

Agile supply chain capabilities: Determinants of competitive objectives

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Abstract

Changing customer and technological requirements force manufacturers to develop agile supply chain capabilities in order to be competitive. Therefore, several companies are stressing flexibility and agility in order to respond, real time, to the unique needs of customers and markets. However, the resource competencies required are often difficult to mobilise and retain by single companies. It is therefore imperative for companies to co-operate and leverage complementary competencies. To this end, legally separate and spatially distributed companies are becoming integrated through Internet-based technologies. The paper reviews emerging patterns in supply chain integration. It also explores the relationship between the emerging patterns and attainment of competitive objectives. The results reported in the paper are based on the data collected from a survey using the standard questionnaire. The survey involved 600 companies in the UK, as part of a larger study of agile manufacturing. The study was driven by a conceptual model, which relates supply chain practices to competitive objectives. The study involves the use of factor analysis to reduce research variables to a few principal components. Subsequently, multiple regression was conducted to study the relationship amongst the selected variables. The results validate the proposed conceptual model and lend credence to current thinking that supply chain integration is a vital tool for competitive advantage.

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1. Introduction

In a bid to cope with market instability, companies now look beyond cost and quality advantage. Speed, quality and flexibility are being emphasized as means of responding to the unique

needs of customers and markets. However, the core resource competencies required to realise the extended range of objectives are often difficult to mobilise and retain by individual companies (Kasarda and Rondinelli, 1998; Gunasekaran, 1998; Gunasekaran and Yusuf, 2002). In the circumstance, companies are under pressure to co-operate and leverage core resource competencies amongst themselves whilst competing. Co-operation is particularly crucial for innovation and

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responsiveness during the early stage of production planning. Through the Internet, businesses and institutions now share common databases and collaborate ever than before (US Internet Council, 2000). In addition, companies submit joint bids for contracts and attribute responsibilities for design and manufacture of complex products, based on their relative competencies (Upton and McAfee, 1996). The drivers of supply chain integration include advances in information technology, complex customer requirements, intense global competition, and the desire to be the first to market with innovative products.

This paper discusses the drivers and emerging patterns of supply chain integration. A conceptual model of supply chain practices as determinants of manufacturing competitiveness and business performance was developed. Also, the relationship between the patterns of supply chain and attainment of competitive and business performance was explored. The exploration was based on the data collected from a survey using the standard questionnaire administered to 600 companies in the UK.

Statistical analyses of the impact of supply chain practices on competitive objectives were extended to include two internal resource competencies of process automation and employee empowerment. The results show that the internal resource competencies are characterised by negative interaction effects in their relationship with competitive and business objectives. This implies that those internal resource competencies are inadequate for enhanced manufacturing performance. Therefore, external competence building through supply chain integration as seamless flows of resource coalitions is essential for enhanced competitive performance.

Further, three patterns of supply chain practices were identified by statistical analysis. In line with statistical procedures, the patterns were interpreted as traditional, lean, and agile supply chains. The traditional pattern, which is renowned for protection, rather than the leverage of core competencies, as well as emphasis on terms and condition for attribution of costs and benefits, did not deliver significantly on competitive objectives. In contrast, the lean pattern, which was underpinned

by upstream and downstream integration with suppliers and customers, had significant influence on competitive objectives. Also, the agile pattern was distinguished by a high degree of co-operation with competitors, data integration, and collaboration for manufacture rather than exclusively marketing. The supply chain practices described as agile enterprise had significant impact on the low cost objective although it was less popular amongst the companies studied.

The organisation of the paper follows as: Section 2 discusses the drivers of supply chain integration. The nature of an agile supply chain is presented in Section 3. Section 4 deals with a conceptual model for assessing the capability of an agile supply chain. Research methodology employed is discussed in Section 5. Section 6 includes results and discussions. Finally, Section 7 presents the summary and conclusions.

2. Drivers of supply chain integration

There are unprecedented pressures on companies to improve their operational efficiency for enhanced competitiveness and overall business performance. Such pressures include competition from foreign products, new product introduction by competitors, falling product life cycles, unanticipated customer shifts, and advances in manufacturing and information technology (Browne et al., 1995). Other pressures include the privatisation of public enterprises, economic downturns and agitation by shareholders for higher returns on investment. These pressures can eat deep into the size of available public and third party loanable funds. In addition, consumer sophistication and the emergence of intelligent products have led to more difficult design specifications and expectations on deliverable value added (Bhattacharya, 1996).

In the light of the pressures specified above, the most difficult challenge facing manufacturers today is how to integrate the upstream outsourcing functions and the downstream delivery functions with product design and manufacture (Helena, 1997). Integration would enable the value creation and transfer process, right from the supplier to the

end customer to operate as a seamless chain along which information, knowledge, equipment and physical assets flow as if water (Gunasekaran and Yusuf, 2002; Yusuf et al., 1999).

Seamless flow of physical and non-physical assets amongst companies would lead to pooling synergy and optimisation of tangible and intangible assets that are potentially available to the individual companies (Kasarda and Rondinelli, 1998; Upton and McAfee, 1996). Companies in a chain can apply the principles of job specialisation to plant operations. This means that design can take place in a remote site far away from some other plants where the components are machined, and assembled in different configurations in a fewer number of factories or at the point of sale (Feitzinger and Lee, 1997). The companies in the chain will have the benefit of focusing on a narrow aspect of operations where they have greatest competitive advantage (Quinn, 1992).

