Agile supply chain transformation matrix: an integrated tool for creating an agile enterprise

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Abstract
Purpose – The purpose of this paper is to propose a tool, the Agile Supply Chain Transformation Matrix (ASCTM), and the implementation methodology for a systematic approach to achieve agility in the supplier-buyer supply chain.
Design/methodology/approach – The conceptual framework for agile capability creation is developed based on literatures in the supply chain management and manufacturing agility field and the ASCTM tool is constructed using the quality function deployment (QFD) and the analytic hierarchy process (AHP) technique. The implementation methodology including the tools to support the implementation of the ASCTM tool are developed based on the QFD/AHP approach and the agility concepts established through the Agility Program at Lehigh University. A practical case study is used to illustrate the applicability of the ASCTM tool.
Findings – This tool can help companies create and improve their agility by relating the business changes with the appropriate approaches for supplier-buyer supply chain configuration and supplier-buyer relationship establishment and determine the business processes and the infrastructures needed to support the creation of agile capability.
Research limitations/implications – The ASCTM tool constitutes an important effort to bridge the gap between theory and practice as it is used to achieve supply chain agility in practice. Additional case studies need to be conducted to validate the practicability of the ASCTM tool.
Originality/value – The ASCTM tool is developed with the aim to help companies identify the most appropriate way to improve their supply chain agility by contrasting the environmental dynamics and changes to the company's ability to keep pace using the systematic approach. This tool is necessary because different companies experience different sets of changes and require different degree of agility and combination of strategies and practices to achieve agility. For practitioners, the ASCTM tool provides a basis for assessing their business situations and a guideline for identifying capability required for creating/improving supply chain agility.

Keywords Agile production, Supply chain management, Quality function deployment, Supplier relations

Paper type Research paper

Introduction – the need for agility tools

Over the last two decades, globalization has resulted in a highly competitive business environment. The turbulent market condition in the twenty-first century has heightened the need for more competitive enterprise strategies. Speed, quality, flexibility and responsiveness, which are the key components of agile capabilities, are necessary to meet the unique needs of customers and markets. Enterprises benefit from having such agile characteristics by anticipating uncertainties and enabling rapid changes to achieve greater responsiveness to the variability in their business (Jackson and Johansson, 2003).

The fundamental drivers for agility include ever-shorter response cycles, representing a change from static systems with significant time allowances, batched information flows and periodic decision making, to dynamic systems where change, information flow and decision making are continuous. In addition, the fundamental challenge in designing agile systems at each operating level is to find the optimal balance in the agility space between the extremes of ideal lean and instant response (Preiss, 2005). Managing in this new framework depends on the availability of some special infrastructure components, especially improved data and information systems (Preiss and Ray, 2000).

Today, companies have moved beyond their own walls to create relationships and integrate parts of their businesses with their partners. This means that the achievements of the companies depend not only on how well their internal processes are performed but also on how well they integrate and manage the relationships with all their business partners (Mentzer *et al.*, 2001; Lambert, 2004). To survive and prosper under the ever-changing business environment, companies need to enhance their supply chain agility by implementing the right approach in configuring the supply chain structure and establishing the relationship with their partners (Christopher and Towill, 2000). The focus of this paper will be on supply chain agile capabilities improvement.

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Literature review – supply chain agility

The meaning and the benefit of agility in supply chains are generally acknowledged. The concept of agility as a business strategy was presented by Dove (1996) as the enterprise's ability to thrive in a continuously changing and unpredictable business environment. An agile enterprise has designed its organization, processes and products in such a way that it can respond to changes appropriately within a useful time frame. This concept was refined by Naylor *et al.* (1999) with a major focus on agility in supply chains. They provided the distinction between lean and agile supply chains by defining "agility" as using market knowledge and a virtual corporation to explore profitable opportunities in a volatile marketplace and "lean" as developing a value stream that eliminates all waste within the supply chain. Christopher (2000) and Hoek (2001) extended the definition of agility into a wider business context by relating agility in supply chains to both the enterprises' processes and the interfaces between those processes and the market. Companies that focus on agility are market-sensitive and will profit by exploiting their supply chains to rapidly and cost effectively respond to unpredictable changes.

The empirical research on how an organization can achieve supply chain agility can be found in Hoek *et al.* (2001), Swafford (2003) and Braunscheidel (2005). Hoek *et al.* (2001) investigated supply chain agility of the companies in Europe and introduced a preliminary framework for creating an agile supply chain. Swafford (2003) undertook an empirically driven study and identified flexibility as a critical factor for determining and influencing companies' supply chain agility. Braunscheidel (2005) conducted a survey study to investigate the antecedents of supply chain agility.

Although the research on supply chain agility mentioned above attempts to establish awareness on the relevance and potential of supply chain agility, none of the work suggests how to achieve supply chain agility in practice. Research focusing on finding the way to approach agility is mostly related to manufacturing and mainly provides only the general guidelines to approach agility without supporting tools and techniques. Such tools and techniques are particularly important because there are no formulae for agility creation. Different companies experience different sets of changes and require different degrees of agility and combinations of strategies and practices to achieve agility (Goldman *et al.*, 1994).

We propose to fill the limitation above by introducing the QFD-based tool, Agile Supply Chain Transformation Matrix (ASCTM), and the implementation methodology to help companies improve agility based on the evaluation and analysis of their business environment, capabilities, and performances. This tool can help companies identify the most appropriate way (from an existing pool of approaches) to improve their supply chain agile capabilities (by focusing the analysis on the purchasing processes) by finding the balance point between the need for adaptation through the long-term collaborative relationship with agile suppliers and the flexibility/adaptiveness the buying company could gain through flexible and loss-coupling relationships. The application of the tool in practice is investigated through a case study with a plastic manufacturing company.

To put our model in the proper perspective, we propose the following definition for an agile supply chain:

An agile supply chain is an integration of business partners to enable new competencies in order to respond to rapidly changing, continually fragmenting markets. The key enablers of the agile supply chain are the dynamics of structures and relationship configuration, the end-to-end visibility of information, and the event-driven and event-based management. An agile supply chain is a key enabler for an enterprise's agility.

Theoretical foundation for model development

In this section, we will describe the theoretical foundations that are used as a basis for developing and implementing the ASCTM tool.

Agile supply chain creation

One of the key performance enhancements for agility is the integration of relationships with business partners in the supply chain (Preiss *et al.*, 1996). The supplier-buyer relationship can take many forms, ranging from *ad hoc*, where the relationship does not go beyond traditional customer-buyer interaction, to a long-term collaboration where the relationship is extended at a strategic level between interdependent partners (Webster, 1992; Mohr and Nevin, 1990; Bititci *et al.*, 2005). Despite a number of researchers suggesting that companies can enhance their agility by capitalizing on their suppliers' agile capabilities through long-term, collaborative relationships (Peck and Jüttner, 2000; Scott and Westbrook, 1991), there are some arguments that a tight relationship with one supplier may prevent a supply chain design from being adaptive and flexible (Rich and Hines, 1997; Jordan and Michel, 2000). Hoek (2001) states that for an electronic supply chain whose structure is extremely dynamic, enterprises need to form a chain that can rotate and re-link as needed to quickly bring available resources in contact and terminate relationships after achieving a specific objective.

