AGILE SUPPLY NETWORK TRANSFORMATION MATRIX: A NEW QFD-BASED TOOL FOR CREATING AN AGILE ENTERPRISE

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Abstract: Under today's volatile business environment, companies are reaching the point where they need to be more agile– intelligent, fast, flexible, and responsive to changes. Leveraging supplier-buyer relationship to create an agile supply chain is one of the strategies that can help companies make a successful transition to an agile enterprise. Here we introduce a model that can be used to successfully transform a business: the Agile Supply Chain Transformation Matrix, a tool based on the Quality Function Deployment (QFD), and the Analytic Hierarchy Process (AHP). More specifically, we have created a tool that can relate the business changes with the appropriate approaches for supply chain configuration and supplier-buyer relationship establishment and determine the business processes and the infrastructures needed to support agility. This tool is built upon the concepts developed through the Agility Program at Lehigh University in partnership with company project sponsors and the Commonwealth of Pennsylvania Department of Community and Economic Development. In particular, through the application of AHP our method can help in relating the changes to the strategies needed for an agile supply chain configuration.

Keyword: Agility, agile supply chain, supply chain design, QFD application, strategic sourcing

1. 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 21st century has heightened the need for more competitive enterprise strategies. Efficiency alone is insufficient. 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. 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 extreme of ideal lean and instant response (Preiss, 2005). Managing in this new framework depends on the availability of some special infrastructures especially the improved data and information system (Preiss and Ray, 2000).

In a broad context, the application of agility differs at each of several levels within an enterprise. Examples of levels include single and families of products and processes, groups of functional departments, an individual company and groups of companies within the supply chains. These levels are interrelated in the way that the strategic decisions at each level enable or constrain available alternatives at the levels above and below.

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In the 21st century, business competition is among supply chains. Companies today have moved beyond their own walls to create relationships and integrate parts of their businesses with their partners (suppliers, customers or even competitors). 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 manage the relationships with all their business partners (Lambert, 2004). To be truly competitive, companies need to implement the right approach in configuring the supply chain structure and establishing the relationship (Christopher et al., 2000).

While the research on supply chain agility attempts to identify the conceptual framework, the characteristics and the benefits of an agile supply chain and propose the technological implementation that can be used to enable agile capabilities, it does not provide sufficient guidelines on how agility can be created in the supply chain, especially on the supply side. Such guidance is particularly important because there are no formulae for agility creation. Each company must define its own pathway to achieve agility (Goldman, et al., 1994).

We propose to fill this guideline-gap by expanding upon our previous work, with the introduction of the Agile Supply Chain Transformation Matrix, a tool based on the QFD modeling methodology that is consistent with the above framework (Baramichai and Zimmers, 2005). 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 mainly on the sourcing processes. Our methodology attempts to find the balance point between the need for adaptation through long-term collaborative relationships with agile suppliers and the adaptiveness companies could gain through flexible and loss-coupling relationships..

2. Literature review

2.1 Agility concept

The meaning of agility in supply chains has been the source of considerable debate and academic discussion. 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 provide 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) has extended the definition of agility into a wider business context by addressing the characteristics of an agile supply chain. In his work, agility in supply chains relates 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.

We assert that an agile supply chain enables enterprises to be agile. 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 structure and relationships 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 enterprise agility.

2.2 Agile supply chain creation

An agile supply chain is a major driver for an enterprise's agility. The integration and relationships with business partners in the supply chain become the keys to performance enhancement for agile enterprise (Preiss, Goldman, Nagel, 1996). According to Webster (1992) , Mohr and Nevin (1990), and Bitici, et al. (2005), 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. Most of the literature suggests that companies can enhance their agility by capitalizing on their suppliers' agile capabilities through the long-term, collaborative relationships.

