Prioritization of Performance Metrics For Lean & Agile Supply Chains

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ABSTRACT

The success of any product in the present competitive market scenario depends on extent of strategic fit among competitive and supply chain strategies. 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 prioritize the performance measures of lean & agile supply chain in those companies

This paper presents an ANP methodology (HoQ-ANP) to translate strategic design requirements into performance measures and to determine the importance weights of performance measures by considering the complex dependency relationships between and within SDRs and SPMs for lean and agile supply chains. In order to deal with the vagueness, uncertainty and diversity in dependency relationships Fuzzy Logarithmic Least square method (LLSM) is used to determine the priority structure of SPMs, inner dependence among SDRs, Inner dependence among SPMs and inter-relationship between SDRs & SPMs. Prioritization of SPMs for Lean and Agile supply chains is determined through a illustrative example.

Key words: Lean and agile supply chains; Quality Function Deployment; Triangle fuzzy numbers, Analytic network Process.

1. INTRODUCTION

In general, a supply chain consists of suppliers, manufacturers who convert raw materials into finished products and distribution-centers, from which finished products are distributed to customer zones. Lee and Billington [1] define a supply chain as a network of facilities that procures raw materials, transforms them into intermediate goods and then final products, and delivers the products to customers through a distribution system. Supply Chain Management has been defined by Mentzer et al. [2] as the systematic, strategic coordination of the traditional business functions and tactics across these businesses functions within a particular organization and across businesses within the supply chain, for the purpose of improving the long term performance of the individual organizations and the supply chain as a whole Li et al., [3]

A Lean Supply Chain (LSC) employs continuous improvement efforts that focus on eliminating waste or non-value steps along the chain. An Agile Supply Chain (ASC) focuses on responding to unpredictable market changes and capitalizing on them through fast delivery and lead time flexibility. It deploys new technologies, methods, tools, and techniques to solve unexpected problems. Lean and Agile supply chain is defined as the combination of lean and agile paradigms that, applied to the strategy of supply chain, respond satisfactorily, to the volatile market demands Hock et al., [4]. There is an important difference between the performance of lean supply chain and agile supply chain. 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., [5]. 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 of the overlap between leanness and agility Narasimhan, et al., [6]. To achieve leagility the de-coupling point is be located at the final assembler. An action that usually requires associated product rationalization Lee and Sasser [7]. Specific products are now pulled by current sales demand whilst upstream of the de-coupling point suppliers now work to level schedules.

Vildan and Tufan [8], explored the strategies for design and performance measurement of different supply chain types. In the study, supply chain performance is analyzed basing on the indicators under market sensitiveness, Reliability, Accessibility and flexibility.

Seyyed Ali Banihashemi [9] examined the patterns of lean and agile supply chain and introduced Leagilty Supply Chain. The author concluded that Lean and agile patterns in the supply chain are the main focus of many manufacturing companies (today) which are seeking to improve performance.

Venkata ramana et al. [10] examined the consistency approaches by confirmatory factor analysis that determines the adoption of performance dimensions of lean and agile supply chains.

Agarwal et al. [11] proposed a framework which encapsulates the market sensitiveness, process integration information driver and flexibility measures of supply chain performance. The proposed framework analyses the effect of market winning criteria and market qualifying criteria on the three types of supply chains: lean, agile and leagile.

Mohamadreza Motadel et. al., [12] identified and prioritized five supply chain agility indicators in the automotive industry of Tehran. The results prove that among the five dimensions of supply chain agility, Information Technology and Flexibility is the most important indicators.

Gunasekaran et. al. [13] developed a framework to promote a better understanding of the importance of SCM performance measurement and metrics.

Arawati et. al. [14] analyzed the relationships between strategic supplier partnership practices, Product quality performance and Business performance and their associations through correlation, cluster analysis and Structural Equation Modeling (SEM).

Bhatnagar and Sohal [15] identified the manufacturing industry of Asian as the research targets and proposed supply chain performance measurement indicators on plant location factor, supply chain uncertainty and manufacturing practices to measure supply chain competitive advantages.