Therefore, we assert that the agile supply chain can be created by establishing long-term collaborative relationships with a group of agile suppliers or adapting the supply chain structures and relationships quickly and efficiently, or implementing both approaches concurrently to cope with unpredictable changes.

Our assertion is further substantiated by two complementary strategies, an "extended enterprise" and a "virtual enterprise." The similarity in both strategies lies in the fact that they pursue enterprise partnership in order to achieve business success in a very competitive and volatile environment. Their major difference lies in the temporary or dynamic nature of one versus the relative stability of the other (Brown and Zhang, 1999). The decision whether to maintain a long-term collaborative relationships with a group of agile suppliers or to adapt the supply chain structures and relationships quickly depends on the characteristics and the types of the changes that are likely to be faced by the companies and our model accommodates this selection.

The quality function deployment (QFD)

The QFD is applied to develop the ASCTM tool. It is a quality system originated in Japan in the late 1960s from the work of Dr Mizuno and Dr Akoa (Akoa, 1990; Mizuno and Akoa, 1994) and has been traditionally employed for developing new products as it provides a method for translating customer requirements into appropriate functional requirements at each stage of product development and production. Recently, a modern QFD that

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offers a better way to perform an analysis (Zultner, 1995) was developed with the major improvements on the quantitative method used to establish the metrics and prioritize the alternatives. Instead of relying on the ordinal scale, the analytical hierarchy process (AHP), which is the simplest prioritization method that provides accurate and reliable results on a ratio scale (Zultner, 2005), is utilized. Using this new approach, the modern QFD has been applied successfully for solving problems in several areas including business process redesign and organizational improvement. Figure 1 – The QFD matrix, displays the house of quality, which is the model used in QFD analysis. We will reference this model throughout the rest of this work.

The sequential procedure for understanding the general hierarchic structure and establishing the priority ratios in AHP is explained as:

- Define the problem and structure the model by relating the factors and alternatives in hierarchy.
- Construct a pair-wise comparison matrix for all factors in all hierarchy levels by comparing pairs of factors with respect to a criterion in the superior level.
- Use hierarchical synthesis to calculate the priority of each criterion in terms of its contribution to achieving your goal.
- Evaluate the consistency of the entire hierarchy, theoretically ≤ 0.1 (Satty, 2001).

Classification of changes in purchasing requirements

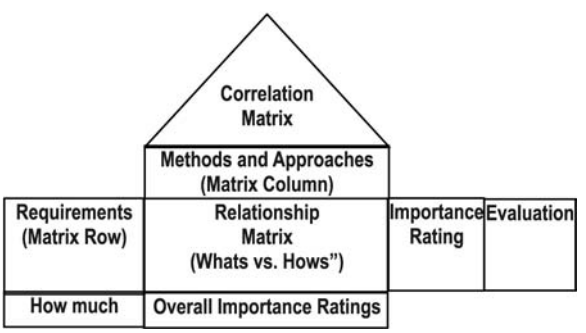
The unpredictable business environment can disturb and cause changes to any supply chain segments such as purchasing, manufacturing and distribution (Jackson and Johansson, 2003; IDC, 2002) and these changes necessitate a company to search for new ways to improve its agile capabilities in order to maintain its competitive advantage (Sharifi and Zhang, 2001). However, since the least useful kind of agility is excessive capabilities for changes that are in the wrong area, in other words, agility that companies never need (Goronson, 1999), assessing the company's business environment and identifying the likely changes and the impact of these changes on each supply chain segment are essential. This information will help companies determine the right approaches to respond to changes so that they can be in a better position for continued survival and growth. We restrict our discussion to the changes related to the purchasing segment since our focus is on the upstream level of the supply chain.

By extending the study performed by Van der Vorst and Beulens (2002) and Zsidisin *et al.* (2004), we classify changes that are critical to determining the reliability, predictability and cost-effective supply of materials and components into seven categories as follows:

1 *Quality*: changes in supplier's quality standard or variation in the quality of supplied items per time period.
2 *Design and feature*: changes or variation in the design of an item acquired from supplier.
3 *Volume and quantity*: increase/decrease or variation in a supplier's order quantity.
4 *Supply lead time*: reduction or variation of the order lead-time.
5 *Supply availability*: unexpected disruption of a supplier or shortage of an item in the market.
6 *Supply cost*: cost reduction or market price increase of an item acquired from a supplier.
7 *Legal*: changes in substantive legal status of a purchased item or service.

Besides classifying changes based on the impacted areas, it is also useful to classify changes according to their characteristics. There are changes that are inherent/intrinsic to the normal course of conducting business. These changes can be effectively handled by implementing a proper planning and control strategy. There are other changes that can be attributed to the volatility of the external business environment. These changes are unlikely to be predicted or anticipated in advance and always have a major impact on a company's business as they could suddenly break historical patterns and create new trends. This classification is important because to handle each type of change, suppliers need to have specific expertise and competency.

Figure 1 The QFD matrix



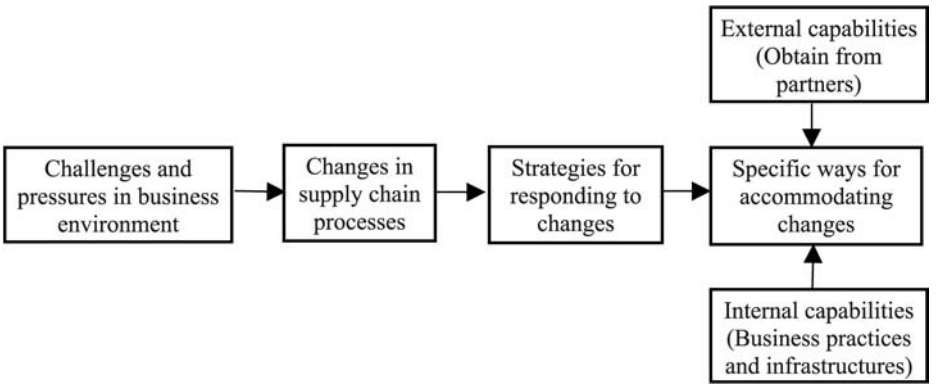
The conceptual framework and model development

Before constructing the ASCTM tool, a conceptual framework was developed based on the relevant literature on agility and was reviewed by a group of supply chain managers. This framework was used as a basis for the formation of the ASCTM tool and methodology to help companies make decisions in their pursuit of supply chain agility.

As illustrated in Figure 2, improving supply chain agile capabilities starts with the evaluation and the identification of business environment and changes occurring within the supply chain processes. Then the areas needing attention can be pinpointed by contrasting these environmental dynamics and changes to the company's ability to keep pace, leading to the determination of specific strategies and approaches for change responses. The next stage following the analysis of strategies and approaches is to identify the business practices and infrastructures that help enhance the company's ability to respond to changes.

