PRIORITIZATION OF STRATEGIC DESIGN REQUIREMENTS FOR LEAN & AGILE SUPPLY CHAINS

D. Venkata Ramana*

K. Narayana Rao**

J. Suresh Kumar*

K. Venkatasubbaiah***

Abstract: *Supply chain management has become one of the most popular approaches to enhance the global competitiveness of business corporations today. Firms must have clear strategic thinking in order to effectively organize complicated business activities, resources, communications, and processes. The success of any product in the present competitive market scenario depends on extent of strategic fit among competitive and supply chain strategies. Competitive strategy deals with the customer needs upon which the company is willing to focus where as supply chain strategy deals with the business processes through which company need to fulfill the customer needs. Therefore, the supply chain strategy must be in alignment with the competitive strategy. The literature on supply chain management it is observed that there are three kinds of supply chain strategies: lean strategy, agile strategy, and lean & agile (Leagile) strategy. Today companies involving manufacturing of volatile and unforeseeable products like apparel and automotive must pioneer in strategy such as the lean & agile supply chain. Considering the importance of lean and agile, this study tries to identify and evaluate lean & agile activities in those companies..*

This paper presents a frame work for the application of quality function deployment (QFD) to translate Customer requirements (CRs) into strategic design requirements (SDRs) for lean & agile supply chains. The analytic network process (ANP) approach is integrated in QFD to determine the importance weights of SDRs considering the complex dependency relationships between and within CRs, and SDRs. In order to deal with the vagueness, uncertainty and diversity in decision-making, the fuzzy set theory and group decision-making technique are used in the super-matrix approach of ANP. An illustrative example is presented to demonstrate the proposed methodology. The results are useful to determine strategic design requirements for lean & agile supply chains of apparel and automotive companies.

*Department of Mechanical Engg, J.N.T.University, Hyderabad

**Department of Mechanical Engg, Govt. Polytechnic, Visakhapatnam

***Department of Mechanical Engg, Andhra University, Visakhapatnam

1. INTRODUCTION

Supply chain performance improvement initiatives strive to match supply and demand, thereby driving down costs simultaneously with improving customer responsiveness. If a product is highly fashionable then, by its very nature, its demand will be unpredictable. Hence, specific supply chains are faced with the situation where they have to accept uncertainty but need to develop a strategy that enables them still to match supply and demand. The challenge faced by a supply chain delivering fashion products is to develop a strategy that will improve the match between supply and demand and enable the companies to respond faster to the marketplace. Commodities that are basic products, such as tinned soups, have relatively long life cycles and have low demand uncertainty due to the fact they tend to be well-established products with a known consumption pattern. The driving force for basic product supply chains is therefore cost reduction. These results in three fundamental supply chain strategies namely, lean strategy; agile strategy; lean and agile (leagile) strategy; The following definitions relate the agile and lean paradigms to supply chain strategies and were developed to emphasize the distinguishing features of each (Naylor et al. 1999).

- **Agility** means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace
- **Leanness** means developing a value stream to eliminate all waste, including time, and to ensure a level schedule.
- **Lean & Agile (Leagile)** is the combination of the lean and agile paradigms within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the marketplace.

The idea of “lean thinking” has been expounded by Womack and Jones (1996) amongst others. Van Hoek (2000) contends that it is more relevant to move from lean or mass customization to agility in terms of research needed. Further, Christopher and Towill (2000) also commented that the leanness may be a constituent of agility under some conditions. Lean manufacturing represents a collection of practices that “work together synergistically to create a streamlined, high-quality system that produces finished products” (Shah and Ward, 2003), a lean supply chain attempts to streamline the whole chain in a similar manner. Similarly, the concept of “agile” instead of “responsive” was adopted to emphasize the overall goals of a supply chain in responding to uncertain and changing environments. Some researchers proposed that an agile manufacture may be thought of as a lean producer and the agility depends on a range of underpinning operations management capabilities such as TQM and JIT (Richards 1996, Brown and Bessant 2003). Although the leagile supply chain has not been considered as a strategic concept, it can be thought of as a support for the cumulative model of lean and agile practices, because the leagility allude to some degree the overlap between leanness and agility (Narasimhan, et al. 2006). Generally, lean supply chains (or efficient) are appropriate for functional stable products and services, while the agile supply chain (or responsive) are better suited for products and services that are innovative and less predictable (Slack et al., 2008).