Advanced information technology (IT), which has turned the world into a global village through “speed of light” transfers of information, data and files, is a major driver of supply chain integration. Through the Internet, a single data file can be accessed simultaneously by spatially distributed entities. Although earlier IT applications were in support of secure and evidential transfers of trading reports, cash and other assets and obligations, the applications were eventually extended to logistics management (Russ and Camp, 1997).

As well, companies’ growth through vertical integration and search for new markets in different countries has given rise to large administrative structures. Consequently, the need to process and transfer large volumes of data in the form of designs, plans, budgets and reports across several administrative and operation units becomes necessary. In addition, companies allying to become integrated global businesses needed mutual access to data on cost, personnel, stocks, sales and profit profiles. This is in addition to being able to monitor several alliance conditions such as compliance, contribution and attribution. The business scenario described necessitate advanced IT applications, with greater functionality than electronic data interchange (EDI). New IT capabilities in terms of reach, easier coding via inheritance,

adding new data and generating automatic upgrades, and protecting components of data files from unwanted parties have therefore emerged (Mutsaers et al., 1998).

Nevertheless, market turbulence arising from factors such as rapid introduction and customisation of products, difficult design specification, and customer shifts make continuous contact with customers and suppliers through supply chain integration most important (Russ and Camp, 1997; Davenport, 1998). In addition, various functions and spatially distributed project units of companies require more co-ordination and integration. Furthermore, as competition intensified, efforts to reduce cost through just-in-time purchasing, scheduling and distribution, led to more frequent monitoring of specified and delivered quality, schedules and other customer expectations as a routine process. For these reasons, some manufacturers have organised hierarchical networks of suppliers and “imposed” their own control structures and systems.

The advents of intelligent products, whose requirements are rather difficult for individual companies, create the greatest challenge for supply chain integration. The need arises to focus on narrow product modules with greatest competitive advantage whilst collaborating with other companies (Quinn, 1992). The processes of conception, design, manufacture and delivery are therefore becoming like a relay race amongst legally separate companies, who work with equal vigour and commitment to add the greatest value to end-customer continually (Badaracco, 1991; Lee and Lau, 1999; Soliman and Youssef, 2001). In this regard, sharing of design and manufacturing knowledge and competencies amongst companies is a vital tool of competition. Sharing enhances tracking of customer expectations whilst also reducing product and process development cycle times (Bhatt, 2000; Perry and Sohal, 2001).

3. The nature of an agile supply chain

Until recently, supply chains were understood mainly in terms of long-term upstream collaboration with suppliers. An equal amount of emphasis

is now paid to downstream collaboration with customers and lateral collaboration with competitors as a means of integrating the total value creation process. A supply chain, therefore, describes the series of linked activities amongst companies that contribute to the process of design, manufacture and delivery of products and services. The agility of a supply chain is a measure of how well the relationships involved in the processes mentioned above enhance four pivotal objectives of agile manufacturing (Hoek et al., 2001). These objectives are customer enrichment ahead of competitors, achieving mass customisation at the cost of mass production, mastering change and uncertainty through routinely adaptable structures, and leveraging the impact of people across enterprises through information technology.

The preceding list shows that enhanced responsiveness is a major capability of an agile supply chain. Enhanced responsiveness is important as an addition to the high level of efficiency in cost, quality and smooth operations flow, which have been associated with lean supply chains. These primary objective of a lean supply chain can be realised by using the most basic forms of data communication on inventories, capacities, and delivery plans and fluctuations, within the framework of just-in-time (JIT) principles (Womack et al., 1990). The aim of integration is to ensure commitment to cost and quality, as well as achieving minimum distortion to plans, schedules and regular delivery of small volumes of orders.

Supply chain agility can be discussed in terms of two dimensions of reach and range of activities covered by networking amongst companies (Browne et al., 1995; Kehoe and Boughton, 2001). Fig. 1 illustrates the two-dimensional framework. On the vertical axis, information reach extends from person to person through to global. On the horizontal axis, the range of activities widens from electronic messaging to Internet-based integration. Accordingly, the degree of freedom in supply chain integration widens from bill of material controls through purchasing efficiency to planning and control of supply chain operations.

An agile supply chain should extend to the highest levels on both dimensions of reach and range. At the highest levels of attainment of two dimensions, the conduct of internal operations will be transparent to suppliers and customers. Also, local teams of employees can think globally and take virtual initiatives with teams in other companies within the supply chain. To this extent, responsiveness to changing competitive requirement becomes easier to master as a matter of routine, and with little penalties in time, cost and quality.