With reference to the above conceptual framework, we developed the ASCTM tool by employing the quality function deployment (QFD) and the analytic hierarchy process (AHP) technique. Since QFD has been used successfully in product design to relate what needs to be achieved with the ways to achieve it, it should provide a means to ensure that the business dynamic/potential changes are embedded in the process of supply chain configuration. In addition, by employing the AHP approach to prioritize the importance of the potential changes and the appropriateness of the change

Figure 2 The conceptual framework for agile capabilities creation



response strategies, the areas that need to be improved can be clearly identified.

There are three phases in the ASCTM tool (Figure 3) consistent with the conceptual framework. In phase 1, the potential changes likely to affect the company are evaluated based on their importance to the current business, leading to the determination of the ways used for accommodating and responding to these changes in phase 2. In phase 3, we identify the business practices and the organizational infrastructure necessary to support the creation of change accommodation/response abilities. To ensure the relevance of the ASCTM tool, it was reviewed by a panel of academic and industry experts in supply chain management

The tools to support model implementation

To support the implementation of the ASCTM tool and methodology, a number of tools were developed to assist companies in carrying out the processes, which are discussed below.

The comprehensive list of the ways for change accommodation and the key business practices and infrastructure.

To support the determination of the ways for change accommodation and the key business practices and infrastructure, two comprehensive lists were developed based on review of literatures and case studies. The first one (Table I) provides the list of ways for the change accommodation, which were identified and categorized based on the eight domains of change framework proposed by Dove (1996). The second one (Table II) provides the list of business practices and organizational infrastructure necessary for agility creation, which were identified according to Dove's design principles on the system response architecture of reusable modules that can be reconfigured in a scalable framework (Dove, 1996). This list is general and can support the analysis of other products. The application of these two lists will be illustrated through the implementation of the tool in the next section.

Agile supply chain portfolio analysis

In this section we introduce the agile supply chain portfolio analysis that we have developed to help companies have a better understanding on the direction of supply chain agility that they should approach (Figure 4). This portfolio classifies the agile supply chain into four categories according to the purchasing objective and the characteristics of the supply market. Companies can use this portfolio to analyze and determine the appropriate strategies for their supply chain partnership and purchasing function by locating themselves in a proper area based on their purchasing objective and the characteristic of the supply market. However, this classification is not conclusive. Many companies may employ a combination of approaches to create agility. The shading in the portfolio indicates the area where the mix strategy might be appropriate. The details related to each type of agile supply chain category are provided in Table III.

Figure 3 Three phases of the ASCTM tool

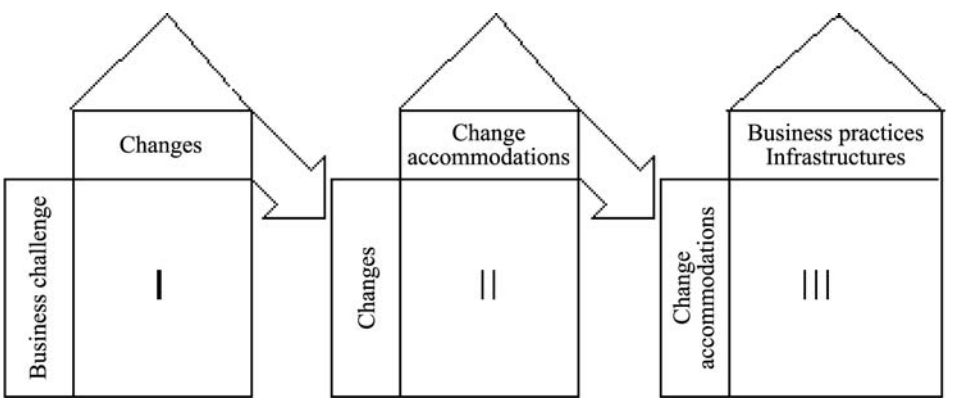


Table I How the changes can be accommodated

Change responses (Dove, 1996)	Our contribution: Supplier unique capabilities	Our contribution: Adaptive relationship
1. Creation (build something new or remove something completely)	Quickly develop product and process innovation; new design and new operational process	New relationship established; new contract generated; new supplier/ partner selected; purchasing contract terminated
2. Expansion/contraction (quantity and capacity changes)	Capacity expansion; production quantity increase/ decrease; lead-time reduction	Second source added to or removed from the network; Increase/decrease magnitude of partnership activity
3. Reconfiguration (reorganizing a set of existing components and their interactive relationship)	Production and delivery rescheduling; production process reconfiguration	Contract contents adjusted; customer assignment rearranged; insource/outsource switching; supplier's responsibilities changed
4. Addition/subtraction (the addition and the removal of some unique capabilities)	New process implementation	New supplier (with unique capability) integrated to the team; current suppliers removed from the team
5. Migration (planned fundamental changes, transitions to next generation replacements)	Information integration; quality improvement; new performance standard; rules and regulations	Closer strategic integration; more outsourced design; closer communication integration
6. Augmentation (incremental improvement of performance factors)	Core competency improvement; faster interaction response	Speed improvement in partnership development and dissolving, supplier integration, communication
7. Variation (performance time operating surprises from time to time)	Production process; capacity assignment and order delivery flexibility; custom job configuration	Switching customer assignments back and forth among partners
8. Correction (recovery, return to service)	Production recovery; expediting production	Relationship reestablished; replace existing supplier with alternative suppliers

Implementation of the ASCTM and the methodology

Although the ASCTM tool, the methodology and the supporting tools were developed based on a review of the literature/case studies and reviewed for relevancy by both academic panels and industry practitioners, the validation for its practical applicability is also necessary. However due to the limitation of the time frame involved in implementing the proposed tools, the tool was not completely applied in a single company. We will use this case study to illustrate the implementation of the ASCTM tool.

Case study introduction

The ASCTM tool has been implemented in a composite medium-size plastics manufacturing company, which we will call "Plastix Corporation". Plastix Corporation offers two major lines of small plastic products, which include automobile parts and premiums (toys, figurines and ornaments) with an average output of 100,000 pieces per month. Between 1997 and 2003, 90 percent of the business for plastic premiums went to only one major customer. However in early 2004, demands from this customer declined sharply as Chinese manufacturers entered the business. Competition from these Chinese manufacturers forced the company to reposition its business to serve more niche markets and develop relationships with several new customers.

The orders placed by these new customers are in small quantities with a wide variety of designs and specifications. This complicates the proper management of materials and sub-components. Currently the company interacts with more than 20 suppliers and purchases more than 100 items. During this business transition, the company required a purchasing system that allowed it to acquire the items it need more quickly and more efficiently.

In this paper, we illustrate the implementation of the ASCTM tool to a product-specific supply chain (the retailing box supply chain). Currently, the company purchases the retailing boxes from local suppliers for different end-item products in various shapes, sizes and materials. After the designs and specifications of the boxes are provided by each end customer, the company decides how these retailing boxes will be acquired and with which supplier the order will be placed to ensure that the retailing boxes are available as needed. The difficulty in managing this item can be attributed to frequent changes in the design, material, specification and quantity required by end customers in each time period.