It is true that the supply chain characteristics of specific strategy depends on the the competitive strategy of the organization. Cooper and Ellaram (1993) reported eleven points of the characteristics of SCM in their study. Christopher and Towill (2001) presented the actions required to qualify in the market and to win orders in the supply chain, identifying quality, cost, response time and service level as the performance indicators of the supply chainentity performance and the successful supply chain. Tan et al., (2002) have identified six practices for supply chain management involving: supply chain integration; information sharing; determining supply chain characteristics; managing customer service; diverse location proximity and JIT. Kopczak and Johnson (2003) extend the framework to include coordination of activities across companies, improving information flows, and collaborative redesign of the supply chain as well as its products and processes. In recent years many papers have treated supply chain designs around the relative merits of “lean” and “agile” philosophies. Christopher and Towill (2002) summarize agility features along six complementary dimensions of: marketing, production, design, organization, management and people. Christopher (2000), comments that some characteristics of the market that recommend the agile supply chain approach are short cycle times, wide variety of product and unpredictable demand, while markets characterized by no innovation in products, limited variety of products and demand with less uncertainty (more or less stable) probably ask for lean supply chains. Vonderembse et al. (2006) discuss supply chain types that are necessary for success across three types of products: standard, innovative, and hybrid. Yinan

Qi et al. (2009) investigated supply chain strategies and empirically test the supply chain strategy model that posits lean, agile, and lean/agile approaches using data collected from 604 manufacturing firms in China. Seyyed Ali Banihashemi (2011), considered leagile supply chain, to study the relationship between product life cycle of different products (standard, innovative, hybrid) and selection of the proper type of supply chain is examined. . Nesrine El-Tawy and David Gallear (2011) proposed framework for the Egyptian Manufacturing Business to show the relationship between the agility principles, lean principles,

The leagile supply chain presents the evolution from lean thinking to mass customization that pursues the responsiveness without particular focus on waste elimination, such as capacity buffer and inventory buffer of reconfigurable components. Finally, the supply chain should evolve to the agility that is a responsive and cost-effective structure.

2. QUALITY FUNCTION DEPLOYMENT

Quality Function Deployment (QFD) is one of the quantitative tools and techniques of Total Quality Management that could be used to translate customer requirements and specifications into appropriate technical or service requirements (Baba et al., 2009). QFD process is initiated with capturing the voice of customer and it can be used to measure customer satisfaction (Durga Prasad et al., 2008).

QFD is a planning process that includes four matrices namely product planning matrix, part planning matrix (part deployment matrix), process planning matrix and production planning matrix respectively, and the first of them is also referred to as House of Quality (HOQ) (Liu, 2009).

The customer portion of HOQ is established by capturing the voice of customer (customer needs) and preparing the priority ratings of the customer needs. The priority ratings reflect the preferences of the customers. A few approaches are also available for the determination of priority ratings of customer needs (Sharma et al., 2007).

The HOQ translates the customer needs obtained from the customer's perception into appropriate design requirements using the designer's perception. The HOQ maps the prioritized list of customer needs to appropriate design requirements and it also gives the priority ratings of the design requirements. Designers have an in-depth knowledge of the functions of the product, and they usually express their information in technical and clear terms (Kazemzadeh et al., 2009).

3. ANALYTIC NETWORK PROCESS (ANP)

The Analytic Network Process (ANP) is a multi-criteria decision making (MCDM) technique which considers the interdependence among criteria and alternatives and it may transform qualitative judgments into quantitative values. The ANP generalizes the AHP by replacing hierarchies with networks. Analytical Hierarchy Process (AHP) employs a unidirectional hierarchical relationship among clusters, while ANP enables interrelationships not only among the clusters but also between the elements of a cluster (Andreas et al., 2009).

ANP uses the same fundamental comparison scale (Saaty, 1980) that is used in the AHP. This comparison scale enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to the criterion. ANP consists of two stages, namely, construction of the network and the calculation of the priorities of the elements (Karsak et al., 2002).

The degree of relative importance of the design requirements (DRs) with respect to each customer need (CN) is presented in the form of a matrix w_1. The transpose of the matrix w_1 forms the interrelationship matrix of HOQ. The set of priority ratings of customer needs are obtained through trapezoidal fuzzy numbers which take care of the vagueness present in the decision maker's judgment. The priority matrix is represented as w. The inner dependence matrix of the DRs with respect to each DR (w_3) gives the correlation matrix (roof) of HOQ. The matrix w_2 represents the inner dependencies of the CNs with respect to each CN. The QFD-ANP methodology employed for systematic mapping of CNs and DRs is shown in Fig. 1.

