to an aggregation/reduction of demand lower down in the supply chain. For example a fourth or fifth tier supplier will see overall demand from the OEM coming from different second or third tier suppliers. They may well see their demand change massively as a result of changes emanating from the OEM, even though the OEM is not visible to them as a customer. Through the structuring of the supplier chain demand can be made to appear piecemeal to core component suppliers at the bottom of the supply chain, e.g. the suppliers of integrated circuits and electronic components. They see relatively small orders from a number of customers, who may be supplying the OEM. In the event of shortages in supply, a relatively common event in the world electronics industry, they may well allocate supplies to large customers, which the OEM will not appear to be, because its is hidden by the tiers of the supply chain.

Insert Figure 3: The Turbulence Pipeline

Mix turbulence relates to the disturbances caused not by a change in the total production volume (which in this case can even remain quite steady) but by a change in the distribution of the volumes of the different products (or product models) manufactured in the same facility. Changes in the mix of products may lead to changes in loading among the different machining cells. If a machining cell is subject to a sudden increase in its inputs, and is not able to respond with a corresponding increase in its processing rates, it may become a bottleneck causing mix turbulence.

The difficulty of managing an complex an entity as the supply chain has pushed organisations to adopt initiatives such as concurrent engineering and late configuration, which attempt to remove some of the causes of turbulence, and thus reduce costs and time-to-solution. Concurrent engineering techniques offer an organisational methodology to reduce design turbulence [10]. The multi-disciplinary design team proposed by this approach brings a kind of holistic awareness into the design phase. Through involving people from different departments such as marketing, finance, purchasing, manufacturing and outbound logistics in the design phase, the need for design rework is reduced and the impact of introducing new products in the production process is attenuated. Design for manufacturing and design for assembly, which are branches of concurrent engineering, may also help to attenuate mix turbulence by avoiding parts proliferation and reducing manufacturing and assembling complexity. "Intelligent" design techniques aim to create product variation that looks very different from the customer's point of view while being quite similar from the manufacturer's point of view.

At production level, late configuration may be used to reduce mix turbulence. In this case most of the parts and subassemblies are manufactured and assembled on a made-to-stock basis. However, the final customer-specified product is manufactured on a make-to-order basis. There will be a waiting time between the order point and the product delivery, during which the manufacturer will be processing the "off-the-shelf" characteristics of the product. This approach is used in markets where the demand for each particular model of one product is so irregular that it is impossible to make detailed forecasts about it. Kitchens, cars and personal computers are examples of markets where this approach has been followed.

A further source of uncertainty that in recent years has received increasing recognition is the generation of deterministic chaos within the industrial environment. Deterministic chaos can be defined as "Random behavior governed entirely by laws" [11]. Control algorithms and heuristics used within the supply chain can generate random demands on other parts of the system. Stacey [12] has discussed this type of behaviour with reference to the strategic management process. Mosekilde *et al*. [13] have demonstrated that human decision-making behaviour can generate deterministic chaos in simple industrial management decisions. Wilding [14] has demonstrated that inventory control algorithms can generate chaos within simple supply chains. It should be emphasised that within chaotic systems, demand data, for example, can be forecast reasonably accurately in the short term; this further emphasises the need for effective short-term decision making, rather than long range planning [15].

Concurrent Engineering and Late Configuration aim to prevent rather than cope with manufacturing turbulence. These techniques are effective to some degree in the elimination of turbulence. However, design solutions have their limits, and by dividing the process into a standard and a configuration stage, manufacturing turbulence is pushed forward rather than eliminated. As manufacturing companies strive to offer a wider range of product configurations in order to please each customer individually they will be constantly threatened by design, volume or mix turbulence. The most usual alternative to cope with manufacturing turbulence is by building stocks. Nevertheless, besides being a costly option it can also be extremely risky when applied to mass customised markets, where most of the products have short life cycles.