The implementation of the ASCTM tool in the Plastix Corporation is carried out by a cross-functional team consisting of managers and representatives from purchasing, materials management, engineering, production planning and manufacturing. The information from the existing and the prospective suppliers is also necessary to support the implementation.

Model implementation steps – phase 1: identifying and prioritizing changes

A QFD matrix is developed to model and relate the business challenges with the possible changes in purchasing requirements. The final deliverable in this phase is the prioritization of the changes according to their importance to the company. The development of this QFD matrix can be outlined as follows:

First, all business challenges and changes related to purchasing requirements are identified and listed in the matrix rows and matrix columns (refer to Figure 1 and Figure 5). Then, the importance ratings of the challenges (the matrix row) and the priority ratios of the changes (the matrix column) are established based on the likelihood of occurrences and the impact on the company's business

Table II Business practices and organizational infrastructure for agility

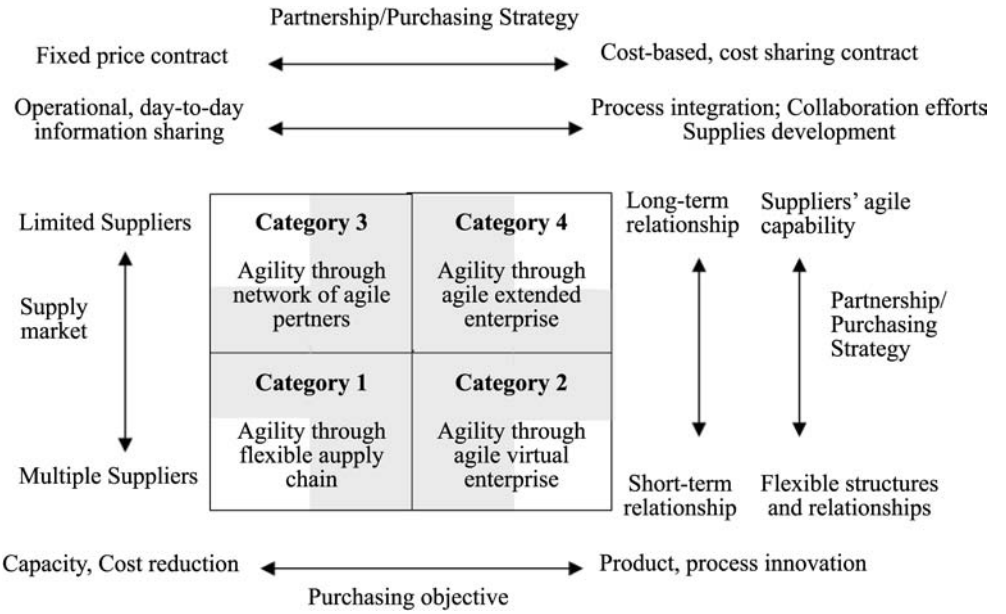
1. Framework and standards	(Establishing a framework and standards needed for network configuration) *Business process*: framework that includes all processes, activities and procedures required to be executed in order to meet the purchasing objective (searching, evaluating, selecting suppliers) under each specific circumstance; Framework that includes all standards, procedures and guidelines for selecting the contract type; Work breakdown responsibilities
2. Encapsulated modularity (system into functional self-sufficient modules)	*Business process*: specific contract content for each specific type of relationship; Multiple modules of standard practices for the purchasing processes (supplier searching, supplier evaluation, supplier selection, contract generation etc.)
3. Facilitated module reuse	(Establishing modules that are readily reusable and ready for reuse/for reconfiguration purposes, System components that facilitate the reuse of modules) *Business process*: templates developed for major purchasing processes *Knowledge*: maintaining historical knowledge and allowing reuse when encountering similar problem
4. Facilitated plug-in compatibility	(Module that is ready to be plugged into the framework structure without any further modification), (System components that facilitate the module to be plugged into the framework structure without any further modification) *Technology*: standardized system and interface (Web, internet-based communication) *Knowledge*: maintaining a list of pre-qualified suppliers; Maintaining knowledge of historical experience to help expedite the development and implementation process *Business process*: minimum performance requirements from suppliers; Certified by a third-party organization *Social and organizational culture*: knowledge sharing with partners; Diversity of business culture
5. Facilitated deferred commitment	(The decision is made on a just-in-time basis. In other words, the time between making decisions and implementation is reduced) *Social and organizational culture*: cross-functional teams; consensus-based decision making; distributed decision making; non-hierarchy decision making *Information/computer technology*; real-time information sharing, computer-based decision making *Knowledge*: knowledge available at the point of decision making
6. Redundancy and diversity	(Identical capability proven ready for reuse with no surprises or unintended consequences) (Diversity available in current system, offering configuration options for custom needs) *Strategy*: multiple sources/partners; redundant sources/partners
7. Peer-to-peer interfacing	(Supporting direct communication among people that need to collaborate and eliminating the hierarchy of communication through silo managers) *Physical structure*: co-location *Business process*: standardized order approval *Social and organizational culture*: cross-functional teams; direct communication both inter- and intra-organization; non-hierarchy decision making *Communication technology*: web-based discussion group
8. Distributed control and information	(Information and decision control distributed to the people that need it in the right place at the right time) *Social and organizational culture*: distributed decision making; non-hierarchy decision making *Information technology*: decentralized information system
9. Self-organization	(Establishing modules and systems that can perform the work, make decisions and change relationships with others) *Business process*: automatic document generation; expert systems for supplier evaluation and selection
10. Facilitated scalability	(Modules or systems that can adjust their size and capacity as needed) *Social and organizational culture*: multi-skill workers; job rotation

respectively using the AHP approach. Because of the space considerations, we are detailing the matrix row in Figure 6, while the matrix column is similarly computed.

As shown in Figure 5, by considering the current business condition, the six important challenges and the six possible changes in the purchasing requirements were identified by the team from the Plastix Corporation. The business characteristics governed by frequent changes in demand patterns were given the highest priority since it has affected the company's ability to control its operational performance. The supplier disruption and the emerging of the new technology were given the low priority because the boxes are supplied mainly by the reliable local suppliers and the technology in this field is relatively mature and progressing slowly. For the priority score of each change, the supply unavailability was given the highest priority when considering its impact on the business. The shortage of supply directly affects the company's service level, which in turn deteriorates the customer's retention and reputation. The variation of quantity was given the lowest priority because the company only incurs some extra cost to dispose of unused items in inventory or to acquire the items needed from the spot market.

Second, the relationship matrix within the QFD matrix can now be completed by determining whether or not a business challenge could bring in a change related to the purchasing

Figure 4 Agile supply chain portfolio analysis



requirement. For each pair of challenge and change, if the relationship between them exists, it must be categorized as strong, medium strong, medium, medium weak and weak. The numeric values for these five ratings are determined through pair-wise comparison.