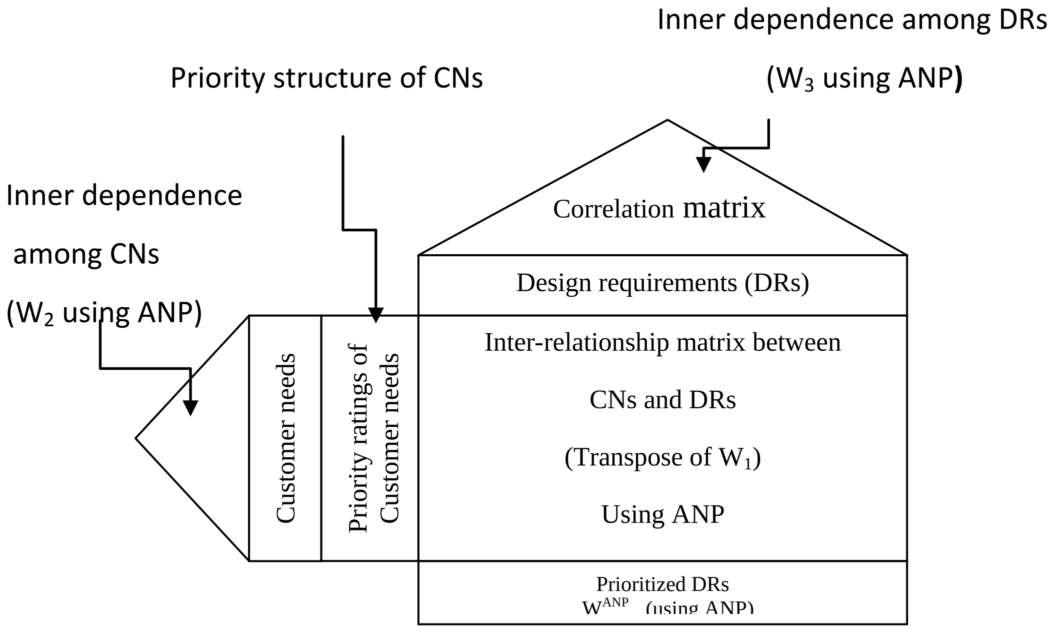

Figure 1: HOQ-ANP methodology

The lack of strategic fit between competitive strategy and supply chain strategy leads to the actions taken in supply chain are not consistent with customer requirements. To achieve strategic fit, the firm has to understand the customer needs and that helps to set competitive strategy. The competitive strategy examines the way in which a firm can compete more effectively to reinforce its market position. Then the supply chain strategy has to be designed in aligning with the competitive strategy to meet the highest satisfaction of the customer. This paper presents a combined QFD-ANP methodology to align competitive strategy and supply chain strategy (Lean & agile) which is very useful to the apparel and electronic industries. The priority of strategic design requirements for lean & agile supply chains are determined. The methodology takes care of vagueness and diversity in decision making by using fuzzy set theory and group decision making technique to enhance the effectiveness and efficiency of the QFD-ANP methodology.

4. METHODOLOGY

Importance weights of SDRs are obtained by formulating the super matrix of HOQ network model. The decision methodology consists of the following steps.

Step 1. Identification of Customer Requirements (CRs)

The customer requirements may be gathered from the literature and opinions of experts involved in lean & agile supply chain operations.

Step 2. Formulation of Design Requirements (DR)

The customer requirements are to be translated into necessary design requirements. QFD is an effective management tool to convert the customer requirements into design requirements by generating them through the brain storming sessions held with the experts involved in lean & agile supply chain operations.

Step 3. Prioritization of Customer Needs (W_1)

Assuming that there are no dependence relationships among the CRs, constructing the pair-wise comparison matrix within the CRs with respect to the design goals, and calculating the importance weighting vector of CRs.

Step 4. Determination of inter- dependency matrix (W_2)

Establish inter- dependency matrix by assuming that there are no dependence relationships within DRs, constructing the pair-wise comparison matrix within them with respect to the inter-dependency relationships between CRs and DRs.

Step 5. Establish the inner dependence matrix of the CRs (W_3)

Inner dependence matrix of the CRs is established by constructing the pair-wise comparison matrix within the CRs with respect to the inner- dependency relationships within them.

Step 6. Establish the inner dependence matrix of the DRs (W_4)

Inner dependence matrix of the DRs is established by constructing the pair-wise comparison matrix within the DRs with respect to the inner-dependency relationships within them.

Step 7. Establish the inter dependent priority matrix of the CRs (Wc)

The inter- dependent priority matrix of the CNs is obtained by the following relation.

$$Wc = W_3 * W_1$$

Step 8. Establish the inter dependent priority matrix of the DRs (W_a)

The inter- dependent priority matrix of the DRs is obtained by the following relation.

$$W_a = W_4 * W_2$$

Step 9. Determination the overall priority of DRs

The overall priorities of the DRs, reflecting the interrelationships within the HOQ, are obtained by the following relation.

$$W_{ANP} = W_a * W_c$$

4.1 Determination of weights from fuzzy pair wise comparison matrix

The assessment of local priorities, based on pair wise comparisons needs some prioritization method to be applied. However, the standard AHP eigen value prioritization approach cannot be used, when the decision-maker faces a complex and uncertain problem and expresses his/her comparison judgments as uncertain ratios, such as ‘about two times more important’, ‘between two and four times less important’, etc. A natural way to cope with such uncertain judgments is to express the comparison ratios as fuzzy sets or fuzzy numbers, which incorporate the vagueness of the human thinking. When comparing any two elements at the same level of the decision hierarchy, the uncertain comparison judgment can be represented by the fuzzy number $\tilde{a}_{ij}$. In this paper, triangular fuzzy numbers, which are a special class of the L-R fuzzy sets, is adopted. $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ where l_{ij}, m_{ij} and u_{ij} are described by the measures between 1 and 9, corresponding to the the mean, the lower and the upper bounds of triangular membership function respectively. The fuzzy membership functions are defined as very low- (1, 1, 3); low- (1, 3, 5); medium- (3, 5, 7); high - (5, 7, 9); very high- (7, 9, 9);

