IDENTIFICATION OF CRITERIA FOR THIRD PARTY LOGISTICS SUPPLIERS (3PL) IN SUPPLY CHAIN MANAGEMENT (SCM) IN INDIAN MANUFACTURING INDUSTRIES

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ABSTRACT

The Indian manufacturing industry is growing rapidly, and supply chain management (SCM) plays the most important role in the industry. In SCM, customer satisfaction in terms of quantity, quality and on time delivery is the most important critical factor. To satisfy this requirement, the best third-party logistics (3PL) service provider is required. Therefore, the selection of the best third-party logistics provider is one of the basic requirements in SCM. Logistics services are the backbone of an economy, providing the efficient, cost effective flow of goods and services on which other commercial sectors depend. The logistics companies work as the outsourced or third-party service providers and support the organization's logistics functions. In this study, we identified some important criteria for 3PL implementation in SCM in Indian manufacturing industries. With the help of this study, supply chain managers from small to medium sized manufacturing industries can simplify the selection process for 3PL vendors. This study will help in the selection of the best vendor from such a competitive group and provide justification for the selection.

Keywords: third party logistics vendor selection; 3PL; supply chain management; AHP; Indian manufacturing; sensitivity analysis

1. Introduction

The 3PL market in India is under-developed and highly fragmented. However, recent trends show that the Indian market has come of age with small family-run businesses giving way/progressing to professional-run corporate enterprises (Chaudhari & Sarode, 2018). This refreshing change is a welcome sign for growth, as professionalism can help build efficiency and reduce costs. The manufacturing industry's success and growth play

an important role in the economic development of any country (Sarode & Kole, 2016). In the current market for each product, there is high competition that creates a challenging situation for each organization. To stay competitive each organization needs to proactively increase and improve its productivity. To stay continuously competitive, choosing the best 3PL service provider plays an important role for manufacturing industries (Sarode & Khodke, 2011). To maintain a competitive edge, every company needs to adjust and adapt to changes in the market and act accordingly. A company's top management plays an important role in selecting any procedure for successful SCM (Aguezzoul, 2014).

Before 20 years ago, logistics was the key factor for only some Indian manufacturing industries, but now these industries seem to be a step ahead of others in their use of logistics. Logistics costs in India are about 13% of the country's total GDP. For example, in 2012-13, the cost of logistics was around $130 billion (Mitra, 2008). Our study seeks to identify and prioritize the dominant CF's (critical factors) for adopting the best logistics practices for Indian industries. The identification and prioritization of CF's may help practitioners/managers better achieve their goals. In this study, we identify and analyze the various critical factors (CF's) in adopting logistics practices.

In this paper, we identify and rank the drivers/enablers for 3PL implementation in supply chains. In order to identify the enablers for 3PL, it is necessary to prepare a method which is capable of collecting appropriate information. Therefore, this paper identified 28 enablers to solve the above problem. Data was collected from various manufacturing industries in India and thirteen main criteria including cost, relationships, services, quality, IT systems, flexibility, government regulations and policy, and others, were categorized into 42 enablers. This paper ranks the enablers in the context of Indian manufacturing using the AHP to enhance the supply chains

The structure of this paper is organized as follows: the literature review is presented in section 2. Section 3 presents the solution methodology with the AHP framework. Ranking of enablers/drivers is discussed in the results and discussion presented in section 4. Section 5 presents a case study of practical application verified by using a sensitivity analysis. The final section 6 summarizes the conclusions and future scope.

1.1 Problem statement

Our main objective in this research is to analyze the key factors required in 3PL's implementation in SCM. Then, we will select and prioritize the factors by using an AHP framework. The final task is to validate the work by using a sensitivity analysis in a case study.

1.2 Research objective

To determine the solutions to the problem, we optimized the objective of our research as follows. We studied the awareness and importance given to the selection of third party logistics members in the industries. Also, we identified several drivers to implement successful 3PL in the supply chain. For this, we found key success factors discussed in the literature. Then, we conducted a pilot study among top management, academic experts, field experts and others to validate and finalize the key success factors. For this survey, we collected responses from industrial experts and evaluate the responses. Based on these responses, we identified the essential enablers for 3PL in SC through MCDM

(multi criteria decision modeling). Further, to validate our work, we studied the awareness and the importance given to the selection by using a case study with the help of a sensitivity analysis.

2. Literature review

This literature review will summarize the literature on logistics related to supply chain management (SCM) and the identification of key success factors to implement successful logistics in organizations. The strategy we used to review the literature was to find relevant keywords by defining the project and the key concepts of the project, and generating keywords using synonyms. Through this process, we found key success factors through a detailed literature review.