In addition to the reach and range approach, agility and capability of a supply chain can be assessed in terms of the stage attained on three inter-dependent dimensions of supply chain maturity (Venkatraman and Henderson, 1998). The three dimensions are shown in Fig. 2 (column 1) as customer interaction, asset configuration and

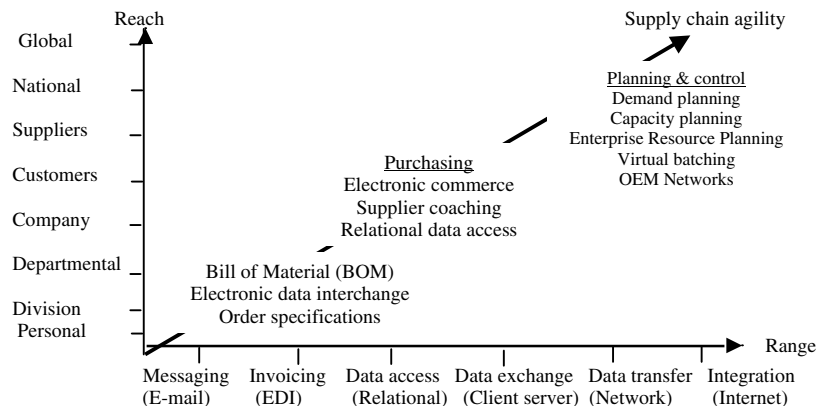


Fig. 1. Reach and range analysis of supply chains (Browne et al., 1995; Kehoe and Boughton, 2001).

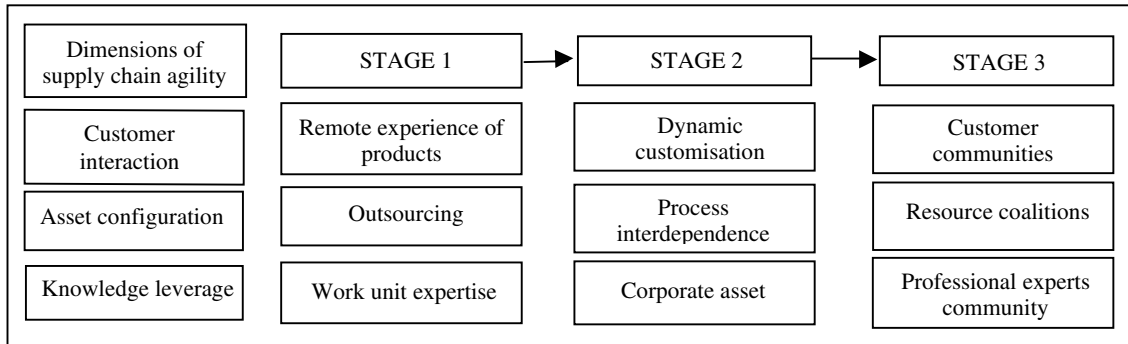


Fig. 2. Three dimensions and stages of supply chain maturity (Venkatraman and Henderson, 1998).

knowledge leverage. The challenge of an agile supply chain will be to improve and ensure balance across the three dimensions. Fig. 2 also shows three stages that can be used to evaluate progress on each of the three dimensions of supply chain maturity.

On customer interaction, the first stage of remote experience of products includes efforts to reach out to customers through sales catalogues, television demonstrations and, most recently, web-based advertisements, demonstrations and shopping. By remotely reaching out to spatially distributed customers through virtual means, a company can identify clusters of unique preferences for dynamic customisation (Stage 2). Eventually, dynamic customisation can be targeted at communities of customers (Stage 3), who have strong commitment to customer-specified product upgrades rather than variety as an end in itself. When a company attains the stage of customer communities, leading edge technology products can be introduced more rapidly due to the advantage of customer-input into their evolution as well as the benefit of market concentration.

As for customer interaction, the asset configuration dimension matures from emphasis on commercial outsourcing of materials and components, to business process inter-dependence. This means delegating critical business processes to members of a chain rather than outsourcing. Eventually, spatially distributed and inter-dependent business processes mature into resource coalitions. At this stage, companies will contribute

and share knowledge and competence within global networks of resources, and focus on limited areas of the value creation processes where comparative advantage is higher. On the third dimension of knowledge leverage, supply chain agility requires advance from emphasis on individual job competencies and structures, to teaming and free flow of tacit knowledge across work units. Ultimately, the principles of free flow of knowledge across work units should extend to entire value chains as joint stakeholders in the process of conceiving, creating and delivering value. At this stage, a company aims to leverage competencies not only internally amongst its own employees and teams, but also within a globally linked but spatially distributed professional community of experts.

Across the three stages of maturity towards virtual organising, the target locus of action would extend from task units to organisation units and to inter-organisational units. Across the three stages as well, performance objectives would mature from operating efficiency through economic value added, to enhanced survival prospects (Venkatraman and Henderson, 1998).

The preceding discussion shows that an agile supply chain should strive to meet the three requirements specified in column 4 of Fig. 2. The requirements are ownership of customer communities or niche markets, membership of manufacturing resource coalitions, and possession of a workforce that operates within a community of professional experts. Inter-organisational leverages should drive competitive strategies, plans and

innovation. Most importantly, the supply chain should enhance growth and long-term survival.

Closely related to the three elements of virtual organising as a means of assessing the agile capabilities of a supply chain, four dimensions of agile supply chain practices have been identified (Hoek et al., 2001). They are:

- Customer sensitivity through continuous enrichment as against focusing on waste elimination.
- Virtual integration, with emphasis on instantaneous response in addition to stable production flows.
- Process integration through self-managing teams as against work standardisation and conformance.
- Network integration through “fluid” clusters of associates who venture into temporal opportunities.