Viladin et. al. [16] explores the strategies for design and performance measurement of different supply chain types based on fuzzy entropy approach.

From the current literature, it is observed that performance measurement and metrics pertaining to leagile supply Chains have not received adequate attention from researchers or practitioners. Hence in this paper, ANP methodology is used to determine the weights of the performance measures through Fuzzy Logarithmic Least Square method (LLSM).

2. Performance Measures of Leagile Supply Chain

2.1 Organizational Performance (ORP)

The definition of organizational performance depends on the views of different stakeholders. Vickery et al. [17] considers that the organizational performance refers to how well an organization achieves its market-oriented goals as well as its financial goals. Thus, they set up the measurement performance items as return on assets, market share and growth rate.

2.2 Operational Performance (OP)

Lippman [18] interviewed operations managers and reported that most of them claimed they were experiencing increases in their operational outcomes, such as reduction in cycle time, cost and quality improvement.

2.3 Customer Service Performance (CSP)

Customer Service performance is the ability to respond to customers' ever-changing wants and needs in a timely way [19].

2.4 Flexibility (FL)

Based on Slack's [20] concept that flexibility is defined as two dimensional, Swafford et al. [21] defined flexibility using two dimensions called range and adaptability.

3. Determination of Weights in Fuzzy Environment

In Multi Criteria Decision Making (MCDM) methods, the ratings and the weights of the criteria are known precisely. However, crisp data are inadequate to model real-life situations, since human judgments including preferences are often vague and one's preference cannot be estimated with an exact numerical value. A more realistic approach may be to use linguistic variables like high, very high, etc. instead of numerical values. A natural way to cope up with such uncertain judgments is to express the comparison ratios as fuzzy sets or fuzzy numbers which incorporate the vagueness of human thinking. When comparing any linguistic variables, the uncertain comparison judgment can be represented by membership functions or the fuzzy number. Here, linguistic values expressed as trapezoidal fuzzy numbers are used to assess the priority of the factors. The fuzzy logarithmic least square method (LLSM) developed by Wang et al. [22] is employed to obtain the vector of triangle fuzzy weights through the optimization model of fuzzy LLSM using fuzzy pair wise comparison matrices of SDRs and SPMs

4. Methodology

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Importance weights of SPMs are obtained by considering the HoQ-ANP frame work and the methodology is discussed in the following steps.

Step 1. Identification of SDRs
Step 2. Prioritization of SDRs (W1)
Step 3. Identification of SPMs
Step 4. Determination of inter-dependency matrix (W2)
Step 5. Establish the inner dependence matrix of the SDRs (W3)
Step 6. Establish the inner dependence matrix of the SPMs (W4)
Step 7. Establish the inter dependent priority matrix of the SDRs (Wc)
Step 8. Establish the inter dependent priority matrix of the SPMs (Wa)
Step 9. Determination of the overall priorities of SPMs (WANP)

4.1 Illustrative Example

The methodology to determine prioritization of performance measures of Lean and Agile Supply Chains are illustrated and given below.

4.2 Strategic Design Requirements and prioritization

The design requirements for lean & agile supply chains are the set of functions either wholly independent or partially influence the performance of the organization. In this study,SDRs namely, Product Development (PD), Sourcing (SOU), Manufacturing (MFG), Demand Management (DM), Information Technology (IT), Management Commitment (MC), Supply Chain Network Design (SCN), Inventory Management (INV) are considered in the study (Venkata Ramanab et al., 2013). Priority weights of SDRs are shown in table 1.

TABLE 1
PRIORITY WEIGHTS OF SDRS

PD	SOU	MFG	DM	IT	MC	SCN	INV
0.155 5	0.181 5	0.131 3	0.108 6	0.225 8	0.019 4	0.090 5	0.076 8

Highest weight (0.2258) is obtained with IT. The IT factor includes Application of IT in manufacturing process, planning and control and other E- Commerce capabilities.

Sourcing factor with a weight of 0.1815 is associated Sourcing Strategy, Multi-criteria supplier selection and supplier integration & development.

Product Development factor has obtained a weight of 0.1555. Product development includes the items related Involving suppliers in product development, Involving customers in product development and application of computer technology in product design.