Sarode and Kole (2016) found in their literature search that 15 critical factors are the most important. Aguezzoul (2014) found that top management support, cost, quality, operational performance, and customer satisfaction are the major critical success factors. In this paper, 87 articles published between 1994-2013 were reviewed, and based on the analysis, cost, relationship, services, quality, information and equipment systems, flexibility, delivery, professionalism, financial position, location, and reputation were the 11 main factors which were classified and sub divided into 45 sub criteria. The authors categorized articles into five groups according to the technique used. Eight papers used the AHP technique for criteria selection. Peng (2012) identified and prioritized logistics out-sourcing service suppliers using AHP and presented a case study of a frozen food enterprise. In this case study, based on an evaluation index system, logistics cost, operating efficiency, service quality, and technology level were targeted as critical success factors.

According to an article by Garg (2018), 16 variables that influence the logistics performance were classified under six levels based on their dependability. Investment by government and Logistics Service Providers (LSP) plays an important role in improving the performance of logistics. According to the author, LSP should improve and concentrate on continuous development in Information Technology and human resources. Luthra (2017) stated that logistics initiatives in business have been growing for the past one to two decades, which has resulted in environmental concerns gaining more attention. In this paper, based on a case study of Indian auto component manufacturers, regulatory factors, competitiveness factors, financial factors and supply chain factors were determined to be important in 3PL implementation, and were further classified into 13 sub-factors for detailed information.

Birgul (2015) identified five key strategic factors broken into 20 sub-factors that help satisfy customer needs in terms of quality, quantity and on-time delivery by third party logistics providers. In this article, an AHP based framework is designed for an IT distribution company. Xu (2017) classified first-order performance evaluation indices as financial performance, operation process, innovation ability and customer relationship, followed by 13 second-order indices. Mangla (2016) provided a structural model of logistics implementation in manufacturing industries in India based on AHP in which he defined five main factors including regulatory factors, global competitiveness factors, economic factors, HR and organizational factors and strategic factors followed by 25 detailed sub-factors.

Korpela (1996) defined and prioritized performance for achieving superior logistics. According to the International Benchmarking Clearinghouse, "Benchmarking is a process in which companies target key improvement areas within their firms, identify and study best practices of others in these areas and implement new processes and systems to enhance their own productivity and quality." Reliability, flexibility, lead-time, cost effectiveness, and value added are prioritized as critical success factors of logistics. Yahya (1999) confirms that in every organization, selection of the best 3PL (Third Party Logistics Providers) is always difficult for top management. Before making any decision, buyers and purchasing managers must analyze the strengths and weaknesses of the 3PL suppliers being considered. In a simple categorized model, eight main criteria are identified, followed by 13 sub-criteria.

Mothilal (2014) identified the key success factors of 3PL in the Indian manufacturing sector using studies from other locations such as the US, North America, Hong-Kong, UK, China, France, and Finland divided into the sectors of 3PL, MNC's, manufacturing, and the automotive industry. When the findings of those studies were compared with those from the Indian industrial 3PL sector, six key success factors were identified of which the main three were breadth of services, industrial focus, and investment in IT. Mitra (2016) conducted a case study in North America about 3PL in manufacturing industries by using statistical data analysis. According to this article, internationalization, industry focus, investment in information systems, availability of skilled professionals and integration of supply chains stand out as the most important success factors. Mitra (2009) carried out an in-depth survey of Indian express delivery service providers in terms of demographics, success factors, performance metrics, problems faced and opportunities for growth by studying clusters of micro and small industries, and medium and large industries and identified fourteen success factors. Globalization, on-time delivery, breadth of services, relationships with customers and investment in IT were found to be the main success factors. Mitra (2010) compared North American 3PL firms with Indian firms and found that 3PL experience and 3PL relationships were the key success factors for North American firms while these are only moderately important factors for Indian firms. According to this research, Indian firms lag behind North American firms because they invest less in information systems, have a low availability of management talent, and poorly integrate their supply chains.

From our in-depth literature review, we summarized the results into 13 main factors and 42 sub-factors as shown in Table 1.