Fig. 3 models the four elements. Customer sensitivity means that collaborative initiatives should be driven by quick response to customer requirements. In this respect, manufacturing processes require integration and specialisation based on relative areas of excellence in core competencies. Network integration requires that companies in the chain have a common identity, which can range from commitment to agile practices, compatibility of structure, information architecture and tradable competencies. The third element is process integration and inter-dependence so that core modules of products can be delegated within networks of agile competitors. Lastly, virtual integration envisages access to information, knowledge and competencies of companies through the Internet.

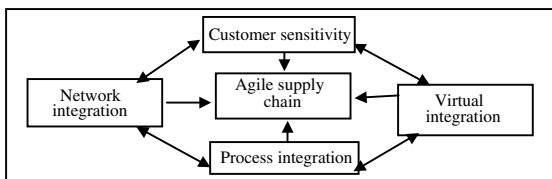


Fig. 3. Elements of an agile supply chain (courtesy: Hoek et al., 2001).

4. A conceptual model for assessing an agile supply chain

In Fig. 4 is a conceptual model for assessing the capability of an agile supply chain. The model consists of four dimensions: (i) value chain practice, (ii) competitive objectives, (iii) impact of change drivers and (iv) business performance. The arrows indicate the direction of impact. The essential differences are the ease of formation and dissolution, relative status and commitment of members, the degree of data integration through the Internet, and goals, which can range from advancement of manufacturing knowledge, outsourcing or marketing. These differences are proposed to determine the attainment of competitive and business objectives as well as the impact of change drivers on operations.

It is expected that patterns of supply chain integration will differ across companies. Conceptually, supply chain practices should range from conditional alliances, to master–servant long-term relationships with suppliers and customer, and to the Internet-based collaboration. Across these range of supply chain practices, access to data and knowledge, as well as the ease of responding real time to changing market conditions differ. Such differences are expected to impact differently on competitive and performance outcomes.

Three supply chain patterns are dominant in the literature (Gunneson, 1997). The first is the traditional alliance, which is the dominant practice among companies seeking global spread, as a strategy of penetrating new markets. It is renowned for difficult conditions on contribution, responsibilities and sharing. Data exchange is limited to sales reports and final accounts, which

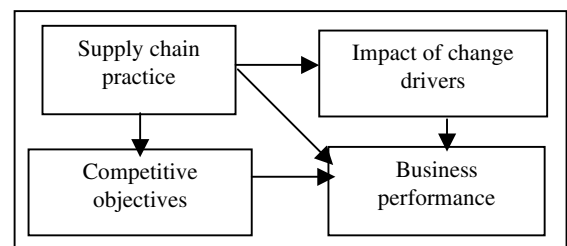


Fig. 4. A conceptual model for assessing an agile supply chain.

are essential for assessing compliance with terms and conditions as well as for tracking resources, profits and losses. Such alliances focus on outsourcing rather than sharing of knowledge and competencies. In the new competitive game plan, the traditional pattern of alliance practice has become increasingly irrelevant.

A concept referred to as the lean supply chain is the second dominant form of alliance practice. It is renowned for long-term collaboration with preferred suppliers and customers. The goal is to secure cost and quality advantage as well as ensure smooth flow of operations, within the framework of just-in-time deliveries of small volumes of output. In support of the goal, collaborative initiatives include electronic linkages, part ownership, coaching and long-term contractual obligations with suppliers and distributors. Data generation and exchange are largely electronic. These forms of data exchange would just have been adequate for monitoring stock, sales, demand and capacity levels. There seems to be no concerted effort to leverage manufacturing competencies amongst companies as equals. As such, the lean model of integration also has limited impact on competitiveness in a turbulent market.

Quite unlike the traditional and lean supply chains, the agile supply chain is underpinned by global exchange of manufacturing competencies. The agile chain has a stronger impact on competitiveness because it enables mobilisation of

global resources to track evolving changes in technology and material development as well as market and customer expectations. Inter-dependent factories can focus and rapidly replicate narrow aspects of the value creation process where competitive advantage is greatest (Quinn, 1992). Focusing and co-operation within the virtual enterprise has the potential to enhance capability for low cost, quality, speed, flexibility and product innovation. These in turn will lead to higher revenues, profits, market-share, customer loyalty and better survival prospects.

Based on the conceptual model in Fig. 4, the relative impacts of three models of supply chains on competitive and business performance measures were identified, based on data from a survey by questionnaire. Attainment of seven dimensions of supply chain practices by companies was studied. Table 1 lists the seven dimensions.

5. Research methodology

In order to explore current attainment of the seven dimensions of supply chain practices and their impacts on competitive performance, a survey by questionnaire was administered to 600 manufacturing companies. One hundred and nine responses (representing a response rate of 18.17%) were considered useful for the study. The companies were asked to indicate the extent to which the dimensions apply to their operations. The

Table 1
Profile of respondents' scores on supply chain practices

Dimensions of supply chain practices	Agree strongly (5), %	Agree (4), %	Neutral (3), %	Disagree (2), %	Strongly (1), %
Co-operation with competitors	14.0	14.0	35.5	13.1	23.4
Long-term collaboration with customers and suppliers	46.7	36.4	9.3	5.6	1.9
Leverage of core resources with other companies operating as a network	9.3	10.3	28.0	22.4	29.0
Difficult operating conditions compel co-operation with other companies	1.9	20.6	36.4	21.5	16.8
Alliances amongst complementary equals are more effective	11.2	29.0	43.0	10.3	2.8
Computer-based data integration with other companies	4.7	10.3	27.1	17.8	38.3
We value alliances for co-manufacture more than for market penetration	2.8	15.9	43.0	16.8	16.6

responses were ordinal on a 5-point Likert scale, which ranged from strongly agree (5) right to strongly disagree (1).