Manufacturing factor has obtained a weight of 0.1313 includes the items related to Production type & control, production system and Product Structure.

Demand Management factor has obtained a weight of 0.1086 includes the items related to Demand Planning, planning intensity and capacity planning.

Supply chain network and inventory management have obtained relatively low weights of 0.0905 and 0.0768 respectively. Supply chain net work includes the items related to Network configuration and Distribution strategies. Inventory management factor includes the items related to Buffer stock, Batch size and Service level. Management commitment is obtained very low weight. The importance weights of customer needs are graphically shown in figure 1.

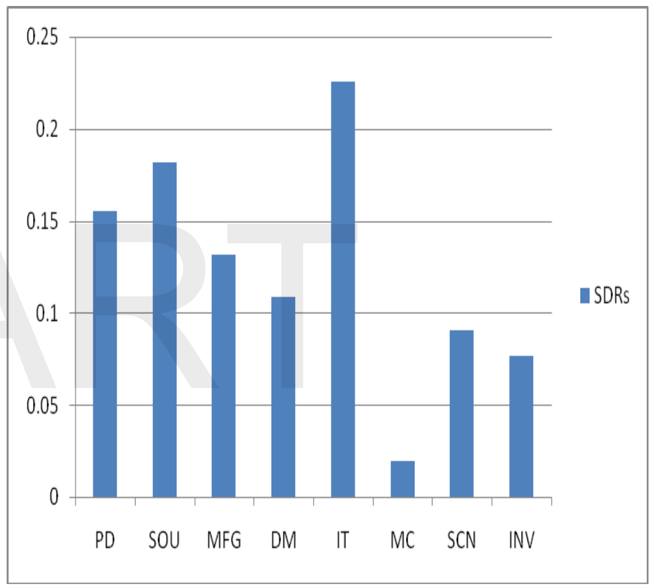

Figure 1. The importance weights of SDRs

4.3 Supply Chain Performance Measures

Supply chain performance measures are useful to measure supply chain competitive advantages. In this study, Operational Performance, Organizational Performance, Customer service Performance and flexibility are considered (Venkata Ramana et al., 2013).

4.4 Inter- Dependency matrix (W2)

Inter-dependency of SPMs and SDRs is determined from fuzzy LLSM using fuzzy pair wise comparison matrices. The Inter-dependency relationships between SDRs and SPMs are shown in table 2.

TABLE 2
INTER DEPENDENCY MATRIX OF SDRS AND SPMS (W2)

Performance measurers/Strategic Design Requirements	OP	CSP	FL	ORP
PD	0.3825	0.3187	0.1087	0.1284
SOU	0.3825	0.1792	0.2951	0.1432
MFG	0.4598	0.0994	0.1090	0.3318
DM	0.1269	0.4132	0.1359	0.3240
IT	0.3999	0.1731	0.1360	0.2910
MC	0.1379	0.3936	0.2932	0.1753
SCN	0.1380	0.3935	0.1753	0.2932
INV	0.1089	0.4598	0.3317	0.0936

From inter dependency matrix of SPMs and SDRs, it is observed that MFG, PD, IT and SOU denotes high impact in case of operational performance. INV, DM, MC, SCN and PD are highly impacting on Customer service performance. Flexibility is highly influenced by INV, SOU, MC and SCN. Organizational Performance is highly influenced by MFG, DM, SCN and IT.Inter-dependency of SPMs and SDRs is graphically shown in the figure 2.