Table 1
Drivers/enablers from the literature

Author & Year ⏩				(Aicha A., 2014) [2]	(Jian liang peng, 2012) [3]	(S. K. Garg, 2018) [4]	(S. Luthra, 2017) [5]	(Birgul K. C., 2015) [6]	(Subo Xu, 2017) [7]	(S. Mangla, 2016) [8]	(J. Korpela, 1996) [9]	(S. Yahya, 1999) [10]	(S. Mothilal, 2014) [11]	(Tugrul U. D., 2015) [12]
Drivers ⏬														
Sr. no.	**Criteria**	**Sr. no.**	**Sub - criteria**											
1	**Cost**	1	Cost Reduction	✓		✓	✓			✓				
		2	Expected leasing cost	✓					✓	✓				
		3	Operation cost	✓	✓			✓	✓	✓				✓
		4	Warehousing cost	✓	✓			✓						
		5	Cost saving	✓			✓	✓		✓	✓			
		6	Economic benefits	✓		✓	✓	✓	✓	✓	✓			
2	**Relationships**	1	3PL opportunistic behaviour	✓				✓	✓		✓	✓	✓	
		2	Reliability	✓		✓		✓			✓		✓	✓
		3	Truth & Trust	✓		✓		✓			✓	✓		
		4	Integration & Co-ordination		✓		✓		✓	✓	✓		✓	✓
3	**Services**	1	Breadth of services	✓		✓	✓		✓	✓		✓	✓	
		2	Pre-sale / post-sale services	✓				✓			✓			✓
		3	Value added services	✓		✓		✓			✓			
4	**Quality**	1	Commitment to continuous improvement	✓	✓	✓			✓					
		2	Environmental issues	✓		✓		✓		✓				
		3	Risk management	✓						✓		✓		
5	**Information systems + Technology**	1	Information accessability	✓		✓		✓	✓	✓	✓			
		2	Information technology		✓	✓		✓	✓	✓	✓	✓	✓	✓
		3	Storage technology		✓			✓	✓					
		4	Transportation technology		✓			✓	✓					
6	**Flexibility & Reputation**	1	Ability to meet future requirement	✓		✓		✓	✓	✓	✓			
		2	Customer satisfaction	✓	✓			✓	✓		✓	✓	✓	✓
7	**Delivery**	1	On time delivery/shipment	✓	✓			✓				✓		✓
		2	Lead time	✓				✓			✓			
		3	Accuaracy of delivery time	✓	✓			✓				✓		✓
		4	Reduction in time & raw material consumption			✓	✓			✓	✓		✓	
8	**Professionalism**	1	Punctuality	✓	✓							✓		
		2	Expertise	✓						✓	✓			✓
		3	Experience	✓						✓				✓
9	**finiancial position**	1	Upgrading of equipments & services	✓		✓					✓	✓	✓	
		2	Improved process efficiency			✓	✓	✓	✓	✓	✓			
10	**locations**	1	Geographyical specialization & coverage	✓				✓		✓		✓		
		2	International scope	✓		✓	✓	✓		✓	✓	✓		✓
11	**Regulatory & policy**	1	Govt. legislation & support			✓	✓			✓		✓		✓
		2	Tax benefits & related policy			✓	✓			✓				
12	**Competitiveness**	1	Competition among firm			✓	✓		✓					
		2	Benchmarking standards				✓	✓	✓	✓		✓		✓
		3	Adopting sustainability				✓	✓	✓					
13	**Supply chain factor**	1	Role of stakeholder & supports				✓			✓	✓			
		2	Top management support				✓		✓	✓		✓	✓	
		3	Skilled human forces			✓			✓	✓	✓		✓	✓
		4	Social responsibility			✓		✓		✓				
		5	Customer Environmental Awareness				✓	✓		✓		✓		✓

3. Methodology

From the literature review, we identified 13 main factors and 42 sub-factors that could be used to rank criteria and sub-criteria for selecting 3PL for SCM (Supply Chain Management) in Indian manufacturing industries. A complex problem can be solved using the techniques of MCDM (Multi-Criteria Decision Making). We propose the framework of criteria and sub-criteria shown in Figure 1 for prioritizing the criteria and sub-criteria defined in Table 2.

3.1 Framework for 3PL implementation in supply chain management

In this section, we prioritized the key success factors for finding the best 3PL in supply chain management by using the Analytic Hierarchy Process (AHP) approach. An AHP-based framework with four levels is shown in Figure 1.

The hierarchy level 1 indicates the objective of the research, i.e., to identify key success factors required for selecting the best 3PL in SCM.
The hierarchy level 2 shows the main key success factors.
The hierarchy level 3 shows the sub-factors of drivers/enablers.
The hierarchy level 4 shows the bottom level, where the key success factors are prioritized.