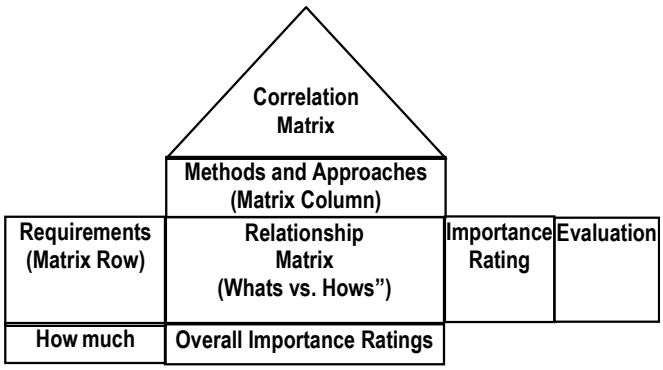


Figure 1 - The QFD

2.3 The Quality Function Deployment (QFD)

The Quality Function Deployment (QFD) is a quality system originated in Japan in the late 1960's from the work of Dr. Mizuno and Dr. Akoa (Akoa, 1994, 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, with the growth of Six Sigma that emphasizes the application of good statistical practices and legitimate measurement methods, several techniques used in traditional QFD seem to be inappropriate. A group of experienced practitioners at the QFD Institutes developed a modern QFD that offers a better way to perform an analysis (Zultner, 1995). One of the major improvements in this modern QFD is on the quantitative method used to establish the metrics and prioritize the alternatives. Instead of relying on the ordinal scale, this modern QFD utilizes the Analytical Hierarchy Process (AHP), which is the simplest prioritization method that provides accurate and reliable results on a ratio scale (Zultner, 2005). In tradeoff analysis it is important to know the priority rather than the rank of a need. 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, displays the house of quality i.e., the QFD matrix which is the model used in QFD analysis. We will be referencing this model liberally 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 following (Satty, 2001):

1. Define the problem and structure the hierarchy of the factors and alternatives by breaking down them into a hierarchy of decision elements.
2. Construct a pair-wise comparison matrix and obtain all judgment by comparing pairs of factors with respect to a criterion in the superior level. This is required to be performed for all levels and clusters in the hierarchy.
3. Use hierarchical synthesis to weight the priority scores of each factor by the weights of the creditors in the superior level, and take the overall weighted priority scores corresponding to those in the net lower level to obtain an overall priority score for the lowest level of the hierarchy.
4. Evaluate the consistency of the entire hierarchy, theoretically ≤ 0.1.

3. Theoretical foundation

3.1 Change response approaches: Two ways for agility creation

Although, most of the literature suggests that long term collaborative relationships with suppliers can help companies create and improve their agility, we argue that in some cases a tight relationship with one supplier may prevent a supply chain design from being adaptive and flexible. For example, 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 either establishing long-term collaborative relationships with a group of agile suppliers, adapting the supply chain structures and relationships quickly and efficiently, or implementing both strategies concurrently when facing with unpredictable changes. The selection of the strategies to be taken 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.

Our assertion is further substantiated by what we believe to be the complementary strategies of an "agile extended enterprise" and an "agile virtual enterprise". The similarity in strategies lies in the fact that they both 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 (Browns and Zhang, 1999). An agile virtual enterprise can be seen as a temporary linking of enterprises to address and respond quickly to changes through high technology and advanced information systems (Beckett, 2003) while the agile extended enterprise depends upon more permanent relationships among partners.

3.2 Business challenges and changes in sourcing segment

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). Identifying the likely change is what leads to a solid list of requirements against which any design can be measured (Dove, 2005). This list will assist companies in identifying the approaches to employ for responding to changes so that they can be in a better position for continued survival and growth.

Regardless of industry or geographic location, the challenges in today's business are compounded by the fact that they are ongoing, unpredictable and difficult to manage, making the overall business climate volatile and the need for adaptability paramount (IDC study, 2002).