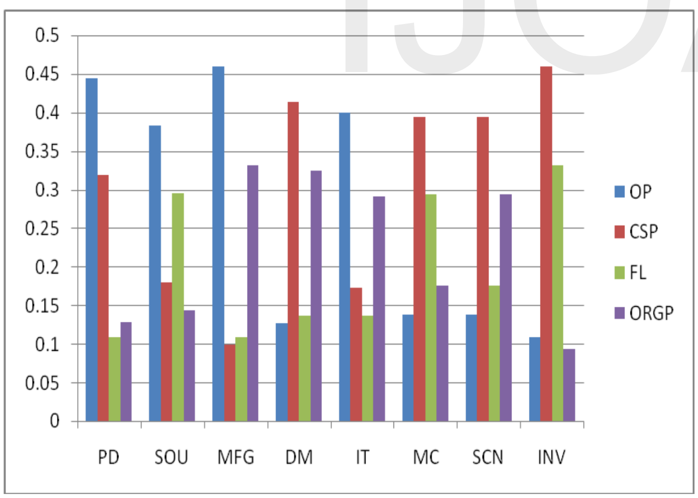

Figure 2. Inter-dependency of SPMs and SDRs

4.5 Inner Dependence Matrix of the SDRs (W3)

Inner dependence matrix of the SDRs is established by constructing the fuzzy pair-wise comparison matrix within the SDRs with respect to the inner- dependency relationships within them. Inner-dependency among SDRs are shown in table 3.

TABLE 3
THE INNER DEPENDENCE MATRIX OF THE SDRS (W3)

	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	0.3576	0.2040
INV	0.0000	0.1201	0.0000	0.1000	0.1047	0.0000	0.0000	0.2789

Normalized values of inner dependency of each SDR on other SDRs are shown graphically in the figure 3.

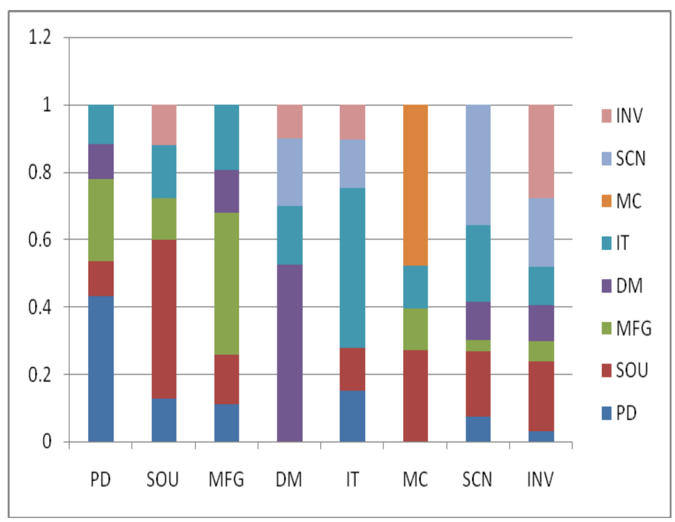

Figure 3. Inner dependence matrix of the SDRs

It is observed that each of the SDRs namely, PD,SOU, MFG,DM,IT, MC,SCN and INV depend on the rest of the SDRs by 56.78%, 52.85%, 57.91%, 47.6%, 52.54%, 52.14%, 64.24%, and 72.11% respectively.

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4.6 Inner Dependence Matrix of the SPMs (W_4)

Inner dependence matrix of the SPMs is established by constructing the fuzzy pair-wise comparison matrix within the SPMs with respect to the inner- dependency relationships within them. Inner-dependency among SPMs are shown in table 4.

TABLE 4
THE INNER DEPENDENCY MATRIX OF THE SPMS (W4)

	Flexibility	Customer service performance	Organizational performance	Operational Performance
Flexibility	0.3825	0.4443	0.4598	0.4686
Customer service performance	0.2950	0.3186	0.3318	0.3286
Organisational Performance	0.1792	0.1283	0.1090	0.1014
Operational Performance	0.1433	0.1088	0.0994	0.1014

The values in the table indicate the extent of impact of each SPM on other SPMs. Inner dependency of each SPM on other SPMs are shown graphically in the figure 4.

