

Is Leagile Supply Chain Suitable for Apparel Manufacturing Organizations? A Multicriteria Decision Making Perspective

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Abstract— The global economy and growing demand have been pushing companies to meet new ways to acquire distinctive competences to respond to customer demands. In a general sense, competition no longer can be defined as something between companies but supply chains and networks of firms. The paradigm Leagile, involving lean and agile, creates a virtually brand new management framework. It is particularly important in the cases of firms exploiting markets in terms of cost, quality, response time and service level where the client seeks for better responsiveness to meet their demands. This paper aims to evaluate the supply chain strategies and select an appropriate strategy for apparel manufacturing industry. It is considered as a multicriteria decision problem and solved using Analytical Hierarchy Process (AHP) through deep review on several contributions and opportunities Leagile in apparel industry. The evaluation factors are developed and used successfully and a case study based on an apparel manufacturing organization is conducted to demonstrate the effectiveness of the method.

Index Terms— Leagile Supply Chain, Agile, Lean, Decoupling Point, Apparel, Analytical Hierarchy Process, Management.

1 INTRODUCTION

IT has been universally acknowledged that business environment has changed dramatically since recent decades.

Besides the trend of globalization and advances in information technology, the increasingly various customer demands are considered to have taken substantial effect on the formation of business strategies and operations, and in turn generate more competitive markets for companies. Therefore, how to rapidly and accurately satisfy customers with what they need has become a business challenge for companies in recent decade. Lean and agile supply chains have been discussed as trade-offs toward search other. Hybrid or Leagile supply chains can be defined as the combination of the lean and agile paradigm within a total supply chain strategy. Such hybrid or Leagile supply chains exploit the benefits of both lean and agile supply chains [1], they use a combination of lean and agile approaches within a supply chain strategy [5]. Being lean means to create a value stream to eliminate all waste is including time, inventory or unnecessary costs and creates a production schedule [6]. In fact goal of lean production to achieve better results with less time and cost and in environments that demand is relatively stable and predictable and product diversity is relatively little, lean manufacturing concepts and techniques to better respond. Source of lean production can be attributed to Toyota Production System that focuses on reducing and eliminating waste. From the perspective of each of these systems factors of Production: materials,

human resources, parts, machinery, and time be used more than required minimum amount and does not create value for the product, called waste and must be removed [3].

The word agile means the ability to fast thinking with a clever method and in fact it is concept of maximum flexibility and an agile organization should be able to respond to possible changes that may occur in the organization. A key feature of agility organization is flexibility. In fact the main origin of "agility" as a concept in business and work is rooted in flexible manufacturing systems. At first was thought the path toward flexibility in production and manufacturing is move from automation towards create ability for rapid changes such as reducing the start-up time and thus faster reaction to changes in product mix or volume.

For over a decade, companies have been achieving huge cost savings by streamlining their supply chains. While affluent, and thus pleasurable; these trends have also exposed organizations to new sets of paradigms such as Lean, Agile, Integration of Lean and Agile, Relationship driven supply chain etc. The question arise here is, Why there is a need to integrate the lean and agile supply chain? To find the answer the previous pages need to be turned; "Lean" is the name that James Womack gave to the Toyota Production System in the book "The Machine that Changed the World." Lean was the term that best described Toyota's system versus the rest of the world's automotive manufacturers at the time. Many companies have since applied lean thinking to their organizations with varying degrees of success. Applying lean to the entire supply chain is not a new concept, but very few have had success doing it. Naylor et al. (1999) defined the lean as, "Leanness means developing a value stream to eliminate all waste including time, and to enable level schedule" [6]. Further the Agility means "using market knowledge and virtual corporation to exploit profitable opportunities in a volatile marketplace" [6]. The leanness is basically to eliminate the waste with in the manufacturing to drive the lowest possible cost and

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highest quality of the product. Agility is to use the Voice of Customers (VOC) to develop new products to satisfy the demand, this is more flexible and high cost than leanness. "In lean production, the customer buys specific products, whereas in agile production the customer reserves capacity that may additionally need to be made available at very short notice" [2], [5].