Data were also collected in the same format on two internal competencies of process automation and employee empowerment. This is in order to compare the performance impacts of emerging patterns of supply chains as external capabilities, alongside the performance impacts of process automation and employee empowerment as internal capabilities. The companies were also asked to indicate their attainment of seven manufacturing objectives, which have to be equally improved upon by agile manufacturers. The objectives are low cost, quality, dependability, speed, volume flexibility, product customisation, and leadership in new technology products. As well, the companies were requested to indicate the direction of change in seven measures of business performance over the last three years. The measures are sales turnover, net profit, market share, percentage of sales from new products, customer loyalty based on the ratio of repeat orders to total sales turnover, and overall performance against competitors. All the competitive and performance objectives studied have been widely used in related prior studies (Vonderembse and Tracey, 1999; Flynn et al., 1995).

The data was analysed using SPSS Release 10.0 for Windows. Reliability tests were conducted for all variables studied. For example, business performance had an F -statistic of 3.66 at $p = 0.008$ and an α coefficient of 0.72. Also, an F -value of 198.01 at $p = 0.00$ and an α coefficient of 0.681 were computed for measures of automation. As for the measures of employee empowerment, a χ^2 of 81.73 at $p = 0.00$ and an α coefficient of 0.746 were computed. Significant F -values indicate that each of the variables employed to measure a concept is unique. Also, a minimum α value of 0.60 for such variables means that the variables converge and are good measures of the concept studied. In addition, the data satisfied the requirements of normal distribution and equal variance across sample sub-groups, which means that parametric tests such as factor and regression analyses are in order (Vonderembse and Tracey, 1999; Henry, 1998).

Factor analysis was used to reduce the research variables to only a few factors. The two most useful results are total variance explained and a component matrix. The former computes explained variances whilst the latter computes the weights of the variables in a few number of easily interpretable factor components. The relationships amongst the factor components were tested with path analysis. The method provides insights into the pattern of relationships amongst a set of variables. Path coefficients were computed with regression analysis, based on standardised scores of the factor components. The most important results of regression analysis are a squared regression coefficient (R^2), which shows the total change in a dependent variable attributable to all independent variables. In addition, an F -statistic reveals the ratio of explained to unexplained variation. Furthermore, a table of standardised regression coefficients reveals the strength of each independent variable on the dependent variable. Higher R^2 and F -values at $p < 0.05$, in addition to only a few variables having significant coefficients at $p < 0.05$ mean that a model was correctly specified (Flynn et al., 1995).

Companies in the study were selected randomly from a database called Financial Analysis Made Easy (FAME), which publishes contact and summary financial information of major UK companies. Attention was paid to spread of the companies across a wide range of industries and size based on sales turnover. About 55%, 20% and 25% of the respondents were small, medium and large-scale companies. The percentage distribution on seven product groups ranged from 23.9% in industrial, hospital and agricultural equipment, to 9.2% in food, chemicals and pharmaceuticals. Furthermore, 37.6% of the companies compete in markets consisting of several companies of relatively equal size, whilst 57.7% trade in markets dominated by a few large companies.

6. Results and discussion

The responses to questions on supply chain practices are summarised in Table 1. The table shows that a higher proportion of the respondents

(40.2%) agreed that insistence on complementary equality was alliances whilst 51.4% disagreed with exchange of core resource capabilities with other companies. The two results provide indication that traditional conditionality in alliance formations remains popular. Furthermore, 83.1% agreed those long-term relationships with suppliers and customers are desirable. However, only 22.5% of companies agreed that difficult operating conditions now compel supply chain integration. In addition, only 15% of companies claimed some computerised data integration with other companies. Similarly, 28% agree on alliances amongst competitors while 19% preferred co-manufacturing to commercial marketing and purchasing alliances. These positions are contrary to the suggestions in the literature. The results show that agile chains, which stress competitors' alliances, exchange of capabilities and computer-based integration are far from realisation.

The results in Table 1 reveal that long-term commercial relationships with customers and suppliers is most popular whilst data integration and open leverage of core resources were yet to be popular in industry.

The seven dimensions of supply chain practice were tested for relationship with manufacturing and business objectives. Table 2 presents the results. The significance levels of correlation coefficients are shown in parentheses. The table shows that customer/supplier collaboration, and computer-based data integration had the widest and strongest relationship with competitive objectives. On the other hand, Table 2 indicates that leverage of core resources has negative correlation with the agile objective of new technology leadership. As well, difficult operating conditions as a driver of co-operation has a negative correlation with sales

turnover. The reasons accounting for the negative relationships are not far fetched. Companies might be playing safe and hoarding their best competencies, processes and data from network members. This can be more so when in a turbulent situation, what happens next would remain largely unknown. Indeed, the bane of the Internet as well as inter-company networking today remains the quality, transparency and honesty contained in available information. This also determines derivable benefits.