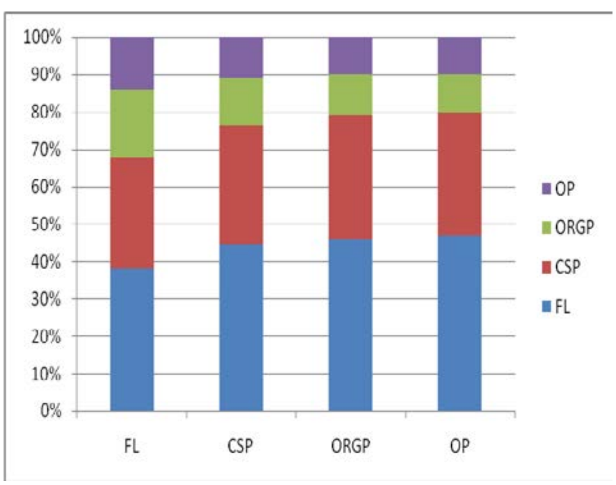

Figure 4. Inner dependency matrix of the SPMs

From the above figure 4, it is observed that each of the SPM namely, FL, CSP, ORGP and OP depend on the rest of the SPMs by 61.75%, 68.14%, 89.1%, and 89.86% respectively.

4.7 Inter dependent priority matrix of the SDRs (Wc)

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

$$W_c = W_3 * W_1 = \begin{pmatrix} PD \\ SOU \\ MFG \\ DM \\ IT \\ MC \\ SCN \\ INV \end{pmatrix} = \begin{pmatrix} 0.1481 \\ 0.1877 \\ 0.1258 \\ 0.1083 \\ 0.2301 \\ 0.0093 \\ 0.0937 \\ 0.0007 \end{pmatrix}$$

Inter- dependent priority of the SDRs is shown graphically in the figure 5.

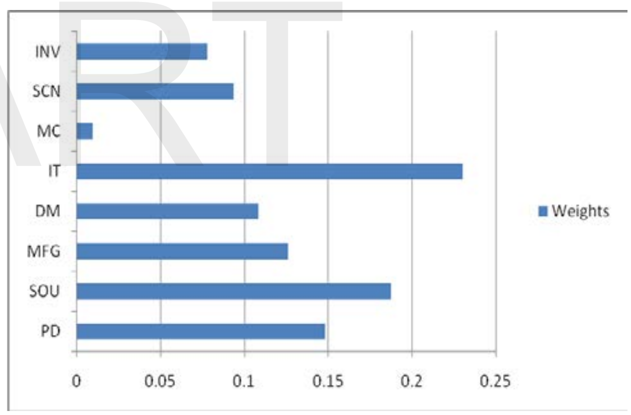

Figure 5. Inter- dependent priority of the SDRs

From figure 5, it is observed that IT, SOU, PD, MFG, DM SCN, INV and MC by 23.01%, 18.77%, 14.81%, 12.58%, 10.83%, 9.37%, 7.77%, and 0.93% respectively by considering the correlation among the SDRs.

4.8 Inter dependent priority matrix of the SPMs

The inter- dependent priority matrix of the SPMs and SDRs is obtained by the following relation and shown in the table 5.

Wa = W4 * W2

TABLE 5
INTER- DEPENDENT PRIORITY MATRIX OF THE SPMS AND SDRS (WA)

	FL	CSP	ORGP	OP
PD	0.4504	0.3222	0.1194	0.1081
SOU	0.4376	0.3174	0.1303	0.1148
MFG	0.4539	0.3250	0.1151	0.1060
DM	0.4440	0.3209	0.1256	0.1095
IT	0.4501	0.3232	0.1188	0.1078
MC	0.4322	0.3154	0.1361	0.1162
SCN	0.4414	0.3197	0.1279	0.1397
INV	0.4252	0.3112	0.1397	0.1179

The inter dependent values of the matrix Wa illustrates how the individual supply chain performance measurers depend on strategic design requirements. From the table 5, it is understood that all the design requirements highly influence the flexibility measure. Organizational performance and operational performance is relatively less influenced by these design requirements. Customer service performance is moderately influenced by the design requirements.

Inter dependent priority of SPMs and SDRs are graphically shown in the figure 6.