Supply Chain Networks

Manufacturing supply chains in the UK are usually headed by an Original Equipment Manufacturer (OEM) [16], who in the past has dominated the supply chain by utilising the threat posed by multiple sourcing. This power culture, though not the practice, is still prevalent in many purchasing departments. Recent business practice has been for the OEM to divest themselves of parts of the chain that are not "value adding" or core activities, and to replace this with partnership relationships with supply networks. Nishiguchi [17] classifies networks in three ways:

- Vertical Integration – where a firm owns most of its supply network. In the automotive industry this may be applied to General Motors.
- Strategic Dualism – where a firm retains key areas of production but out-sources components. Chrysler may be fit into this category.
- Clustered Control – where an assembler deals with a first tier of suppliers who, in turn, manage the second tier and so on. BMW may be seen as an example of this category.

A fourth type of network has emerged which maximises the benefits of close regional contacts and strong ties between resources. Many writers, for example [18], have pointed out the benefits of having close regional networks to spur innovation and develop new products. An example is the way the UK motor racing industry leads the world, providing a design and development base for all the leading Formula 1 teams and many American Indycar teams. It is based on a network of chassis builders and component suppliers mainly located in Southeast England. These regional networks have three key advantages:

- Network organisations co-located in one region have the potential for more face-to-face interaction, therefore more information is communicated among members.

- There is a degree of trust between network participants, which is crucial to improving time and quality performance. These networks usually evolve over time.
- They provide an experience base for other organisations to draw upon, which they are attracted by.

The Japanese automotive industry practice of encouraging suppliers to set up nearby (or actually on site!) is designed to take advantage of these factors. However for smaller OEMs such as Rover, many first tier suppliers such as TRW may actually be much larger, and getting them to co-locate may be very difficult. They may have very valid concerns about viable order quantity and economies of scale. A recent and increasing trend has been for the supplier to actually provide the labour and systems for installing the supplied part in the OEMs manufacturing process, or to second “guest” engineers to the OEM.

Agility and the agile supply chain

Agility is the basis for achieving competitive advantage in changing market conditions. Its origins can be traced to an industry-led, federally-funded programme, the Agile Manufacturing Enterprise Forum (operating as the Agility Forum) at Lehigh University, Pennsylvania. In 1995, Steven Goldman and his Agility Forum colleagues drew international attention to agility through their book *Agile Competitors and Virtual Organisations* [19]. This book focused on "agile product development" in market conditions of increased complexity and increased urgency, and particularly the capabilities required by manufacturers to:

- Enrich the customer (through a greater variety of value-adding, short-lifetime, bespoke or customised goods and services)
- Master change (created by changing market conditions, including the actions of competitors, and internally-created by the need to develop a variety of customer-enriching products)
- Leverage resources (make every part of the organisation contribute to its competitive advantage)
- Co-operate to compete (access the complementary resources of the supply chain and alliance partners).

The authors further propose regarding the supply chain as a customer-supplier relationship:

- A customer is no longer the recipient in a one-time transaction but a subscriber to the solutions of a supplier.
- A supplier no longer hands over goods in response to an order but is a long-term supporter or partner of the customer.
- A sale is no longer a one-time event, but an on-going transfer of products and services, and of payment, between the supplier and customer.

This view is consistent with that of regarding the supply chain as being more than the exchange of data and information, and requiring higher levels of human knowledge and expertise to colour its operations. Viewing agile production as involving (but by no means limited to) the management of supply chain relationships, Goldman *et al.* draw attention to the need for that relationship to be balanced over three dimensions: the enrichment of the customer by the supplier; the reward of the supplier by the customer; and the linkage of business processes between the two. At the least integrating level of each dimension, a (non-agile) supply chain relationship would involve enrichment through the delivery of simple standardised parts; reward through payment of unit price; and linkage through mail, fax and phone. At the most integrated level, an (agile) supply chain relationship would involve enrichment by the supplier providing a solution that is easily integrated by the customer, and which adds value to the customer's customer; reward of the supplier through shared risk and revenue; and business linkage based on highly-integrated business processes using today's telecommunications tools. Thus, according to Goldman *et al.*, a fully-agile supply chain is as much to do with business relationships and technology as it is to do with production process.