Several examples abound on the negative relationship between leverage of core resources and technology leadership on one hand, as well as between difficult operating conditions as a driver of integration and sales turnover growth. It is known world wide that several years of alliance relationship between Honda and Rover led to the sale of the latter to the former. As well, Volkswagen has just bought up Skoda Auto after several years of co-operation. Where competitive situation and structures of allying companies are incompatible, trust will be low. This can result in lower competitive and performance outcomes. Nevertheless, subsequent results indicate that failed efforts at integration can be attributed to traditional alliances, which pursue objectives and utilise structures different from those of agile supply chains.

Finally, computer-based data integration, which occupies the centre-stage in the requirements of agile supply chain, correlated significantly with sales turnover and market share growth. It therefore has the strongest relationship with bottom line measures of business success, followed by collaboration with customers and suppliers.

As explained earlier, path analysis is more useful in revealing the direction and strength of

Table 2
Significant correlation between supply chain practices and manufacturing objectives

	Customer/supplier alliances	Protection of core competence	Difficult conditions compel alliances	Data integration
Product customisation	0.198 (0.41)		0.22 (0.03)	
New technology leadership	0.20 (0.04)	−0.25 (0.01)		
Dependability	0.234 (0.02)			
Sales turnover growth	0.215 (0.03)		−0.23 (0.02)	0.254 (0.01)
Market share growth				0.219 (0.026)

relationship among a complex set of variables. Proper comprehension demands a compact analysis, which is achievable by employing factor analysis to reduce research variables into a few principal components. Table 3 presents the principal components of factor analysis, as emerging patterns of supply chains. Three distinct patterns were significant in terms of eigenvalues not less than one. The three patterns, which are described as agile, lean and traditional, account for 61.03% of variance in the distribution of respondents' scores.

In the traditional model, three variables were loaded highly at over 0.60 out of a total coefficient of 1.00 for a perfect fit. Leverage of core resources was negative at 0.658. Difficult competitive condition as a driver of co-operation was positive at 0.668. This can be interpreted as an alliance formed in haste, and lacking in structures for networking as a competitive strategy. As well, the high loading of complementary equality at 0.731 can imply lack of trust, which means that attention would have been placed more on rules than the output of the process. This is the traditional type of supply chains. Traditional supply chains are renowned for mutual suspicion of partners, complex negotiations on structure, protection of core areas of strength, compliance and sharing of costs and benefits.

In the model described as lean, alliance with customers and suppliers was loaded solely at 0.907. All other dimensions of alliance practice were compressed by the statistical procedure as insignificant. This is the lean pattern of alliance

practice, which is largely defined by long-term relationship with customers downstream and suppliers upstream. In a manufacturing environment characterised by just-in-time practices, lean alliances are essential in ensuring consistent flow in the fragile balance of daily, repeated deliveries of small orders as pulled by customers. The original equipment manufacturers occupy the centre stage and dictate the tune through part ownership and coaching. They employ the lean network as a means of aggressive selling and distribution as well as for cost and quality gains. The relationship is more for commercial outsourcing and distribution than for product and process development.

In relation to the two preceding patterns of alliance practice, the agile model was significantly populated by integrated data exchange at 0.727, alliances for design and manufacture rather than marketing at 0.665, alliances with competitors at 0.638 and leverage of core resources at 0.461. This is the most advanced pattern of current practice in supply chain integration. The variables that define the pattern are closest to the requirements of agile value chains as specified in the literature. However, the results in Table 1 reveal that the variables that constitute agile pattern the lowest percent of perceived relevance or desirability to current operations of the companies studied. Yet, several exploratory tests including the results in Table 2 show that computer-based data integration, which defines the agile pattern, has the strongest positive relationship with sales turnover and market share growth. Nevertheless, as market turbulence intensifies, manufacturers will tend to place more

Table 3
Factor models of supply chains

Dimensions of supply chain practices	Emerging patterns of supply chains		
	Agile	Lean	Traditional
Co-operative alliances with competitors	0.638		
Long-term collaboration with customers and suppliers		0.907	
Leverage of core resources with other companies	0.461		–0.658
Difficult conditions as a driver of co-operation			0.668
Alliances amongst complementary equals	0.357		0.731
Computer-based data integration with other companies	0.727		
Alliances for design and manufacture rather than marketing	0.665		0.316
Eigenvalues	1.691	1.087	1.494
Percentage of variance explained	24.15	15.53	21.35

emphasis on variables loaded in the agile alliance model.

The method of factor analysis was also employed to reduce other variables in the study to their principal components. The standardised coefficients of each variable that were loaded in the factor components were used for multiple regression analysis. The significant regression results indicate the strengths of impact of the different patterns of alliance practice as well as the internal resource capabilities of process automation and employee empowerment on competitive objectives and business performance measures. The significant path coefficients are reported in Fig. 5.