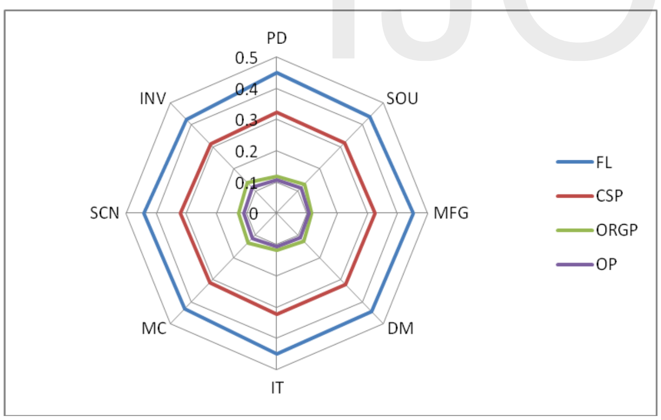

Figure 6. Inter- dependent priority of the SPMs and SDRs

From the figure, it is understood that all the design requirements have influence on the performance measures of lean and agile supply chains.

4.9 Overall priorities of SPMs

The overall priorities of the SPMs reflecting the interrelationships within the HoQ are obtained by the following relation. The ranking of design requirements basing on the overall priority is shown below.

$$W_{ANP} = Wa * Wc$$

$$W^{ANP} = \begin{pmatrix} FL \\ CSP \\ ORG \\ OP \end{pmatrix} = \begin{pmatrix} 0.4360 \\ 0.3144 \\ 0.1216 \\ 0.1082 \end{pmatrix}$$

From the study, it is understood that the most important Supply chain Performance Measurers is Flexibility with a relative importance value of 0.4360 followed by Customer Service Performance with a weight of 0.3144. Organizational Performance and Operational Performance are also more important measurers for lean & agile supply chain with importance weights 0.1216 and 0.1082 respectively for lean & agile supply chain. Prioritization of performance measures through ANP takes care of inner dependency and inters dependency of strategic design requirements and performance measurers.

Over all priority of SPMs are graphically shown in the following figure 7.

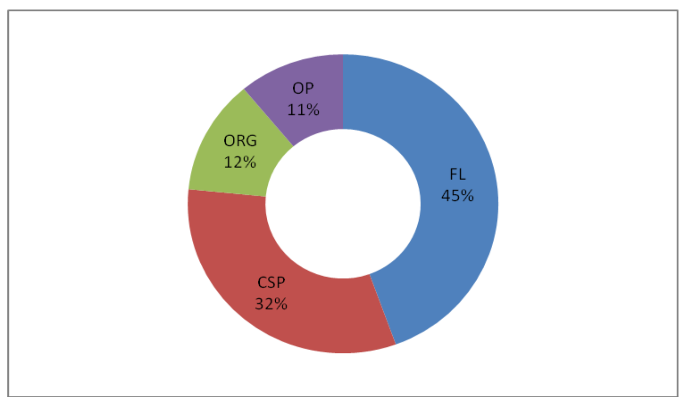

Figure 7. Over all priority of SPMs

5. CONCLUSIONS

An integrated approach for rating of SPMs importance for lean and agile supply chain is developed in this paper. The ANP approach is integrated into HoQ to prioritize SPMs considering SDRs. In the study, Flexibility, Customer service Performance, Organizational Performance and Operational Performance have contributed 43.60%, 31.44%, 12.16%, and 10.82% respectively. It indicates that the relative importance of the Strategic Design Requirements in the competitive strategy of lean and agile supply chains. It is also observed that, Supply chain Performance Measurers like use of Flexibility, Customer service Performance, Organizational Performance and

Operational Performance are of great importance in deciding the strategy of lean & agile supply chains. Further, it is observed that Organizational Performance, Operational Performance, Flexibility and Customer service Performance, policies are also contributing towards lean & agile supply chains. This method can be used to model the translating information from SDRs more holistically. In addition, the fuzzy theory in determining inner dependence and inter dependence matrices of SDRs and SPMs are incorporated in 1.
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. 2.

REFERENCES 3.

[1] . Lee H, Billington C (1995). The Evolution of supply chain management models and paractive at Hewlett-Packard. Interface, 25(5).

[2]. Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.W., 4.
Smith, C.D. & Zacharia, Z.G. (2001). What is supply chain management. in Mentzer, J.T. (Ed.), Supply Chain Management,Sage, Thousand Oaks, CA, pp. 1-25.