A further marrying of the lean and agile paradigms can be achieved through the creation of a 'de-coupling point' using what may be termed strategic inventory. Here the idea is to hold inventory in some generic or modular form and only complete the final assembly or configuration when the precise customer requirement is known. An example is the customized PC [3]. This concept of 'postponement' is now increasingly widely employed by organizations in a range of industries [8]. As shown in Figure 1, by utilizing the concept of postponement, companies may utilize lean methods up to the decoupling point and agile methods beyond it. Companies such as Hewlett Packard have successfully employed such strategies to enable products to be localized much closer in time to actual demand [4].

Separating demand patterns into "base" and "surge" elements is an employment of hybrid strategy. Base demand can be achieved by classical lean manufacturing with low cost and less flexibility and surge demand by agile with high cost and high flexibility. Base demand is forecast-based but surge demand is information based. The decoupling point separates Lean and Agile boundaries through base and surge demands. Decoupling point is identified by the experienced employees and top management to maintain pull system. A transition point is established, before transition point is called lean SC and beyond transition point is called agile SC.

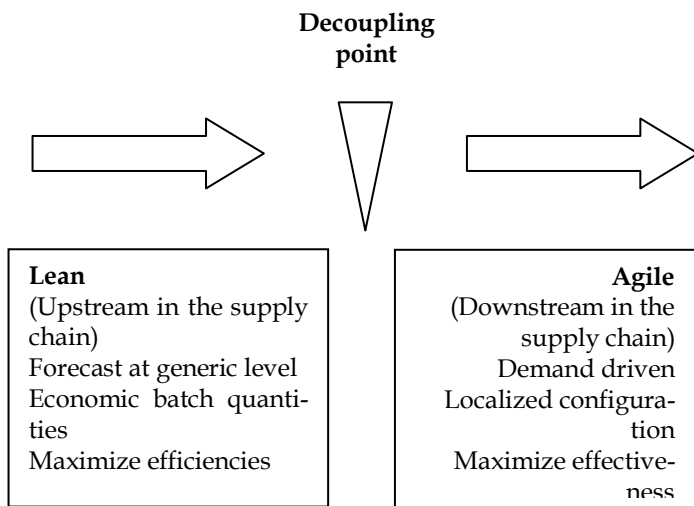


Fig. 1. The decoupling point [3]

2 RESEARCH METHODOLOGY

Firstly the current state of Supply Chain strategy in Bangladeshi apparel manufacturing industries is explored. Then we have applied AHP to select the appropriate SC strategy for apparel manufacturing industries. For this regards we choose some garments companies of Bangladesh and then build up

some questionnaires for collecting data from these companies. For this research we have chosen f Fatullah Apparel Ltd (FA), Fakira Apparel Ltd, Ever smart Bangladesh, Ananto Group and Viyellatex Group. Fatullah Apparel is taken as a case study.

2.1 The Decision Analysis Model: Analytical Hierarchy Process (AHP)

Saaty (1980) [7] proposed AHP as a decision aid to help solve unstructured problems in economics, social and management sciences. AHP has been applied in a variety of contexts: from a simple everyday problem of selecting a school to the complex problems of designing alternative future outcomes of a developing country, evaluating political candidacy, allocating energy resources and so on. AHP enables the decision makers to structure a complex problem in the form of a simple hierarchy and to evaluate quantitative and qualitative factors in the systematic manner under multiple criteria environment in confliction.

The application of the AHP to the complex problem usually involves four major steps:

1. Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form
2. Make a series of pair wise comparisons among the elements according to a ratio scale
3. Use the eigen value method to estimate the relative weights of the elements
4. Aggregate these relative weights and synthesizes them for the final measurement of given decision alternatives.

Saaty (1980) [7] proposed carrying out paired comparisons between the different elements because the human brain is perfectly designed to make comparisons between two elements, hence proposing the scale in Table 1.