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix}$$

where $\tilde{a}_{ji} = 1/\tilde{a}_{ij}$

The normalized triangular fuzzy weight vector of the matrix $\tilde{A}$ can be expressed as given below.

$$\tilde{w} = (\tilde{w}_1, \tilde{w}_2 .... \tilde{w}_n)^T$$
$$= ((w_{1L}, w_{1G}, w_{1U}), (w_{2L}, w_{2G}, w_{2U}), \ldots (w_{iL}, w_{iG}, w_{iU}))^T$$
$$\text{where } w_{iL} \le w_{iG} \le w_{iU} \quad \forall\ i$$

The fuzzy logarithmic least square method (LLSM) developed by Wang et al (2006) is employed to obtain the vector of triangle fuzzy weights $\tilde{w} = (\tilde{w}_1, \tilde{w}_2 .... \tilde{w}_i)^T$ through the optimization model of fuzzy LLSM . The optimization model is shown below.

$$\min f = \sum_{i=1}^{n} \sum_{j=1, j\ne i}^{n} ((\ln w_{il} - \ln w_{ju} - \ln a_{ijl})^2 + (\ln w_{ig} - \ln w_{jg} - \ln a_{ijg})^2$$
$$+ (\ln w_{iu} - \ln w_{jl} - \ln a_{iju})^2)$$

subject to

$$w_{il} + \sum_{j=1, j\ne i}^{n} w_{ju} \ge 1,$$
$$w_{iu} + \sum_{j=1, j\ne i}^{n} w_{jl} \le 1,$$
$$\sum_{i=1}^{n} w_{jg} = 1,$$
$$\sum_{i=1}^{n} (w_{jl} + w_{iu}) = 2,$$
$$0 < w_{jl} \le w_{jg} \le w_{iu} < 1.$$

The triangular fuzzy number $\tilde{w}_i = (w_{il}, w_{ig}, w_{iu})$ can be defuzzified by the following equation to obtain the crisp relative importance weight.

$$w_i = \frac{(w_{il} + 2w_{ig} + w_{iu})}{4} \quad i = 1, 2.....n.$$

5 ILLUSTRATIVE EXAMPLE

5.1. Customer Requirements (CRs) : The supply chain determinants discussed by Agarwal et al., (2006) are considered as the customer requirements and are shown in table 1.

Table 1 : Customer Requirements (CRs)

Sl.No	Customer Requirements (CRs)
1.	Quality (Q)
2.	Cost (C)
3.	Lead Time (LT)
4.	Service Level (S L)

5.2. Strategic Design Requirements (SDRs):

The customer requirements are to be translated into necessary design requirements. The set of design requirements were generated through the brain storming session held with general managers, production and technical managers, quality control head, administrative head, shift leaders, and supervisors of automobile, garment and electronic industries. The strategic design requirements are shown in the table 2.

Table 2 : Strategic Design Requirements (SDRs)

Sl.No	Strategic Design Requirements (SDRs)
1.	Product Development (PD)
2.	Sourcing (SOU)
3.	Manufacturing (MFG)
4.	Demand Management (DM)
5.	Information Technology (IT)
6	Management Commitment (MC)
7	Supply Chain Network Design (SCN)
8	Inventory Management (INV)

The network model of HOQ for design of lean & agile supply chain is constructed through analyzing the inner dependency relationships between customer requirements and strategic design requirements. Also, their inter dependency are also analyzed. After determining the detailed inner dependency and inter dependency relationships in the ANP network, questionnaires were designed and given to the stakeholders to construct fuzzy pair-wise comparison matrices.

5.3. Prioritization of Customer Requirements (W_1)

The fuzzy pair wise comparison approach is used to achieve the weights of customer needs. The fuzzy pair wise comparison matrix obtained from questionnaire survey is shown below. Crisp weights of customer needs are obtained by solving the mathematical model described in section 4.1 using Lingo solver .The importance weights of customer needs are shown in the matrix W_1.

$$W_1 = \begin{pmatrix} Q \\ C \\ LT \\ SL \end{pmatrix} = \begin{pmatrix} 0.1359 \\ 0.1646 \\ 0.2947 \\ 0.4048 \end{pmatrix}$$

Highest weight (0.4048) is obtained with service level. The service level depends on joint development of products that may respond to market demand, strategic relations with suppliers, IT integration, sustainable business environment, skill of workers, availability of working capital etc.