Three boxes, which were labelled as teaming, training and intelligent automation in Fig. 5 depict three of the four components to which process automation and employee empowerment were factored. The four factor, which was described as flexible automation has no significant relationship with any other variable in the regression model. Such variables or factors are often excluded from path analysis results. In addition, two boxes were labelled as lean supply chain and agile supply chain, respectively. The third pattern of supply chain, which was explained earlier as the traditional supply chain, did not relate to any other factor model. It was therefore excluded. The next four boxes in Fig. 5 were labelled as cost leadership, quality leadership, time-based technology leadership, and flexibility leadership. They represent the core competitiveness dimensions to which seven manufacturing objectives were reduced by

factor analysis. Finally, two boxes were labelled, respectively, as impact of change driver and business performance. The former is an aggregate measure of the direction of impact of change drivers such as globalisation, new product introduction, product customisation and IT on the operations of a company. The other box, which is business performance, is also an aggregate measure of growth in performance measures such as sales turnover, net profit and market share. The arrows indicate the directions of impact whilst the coefficients measure the strength of impact.

The results in Fig. 5 show that internal resource competencies have limited impacts on the competitive leadership models. Teaming imparts positively on flexibility leadership and business performance whilst it has a negative indirect influence on the impact of market turbulence. The only impact of training as a resource capability is negative on flexibility leadership. Nevertheless, intelligent automation impacts directly on quality leadership, market turbulence, and indirectly on business performance. The limited impacts of the internal resource competencies of intelligent automation, training and teaming can be attributed to negative interaction effects amongst them. Teaming and intelligent automation have negative interaction effects on quality leadership. Also, training and teaming have non-compensating effects on flexibility leadership. There is the challenge therefore, of how to harmonise current teaming and training practices with the requirements of intelligent automation. This challenge

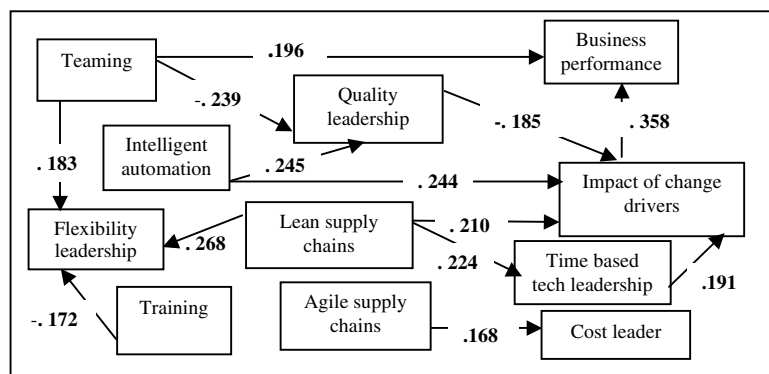


Fig. 5. Path empirical results.

provides further justification for supply chain integration as an additional source of resource competencies.

Fig. 5 shows that the lean supply chain impacts on flexibility leadership, time-based technology leadership, and impact of change drivers. Not only this, the impacts extend indirectly to overall business performance. Much more importantly, the lean supply chain has positive interaction with teaming in relation to flexibility leadership. It also interacted positively with intelligent automation in relation to the impact of change drivers. Furthermore, the agile supply chain impacts on cost leadership, although the impact did not translate to business performance. As more companies embrace and further emphasise the variables loaded that define agile supply chain in Table 3, its range and spread of impact on competitive capabilities will increase. The current low level of adoption of agile supply chain and the limited range of impact as shown in Fig. 5, tally with the findings of Gordon and Sohal (2001). Their results showed that variables, which defined the agile supply chain, had lower adoption and impact on competitiveness, in relation to each of alliances with customers and alliances with suppliers.

In the light of relationships revealed in Fig. 5, it is tenable that the two models of alliance practice as well as intelligent automation remain the most critical resource competencies for companies. There were no negative interaction effects amongst them. This implies that internal and external competence building are both desirable for enhanced competitive performance. Similarly, the lean and agile supply chains had no negative interaction effects. This implies that the two can be integrated. The lean chain only needs to embrace virtual networking, embrace competitor alliances, and harp more on joint design and manufacture rather than commercial outsourcing and distribution.

7. Summary and conclusions

This paper discussed the nature of an agile supply chains and explores some of its attributes and capabilities. The attributes include Internet-

based collaboration, a significant amount of sales turnover and profit from virtual business, open leverage of capabilities within networks of companies and manufacturing, rather than outsourcing and marketing alliances. Subsequently, the level of adoption of seven core dimensions of alliance practice often mentioned in the literature was studied through a survey by questionnaire. This was done alongside the two core internal resource competencies of process automation and employee empowerment. Companies' attainments of several measures of manufacturing performance were also investigated. In order to enable a focused analysis, the variables were reduced into a few principal components through factor analysis. Thereafter, multiple regression was applied to compute path coefficients. This was in order to reveal the strength of impact amongst the principal components of research variables.

The results show that only a few companies have adopted agile supply chain practices. In contrast, most companies have embraced long-term collaboration with supplier as well as customer, which was conceptualised in this study as lean supply chain practices. The traditional model of alliance practice has limited influence in the study. The lean and agile models of supply chains had no negative interaction effects on competitive and performance measures. We suggest that they can be integrated in order to generate greater synergy in their impacts. Integration would require the lean model to improve on Internet-based data integration, embrace several competitors in lean networks, and emphasise collaborative design and manufacture. Whilst the dominant thinking in the literature is that lean initiatives focus on cost and quality, the lean supply chain impacts flexibility and time-based technology leadership objectives rather than cost and quality. In contrast however, the agile supply chain influenced cost rather than flexibility and time-based technology leadership.