Third, to justify the importance of the change, we consider both the probability of occurrence and the level of impact it creates. The importance scores of each change listed in the matrix columns (Figure 5) are calculated by adding together all the weighted scores within the same column. These weighted scores are obtained by multiplying the score in the cell with the importance rating of the corresponding challenge and the prioritized rating of the corresponding change (Figure 6). Management should review these scores because they detail the area of change that should be a primary concern for future efforts on change response ability development and agility improvement

Fourth, the "roof" in Figure 1, which describes the correlation between changes, is filled by determining whether each pair of changes is complementary (+) or in conflict (−). In this context, complementary means that both changes can occur simultaneously and thus require special attention. For the Plastix Corporation, the correlation matrix in Figure 5 indicates the likelihood of the company to be pressured by both design and quantity variation. In this case, the company may need an additional analysis to make sure that the approaches it uses to handle the design variation can be used adequately to accommodate changes in quantity.

Model implementation steps – phase 2: identifying the way to accommodate changes through the appropriate mix of approaches for agility creation

With the changes identified in the first phase, the second QFD matrix can be developed to help the company determine the appropriate change response strategies and the ways used for accommodating changes under the proposed strategies. The analysis in this phase begins with identifying the strategies to employ in response to the changes. Knowledge and market intelligence are the keys here. Then, the relationship between the changes and the ways used for accommodating them is examined using the QFD matrix (see Figure 7). The methodology is as follows.

First, appropriate change response strategies are identified for each specific change. The agile supply chain portfolio analysis explained previously can be used to support the strategy selection by considering the purchasing objectives; the source of uncertainties, the characteristics of purchased items, and the characteristic of supply markets (see Table III). In cases that a mix or combination of strategies is necessary to respond to changes, they should be prioritized according to their appropriateness. The hierarchic model for prioritizing the change response strategy based on three factors (implementation cost, applicability ease, and risk) using AHP is illustrated in Figure 8. The hierarchic model can be adapted by other companies to support their decision making process.

In case that a mix or combination of strategies is necessary to respond to changes, they should be prioritized according to their appropriateness. The hierarchic model for prioritizing the change response strategy based on three factors (implementation cost, applicability ease, and risk) using AHP is illustrated in Figure 8. The hierarchic model can be adapted by other companies to support their decision-making process.

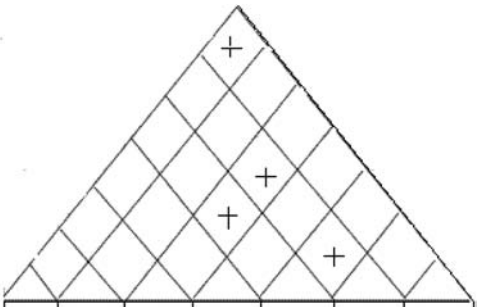
Table IV details the change response strategies that have been employed by the Plastix Corporation to respond to the changes in the retailing box purchasing requirements. Appropriate change response strategies for each specific change appear in the strategy column of Figure 7.

As illustrated in Figure 8, in case the Plastix Corporation has to deal with the variation in order quantities, relying on an existing suppliers' change response capability (strategy 1) and adding new suppliers to obtain capacity (strategy 2) were identified as two strategies to be employed for handling the change. Although, the first strategy is more convenient to implement, the second strategy is still necessary due to the

Table III Four classifications of agile supply chain

Factors	Agility through the flexible supply chain	Agility through agile virtual enterprise	Agility through network of agile partners	Agility through agile extended enterprise
Purchasing objectives	To eliminate non-core processes to obtain capacity, and to reduce cost	To gain access to a wide range of particular capabilities and resources offered by other members, while continuing to develop their core competencies and retain their own independence	To obtain capacity, reduce cost, and take advantage of supplier's capabilities and performances to respond to changes in operational level	To leverage on supplier's unique capabilities, skills, competencies, technical knowledge, and intellectual strengths to respond, and take advantage of changes and new opportunities
Source of uncertainties	The variability of the supply cost and the changing needs of customers for the different types of items	The emergence of the new market with short life cycle and rapidly changing needs	The variability of the customer's requirements from period to period	The evolving market with unstable design, technology and manufacturing processes
Characteristic of market	Mature market Many suppliers exist The relationship and the switching cost is low Suppliers can be easily identified and reached	Emerging market Many suppliers exist Suppliers are geographically located but easily identified The relationship and the switching cost is low	Mature market Limited numbers of supplier The relationship and the switching cost is high	Emerging/growing niche market Limited numbers of supplier The relationship and the switching cost is high
Characteristics of purchased items	Commodity items and standardized products with well structured manufacturing process	A certain group of products or a particular type of service that competes within the niche market	Customizable products, components, and subassembly parts	Innovative products
Supply chain structures	Supply chain structures are dynamic and can be quickly established and reconfigured to locate and bring the required suppliers into the chain	Supply chain structures can be quickly adapted and reconfigured to gain excess to new capabilities The structures are frequently reshaped and changed to better fit the task at hand	Supply chain structures are relatively permanent, allowing companies to capitalize on supplier's capability to respond to changes on demand patterns	Supply chain structures are permanent Several processes are tightly integrated The disbandment can affect the performance and is difficult to accomplish
Type of relationship	Market exchange relationship with no long term commitment Relationship based on short-term contract	Temporary, cooperative partnership Partnership is defined through mutual/sharing benefits	Long-term, cooperative partnership Partnership is clearly defined by contracts	Collaborative, Long-term, partnership Partnership is defined through mutual benefits and joint objectives
Level of cooperation	Operational coordination and monitoring along structured routines, information exchanges Coordination occurs mainly during bidding and contract negotiation No joint efforts and cooperation	Collaborative effort to allocate resources and match different capabilities, or core competencies in a more effective manner Partnership relies on telecommunication infrastructure to share information on objectives and strategies without physical integration	Coordination through sharing detailed operational information (order assignment, workflow, stocking policy, customer's demand, inventory level, and, delivery schedule Partnership may require some dedicated resources of suppliers	Collaboration effort to develop mutual core competencies and to create tactical and strategic plans Sharing knowledge and learning and some extent of physical and process integration Collaboration in the design, development, manufacturing, and costing processes
Termination of partnership	When cost increases beyond a certain threshold or purchasing requirements are not efficiently met. An uncoupling can be done easily so that a connection can be made with more beneficial suppliers in a timely manner	When the market for the product or service declines When the opportunity has disappeared	When something adverse happens When other players offer better performance in terms of product function, cost or service (Normally supplier has a promise of repeat business)	When the company diversifies its market to a different type of product When the market for the product or service declines When other players offer better performance
Driving factors	Supplier database and internet technology to help locate new suppliers and electronic data exchange to expedite the transaction processes Distributed authority on supplier selection and purchasing order release Web-based technology to facilitate the bidding and contract negotiation processes	Telecommunication infrastructure, electronic-based communications, computer network, electronic workspace, and information sharing/ transparency Shared value, vision, culture, and goals and relationship that emphasizes trust, co-density, and fairness Responsibility-based, self-organized workers	Sharing of operational information Supplier flexibility Internet and web-based communication technology Flexible contract	Sharing of operational/strategic information Collaborative efforts to achieve mutual goals and objectives Knowledge transfer, process integration and synchronization Shared value, vision, culture, and goals Trust-based relationship