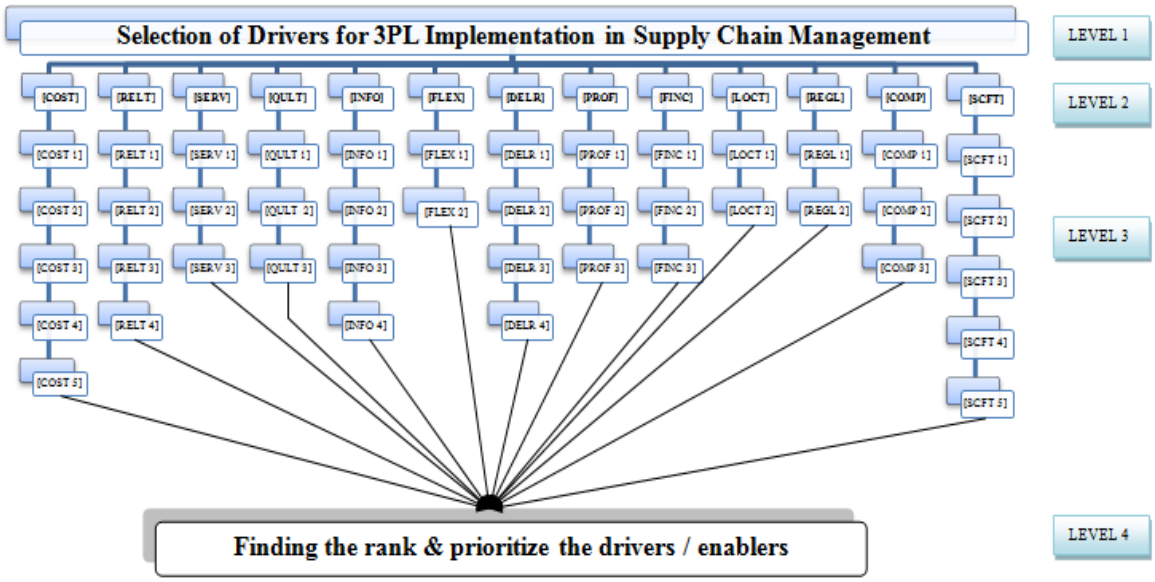

Figure 1 AHP framework for identification of key factors for 3PL implementation in SCM

Table 2
Definitions of symbols in Figure 1

SR. No.	DRIVERS	SYMBOL	SR. No.	DRIVERS	SYMBOL
1.	**COST**	[COST]	a.	On time delivery/shipment	[DELR 1]
a.	Cost Reduction	[COST 1]	b.	Lead time	[DELR 2]
b.	Operation cost	[COST 2]	c.	Accuracy of delivery time	[DELR 3]
c.	Warehousing cost	[COST 3]	d.	Reduction in time of raw material consumption	[DELR 4]
d.	Cost saving	[COST 4]	8.	**PROFESSIONALISM**	[PROF]
e.	Economic benefits	[COST 5]	a.	Punctuality	[PROF 1]
2.	**3PL RELATIONSHIPS**	[RELT]	b.	Expertise	[PROF 2]
a.	3PL opportunistic behavior	[RELT 1]	c.	Experience	[PROF 3]
b.	Reliability	[RELT 2]	9.	**FINIANCIAL POSITION**	[FINC]
c.	Truth & Trust	[RELT 3]	a.	Upgrading of equipment & services	[FINC 1]
d.	Integration & Co-ordination	[RELT 4]	b.	Improved process efficiency	[FINC 2]
3.	**SERVICES**	[SERV]	10.	**LOCATIONS**	[LOCT]
a.	Breadth of services	[SERV 1]	a.	Geographical specialization & coverage	[LOCT 1]
b.	Pre-sale / post-sale services	[SERV 2]	b.	International scope	[LOCT 2]
c.	Value added services	[SERV 3]	11.	**REGULATORY & POLICY**	[REGL]
4.	**QUALITY**	[QULT]	a.	Govt. legislation & support	[REGL 1]
a.	Commitment to continuous improvement	[QULT 1]	b.	Tax benefits & related policy	[REGL 2]
b.	Environmental issues	[QULT 2]	12.	**COMPETITIVENESS**	[COMP]
c.	Risk management	[QULT 3]	a.	Competition among firm	[COMP 1]
5.	**INFORMATION SYSTEMS + TECHNOLOGY**	[INFO]	b.	Benchmarking standards	[COMP 2]
a.	Information accessibility	[INFO 1]	c.	Adopting sustainability	[COMP 3]
b.	Information technology	[INFO 2]	13.	**SUPPLY CHAIN FACTORS**	[SCFT]
c.	Storage technology	[INFO 3]	a.	Role of stakeholder & supports	[SCFT 1]
.d.	Transportation technology	[INFO 4]	b.	Top management support	[SCFT 2]
6.	**FLEXIBILITY & REPUTATION**	[FLEX]	c.	Skilled human forces	[SCFT 3]
a.	Customer Satisfaction	[FLEX 1]	d.	Social responsibility	[SCFT 4]
b.	Ability to meet future requirement	[FLEX 2]	e.	Customer Environmental Awareness	[SCFT 5]
7.	**DELIVERY**	[DELR]			

3.2 Overview of AHP

The AHP is a measurement tool used to determine the relative weights of the respective criteria. This tool mainly works on the prioritization of the key factors. With the help of this tool, we can particularly check inconsistency, the correlation of each criterion with our structure. The root of the AHP method is a non-linear framework multi criteria decision-making tool. From 1971-1975, T.L. Saaty developed the AHP at Wharton School (Pennsylvania University, Philadelphia, Pennsylvania). For the AHP calculation, we need to conduct a pairwise comparison of our survey results with a one to nine rating.