Further evidence in support of the development of collaborative supply chains irrespective of their form, emanates from the negative interaction effects amongst internal resource competencies of intelligent automation, teaming and training. The negative interaction or compensation effects limited their impacts on competitive objectives,

change drivers, and business performance. The attrition between teaming and intelligent automation, as well as between teaming and training compel development of external competencies in the drive for enhanced competitive performance.

The high agreement on supplier/customer collaboration is an indication that the lean pattern of supply chain is predominant amongst UK manufacturers. Nevertheless, the lean supply chain has a higher level of impact on competitive objectives in contrast to the agile supply chain, should not be seen as the evidence that the former is superior to the latter. It will take some time before current investment and research efforts in agile supply chains lead to more appreciable results on competitive outcomes.

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References

- Badaracco, J.L., 1991. *The Knowledge Link. How Firms Compete Through Strategic Alliances*. Harvard Business School Press, Boston, MA.
- Bhatt, G.D., 2000. An empirical examination of the effects of information systems integration on business process improvement. *International Journal of Operations and Production Management* 20 (11), 1331–1359.
- Bhattacharya, A.K., 1996. Product market, turbulence and time compression: Three dimensions of an integrated approach to manufacturing system design. *International Journal of Operations and Production Management* 16 (9), 34–37.
- Browne, J., Sackett, J., Wortmann, J., 1995. Future manufacturing systems—towards the extended enterprise. *Computers in Industry* 25, 235–254.
- Davenport, T.H., 1998. Putting the enterprise into the enterprise system. *Harvard Business Review* 76 (4), 121–131.
- Feitzinger, E., Lee, H.L., 1997. Mass customisation at Hewlett-Packard: The power of postponement. *Harvard Business Review* 75 (1), 116–121.
- Flynn, B., Sakakibara, S., Schroeder, R.G., 1995. The impact of quality management practices on performance and competitive advantage. *Decision Sciences* 26 (5), 659–691.
- Gordon, J., Sohal, A.S., 2001. Assessing manufacturing plant competitiveness. *International Journal of Operations and Production Management* 21 (1/2), 233–253.
- Gunasekaran, A., 1998. Agile manufacturing: Enablers and an implementation framework. *International Journal of Production Research* 36 (5), 1223–1247.
- Gunasekaran, A., Yusuf, Y., 2002. Agile manufacturing: A taxonomy of strategic and technological imperatives. *International Journal of Production Research* 40 (6), 1357–1385.
- Gunneson, A.O., 1997. *Transitioning to Agility. Creating the 21st Century Enterprise*. Addison Wesley Publishing Company, New York.
- Helena, M.J., 1997. *Management and Improvement of the Extended Enterprise*. The Institution of Electrical Engineers, Savoy Place, London.
- Henry, C., 1998. The human factor in advanced manufacturing technology adoption. An empirical analysis. *International Journal of Operations and Production Management* 18 (1), 87–106.
- Hoek, R.I., Harrison, A., Christopher, M., 2001. Measuring agile capabilities in the supply chain. *International Journal of Operations and Production Management* 21 (1/2), 126–147.
- Kasarda, J.D., Rondinelli, D.A., 1998. Innovative infrastructure for agile manufacturers. *Sloan Management Review* (Winter), 73–83.
- Kehoe, D., Boughton, N., 2001. Internet based supply chain management. A classification of approaches to manufacturing planning and control. *International Journal of Operations and Production Management* 21 (4), 516–524.
- Lee, W.B., Lau, H.C.W., 1999. Factory on demand: The shaping of an agile network. *International Journal of Agile Manufacturing Systems* 1/2, 83–87.
- Mutsaers, E., Zee, H., Gieritz, H., 1998. The evolution of information technology. *Information Management and Computer Security* 6 (3), 115–126.
- Perry, M., Sohal, A.S., 2001. Effective quick response practices in a supply chain partnership. An Australian case study. *International Journal of Operations and Production Management* 21 (5/6), 840–854.
- Quinn, J.B., 1992. *Intelligent Enterprise*. The Free Press, New York.
- Russ, M., Camp, S.M., 1997. Strategic alliances and technology transfer: An extended paradigm. *International Journal of Technology Management* 14 (5), 513–527.
- Soliman, F., Youssef, M., 2001. The impact of some recent developments in e-business on the management of next generation manufacturing. *International Journal of Operations and Production Management* 21 (5/6), 538–564.
- Upton, D., McAfee, A., 1996. The real virtual factory. *Harvard Business Review* (July–August), 123–133.
- US Internet Council, 2000. *State of the Internet*. Advanced News Media Release, International Technology and Trades Associates (I.I.T.A) Incorporated, pp. 45–56.

- Venkatraman, N., Henderson, J.C., 1998. Real strategies for virtual organisations. *Sloan Management Review* (Fall), 33–48.
- Vonderembse, M., Tracey, M., 1999. The impact of supplier selection criteria and supplier involvement on manufacturing performance. *Journal of Supply Chain Management* 35 (3), 33–39.
- Womack, J.P., Jones, D.T., Roos, D., 1990. *The Machine that Changed the World*. Rawson Associates, New York.
- Yusuf, Y.Y., Sarhadi, M., Gunasekaran, A., 1999. Agile Manufacturing: The drivers, concepts and attributes. *International Journal of Production Economics* 62, 33–43.