Figure 5 Model phase one



	Importance rating	Variation in design	Unexpected change in product design	Supply Unavailability	Cost reduction	Unexpected increase in quantity	Variation in quantity level
Priority ratios of the changes		0.065	0.167	0.442	0.163	0.105	0.059
Competitor entering business	0.111				0.51		
Customizable product	0.168	0.51					0.51
New technology introduced	0.065		0.51				
Global business	0.257		0.13		0.13	0.51	
Supplier disruption	0.028			0.51			
Business Characteristic	0.370	0.51					0.51
Importance to the company (Scores)		0.018	0.011	0.006	0.015	0.014	0.016
Scaled importance score		1.80	1.10	0.60	1.50	1.40	1.60

capacity limitation of each supplier. The appropriateness of the first and the second strategy can be attributed to the potential of the existing suppliers to offer flexibility in purchasing quantity adjustment and the availability of suppliers in the market from which the company can acquire the boxes respectively. After applying the AHP model (in Figure 8) to evaluate the relative importance of these two strategies, more priority was given to the first one because it is easier and more cost effective to implement. Therefore, the first strategy should be implemented as the primary strategy, complemented by the second strategy when it is necessary.

Second, the QFD matrix is constructed by listing the changes with the associated strategies in the matrix rows and the ways to accommodate these changes in the matrix columns (Figure 7). The ways to accommodate changes can be identified and classified into two groups according to the change response approaches discussed earlier in the theoretical foundation. The first group consists of the ways that aim toward adaptive and flexible structures and the second group consists of the ways that aim toward the supplier's agile capabilities. The comprehensive list of the ways for change accommodation (Table I) discussed earlier can be used to support this identification. The importance rating of each change is taken from the overall priority rating score determined in phase 1. However, for the change that requires more than one strategy to handle, the priority score needs to be allocated among all strategies by weighting it with the strategy priority scores determined in the first step to obtain the importance rating score of that change relative to each specific strategy.

Third, the relationship between the changes and the ways to accommodate them is evaluated using numeric values as strong, medium strong, medium, medium weak and weak (Relationship Matrix – Figure 1).

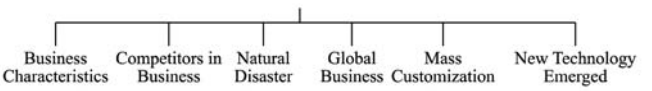
Fourth, the importance score of each way used for accommodating changes is calculated by adding together all the weighted scores in the same column.

Fifth, interrelationships among the ways used for accommodating changes are determined. These can be one- or two-way relationships. For example, if the company can speed up the contract generation process, the new supplier

Figure 6 Prioritizing the likelihood of the business challenge

Step 1: Constructing the hierarchic model

The most likely challenges are identified at the top level of the hierarchy. See Matrix Row (reference Figure 1-The QFD matrix) of Figure 1-Model Phase one in the Appendix



Step 2 and 3: Setting priorities and establishing the ratio scales.

The weight or priority of each challenge is determined through pair-wise comparison. For the relative importance, we use the range one through nine (Satty, 1994). For example, the global business factor (Glob) is assigned a five when compared to the new technology factor (Tech). This means that the chance for expansion into the international market is five times higher than the chance to face changes in the underlined technology.

The priority score or the weight of each challenge and the consistency score is calculated using the mathematical procedure in Satty (2001).

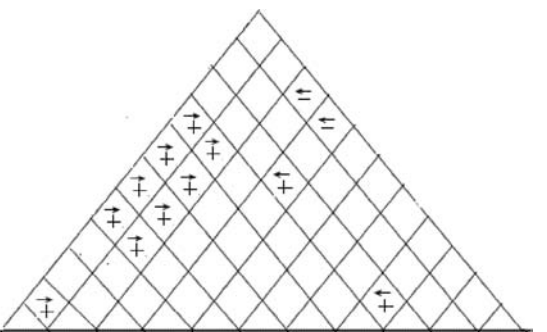
Pair-wise comparison

	Mass	Comp	Dis	Tech	Bus
Glob	2	3	7	5	½
Mass		2	6	4	1/3
Comp			5	3	¼
Dis				1/5	1/7
Bus					1/5
Consistency 0.03					

Priority scores

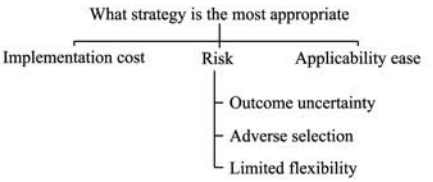
Glob	Mass	Comp	Dis	Tech	Bus
0.257	0.168	0.111	0.028	0.065	0.350

Figure 7 Model phase two



	Change response strategy	Important rating	New supplier selected	New contract generated	Existing supplier removed	Rescheduling suppliers' assignment	New supplier integrated for capability	New supplier integrated for capacity	Order consolidation	Supplier's delivery quantity flexibility	Supplier's production quantity increase/decrease	Supplier's custom job configuration	Manufacturing Improvement
		Adaptive and flexible relationship								Suppliers' agile capability			
Variation in design	3	1.70				0.51				0.26	0.13	0.51	
Variation in quantity	2	0.46	0.51	0.13				0.51					
	4	1.24								0.51	0.51		
Unexpected change in design	1	1.10	0.51	0.51	0.26		0.51						
Rapid need for cost reduction	4	1.40							0.06				0.51
Unexpected increase in quantity	1	0.51	0.51	0.13				0.51					
	4	0.99								0.51	0.51		
Supply unavailability (disruption)	1	0.31	0.51	0.13			0.51						
	3	0.39				0.513				0.51	0.51		
Importance to company (score)			1.2	0.7	0.3	1.0	0.7	0.5	0.1	0.7	1.5	0.8	0.7
Scaled importance score			12	7	3	10	7	5	1	17	15	8	7

Figure 8 Prioritizing the appropriateness of the change response strategy



Step 1: Constructing the hierarchic model

The change response strategy appropriateness is identified at the top of the hierarchy. Similar to procedures described in Figure 5 - Prioritizing the likelihood of the business challenge, the next level enumerates the factors (implementation, applicability, risk) that are used to determine the strategy's appropriateness. The risk factors are decomposed into seven sub-factors, 1.adverse selection, 2.dishonesty and opportunism, 3.information vulnerable, 4.knowledge access, 5.limited flexibility, 6.legal and intellectual property, 7.outcome uncertainty (Zsidisin et al., 2004; Spekman and Davis, 2004), but we only use three because the priorities of the other four risk factors are so small with the regard to the other three, that they are of no significance in our calculations.

Step 2: Computing factor weight score

Pair-wise comparison is used to compute the weight scores of the three factors in level one.

	Risk	Applicability	Priority scores
Implementation cost	3	1/2	0.320
Risk		1/4	0.122
Applicability			0.558
Consistency 0.02			

The weight scores of the risk sub-factors are also pair-wise compared and computed.