Challenges in the business environment can disturb and cause changes to any supply chain segment such as sourcing, manufacturing and distribution. We restrict our discussion to the changes related to the sourcing 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 eight categories as follows:

1. Process: Unexpected need for new supplier manufacturing capabilities.
2. Quality: Unexpected changes in supplier's quality standard or variation in the quality of supplied items per time period.
3. Design: Changes or variation in the design of an item acquired from supplier.
4. Quantity: Increase/decrease or variation in a supplier's order quantity.
5. Lead time: Unexpected reduction or variation of the order lead-time.
6. Availability: Unexpected disruption of a supplier or shortage of an item in the market.
7. Cost: Unexpected cost reduction or market price increase of an item acquired from a supplier.
8. Legal: Unexpected changes in substantive legal status of a purchased item or service

In order to manage changes, specific approaches have to be customized based on the different characteristics of changes. 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 variations in the external business environment. These unexpected changes are unlikely to be predicted or anticipated in advance and occur within a volatile business environment. These unexpected changes occur infrequently and they always have a major impact to company business as they could suddenly break historical patterns and create new trends.

4. Model development and case study

The contrasting of the environmental dynamics to the enterprise's ability to keep pace assists in pinpointing the areas needing attention and leads to the identification of key practices. Our tool was developed by applying the methods used in the Quality Function Deployment (QFD), specifically a three-phase model, and the Analytic Hierarchy Process (AHP). This model allows companies to work back from the objectives to the means for achieving them. 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 approaches used for 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 agile capabilities.

4.1 Case study introduction

We illustrate our tool, the Agile Supply Chain Transformation Matrix, through a case study of a composite medium-size plastics manufacturer (Plastix Corporation) by focusing on a product-specific supply chain (the retailing box supply chain). Currently, the company buys the retailing boxes from local suppliers in various shapes, sizes and materials for different end-item

products. After the design 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, specification and quantity required by end customers in each time period.

4.2 Model development and implementation steps

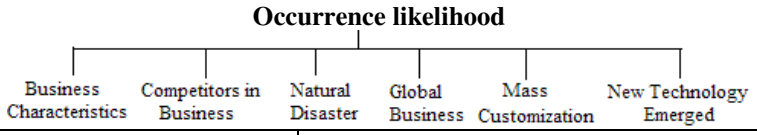
4.2.1 Phase 1: Identifying and prioritizing changes

A QFD matrix is developed to model and to relate the business challenges with the possible changes in sourcing requirements to identify the importance of each change based on the probability of occurrence and relative impact. For the "Plastix Corporation, seven most important challenges were determined by the teams consists of vice presidents and the business analysts. Then the second team consists of managers from cross functional departments (product design, materials management, engineering, production planning, manufacturing) identified the seven possible changes related to sourcing and purchasing requirements (see Figure 3 – Model Phase One). The development of this QFD matrix can be outlined as follows:

All business challenges and changes related to sourcing are identified and listed in the matrix rows and matrix columns (reference Figure 1) respectively (see Figure 3 – Model Phase One). Then, the importance ratings of the challenges, the matrix row (Figure 2 - Prioritizing the likelihood of the business challenge) and the priority ratios of the changes, the matrix column (prioritizing the change in purchasing and sourcing) are established using the AHP approach we have described. Because of space considerations, we are detailing the matrix row, while the matrix column is similarly computed.

Step 1: Constructing the hierarchic model

The most likely challenges are identified at the top level of the hierarchy. See Figure **3**, Matrix Row (reference Figure 1).



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 (2000).

Pair-wise comparison

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

Priority scores

	Glob	Mass	Comp	Dis	Tech	Bus
Rating	0.257	0.168	0.111	0.028	0.065	0.370

Figure 2 - Prioritizing the likelihood of the business challenge

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 sourcing. 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.

The importance score of each change listed in the matrix columns (Figure **3**) is 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. Management should review these scores because they detail the most likely changes to impact their business.

The "roof" in Figure 1, which describes the correlation between changes, (see Figure **3**), 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.

As shown in Figure **3**, for the retailing box item, it is possible that the "Plastix" corporation will face a variation in both design and quantity. Therefore, the company may decide to perform additional analysis to make sure that the approaches they use to handle the design variation can be used adequately to accommodate changes in quantity.