TABLE 1
FUNDAMENTAL SCALE FOR PAIRED COMPARISON

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equal to the objective.
3	Moderate importance	Experience and favor slightly favor one activity over another.
5	Strong importance	Experience and favor strongly favor one activity over another.
7	Very strong or demonstrated importance	One activity is favored very strongly over another, its dominance demonstrated in practice.
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2,4,6,8	For compromise between the above values	Sometimes one need to interpolate a compromise judgment numerically because there is no adequate word to describe it.

3 STEPS OF PROPOSED SUPPLY CHAIN STRATEGY SELECTION PROCESS

In this section the proposed steps of AHP to assess and select supply chain strategy are described. These steps can be

followed to determine which one among Lean, Agile, and Leagile is suitable for an apparel manufacturing organization.

STEP 1 UNDERSTANDING THE SC STRATEGIES

There are three strategies and they are Lean, Agile, and Leagile. Nowadays, Apparel Industry applied those strategies according to their needs. Sometimes industry judges these strategies badly and fails to adopt. Now, local industry under case study needs to be surveyed and also understanding what strategy is essential for that industry as per demand, responsiveness and profit margin.

Step 2 Determining key SC strategy evaluation and selection factors and sub-factors

After surveying and analyzing the whole FA's supply chain, we have selected six key evaluation factors listed in Table 2, which are the basis for assessing the suitability of the SC model for Fatullah Apparel. To solve this multicriteria decision making problem by AHP, the defined seven main factors are taken as objective functions, which are used to assess the output. They are:

Objective 1: Lead time (LT)

Objective 2: Quality (Q)

Objective 3: Service level (SL)

Objective 4: Cost (C)

Objective 5: Responsiveness (R)

Objective 6: Efficiency (E)

Step 3 Computing weighted value of each supply chain strategy by using AHP method

Now, using AHP the weight of each key evaluation factor is determined by doing pairwise comparisons among the key factors. So, we begin by writing down a 6 × 6 matrix which is known as pair wise comparison matrix A. The entry in row i and column j of A (a_{ij}) indicates how much more important objective i is than objective j. Then,

$$A = \begin{matrix} & \begin{matrix} LT & Q & SL & C & R & E \end{matrix} \\ \begin{matrix} LT \\ Q \\ SL \\ C \\ R \\ E \end{matrix} & \begin{bmatrix} 1 & 5 & 2 & 2 & 2 & 3 \\ 0.20 & 1 & 4 & 2 & 4 & 2 \\ 0.50 & 0.125 & 1 & 4 & 1 & 2 \\ 0.50 & 0.50 & 0.125 & 1 & 5 & 3 \\ 0.50 & 0.125 & 1 & 0.20 & 1 & 2 \\ 0.33 & 0.11 & 0.50 & 0.33 & 0.5 & 1 \end{bmatrix} \end{matrix}$$

Now, divide each entry in column i of A by the sum of the entries in column i. This yields a new matrix A_{norm} (for normalised) in which the sum of the entries in each column is 1.

$$A_{norm} = \begin{matrix} & \begin{matrix} LT & Q & SL & C & R & E \end{matrix} \\ \begin{matrix} LT \\ Q \\ SL \\ C \\ R \\ E \end{matrix} & \begin{bmatrix} 0.330 & 0.729 & 0.232 & 0.210 & 0.148 & 0.230 \\ 0.066 & 0.146 & 0.464 & 0.210 & 0.296 & 0.154 \\ 0.165 & 0.018 & 0.116 & 0.420 & 0.074 & 0.154 \\ 0.165 & 0.073 & 0.014 & 0.105 & 0.370 & 0.230 \\ 0.165 & 0.018 & 0.116 & 0.021 & 0.074 & 0.154 \\ 0.109 & 0.016 & 0.058 & 0.035 & 0.037 & 0.077 \end{bmatrix} \end{matrix}$$