	Adverse selection	Limited flexibility	Priority scores
Outcome uncertainty	1	3	0.443
Adverse selection		2	0.387
Limited Flexibility			0.169
Consistency 0.02			

Step 3: Calculate the priority scores

In this case, since the implementation cost and the applicability factors are not further decomposed, the weight scores obtained in step 2 are used as the priority scores. However, for the risk factor, the decomposed sub-factors have to be weighted.

	Weight/Priority scores
Implementation cost	0.320
Applicability	0.558
Risk	0.122
Outcome uncertainty	0.054= (0.443*0.122)
Limited flexibility	0.021= (0.169*0.122)
Adverse selection	0.047= (0.387*0.122)

Step 4: Evaluating change response strategies using pair-wise comparison against the factors listed in the hierarchic model

Two strategies, adding a new supplier and relying on existing suppliers were identified as the alternatives to be employed when faced with the variation in order quantities. The appropriateness of these change response strategies is evaluated by pair-wise comparison against the implementation cost and the applicability factor in level one and the risk's sub-factors in level two of the hierarchic model. The scores obtained are weighted by their priority scores (obtained in step 3) and then added up to obtain the strategy's priority score. Our model is customizable so that the priority scores of factors and sub-factors are specific to each company. The results appear in Figure 2– Model Phase Two in the Appendix

	Strategy 1	Strategy 2
Implementation cost (0.320)	0.333	0.667
Applicability (0.558)	0.5	0.5
Risk (0.122)	0.5	0.5
Outcome uncertainty (0.054)	0.5	0.5
Limited flexibility (0.021)	0.75	0.25
Adverse selection (0.047)	0.333	0.667
Strategy priority score	**0.444**	**0.556**

Table IV Examples of change response strategy

Change response strategy	Supply market and purchasing condition	
1. Replace with new suppliers	It is relatively easy and economically feasible to locate the potential suppliers	Existing suppliers do not have sufficient ability to respond to change and need to be removed from the chain
2. Add additional suppliers		New suppliers need to be added to the chain to complement existing suppliers in responding to changes
3. Rearrange assignments among existing suppliers	It is difficult to locate potential suppliers or it is not cost effective to switch suppliers	After rearranging the customer assignment, the existing suppliers have sufficient ability to respond to changes
4. Rely on supplier's change response capability		Existing suppliers have sufficient ability to respond to change

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can be integrated to obtain capacity/capability more quickly. An arrow is used to indicate the relationship direction by pointing the head to the way that can be better accomplished with the achievement of that identified at the tail. Negative interrelationships often suggest that tradeoffs may be required.

Model implementation steps – phase 3: key deployment area analysis

At this point, companies will have specific ideas about the approach they should take to respond to changes. The question is how these change responses can be implemented quickly and properly in order to create and improve its supply chain agility. This necessitates three requirements that a company should consider:

1 Ensure that agile suppliers are selected and integrated into the supply chain.
2 Ensure that the company has the appropriate level of supplier-buyer integration, sufficient internal infrastructure and a proper relationship to enhance and capitalize on supplier's agile capabilities.
3 Ensure that company has sufficient ability to adapt its supply chain structure and relationship to respond to changes quickly and efficiently

For the first consideration, companies need to develop supplier evaluation and selection processes that incorporate criteria for evaluating suppliers based on their agile capabilities, which will be left for future research. In this phase, the focus will be on the second and the third considerations by identifying the business practices and infrastructure that are necessary to support the use of supplier's agile capabilities and the creation of supply chains with adaptable structures and relationships. The methodology is as follows.

First, all necessary practices and infrastructures are identified and organized into two groups, those that support the use of supplier agile capabilities and those that help enhance the creation of the adaptable structures and relationships. For the first group, the identification can be done in a straightforward manner by focusing on the need for the proper relationship and appropriate integration level with each supplier. For the second group, the identification isn't a trivial task since special characteristics are normally required when developing a system to support the reconfiguration and adaptation. We decompose the business practices and organizational infrastructures into six major categories, which include: legal explicit process; communication and computer-based technology; social and organizational culture; partnership strategy; knowledge and information; physical structures.

The list of the business practices and organizational infrastructures in Table II discussed earlier can be used to support the identification. The list provides examples of a set of enabling characteristics for agility creation.

Second, the QFD matrix is constructed by listing the change accommodation approaches in the rows and the business practices and enterprise infrastructures in the columns of the matrix Figure 9. The column for the change accommodation approach priority ratings can be filled with the importance scores determined in phase 2.

In the case of the Plastix Corporation, several brainstorming sessions were held in order to complete the analysis. In the first few sessions, the team members proposed a large number of business practices and infrastructures which were later eliminated or grouped together yielding those that are most critical as displayed in the columns of the matrix in Figure 9.

Third, the relationship between the change accommodation approaches and the business practices/organizational infrastructures is evaluated by considering the importance of each business practice and infrastructure in supporting the implementation of change accommodation. The five numeric values similar to those used in the first two phases can be applied for evaluating the relationship.

Fourth, the importance score for each business process and infrastructure is calculated as in phase 2. The scores obtained can help companies to identify and prioritize the business practices that need to be reinforced and the infrastructure that needs to be established in order to improve their agility. By explicitly identifying these importance scores, money and other resources can be invested and allocated appropriately to each specific organizational component. In addition, the performance assessment on the company's current ability to accommodate the changes when they occur is also incorporated into the model. This assessment focuses on a balanced response-to-change capability across four metrics; time, cost, robustness, and scope (Dove, 1996).