4.2.2 Phase 2: Identifying the appropriate mix of approaches for agility creation and identifying the way to implement them.

The second QFD matrix is now developed to help the company with the strategic decision regarding the response to changes and the timely and cost effective ways to accommodate these changes using the two response approaches we detailed in the theoretical development previously. The company has to identify the best way to arrange the relationships with their suppliers and construct the supply chain so that the impact is minimal. The company must begin by identifying the strategies to employ in response to the changes. Knowledge and market intelligence are key here. A team consisting of personnel from product design, materials management, engineering, production planning, manufacturing and suppliers' representatives came up with several approaches to accommodate each change. The team includes suppliers' representatives in the first and second brainstorming sessions to obtain information regarding each supplier's capability to respond to change. Then, the relationship between the changes and the ways used for accommodating them, through a particular strategy, is examined using the QFD matrix (Figure 4 – Model Phase Two). The methodology is as follows:

Appropriate change response strategies are identified for each specific change by considering the functional and operational characteristics, market conditions, and business environment of the purchased item, in this case, the retailing box. A mix or combination of strategies may be necessary to respond to changes. The AHP approach prioritizes the appropriateness of these strategies. Table 1 - Examples of change response strategy, is an example of change response strategies that have been employed by the "Plastix Corporation" to respond to the changes in the retailing box sourcing requirements. These rankings appear in Figure 4 – Model Phase Two, in the Strategy column.

Change response strategy	Supply market and sourcing condition	
1. Replace with new suppliers	It is relatively easy and economically 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 response to change capability		Existing suppliers have sufficient ability to respond to change.

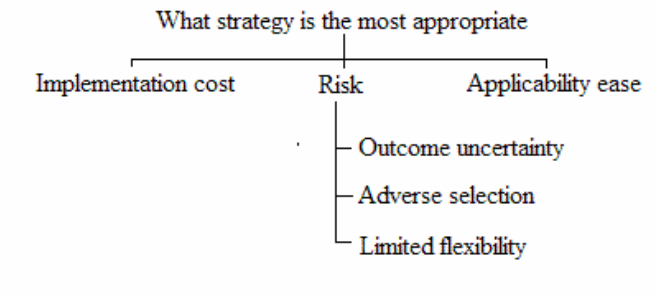
Table 1 - Examples of change response strategy

The hierarchic model for prioritizing the change response strategy using AHP is illustrated next. Other companies can adapt this model to support their decision making process.

Second, the QFD matrix is constructed by listing the changes obtained from Phase One with the associated strategies in the matrix rows and the ways to accommodate these changes in the matrix columns (Figure 4 – Model Phase Two). The ways to accommodate changes can be classified into two groups according to the change response approaches. 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 capability. We apply the framework reported by Dove (1996) on eight domains of change responses to help identify and categorize the ways to accommodate changes as shown in Table 2. The importance rating of each change can be taken from the overall priority rating scores determined in Phase One. However, for the change that has alternative strategies, 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 (Correlation Matrix - Figure 1 - The QFD). Similar to Phase One, the relationship must be categorized as strong, medium strong, medium, medium weak and weak.

Fourth, the importance score used for accommodating changes is calculated by adding together all the weighted scores in the same column. The analysis in this phase conveys several pieces of information that are necessary for developing sourcing strategies. The agile supply chain portfolio analysis introduced earlier can be used to assist the decision making. For example, if the analysis indicates that the company should respond to the change by creating adaptive structures and relationships (most ways used to accommodate changes fall under this approach), the inappropriate strategy would be maintaining the long-term contract and tightly integrating with any particular supplier.



Step 2: Computing factor weight score

Pair-wise comparison is used to compute the weight scores of the three factors in level one. The weight scores of the risk sub-factors are also pair-wise compared and computed.

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

	Adverse selection	Limited flexibility	Weight/Priority scores
Outcome uncertainty	1	1	0.443
Adverse selection		1/2	0.387
Limited Flexibility			0.169

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.