3.3 Key points of AHP methodology

1) Identify key factors and structure prioritization hierarchy model.
2) Preparation of questionnaire and data collection for further calculations.
3) From the survey data, visualize standardized weights for each key factor and their related sub-factors.
4) Then, check the consistency of each key factor and their sub factors by calculating the consistency ratio (CR) and eventually revising comparative matrices by asking experts, if their consistency is too low, to review and revise their judgments.
5) If the CR is less than 0.1, consider that the judgments are consistent.

The acceptable CR range varies depending on the size of the matrix. These are the guidelines for the CR.

- Where the CR value is equal to or less than the recommended value for a specific matrix size, it implies that the matrix evaluation is acceptable or

indicates a good level of consistency in the comparative judgments represented in that matrix.

- If the CR is more than an acceptable value, the judgments in that matrix are inconsistent and the evaluation process should be reviewed, reconsidered, and improved.

3.4 Survey instrument construction

Based on the literature review, a list of drivers used in Sustainable Supply Chain Management (SSCM) was developed. In the pretesting phase of the questionnaire, industry representatives were consulted about their views on the drivers and sub-drivers which were selected. The sub-drivers in the questionnaire were pairwise compared on a five-point Likert scale. We performed two surveys; the first survey included an overview of all sub-drivers and the second survey consisted of pairwise comparing the main drivers. Both questionnaires were divided into two sections; the first section collected organizational information, and the second section was the body of the survey arranged in tabular format with multiple choice grid variables ranging from not important to very important, and used the Likert scale for ease of understanding on the part of the respondent. In the second survey for pairwise comparing the main drivers, Saaty's nine-point scale was used.

3.5 Collection of data

Collection of data included meeting our focused manufacturing industries in India and sending them questionnaires. Academicians with relevant subject expertise and people from industry were asked to examine the questionnaire and brainstorm a list of criteria. The pilot study accepted the first fifteen emailed responses and subsequent follow-ups were done. The suggestions were analyzed and incorporated into questionnaires before executing it thoroughly. Further data was collected using 103 respondents from top- and mid-level management executives in industrial engineering, operations, and sustainable supply chain management (SSCM). The questionnaires were designed to facilitate the AHP pairwise comparison data. The questionnaires were sent to relevant experts in 103 companies selected using the Indian Industry directory and internet searches. Of the 103 questionnaires, 53 questionnaires were received at the end of four months, representing a response rate of 51.46%. Due to time constraints, we began analysis on the 53 responses since the response rate was greater than 20% which is considered acceptable for data analysis (Malhotra & Grover, 1998).

3.6 Response from survey

We used the Likert scale in the questionnaires throughout all sectors including pharmaceuticals, automobile, IT, FMCG, manufacturing, etc. We received a 60% response from the manufacturing sector, 27% from the logistics sector, and 13% from other sectors as shown in Figure 2.

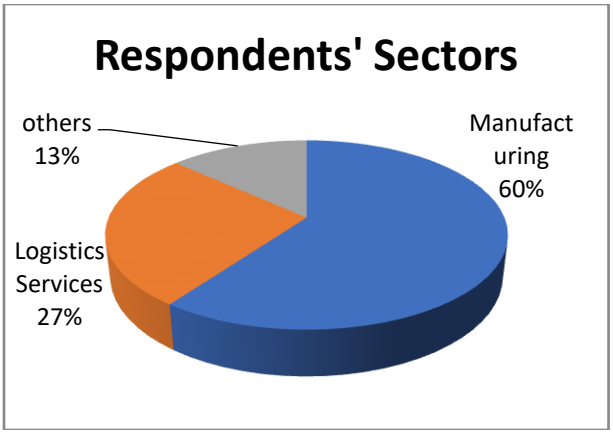

Figure 2 Aggregation of survey

4. Results and discussion

The data was collected with the help of questionnaires and processed using the AHP tool as mentioned above. The results are discussed in this section.

4.1 Relative weightage for SSCM drivers

Since we had already performed a pilot study, we decided on a sample size of 103 questionnaires that were sent via email. Since the rate of return of questionnaires was low, a strong request was made personally to the individuals that had received them. The 53 responses were used to construct a (13 x 13) matrix for the pairwise comparisons, depicted in Table 3.