Goldman *et al.* set out a strategic blueprint for an agile manufacturing process, while also demonstrating that such a process could only survive in an enterprise that was itself agile. More recently, Metes *et al.* [20] addressed agility at the whole-enterprise level. Their book *Agile Networking* identified how business processes built upon Internet and intranet networking provided capabilities required by the truly agile enterprise. Among a number of other networking-based processes that enable agility, these authors refer specifically to change proficiency and agile networked alliances.

In discussing change proficiency, Metes *et al.* outline an agile capability most fully developed by Dove (see [21]). Change proficiency is an analysis of a producer's proficiency in eight "Change Proficiency Domains": creation, capacity, capability, reconfiguration, migration, performance, improvement and recovery. Through this analysis, fully defined by Dove, it is possible for any producer, or, in this instance, a supply chain or member within it, to optimise its ability to respond to change

Agile networked alliances are network-enabled relationships between organisations that can be formed and dissolved rapidly, but while in operation enable an affiliation between parties that is focused on enriching customers, mastering change, leveraging (all parties') resources, and thus co-operating to compete for mutual commercial benefit. While not identified as such by Metes *at al.*, an agile networked alliance within a supply chain could be viewed as an agile supply chain. Rather than vertical, dualistic, clustered, or regional, as described earlier, an agile supply chain would be based on relationships exhibiting a high-level balance of enrichment, reward and linkage as defined by Goldman *et al*. and incorporating knowledge and expertise as argued here. It would display high levels of change proficiency as fully explored by Dove [22]. Members would also display Metes *et al.*'s criteria for membership of an agile networked alliance: the proficiency, culture and the technology for open, inter-company networking; a mature appreciation of the intellectual assets that can and cannot be disclosed; and the ability to operate rapid decision-making and approval processes - including those needed to establish and dissolve the network.

At a strategic level, an agile supply chain can be described. However, to describe the strategic model does not help in creating a mechanism that implements it. We believe that virtual teaming, a new working arrangement that incorporates technology, process, and human factors, offers the means of co-ordinating and controlling an agile supply chain. Our argument, developed below, is that virtual teaming offers a new model and direction for minimising supply chain turbulence. Its principal virtue is that it permits human collaboration regardless of location. This means that the delay and disturbance to communication that is caused by supply chain members being geographically separated can be overcome. Indeed, a successful agile supply chain based on virtual teaming principles would operate more like a continuous collaboration between members, rather than episodic meetings. Such collaboration supplies the strategic oversight and flexibility - based on knowledge and expertise as shown in Figure 2 - necessary to be effective in dealing with the complexity resulting from supply chain turbulence. That collaboration also leads to greater responsiveness in solving supply chain problems. It provides the means to operate a regional network, as described by Porter, regardless of the geographical distribution of its members.

Virtual Teaming

Recent developments in communication and information technology, coupled with an increased need to co-ordinate organisational activities across geographically dispersed locations, have led to the development and use of virtual teams. The term virtual team, as used in this paper, is defined by Henry & Hartzler [23] as follows:

> "*groups of people who work closely together even though they are geographically separated and may reside in different time zones in various parts of the world.*" Also as "*cross-functional workgroups brought together to tackle a project for a finite period of time through a combination of technologies*." and "*members may occasionally meet face-to-face, but this is clearly the exception due to the physical separation of their "home" location.*"

The following characteristics clarify the definition of virtual teams

- Team members are goal oriented.
- Members are dispersed geographically (nationally or internationally)
- The team works apart more than in the same location.
- The team is a collection of individuals who work together to attain a goal by using computer-supported networking.
- Team members are involved in a co-ordinated undertaking of interrelated activities.
- Members are mutually accountable for team results.
- Team members solve problems and make decisions jointly.
- They are of finite duration, with a beginning and ends (few teams are permanent).

Virtual teaming eliminates the necessity for physical co-location thus enabling manufacturers to rapidly and continuously collaborate with suppliers world-wide irrespective of geographical constraints. To achieve high levels of performance, virtual teaming requires the co-ordinated development of people, process and technology, as identified by Gundry [24] in Figure 4.