Step 1: Constructing the hierarchic model

The change response strategy appropriateness is identified at the top of the hierarchy (left image) similarly to Figure 2, the next level enumerates the factors that are used to determine the strategy appropriateness (implementation,, applicability risk,). The risk factors are decomposed into seven sub-factors (Zsidisin et al., 2004; Spekman and Davis, 2004), but we only use three because the priorities of four risk factors are so small with the regards to the other three, that they are of no significance in our calculations. See the matrix row (reference Figure **1**) in Figure 4 – Model Phase Two.

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

The appropriateness of all 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 4 – Model Phase Two.

	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)

Fifth, interrelationships among the ways used for accommodating changes are determined. These can be one- or two-way relationships. For example, if the supplier has flexibility in delivering the products or services, the switching assignment among suppliers should be achieved more quickly. An arrow is used to indicate the relationship direction by pointing the head in the direction of the approach that is impacted. These interrelationships assist in identifying areas where improvements compliment or cause adverse effects to alternatives. Negative interrelationships often suggest that tradeoffs may be required.

Change responses (Dove, 1996)	Our contribution	
	Supplier unique capabilities	**Adaptive relationship**
1. Creation (Build something new or remove something completely)	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 that need to be accommodated 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.

Table 2 - How to accommodate changes

4.2.3 Phase 3: Key deployment area analysis

At this point, companies will have specific ideas about how to create and improve agility in their supply chain. The focus is on three considerations in order to identify the business practices and infrastructures required to support the use of supplier agile capabilities and create a supply chain with adaptable structures and relationships:

1.) Ensure that agile suppliers are selected and integrated into the system. The company needs to develop supplier evaluation and selection processes that incorporate criteria for evaluating suppliers based on their agile capabilities.

2.) Ensure that companies have the appropriate level of supplier-buyer integration, sufficient internal infrastructure and a proper relationship to enhance and capitalize on supplier agile capabilities.

3.) Ensure that the supply chain configuration and relationships can be adapted quickly and efficiently.

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 lead to adaptive relationships and structures(Baramichai, M. and Zimmers, E. W. 2005). 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. To perform the analysis in this

phase, representatives from all related functional departments are teamed together in brainstorming sessions. Each of them will provide information related to the areas in which they specialize. In general, this team includes production engineers, lawyers, product designers, analysts, shop-floor supervisors as well as manager from planning, information system, quality and research and development departments.

For the second group, the identification tends to be more involved since special characteristics are normally required when developing an adaptive system. We will use the design principles based on the system response architectures of reusable modules that can be reconfigured in a scalable framework (Dove, 1996, 1999). These design principles form a set of enabling characteristics of enterprise elements for enterprise agility. In the table below, we decompose the business practices and organizational infrastructures into six major categories:

1.) Legal, Explicit Process

2.) Information And Communication

3.) Social And Organizational Culture

4.) Strategy

5.) Knowledge

6.) Physical Structures

Table 3 displays examples of business practices and organizational infrastructures according to Dove's (in italics) design framework.

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. The column for the change accommodation approach priority ratings can be filled with the importance scores determined in Phase Two.

Third, the relationship between the change accommodation approaches and the business practices and organizational infrastructures is evaluated to analyze how important each business practice and infrastructure is in supporting the implementation of the change accommodation approach and promote the company's agile capability. The relationship can be categorized into one of the five ratings (same as those used in the first two phases). The numeric values for these five ratings can be determined and applied to evaluate the relationship.