The above matrix considers Table 1 to measure pair wise comparison. As for example, the specialist does not want to show any compassion about lead time, hence they ranked Lead time (LT) as top among other objective functions. If we consider row 1 we see, lead time is slightly favourable over Q, hence ranked as 2 in the row. Again, LT is strongly favoured over SL, C and is extremely favoured over Responsiveness, Efficiency; this is reflected by their points shown in row 1 in the pair wise comparison matrix. Estimate W_i as the average of the entries in row i of A_{norm} . This yields the weights of the key evaluation factors:

$$W_{LT} = 0.313 ; W_Q = 0.223 ; W_{SL} = 0.158 ; W_C = 0.159 ; W_R = 0.091 ; W_E = 0.055 .$$

Now we need to produce matrix of sub-factors for the judgment of SC strategy and for that lead time as a key evaluation factor is selected at first. To be competitive one needs to maintain lead time with respect to demand of customer. So the sub-factors pair wise comparison matrix is obtained as

$$A = \begin{matrix} & \begin{matrix} MP & MIS & ITAL & LM & FPP \end{matrix} \\ \begin{matrix} MP \\ MIS \\ ITAL \\ LM \\ FPP \end{matrix} & \begin{bmatrix} 1 & 5 & 2 & 4 & 3 \\ 0.20 & 1 & 4 & 2 & 8 \\ 0.50 & 0.25 & 1 & 5 & 3 \\ 0.25 & 0.50 & 0.20 & 1 & 2 \\ 0.33 & 0.125 & 0.33 & 0.50 & 1 \end{bmatrix} \end{matrix}$$

TABLE 2
KEY FACTORS AND SUB-FACTORS OF THE PROPOSED SELECTION MODEL

Evaluation factors	
1. Lead time	<ol style="list-style-type: none"> 1. Modular products 2. Market information sharing 3. Information technology applied to logistics 4. Lean manufacturing 5. Flexible production planning
2. Quality	<ol style="list-style-type: none"> 1. Simultaneous engineering 2. Multi ability team 3. Supply agreement 4. ERP integration 5. Business stability
3. Service level	<ol style="list-style-type: none"> 1. Interview about product/service 2. Customer attendance 3. Booked delivery 4. Delivery reliability 5. New products development
4. Cost	<ol style="list-style-type: none"> 1. Information technology applied to production 2. Local supply instead of global supply 3. Productivity and demand variation 4. Manufacturing lead time 5. Stock localization near the final customer
5. Responsiveness	<ol style="list-style-type: none"> 1. Customer's demand 2. Information enrichment 3. Product life cycle 4. Customized products
6. Efficiency	<ol style="list-style-type: none"> 1. Market demand 2. Inventory 3. Product variety

Now, divide each entry in column i of A by the sum of the entries in column i. This yields a new matrix A_{norm} (for normalised) in which the sum of the entries in each column is 1.

	MP	MIS	ITAL	LM	FPP
A_{norm}	MP	MIS	ITAL	LM	FPP
	0.438	0.727	0.266	0.320	0.176
	0.088	0.145	0.531	0.160	0.471
	0.219	0.036	0.132	0.400	0.176
	0.110	0.073	0.027	0.080	0.117
	0.144	0.018	0.044	0.040	0.059

Estimate W_i as the average of the entries in row i of A_{norm} . This yields the weights of the sub-factors under the key factor 'Lead Time':

$$W_{MP} = 0.385; \quad W_{MIS} = 0.279; \quad W_{ITAL} = 0.193; \\ W_{LM} = 0.0814; \quad W_{FPP} = 0.0610;$$

Similarly the weights of all the sub-factors under the remaining other key factors can be determined. Again, it needs to find out best suited strategy using the sub factors of key factor. The same way can be applied for sub factors as what already applied on key factor. For this reason, every sub factors are used to find out the best strategy for this Company using AHP method. In case of lead time, we measure its sub factors.