Lead time factor with a weight of 0.2947 is associated with Material handling equipments, Machinery and facility layout, Skill of workers, Importing of raw material, purchasing practices etc.

Cost factor is obtained a weight of 0.1646. Costs are affected by supply chain network design, inventory policies, importing of raw material, poor resource utilization, under capacity utilization, Wastage and scraps, rework etc.

The other factor quality is obtained a weight of 0.1359 associated with quality of finished products, raw materials, quality awareness in the industry, skill of workers, management commitment etc.

5.4. Inter- dependency matrix (W_2)

Inter-dependency relationships between CRs and SDRs are also obtained with the fuzzy pair wise comparison approach. The fuzzy pair wise comparison is obtained from questionnaire survey. After the pair wise comparison matrices are prepared, by adopting Fuzzy LLSM method, the importance weights of SDRs with respect to each customer need are determined and shown in the Table 3.

Table 3: The importance weights of the design requirements (W_2)

	Quality (Q)	Cost (C)	Lead Time (LT)	Service Level (S L)
Product Development (PD)	0.1456	0.1547	0.4443	0.0000
Sourcing (SOU)	0.3092	0.0000	0.2045	0.1236
Manufacturing (MFG)	0.3226	0.2817	0.1143	0.0000
Demand Management (DM)	0.0000	0.0000	0.0000	0.2774
Information Technology (IT)	0.0718	0.0000	0.1087	0.4674
Management Commitment (MC)	0.1508	0.0000	0.0000	0.0524
Supply Chain Network Design (SCN)	0.0000	0.3311	0.0172	0.0312
Inventory Management (INV)	0.0000	0.2325	0.1110	0.0390

Table 3 shows the relative importance of design requirements denotes the impact of the SDRs on each of the customer need. Manufacturing has an importance degree of 0.3226 on quality indicates flexibility manufacturing strategies are necessary to meet the quality need of the customers. Sourcing processes have relative importance of 0.3092 to ensure the quality of the product. Management commitment towards continuous improvement in their processes has relative importance of 0.1508. Product development shows relative importance of 0.1456 indicates that product development strategies have also influence quality. Information technology shows little relative importance on quality.

Cost is highly influenced by the Supply chain network design (SCN), manufacturing (MFG) and inventory management (INV) with importance degrees of 0.3311, 0.2817and 0.2325 respectively. The manufacturing strategy makes use of manufacturing tactics that can work to increase a company's bottom line profits by reducing overhead costs. Supply chain network design in upstream side should be based on minimizing cost and maximizing quality. Enterprise-wide inventory should be lowest in the supply chain strategy. Product development also shows moderate importance on the cost.

In case of lead time, product development has relative importance of 0.4443 followed by sourcing with relative importance of 0.2045 indicate that their relative contribution towards customer responsiveness. Manufacturing aspects, inventory management, for new product introduction and use of information technology moderately influence the lead time with importance degree of 0.1143, 0.1110 and 0.1087 respectively.

Use of information technology highly (0.4674) influences the service level required by the customer. Proper implementation of demand management aspects are also greatly (0.2774) influences service level. Supplier selection and purchasing procedures also influence service level by a relative importance of 0.1236. Service level is also influenced by management commitment, inventory management and supply chain network design.

5.5. Establish the inner dependence matrix of the CNs (W_3)

With the help of fuzzy pair-wise comparisons, the inner dependencies among the customer needs are calculated by analyzing the impact of each customer need on other customer need. The importance weights of customer needs with respect to each customer need are determined from the fuzzy pair-wise comparisons between the CNs in respect of each CN using fuzzy LLSM method.

The inner dependency matrix, by determining the weights from the fuzzy pair-wise comparisons between the CNs in respect of each CN is shown in Table. The values in the matrix indicate the extent of impact of each customer need on other.

Table 4: The Inner Dependence matrix of the customer needs (W_3)

W_3	Q	C	LT	SL
Q	0.4186	0.1811	0.0000	0.1246
C	0.2482	0.5390	0.0000	0.1236
LT	0.1265	0.1111	0.5500	0.2844
SL	0.2067	0.1688	0.4500	0.4674

The values in the above matrix indicate the extent of impact of each customer need on other. From the results, it is observed that quality depends on cost, lead time, and service level by 24.82%, 12.65% and 20.67% respectively. Cost depends on quality, lead time and service level by 18.11%, 11.11% and 16.88% respectively. Zeros are assigned to the importance weights of customer needs indicate that quality and cost are independent with respect to lead time. Service level is influenced by quality, cost and lead time by 12.46%, 12.36% and 28.44% respectively.

5. 6. Establish the inner dependence matrix of the DRs (W_4)

The inner dependencies among the design requirements are obtained through analyzing the impact of each DR on other DR by establishing fuzzy pair-wise comparisons. The importance weights of DRs with respect to each DR are determined from the fuzzy pair-wise comparisons between the DRs in respect of each D using fuzzy LLSM method.