Table 3
Pairwise comparison matrix for drivers

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	5.019	4.566	4.453	3.849	3.585	4.283	4.226	4.377	3.906	4.075	4.660	4.642
2	0.199	1	3.453	2.981	3.170	2.925	3.170	3.189	3.321	3.264	3.302	3.057	3.377
3	0.219	0.290	1	3.528	3.200	3.075	3.170	3.075	3.264	3.434	3.434	3.528	3.509
4	0.225	0.335	0.283	1	4.208	3.377	4.094	4.057	3.849	3.811	4.132	4.321	4.358
5	0.260	0.315	0.313	0.238	1	5.094	5.642	5.623	5.774	5.585	5.623	5.717	5.585
6	0.279	0.342	0.325	0.296	0.196	1	7.038	6.792	6.547	6.604	6.434	6.434	6.642
7	0.233	0.315	0.315	0.244	0.177	0.142	1	4.981	4.868	4.585	4.528	4.453	4.830
8	0.237	0.314	0.325	0.246	0.178	0.147	0.201	1	3.509	3.340	3.321	3.226	3.245
9	0.228	0.301	0.306	0.260	0.173	0.153	0.205	0.285	1	3.151	3.132	3.208	3.340
10	0.256	0.306	0.291	0.262	0.179	0.151	0.218	0.299	0.317	1	3.245	3.075	3.302
11	0.245	0.303	0.291	0.242	0.178	0.155	0.221	0.301	0.319	0.308	1	3.717	3.283
12	0.215	0.327	0.283	0.231	0.175	0.155	0.225	0.310	0.312	0.325	0.269	1	3.321
13	0.215	0.296	0.285	0.229	0.179	0.151	0.207	0.308	0.299	0.303	0.305	0.301	1
SUM	**3.812**	**9.464**	**12.038**	**14.212**	**16.862**	**20.111**	**29.674**	**34.447**	**37.757**	**39.616**	**42.800**	**46.697**	**50.434**

Table 4
Normalized matrix for pair wise comparison of drivers

	1	2	3	4	5	6	7	8	9	10	11	12	13	SUM	CRITERIA WEIGHT (W)
1	0.262	0.530	0.379	0.313	0.228	0.178	0.144	0.123	0.116	0.099	0.095	0.100	0.092	**2.660**	**0.205**
2	0.052	0.106	0.287	0.210	0.188	0.145	0.107	0.093	0.088	0.082	0.077	0.065	0.067	**1.567**	**0.121**
3	0.057	0.031	0.083	0.248	0.190	0.153	0.107	0.089	0.086	0.087	0.080	0.076	0.070	**1.357**	**0.104**
4	0.059	0.035	0.024	0.070	0.250	0.168	0.138	0.118	0.102	0.096	0.097	0.093	0.086	**1.335**	**0.103**
5	0.068	0.033	0.026	0.017	0.059	0.253	0.190	0.163	0.153	0.141	0.131	0.122	0.111	**1.469**	**0.113**
6	0.073	0.036	0.027	0.021	0.012	0.050	0.237	0.197	0.173	0.167	0.150	0.138	0.132	**1.413**	**0.109**
7	0.061	0.033	0.026	0.017	0.011	0.007	0.034	0.145	0.129	0.116	0.106	0.095	0.096	**0.875**	**0.067**
8	0.062	0.033	0.027	0.017	0.011	0.007	0.007	0.029	0.093	0.084	0.078	0.069	0.064	**0.582**	**0.045**
9	0.060	0.032	0.025	0.018	0.010	0.008	0.007	0.008	0.026	0.080	0.073	0.069	0.066	**0.483**	**0.037**
10	0.067	0.032	0.024	0.018	0.011	0.008	0.007	0.009	0.008	0.025	0.076	0.066	0.065	**0.417**	**0.032**
11	0.064	0.032	0.024	0.017	0.011	0.008	0.007	0.009	0.008	0.008	0.023	0.080	0.065	**0.356**	**0.027**
12	0.056	0.035	0.024	0.016	0.010	0.008	0.008	0.009	0.008	0.008	0.006	0.021	0.066	**0.275**	**0.021**
13	0.057	0.031	0.024	0.016	0.011	0.007	0.007	0.009	0.008	0.008	0.007	0.006	0.020	**0.211**	**0.016**
SUM	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		

Table 5
Calculation of λ_{max}

	1	2	3	4	5	6	7	8	9	10	11	12	13	Consistency Vector
1	1.000	5.019	4.566	4.453	3.849	3.585	4.283	4.226	4.377	3.906	4.075	4.660	4.642	17.836
2	0.199	1.000	3.453	2.981	3.170	2.925	3.170	3.189	3.321	3.264	3.302	3.057	3.377	10.966
3	0.219	0.290	1.000	3.528	3.200	3.075	3.170	3.075	3.264	3.434	3.434	3.528	3.509	11.209
4	0.225	0.335	0.283	1.000	4.208	3.377	4.094	4.057	3.849	3.811	4.132	4.321	4.358	15.904
5	0.260	0.315	0.313	0.238	1.000	5.094	5.642	5.623	5.774	5.585	5.623	5.717	5.585	32.467
6	0.279	0.342	0.325	0.296	0.196	1.000	7.038	6.792	6.547	6.604	6.434	6.434	6.642	42.123
7	0.233	0.315	0.315	0.244	0.177	0.142	1.000	4.981	4.868	4.585	4.528	4.453	4.830	22.042
8	0.237	0.314	0.325	0.246	0.178	0.147	0.201	1.000	3.509	3.340	3.321	3.226	3.245	11.653
9	0.228	0.301	0.306	0.260	0.173	0.153	0.205	0.285	1.000	3.151	3.132	3.208	3.340	3.132
10	0.256	0.306	0.291	0.262	0.179	0.151	0.218	0.299	0.317	1.000	3.245	3.075	3.302	1.030
11	0.245	0.303	0.291	0.242	0.178	0.155	0.221	0.301	0.319	0.308	1.000	3.717	3.283	0.319
12	0.215	0.327	0.283	0.231	0.175	0.155	0.225	0.310	0.312	0.325	0.269	1.000	3.321	0.084
13	0.215	0.296	0.285	0.229	0.179	0.151	0.207	0.308	0.299	0.303	0.305	0.301	1.000	0.091