For Modular product,

	Leagile	Lean	Agile
A	Leagile	Lean	Agile
	1	4	3
	0.25	1	2
	0.33	0.5	1

	Leagile	Lean	Agile
A_{norm}	Leagile	Lean	Agile
	0.633	0.727	0.50
	0.158	0.182	0.333
	0.209	0.091	0.167

By following same equations the weights of each SC strategy for Modular Product (MP) sub-factor is found as:

$$Leagile_{MP} = 0.620; \quad Lean_{MP} = 0.224; \quad Agile_{MP} = 0.156.$$

For Market information sharing,

	Leagile	Lean	Agile
A	Leagile	Lean	Agile
	1	2	3
	0.50	1	5
	0.33	0.2	1

	Leagile	Lean	Agile
A_{norm}	Leagile	Lean	Agile
	0.546	0.625	0.333
	0.273	0.312	0.556
	0.180	0.0625	0.111

By following same equations the weights of each SC strategy for Market information sharing (MIS) sub-factor is found as:

$$Leagile_{MIS} = 0.501; \quad Lean_{MIS} = 0.380; \quad Agile_{MIS} = 0.118.$$

For Information technology apply to logistics,

	Leagile	Lean	Agile
A	Leagile	Lean	Agile
	1	2	3
	0.50	1	4
	0.33	0.25	1

	Leagile	Lean	Agile
A_{norm}	Leagile	Lean	Agile
	0.546	0.615	0.375
	0.273	0.308	0.50
	0.180	0.077	0.125

By following same equations the weights of each SC strategy for Information technology apply to logistics (ITAL) sub-factor is found as:

$$Leagile_{ITAL} = 0.512; \quad Lean_{ITAL} = 0.360; \quad Agile_{ITAL} = 0.127.$$

For Lean manufacturing,

	Leagile	Lean	Agile
A	Leagile	Lean	Agile
	1	2	4
	0.50	1	4
	0.25	0.25	1

	Leagile	Lean	Agile
A_{norm}	Leagile	Lean	Agile
	0.571	0.615	0.444
	0.286	0.308	0.444
	0.143	0.077	0.111

By following same equations the weights of each SC strategy for Lean manufacturing (LM) sub-factor is found as:

$$Leagile_{LM} = 0.543; \quad Lean_{LM} = 0.346; \quad Agile_{LM} = 0.110.$$

For Flexible production planning,

	Leagile	Lean	Agile
A	Leagile	Lean	Agile
	1	4	2
	0.25	1	4
	0.50	0.25	1

	Leagile	Lean	Agile
A_{norm}	Leagile	Lean	Agile
	0.571	0.762	0.286
	0.143	0.190	0.571
	0.286	0.048	0.143

By following same equations the weights of each SC strategy for Flexible production planning (FPP) sub-factor is found as:

$$\text{Leagile}_{\text{FPP}} = 0.540; \text{Lean}_{\text{FPP}} = 0.301; \text{Agile}_{\text{FPP}} = 0.159.$$

By the same procedure the pair wise comparisons of the sub factor of the dominating factors to the goal function have calculated and the relative performance of the SC strategy against each of these sub factors have evaluated. For example the relative weights of the sub factors of Lead Time (LT) are:

$$W_{\text{MT}} = 0.385; \quad W_{\text{MIS}} = 0.279 \quad ; \quad W_{\text{ITAL}} = 0.193 \quad ; \\ W_{\text{LM}} = 0.0814; \quad W_{\text{FPP}} = 0.0610$$

And the relative performances of the SC strategy against each of these sub factors are shown in the Table 3 Each of the sub-factor is weighted and the highest weight has been selected as it achieves. Weight and propose supply chain are

TABLE 3
CALCULATION OF FINAL SCORE AGAINST 'LEAD TIME' FACTOR

	MP	MIS	ITAL	LM	FPP	Alternative priority weight
weight	0.385	0.279	0.193	0.0814	0.0610	
Leagile _{LT}	0.620	0.501	0.512	0.543	0.540	0.554
Lean _{LT}	0.224	0.380	0.360	0.346	0.301	0.308
Agile _{LT}	0.156	0.118	0.127	0.110	0.159	0.136

multiplied and adding each of the weight we found the propose supply chain for FA.

Step 4 Validation of the result and finally select the best suited SC Strategy.