The inner dependency matrix W_4 is obtained by determining the weights from the fuzzy pair-wise comparisons between the SDRs in respect of each SDR. The Inner dependence values of design requirements indicate the extent of impact of each design requirements on the other and are shown in Table 5.

Table 5: The inner dependency matrix of the DRs

W4	PD	SOU	MFG	DM	IT	MC	SCN	INV
PD	0.4322	0.1268	0.1118	0.0000	0.1513	0.0000	0.0731	0.0312
SOU	0.1031	0.4715	0.1461	0.0000	0.1246	0.2721	0.1950	0.2058
MFG	0.2433	0.1248	0.4209	0.0000	0.0000	0.1232	0.0321	0.0620
DM	0.1048	0.0000	0.1275	0.5240	0.0000	0.0000	0.1134	0.1053
IT	0.1166	0.1568	0.1937	0.1760	0.4746	0.1261	0.2288	0.1128
MC	0.0000	0.0000	0.0000	0.0000	0.0000	0.4786	0.0000	0.0000
SCN	0.0000	0.0000	0.0000	0.2000	0.1448	0.0000	0.2610	0.2040
INV	0.0000	0.1201	0.0000	0.1000	0.1047	0.0000	0.0000	0.2789

5.7. Establish the inter dependent priority matrix of the CNs (Wc)

Using the following relation, the inter- dependent priority matrix of the CNs is obtained and shown in the matrix.

Wc = W3 * W1

$$w_c = w_3 * w_1 = \begin{pmatrix} Q \\ C \\ LT \\ SL \end{pmatrix} = \begin{pmatrix} 0.1371 \\ 0.1725 \\ 0.3127 \\ 0.3777 \end{pmatrix}$$

The inter dependent values shown in matrix w_c illustrates how individual customer needs always effectively aligned or directed toward a common goal of achieving lean & agile supply chain, and adoption of best practices. From the values shown in the matrix, it is observed that service level and lead time greatly impacts on lean & agile supply chain by considering the correlation among the customer needs. Also, quality and cost are impacting lean & agility of the supply chain by 30.96%.

5.8. Establish the inter dependent priority matrix of the DRs (W_A)

The inter- dependent priority matrix of the DRs is obtained by the following relation and shown in the table 6.

$W_a = W_4 * W_2$

Table 6: The inter- dependent priority matrix of the DRs

	Quality (Q)	Cost (C)	Lead Time (LT)	Service Level (S L)
Product Development (PD)	0.1491	0.1298	0.2519	0.0899
Sourcing (SOU)	0.2579	0.1696	0.1987	0.1449
Manufacturing (MFG)	0.2284	0.1822	0.1892	0.0253
Demand Management (DM)	0.0564	0.1142	0.0748	0.1530
Information Technology (IT)	0.1810	0.1746	0.1741	0.3082
Management Commitment (MC)	0.0722	0.0000	0.0000	0.0251
Supply Chain Network Design (SCN)	0.0104	0.1338	0.0429	0.1393
Inventory Management (INV)	0.0447	0.0648	0.0669	0.1024

The inter dependent values shown in matrix w_A illustrates how the individual design requirements always effectively aligned or directed toward a common goal by considering the correlation among the design requirements. The inter dependent of SDRs & CRs is shown graphically in the figure 2.