The result of the calculations was the prioritization of the key factors in the sustainable supply chain as shown in Table 6. The most important drivers are discussed next.

4.2 Discussion

Cost

Logistics and supply chain costs play an important role in every organization. Purchase price, freight insurance, warehousing, custom duties, and other costs account for 5- 50% of a product's cost. In this category, five enablers are listed as follows: cost reduction [COST1] ranked first among all drivers at 0.1058. Operation costs [COST2] has a global weightage of 0.0496, warehousing costs [COST3] has a weightage of 0.0291. Cost saving [COST4] also plays an important role at 0.0135. The overall company initiative toward economic benefits, [COST5], is 0.0070.

Relationships

Relationships also play an important role in supply chain management. There are strategic, tactical, transactional, internal, and possibly more types of relationships among members of the supply chain community. Logistic member's opportunistic behavior [RELT1] ranked fourth in overall drivers at 0.0733; reliability [RELT2] plays an important role with a weightage of 0.0293. Relationships between suppliers and customers [RELT3], which some like to call 'partnerships', play an especially important

role with a weightage of 0.0122. To make supply chains work properly, integration and coordination [RELT4] are necessary with a weightage of 0.0063.

Services

In today's competitive world, the customer is the focus of every industry. While focusing on service (it is impossible to be perfect), each company aims to provide the best service to their customers. Therefore, breadth of service [SERV1] is important at 0.0728, ranking fifth in overall drivers. The customer wants a smooth and easy experience, so companies' pre-sale/post-sales services [SERV2] are important at 0.0231. It is up to a company how good the service can be that they deliver. If a company is starting to build long-term relationships with customers to gain their loyalty, it should consider shifting from product-orientated strategy to a customer-focused strategy, so value-added services [SERV3] are important at (0.0081).

Quality

Supply chain management plays a key role in product quality and overall profitability. For this reason, quality control in the supply chain is critical for maintaining a competitive edge in the marketplace while reducing operation costs. Without quality control, waste becomes more than a tolerable amount, so risk management [QULT3] at 0.0075 is necessary. With globalization, the world has literally become a global village, to keep up in a continuously competitive environment, a company must be committed to continuous improvement. [QULT1] is required and ranks third among drivers with a global weightage of 0.0781. Logistic activities are regarded as a significant source of environmental pollution and greenhouse emission, harmful to both health and ecosystem qualities, so environmental issues [QULT2] are important at 0.0174.

Information systems technology

A supply chain's information system plays an important role in achieving its efficiency and effectiveness. IT systems can ensure that their logistics functional operations provide customer satisfaction for the lowest total cost. Therefore, information accessibility [INFO1] is ranked sixth at 0.0634 while information technology [INFO2] is ranked 11th in overall drivers. Having the latest technology to manage storage [INFO3] and transportation [INFO4] play an important role with a global weightage of 0.0128 and 0.0060, respectively.

Flexibility and reputation

Customer satisfaction is a measure that determines how happy customers are with a company's product, services, and capabilities in general. With the help of some reports and surveys about customer satisfaction, a company can improve or change its products and services, which is why customer satisfaction [FLEX1] is ranked second with a weightage of 0.0792. In this competition, each company must maintain its ability to meet future requirements, so [FLEX2] is ranked 12th with a weightage 0.0298.

Delivery

Delivery requirements and the customer's expectation are two items that need to be a priority for every organization. Products should be delivered and arrive on time; therefore, on-time delivery [DELR1] is important, ranking eighth among all factors, with 0.0398. Lead-time [DELR2] is ranked 20th with a weightage of 0.0145. On-time delivery (OTD) performance affects more than customers do. Failing OTD is usually an indicator

of poor production efficiency and materials handling procedures; therefore, accuracy of delivery time [DELR 3] is necessary at 0.0088, and reduction in time of raw material consumption [DELR4] is important at 0.0038.

Professionalism

Punctuality means completing a task within the expected time. Being punctual indicates a respect for the value of time. It is an etiquette which motivates a person to perform a task in a timely manner; therefore, punctuality [PROF1] is ranked tenth at 0.0317. Skills are the expertise or talent needed to do a job or task well. Expertise is what makes you confident and dependable at your job, so it has a special place in the key factors with a weightage of 0.0102 [PROF2]. Business experience is important for gaining the upper hand. There are not many shortcuts that are useful to gain competitive advantages against rivals. Knowledge and insights learned from experience are what make a company better than others; therefore, experience [PROF3] is required and has a weightage of 0.0031.