Finally the overall score for each alternative SC strategy is calculated by multiplying each weight of key factors and SC strategic performance to that factor, and then summing them to get the final score. Assessment of sub factors is shown in Table 4.

TABLE 4
CALCULATION OF THE OVERALL SCORE FROM ASSESSMENT OF SUB FACTORS

	LT	Q	SL	C	R	E	Final Score
Weight	0.313	0.223	0.158	0.159	0.091	0.055	
Leagile SC	0.554	0.524	0.533	0.520	0.542	0.329	0.525
Lean SC	0.308	0.303	0.283	0.250	0.324	0.524	0.307
Agile SC	0.136	0.162	0.195	0.165	0.133	0.283	0.167

We have checked the degree of consistency and found that the pair wise comparison matrices do not exhibit any serious inconsistencies. As all the values are found from valid consistent matrices, the result can be treated as correct. As far, the Leagile SC achieves highest weighted value, and then it is best suited for the Company which is taken under this case study.

4 DISCUSSIONS

The purpose of this research is to form an understanding of how Leagile SC is connected to Apparel Industry and to propose a MCDM model to identify its appropriateness for Apparel Industry. It is clear by using AHP method that, these industries require Leagile in order to compete in a volatile market. These have been done by using SC attributes of that industry and the result is fruitful. Traditional strategy is not fruitful because it is not responsive as agile and not also efficient as lean. The priorities of the SC strategies have been listed in table 5 where Leagile has the highest priority.

TABLE 5
SELECTION OF SC STRATEGY FOR FA

Supply Chain Strategy	Priority (in percentage)
Leagile SC	52.5%
Lean SC	30.7%
Agile SC	16.7%

The Leagile SC strategy is found high weighted than the two strategies. So, Leagile SC is best suited for Fatullah Apparel Ltd. Selection of strategy based on attributes of FA which are lead time, quality, service level, cost, responsiveness and efficiency. But the FA requires changing or improving lead time, service level and responsiveness in order to achieve Leagile SC.

Lead time consists of modular products, market information sharing, information technology apply to logistics, lean manufacturing, flexible production planning. Modular products and market information sharing is a vital point in order to improve lead time because of whether it is required or not. But to be competitive in a volatile market one must need to improve these things in order to compete in a volatile market.

Modular product reduces lead time to customer drastically, to be exact it also reduces overall cost by 0.5% mainly production cost. Supply chain must be informative and to be informative one needs to collect real time data that means POS data. At the same time to be maintain lean and flexible production in order to compete by FA.

Service level is one of the drivers which lead to desired level. Service level consists of interview about product/ service, customer attendance, booked delivery, delivery reliability, new products development.

Interview about product/ service should be maintained by FA in order to compete. This will also help for further product production because new problems, ideas can be arise by that. Customer attendance and booked delivery must be main-

tained by systematic way. Product should be based on customer oriented that can be done by modular product which reduces lead time. New product introduced must be established every time in order to be competitive.

Responsiveness is one of the key factors for Leagile sc. FA should be responsive to customer in order to compete. Responsiveness consists of customer's demand, information enrichment, product life cycle, customized products. Customer demand can be maintained by using POS real data which will determine how much demand is for the product.

Main theme of responsiveness is the information enrichment. Supply chain of FA should be informative by collecting real time data and sharing that information among the stages of supply chain.

Product life cycle should be short to achieve desired profit. FA should maintain some facility in order to produce Customized product or customer order. Customized product should be product on time and should be delivery on time. Supply chain infrastructure should be modified in order to achieve responsiveness.

4 CONCLUSION

Selection of appropriate SC strategy is based on using Analytical Hierarchy Process and it is seen that Leagile SC Strategy is best suited for Fatullah Apparel Ltd. FA should use decoupling point as a transit point where lean and agile are separated. Lean product can be produced by using POS real time data which can be called modular product. So lean produces modular product and assembly of product also performed on agile stages. After performing lean as a modular product the company needs to wait for customer response. That time Company needs to postpone activity, but when responses are coming company should be utilized it in an effective way. So all the parameters of FA welcome Leagile as a supply chain strategy.

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