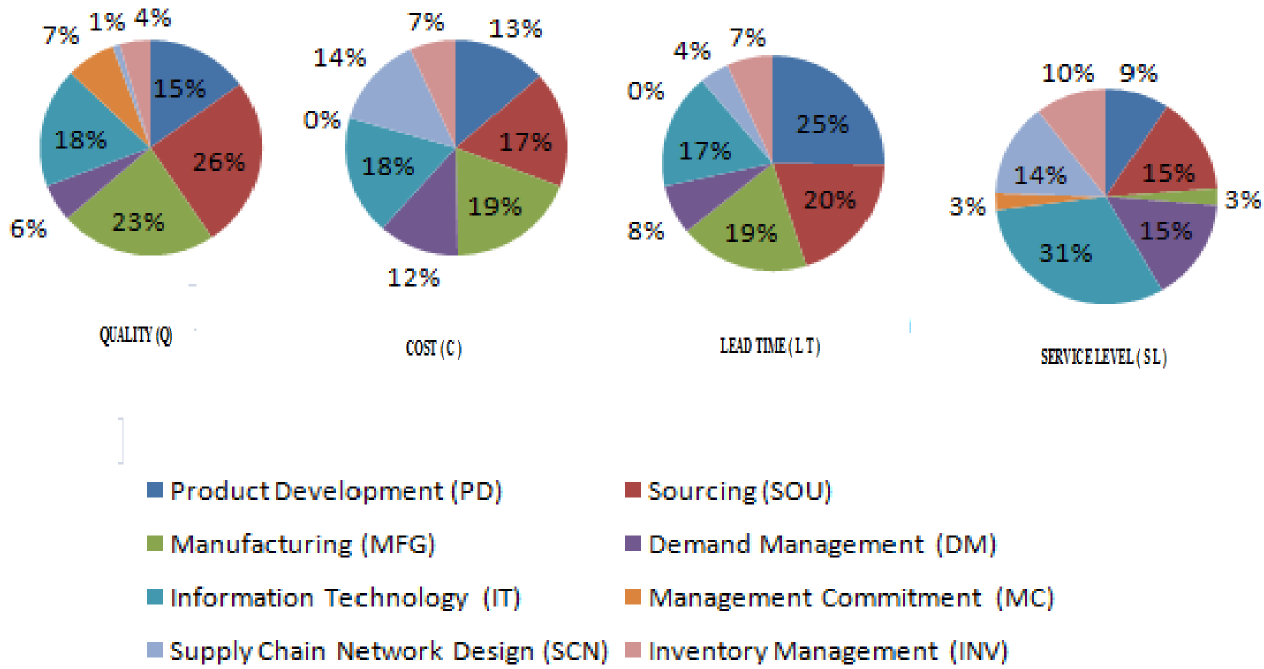

Figure 2: The inter dependent of SDRs & CRs

5.9. Determination the overall priority of SDRs

The overall priorities of the SDRs, reflecting the interrelationships within the HOQ, are obtained by the following relation.

$W_{ANP} = Wa * Wc$

$$W^{ANP} = \begin{pmatrix} PD \\ SOU \\ MFG \\ DM \\ IT \\ MC \\ SCN \\ INV \end{pmatrix} = \begin{pmatrix} 0.1555 \\ 0.1815 \\ 0.1313 \\ 0.1086 \\ 0.2258 \\ 0.0194 \\ 0.0905 \\ 0.0769 \end{pmatrix}$$

The ANP analysis results indicate that the most important design requirement is use of information technology with a relative importance value of 0.2258 followed by sourcing with a weight of 0.1815. Product development, manufacturing strategies, and demand management are also more important design requirements for lean & agile supply chain with importance weights 0.1555, 0.1313 and 0.1086 respectively. Management commitment got the least important design requirement with a weight of 0.0194 according for lean & agile supply chain from the ANP which takes care of inner dependency and inter dependency of customer requirements and strategic design requirements.

6. RESULTS AND DISCUSSION

ANP analysis is carried out to determine overall priority of the design requirements. The relative importance of the strategic design requirements are shown graphically in the following figure 3. Further, the ranking of design requirements basing on the overall priority is shown in table 7.

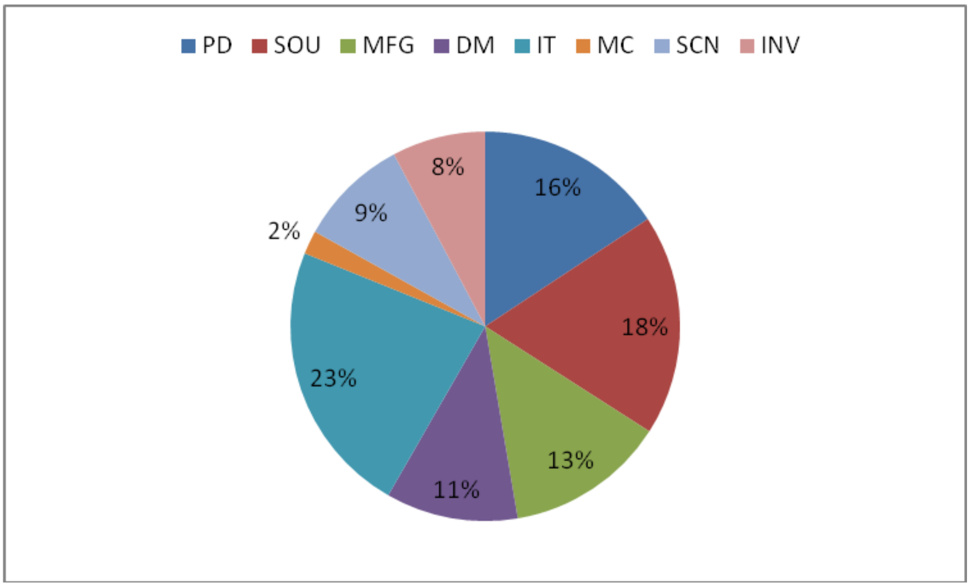

Figure 3: Overall priority of the design requirements

SDRs	PD	SOU	MFG	DM	IT	MC	SCN	INV
Ranking	III	II	IV	V	I	VIII	VI	VII

Table 7: Ranking of Design requirements

Each of these strategic design requirements for lean & agile supply chain are the set of functions either wholly independent or partially dependent on other design requirements. These requirements are discussed in brief as follows.