We believe that a successful virtual team can be the agent that implements a strategy for reducing turbulence in the supply chain. That is, it acts as the mechanism that does the work within an agile supply chain. In that context, we need to presume that such a team is composed of decision-making members of the companies party to a supply chain, who are not necessarily co-located, and have access to virtual teaming technologies (see below). The team has received training and education to help it overcome the virtual teaming challenges described in figure 4, and its members work together apart without the need for face to face meetings

Insert Figure 4: Factors for Successful Virtual Team Implementation (Source: after Gundry, 1998[24])

The potential of such a virtual team is considerable. Ideally, and in principle, a virtual team will help reduce supply chain turbulence better than a contractual arrangement or other slow-time, episodic, transactional, often confrontational approach because and if:

- Members are committed to the agile strategy of mastering change, and the team is built on the certainty of change. The team sees mastering turbulence as a collective team problem. Change, variances or other exception conditions are not seen as a 'fault' of any one member.
- Team members discover new, own-team, solutions to change issues that would never have been developed in any one of the subscribing companies alone.
- Rich and sustaining relationships (trust) between team members energise and give priority to devoting attention to the team's work and communication, in an attention economy when it's only a part of the work of each member. Trust has to substitute for hierarchical and bureaucratic controls, but virtual teams with high trust offer this valuable social asset back to their sponsoring organisations for use in future opportunities to co-operate.
- Virtual team facilitation and team-building techniques allow these relationships to be built and sustained even though the team meets face to face only infrequently. It allows them to be sustained even though they are subject to erosion from local pressures in the subscribing companies.
- Team members are however embedded in and close to the operations of their own companies, where the 'source' of turbulence emerges, enabling rapid reporting and notice of change and exceptions, and assessment of impacts.
- Fast-track, synchronous group messaging systems such as audio and video conferencing, and possibly shared applications, allow the team to "meet" at very short notice to handle emerging exceptions and problems. Delay is deadly to mastering supply chain turbulence.
- In parallel, sustained, group asychnronous messaging systems such as computer conferencing form the backbone of the team's continuous and, importantly, all-informed communication - sharing issues, announcing upcoming problems, changes, etc., allowing unforeseen impacts to be recognised, and maintaining context and relationships.

Virtual teams, as identified above, require modern networking technologies in order to achieve high levels of mutual affinity and fast decision-making amongst their members. Figure 5 (adapted from [25]) identifies some of the tools commonly utilised for co-ordinating collaborative work.

Insert Figure 5: Collaboration Technologies
Adapted from Szewczak and Khosrowpour, [25, p193]

Virtual teaming is, however, far more than the mere application of technology. It requires the simultaneous and synergistic attention to process and teaming factors, as shown in Figure 4. However, it is generally common for organisations to concentrate on the technology aspect to the exclusion of 'softer' factors. Clegg *et al.* [26] conduced extensive research that concluded that organisations are typically not successful in attending to the non-technical aspects of IT projects. In particular, the majority of companies fail to consider how work should be organised and jobs designed to make the new technologies effective.

Having identified above what in principle an ideal virtual team could contribute to an agile supply chain, we now present evidence from two sources. The first is of virtual teamworking by automotive suppliers in the UK and the second from a survey of automotive suppliers regarding current working practices and the perceived benefits and drawbacks of virtual teaming in the supply chain.

The TEAM project

The Team-based European Automotive Manufacture [27] multimedia and communications project (ACTS AC070) demonstrated the benefits that can be achieved by using appropriate information systems to support collaborative working between geographically distributed project teams. The findings are based on an analysis of two Virtual Teams comprising design, logistics and quality engineers plus business managers from key suppliers over many meetings tackling problems that would normally require face to face meetings, or problems which normally one of the parties would attempt to resolve themselves. They used a Computer-Supported Collaborative Working system (CSCW) that provided facilities for audio and video links, a shared whiteboard, sharing of documents, real time sharing of CAD applications and a Web-based product library with controlled access. Interviews with key participants and with members of the organisational hierarchy were conducted so that the critical success factors related to the introduction of such technology could be derived. The benefits of effective Virtual Teams were found to include:

- *Reduction in non-value-adding activities such as travel and delays imposed by mail;*
- *The ability to react quickly and flexibly to problems;*
- *A more accurate understanding of the design issues due to the interactive nature of the discussions;*
- *Potential time-savings of up to 50% for some stages of the Product Introduction Process.*

Collaborative working among Rover Suppliers

A mail survey of the automotive suppliers was conducted in the summer of 1998 [28] to identify current working practises and attitudes to virtual teaming. Three hundred questionaires were sent to suppliers of components, sub-systems, systems and services to Rover Group. Replies from seventy companies were received within the desired timeframe. The majority of these companies employed less than 1000 people at the relevant site, 76% participated in engineering design with Rover, and 72% utilised collaborative team working, defined as *cross-functional and organisational workgroups brought together to tackle a project for a finite period.*

In the six month period to June 1998, each company had on average 36.16 meetings and on average there were 3.33 people from Rover and 2.7 people from the supplier at each meeting. Figure 6 identifies the tools used to enable collaborative work, and the frequency of use in that 6 month period.

Insert Figure 6: Methods of Communication used with Rover and how often

Clearly communication is mainly via face-to-face meetings. Figure 7 highlights that communication difficulty causes the most significant problems in collaborative teaming.

Insert Figure 7: Difficulties faced in using teamworking

More detailed results of the survey were these:

- The companies indicated a strong desire (81%) to use virtual teaming utilising tools like video conferencing to support their collaboration.
- The most important benefits from using virtual teaming identified (% of respondents) were:
  - Time savings (25%) – *time saved waiting for meetings, time wasted in travelling*.
  - Cost saving (23%)
  - Ability to quickly pull in extra expertise into a meeting (20%)
  - Reduction in wasted time (17%). *This is viewed as time saved due to reduced uncertainty and confusion as a result of the ability to schedule shorter meetings more frequesntly*
- The issues that worried the companies most about adopting virtual teaming tools were:
  - Lack of physical presence / loss in richness of interaction (35%)
  - Loss of social contact (26%)
  - Requirement for IT expertise (16%)
  - Security of information (12%)
  - Availability of in-house data in right format (11%)

From the data presented we see that virtual teaming is becoming accepted in principle within automotive supply chain relationships. Eight out of ten companies in the Rover supply chain wished to use a virtual teaming technology, and typically cited "better, faster cheaper" advantages. Issues and barriers, however, remain: the most prominent being to do with the "teaming" aspects of virtual teaming as shown in Figure 4. It is likely that the members of the Rover supply chains saw only the application of a technology, not a capability for allowing a team, with a common purpose to apply broader expertise and knowledge, to operate regardless of distance.

Conclusion

The design, manufacture and delivery of a product requires ever-higher levels of knowledge and expertise within the supply chain - above and beyond the exchange of information and data - if turbulence in tiered supply chains is to be fully overcome. The agility philosophy goes so far as proposing that successful, agile, supply chains are built on rich relationships amongst all parties: certainly embodying knowledge and expertise. Virtual teaming is the most appropriate framework and mechanism in which to examine how such rich relationships - and the exchange of knowledge and expertise - can be created across a distributed supply chain. In principle, virtual teaming could allow joint commitment, feelings of mutuality, trust and creativity, and rapid decision-making to operate within a supply chain, regardless of the geographical location of its members. For this to be possible, however, a virtual team needs to be built by concentrating on process, teaming and technology factors. However experience from other IT-based initiatives is that technology will be concentrated on to the exclusion of other factors. Data from the two sources shown here supports this contention. The TEAM and survey data show recognition of the value of virtual teaming within the supply chain. However, the TEAM experience shows that not all problems have been overcome, the remaining problems are in the process and teaming areas. However, if implemented correctly, virtual teaming could be a significant innovation in effective management of an agile supply chain.

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Virtual Teaming in the Agile Supply Chain

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