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 sourcing objective (searching, evaluating, selecting suppliers) under each specific circumstance; Framework that includes all standards, procedures and guidelines for selecting the contract type, preparing the contract content and writing the final contract for each specific type of relationship; Work breakdown responsibilities; Multiple modules for sourcing processes including supplier searching and evaluation.
2. 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 sourcing processes. *Knowledge*: Maintaining historical knowledge and allowing reuse when encountering similar problem.
3. Facilitated plug 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). *Information and communication:* Standardized system and interface (Web-based, 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.
4. 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, cross-functional collaboration; Consensus-based decision making; Distributed decision making, non-hierarchy decision making *Information and communication;* Real time information sharing *Knowledge:* Knowledge available at the point of decision making
5. Peer-to-peer interfacing (Supporting direct communication among people that need to collaborate and eliminating the hierarchy of approval and sign-off as well as communication through silo managers) *Social and organizational culture:* Cross-functional teams; Direct communication both inter and intra organization; Distributed decision making, non-hierarchy decision making *Information and communication*: Web-based discussion group
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. 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 and communication*: Decentralized information system
8. 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 suppliers evaluation and selection
9. Facilitated scalability (Modules or systems that can adjust their size and capacity as needed) *Social and organizational culture*: Multi-skill workers; Job rotation

Table 3 - Business practices and organizational infrastructures for agility

Fourth, the importance score for each business process and infrastructure is calculated as in Phase Two. The scores obtained help companies identify and prioritize the business practices that they need to reinforce and the infrastructure that they need 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 the 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 companies experience difficulties by incorporating conflicting systems or practices, tradeoff analysis must be performed in this case to manage and resolve conflicts.

5. Conclusions and areas for further study

We have provided a model, the Agile Supply Chain Transformation Matrix, and the framework necessary for a systematic approach to achieve agility in the supplier-buyer supply chain. Our model, based on the modern QFD concept and the AHP approach, covers different levels of agility and is customizable to companies dealing with this specific aspect of the supply chain. We relate business changes to approaches in order to determine the business processes and infrastructure. Further studies will extend the applicability of our tool as follows:

1. The model limits the analysis to only the change response capabilities and does not explicitly address the company's ability to recognize the changes. To be agile, companies need to sense and respond quickly and efficiently to unpredictable changes. Further development is needed to incorporate this additional capability.
2. The model has been tested with a case from a single company. Additional cases need to be studied.
3. The scope of the model is limited to the identification of business practices and the enterprise infrastructures needed. Current studies are extending the model to develop 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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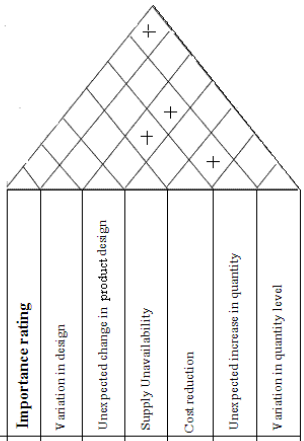
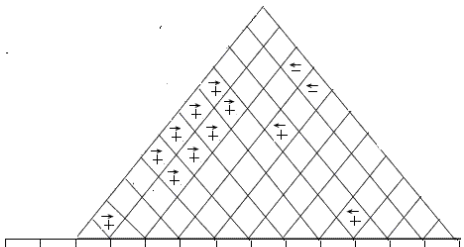
Appendix



	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				0.513		
Customizable product	0.168	0.513					0.513
New technology introduced	0.065		0.513				
Global business	0.257		0.129		0.129	0.513	
Supplier disruption	0.028			0.513			
Business Characteristic	0.370	0.513					0.513
Importance to the company (Scores)	0.000	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

Figure 3 – Model Phase One



	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	Supplier's leaness
		Adaptive and flexible relationship								**Suppliers' agie capabiity**			
Variation in design	3	1.80				0.513				0.26	0.129	0.513	
Variation in quantity	2	0.44	0.513	0.129				0.513					
	4	1.16								0.513	0.513		
Unexpecected change in design	1	1.10	0.513	0.513	0.26		0.513						
Rapid need for cost reduction	4	1.50							0.063				0.513
Unexpected increase in quantity	1	0.47	0.513	0.129				0.513					
	4	0.93								0.513	0.513		
Supply unavailability (disruption)	1	0.27	0.513	0.129			0.513						
	3	0.33				0.513				0.513	0.513		
Importance to company (score)			1.17	0.72	0.29	1.09	0.70	0.47	0.09	1.71	1.47	0.92	0.77
Scaled importance score			11.7	7.2	2.9	10.9	7.0	4.7	9.0	17.1	14.7	9.2	7.7