Product Development (PD): Due to short period of product life cycle new product introduction to market as an appropriate and successful strategy. Hybrid products tend to have a long product life cycle with a certain degree of improvement or innovation offered periodically. A product design strategy that shifts product differentiation closer to the consumer by postponing identity changes, such as assembly or packaging.

Sourcing (SOU): The superior criteria for selection should be: speed, flexibility, price and quality. There should be minimum and reliable suppliers. Just in time (JIT) supply processes ensure that certain parts of the product arrive on the assembly line just in time to be fitted to the particular product.

Manufacturing (MFG): Flexible manufacturing concept may be adopted. Flexible manufacturing strategies are incorporated by a business to make a factory capable of producing multiple products/models. The strategy makes use of manufacturing tactics that can work to increase a company's bottom line profits by reducing overhead costs.

Demand Management (DM): The customer's demand is uncertain; products design may also need to be reconsidered several times. When there is an unpredictable demand leagile supply chain is best suitable by deciding the decoupling point.

Information Technology (IT): IT has greatest influence on lead time, quality and service level. Information technology applied to logistics inbound and outbound increases the speed of the information, providing faster and more accurate data for decision making. Delivery / service on time and communication system for customer service qualify the chain as order winner. The information technology applied to the production justifies the use of lean tools in a productive environment, making the material and the information itself to flow faster.

Management Commitment (MC): While traditional ERP systems manage enterprise processes such as order placement ending with payment, collaborative commerce redefines business processes to include customer satisfaction. The implications for collaborative commerce implementations are clear: information technology allows organizations to interconnect, but trust is just as important. The interplay between trust and technology can reduce transaction costs and encourage trust in and amongst organizations. Technology can reduce transaction costs by managing opportunism, helping to build alliances by increasing the opportunities for outsourcing, and increasing trust between organizations through the use of interaction technology. E-business is about connections. Connecting with outsiders means lower transaction costs and transaction costs can be reduced by trust, built by a combination of experience and by interaction technologies.

Supply Chain Network Design (SCN): The considered strategy is based on the both principles of Lean and agility, beside push and pull of materials. Here, the tradeoff between positioning of decoupling point throughout an exemplary network, and reduction of inventory level along throughput time is possible. In order to achieve leagile supply chain, the upstream of the decoupling point should be designed to be lean while downstream should be agile.

Customers expect quality service defined as reliable product deliveries of the right amount, at the right time with no damage to product and at a low cost. The company, however, must balance customer satisfaction with the need for profitability. Supply chain network design in upstream side should be based on minimizing cost and maximizing quality where as Supply chain network design in down stream side should be based on maximizing service level and minimizing lead time.

Inventory Management (INV):

Customer service, as measured by order-to-ship time, will be best in the lean system. This hypothesis should hold true as long as sufficient quantities of the right inventory are on hand at the appropriate stock keeping locations. If backorders exist in the lean system, considerable time may be required to acquire supplies and realign production priorities. Enterprise-wide inventory will be lowest in the agile system. In lean & agile supply chain network Vendor Managed Inventory (VMI) played a vital role.

The (lean & agile) league model, as its name implies, incorporates elements of both the lean and agile operations. Both DCs are utilized, but they hold no finished goods inventory. Instead, each holds semi processed, generic assemblies that can be made into any of the SKUs. When a customer order is received, light manufacturing tasks are performed to customize the assemblies into final SKUs to fill a specific customer's order. At the same time, the distribution center places an order for replacement of the generic assemblies to resupply those used to fill customer orders. In this arrangement, both distribution centers must house production machinery and labor to support the forward-positioned postponement operations.

7. CONCLUSIONS

An integrated approach for rating of SDRs' importance for lean and agile supply chain is developed in this paper. The ANP approach is integrated into QFD to prioritize SDRs considering customer requirements. In the study, service level, lead time, cost and quality have contributed 37.77%, 31.25%, 17.25%, and 13.71% respectively. It indicates that the relative importance of the customer requirements in the competitive strategy of lean and agile supply chains.

It is also observed that, strategic design requirements like use of information technology, sourcing procedures; new product development, flexible manufacturing functions and demand management are of great importance in deciding the strategy of lean & agile supply chains. Further, it is observed that supply chain net work design, management, commitment and inventory reduction policies are also contributing towards lean & agile supply chains.

This method can be used to model the translating information from CRs more holistically. In addition, the fuzzy theory in determining inner dependence and inter dependence matrices of CRs and SDRs are incorporated in the super-matrix. LLSM optimization model is introduced as the critical techniques in the super-matrix approach, which is used to solve the weight vectors. This approach can improve the accuracy of the obtained weights for decision-making.

The approach can be extended and applied to solve other decision- making problems that involve multi-criteria decision-making considering importance of decision variables from different perspectives. When the number of design requirements to be compared is not very large, the ANP approach is a more effective approach than other approaches. The future work will focus on the development of priority of design requirements basing on competitiveness and implementation difficulty.

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