[3]. Li, S., Rao, S.S., Ragu-Nathan, T.S., Ragu-Nathen, B. (2005), Development and validation of a measurement instrument for studying supply chain management practices, Journal of Operations Management, 23, 618-641 5.

[4]. Hock R., Harrison A., Chirstopher M. (2001) Measuring agile capabilities in the supply chain – International Journal of Operations and Production Management, 21, 7,126-147.

[5]. Slack N. (2008): Ger. de Operações e Processos – Ed. 6.
Bookman.

[6]. Narasimhan, R., Morgan, W., Kim, S.W., (2006), Disentangling leanness and agility: An empirical investigation, 7.
Journal of Operations Management, 24, 440-457.

[7]. Lee, H. L., and Sasser, M. M., 1995, Product universatility and design for supply chain management. Production Planning and Control, 6(3), 270- 277. 8.

[8]. Vildan Özkir and Tufan Demirel (2011), A comprehensive analysis for the metrics of supply Chain design strategies, 15th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 9.
2011, Prague, Czech Republic, 353-356.

[9]. Seyyed Ali Banihashemi (2011), Improving supply chain performance: The strategic integration of lean and agile supply chain, African Journal of Business Management Vol. 5(17), pp. 7557-7563

[10]. Venkata Ramanaa. D., Narayana Rao.K. and Suresh Kumar. J., (2013), Evaluation of performance metrics of Leagile supply chains through Fuzzy MCDM, Decision Science Lettres, 2, pp. 1-12.

[11]. Ashish Agarwal, Ravi Shankar, M.K. Tiwari, (2006), Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach, European Journal of Operational Research, 173, 211–225.

[12].Mohamadreza Motade, Abbas Toloie-Eshlaghy and Delnaz Halvachi-Zadeh (2011), Assessment of Supply Chain Agility in the Automotive Industry of Tehran, European Journal of Scientific Research, 61, 2, 210-229.

[13]. A. Gunasekaran, C. Patel and Ronald E. McGaughey, (2004) A framework for supply chain performance measurement, International Journal of Production Economics, 87, 333–347

[14]. Arawati Agus and Za' faran Hassan, (2008), The strategic supplier partnership in a supply chain Management with quality and business performance, International Journal of Business and Management Science, 1,2, 129-145.

[15]. Bhatnagar, R. and Sohal, A. S., 2005, "Supply chain competitiveness: Measuring the impact of location factors, uncertainty and manufacturing practices," Technovation, Vol. 25, No. 5, pp. 443-456.

[16]. Vildan Özkir and Tufan Demirel (2011), a Comprehensive Analysis for the Metrics of Supply Chain Design Strategies, 15th International Research/Expert Conference"Trends in the Development of Machinery and Associated Technology", Prague, Czech Republic, 12-18 September, 353-356.

[17]. Vickery, S. K., Droge, C. and Markland, R. E., 1991, "Production competence and business strategy: Do they affect business performance?" Decision Science, Vol. 24, No. 2, pp. 435-455

[18]. Lippman, S. (2001). Supply chain environmental management, ecological Quality Management, 11(2), 11-14.

[19]. Zelbst, P. J., Green, K. W., Abshire, R.D., and Sower, V.E. (2010), "Relationships among market orientation, JIT, TQM, and agility. Industrial Management & Data Systems, Vol.110 (5), 2010, pp. 637-658.

[20]. Slack, N. (1987), "The flexibility of manufacturing systems", International Journal of Operations & Production Management, Vol. 7 No. 4, pp. 35-45.

[21]. Swafford, P., Ghosh, S., Murthy, N. (2006), "The antecedents of supply chain agility of a firm: Scale development and model testing", Journal of Operations Management 24, pp. 170–188.

[22]. Wang Y. M. on lexicographic goal programming method for generating weights from inconsistent interval comparison Matrices, Applied Mathematics and computation, 173, 2006, 985 – 991.

[23]. Venkata Ramanab. D, Narayana Rao.K., Suresh Kumar. J. and Venkatasubbaiah. K.,(2013), Prioritization of Strategic Design Requirements for Lean & Agile supply chains, International Journal of Advanced Research in Engineering and Applied Sciences, 2,1,62-82.