Figure 4 – Model Phase Two

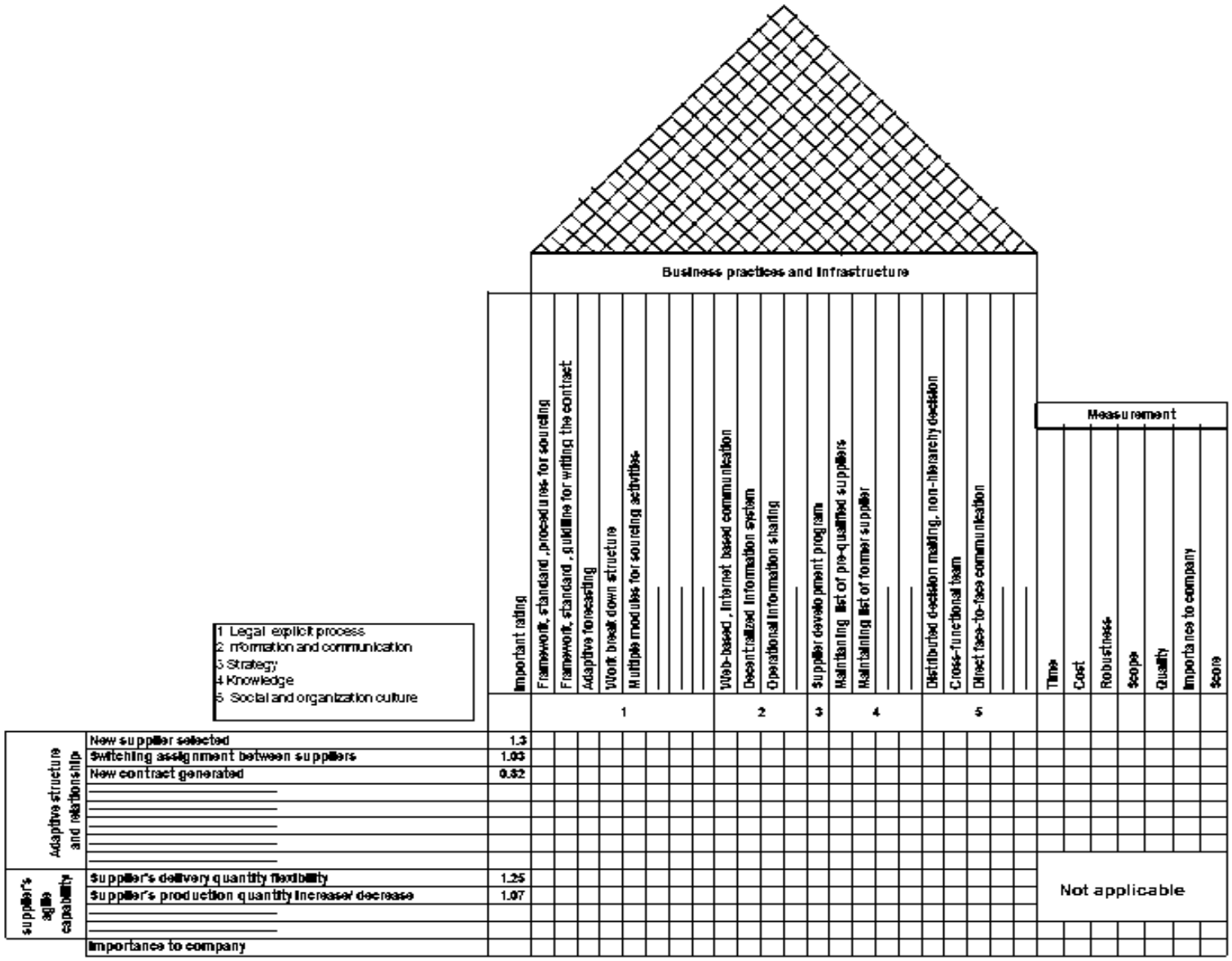


Figure 5 - Model Phase Three