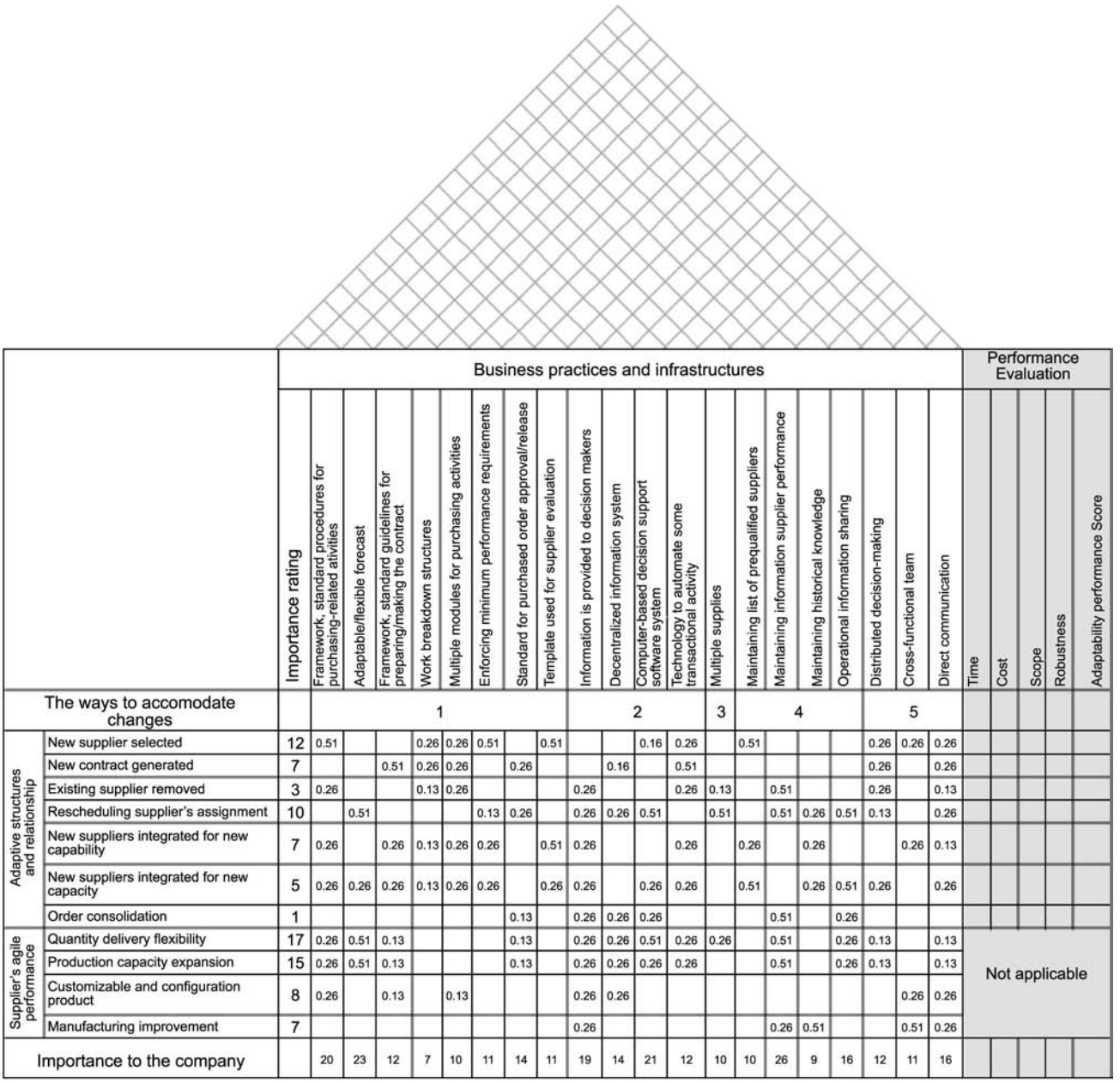
Fifth, the correlation matrix is completed by determining which business practices and infrastructures support (+) or conflict (−) with one another. Since the company may experience some difficulties if its business practices and infrastructures are not consistent, tradeoff analysis should be performed in this case to manage and resolve the conflicts.

Final recommendations

Based on the information obtained from the ASCTM tool, the Plastix Corporation needs to reposition its purchasing strategy and practices for the retailing box to aim for more adaptability of the supply chain structure and relationship by maintaining only the arm-length relationship with suppliers. The selection of suppliers should be based on cost, quality, and also flexibility in purchasing quantity adjustment. The following suggestions are given to the Plastix Corporation as starting points for agility improvement:

1 Reduce the time used for locating and establishing the relationship with new suppliers by:
   - developing a standard framework and guidelines for supplier selection and contract generation processes;
   - maintain a list of pre-qualified suppliers; and
   - increase the use of e-action and e-bidding to reduce communication time.
2 Revise the supplier selection strategy to put more weight on supplier's lead-time, responsiveness, and flexibility and negotiate for contracts that allow the adjustment of purchasing quantity.
3 Develop standard performances and practices for new suppliers to reduce the time used for integrating them into the supply chain.
4 Consider the application of more computer-based systems to help making a decision related to order allocation and scheduling.

Figure 9 Model phase three



		Importance rating	Framework, standard procedures for purchasing-related ativities	Adaptable/flexible forecast	Framework, standard guidelines for preparing/making the contract	Work breakdown structures	Multiple modules for purchasing activities	Enforcing minimum performance requirements	Standard for purchased order approval/release	Template used for supplier evaluation	Information is provided to decision makers	Decentralized information system	Computer-based decision support software system	Technology to automate some transactional activity	Multiple supplies	Maintaining list of prequalified suppliers	Maintaining information supplier performance	Maintaining historical knowledge	Operational information sharing	Distributed decision-making	Cross-functional team	Direct communication	Time	Cost	Scope	Robustness	Adaptability performance Score
			Business practices and infrastructures																				Performance Evaluation				
The ways to accomodate changes			1								2				3	4				5							
Adaptive structures and relationship	New supplier selected	12	0.51			0.26	0.26	0.51		0.51			0.16	0.26		0.51				0.26	0.26	0.26					
	New contract generated	7			0.51	0.26	0.26		0.26			0.16		0.51						0.26		0.26					
	Existing supplier removed	3	0.26			0.13	0.26				0.26			0.26	0.13		0.51			0.26		0.13					
	Rescheduling supplier's assignment	10		0.51				0.13	0.26		0.26	0.26	0.51		0.51		0.51	0.26	0.51	0.13		0.26					
	New suppliers integrated for new capability	7	0.26		0.26	0.13	0.26	0.26		0.51	0.26			0.26		0.26		0.26			0.26	0.13					
	New suppliers integrated for new capacity	5	0.26	0.26	0.26	0.13	0.26	0.26		0.26	0.26		0.26	0.26		0.51		0.26	0.51	0.26		0.26					
	Order consolidation	1							0.13		0.26	0.26	0.26				0.51		0.26								
Supplier's agile performance	Quantity delivery flexibility	17	0.26	0.51	0.13				0.13		0.26	0.26	0.51	0.26	0.26		0.51		0.26	0.13		0.13	Not applicable				
	Production capacity expansion	15	0.26	0.51	0.13				0.13		0.26	0.26	0.26	0.26			0.51		0.26	0.13		0.13					
	Customizable and configuration product	8	0.26		0.13		0.13				0.26	0.26									0.26	0.26					
	Manufacturing improvement	7									0.26						0.26	0.51			0.51	0.26					
Importance to the company			20	23	12	7	10	11	14	11	19	14	21	12	10	10	26	9	16	12	11	16					

Conclusions and areas for further study

We have provided a model, the Agile Supply Chain Transformation Matrix, and the implementation methodology necessary for a systematic approach to achieve agility in the supplier-buyer supply chain. Due to changes in the business environment taking place more and more rapidly these days, many companies need to improve their agility continuously. There is however, an overall lack of understanding as to how this might be achieved and what tools /methodology/ techniques can be used in practice. A comprehensive methodology, tool, and technique to help companies improve agility are needed in industry. The methodology and the ASCTM tool proposed in this paper, though it still needs to be fully developed and validated, constitutes an important effort to bridge the gap between theory and practice. For practitioners, the proposed methodology and tool provides a basis for assessing their business situations and a guideline for recognizing capabilities required for improving supply chain agility.

Further studies will extend the applicability of our tool as follows:

- The model limits the analysis to only the change response capabilities and does not explicitly address the company's ability to recognize the changes. Further development is needed to incorporate this additional capability.
- Additional case studies need to be conducted with additional companies to test and validate the practicality of the model.

- Development of the criteria for supplier performance evaluations in order to ensure the selection of appropriate suppliers consistent with the agility approach adopted by each company.

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