Financial position

Before choosing any third party, it is important to have a statement of their financial position to determine the state of their liquidity risk, financial risk, credit risk and business risk. Therefore, the selected vendor should always be financially able to upgrade their equipment and services. Therefore, this is ranked ninth with a weightage 0.0325. In this field, process efficiency can be defined as the amount of effort required to produce a business outcome. Therefore, it is very important that a company should always have the ability to improve process efficiency [FINC] at 0.0045.

Location

If a business owner can develop the best product, construct the most stunning business space, hire the best employees, and have a rock-solid business plan, but chooses the wrong location then all his efforts will have been in vain. Choosing the right location is crucial because it influences many factors such as customer and vendor access, employee safety, protection from natural disasters and building functionality. Therefore, geographic specialization and coverage [LOCT1] ranked 15th in all drivers with a weightage of 0.0272. Sourcing products from overseas can often equate to low-cost country sourcing, where products or materials originate because their exceptionally low labor and production costs results in modest purchasing prices. Therefore, international scope [LOCT2] is important with a weightage of 0.0045.

Regulatory policies

The Indian government has amended many rules and regulations to protect the environment for future generations. In today's competitive world, each organization looks toward success in any way it can. A government’s role is thus vital to protect the environment and the heath and other benefits for human beings. Therefore, government regulations and support [REGL1] ranked 16th overall with 0.0236. Nevertheless, at the same time, government tax policy directly influences interest rates. If interest rates increase because of government spending, then it leads to decreased consumer spending. If interest rates decrease, it leads to an increase in investment and businesses can increase their productivity. Therefore, these policies [REGL2] received a weightage of 0.0034.

Competitiveness

In a market for the same product, there are often many manufacturers, so there is high competition in every field. To compete, each organization moves toward price cutting, increases its advertising, improves its product quality along with many other improvements. Therefore, competition among firms [COMP1] is ranked 19th with 0.0146. Benchmarking standards are a set of standards used as a point of reference for evaluating performance or level of quality of products or services. Benchmarks can be developed from an organization's own experience, from the experience of other organizations in the industry, or from legal requirements such as environmental regulations; therefore, benchmarking [COMP2] reaches a global weight of 0.0049. Sustainability [COMP3] receives a global weightage of 0.0015.

Supply chain factors

A small business's success and creditability are related to the actions of numerous stakeholders, as they are the ones that affect the business; therefore, the role of the stakeholder [SCFT1] gains a weight of 0.0079. Similarly, top management support is critical to the success of a manufacturing strategy. Top management support is how companies get the necessary resources (facilities, capital, IT, & human resources) to achieve benefits from their different strategies. Top management receives a global weightage of 0.0041. Skilled human resources mean highly trained, educated, or experienced members of the workforce that can complete complex tasks on the job. Thus, skilled workers have a weightage 0.0022. Social responsibility involves sensitivity towards social, cultural, economic, and environmental issues, so it is weighted at 0.0012. In today's world, the impact of an organization on the environment is always under observation. Each organization needs to be aware of the impact of its actions on the environment. Therefore, it has 0.0006 global weights.

Table 6
Drivers ranked for 3PL in SCM in Indian manufacturing industries

Sr. no.	Criteria	Global Weights	Sr. no.	Sub - criteria		Local Weights	Rank	Global Weights	Rank
1	Cost [COST]	0.205	1	Cost Reduction	[COST 1]	0.516	12	0.1058	1
			2	Operation cost	[COST 2]	0.242	17	0.0496	7
			3	Warehousing cost	[COST 3]	0.142	25	0.0291	14
			4	Cost saving	[COST 4]	0.066	37	0.0135	21
			5	Economic benefits	[COST 5]	0.034	42	0.0070	29
2	Relationships [RELT]	0.121	1	3PL opportunistic behaviour	[RELT 1]	0.606	9	0.0733	4
				Reliability	[RELT 2]	0.242	17	0.0293	13
			3	Truth & Trust	[RELT 3]	0.101	31	0.0122	23
			4	Integration & Co-ordination	[RELT 4]	0.052	40	0.0063	30
3	Services [SERV]	0.104	1	Breadth of services	[SERV 1]	0.700	7	0.0728	5
			2	Pre-sale / post-sale services	[SERV 2]	0.222	21	0.0231	17
			3	Value added services	[SERV 3]	0.078	32	0.0081	26
4	Quality [QULT]	0.103	1	Commitment to continuous improvement	[QULT 1]	0.758	4	0.0781	3
			2	Environmental issues	[QULT 2]	0.169	23	0.0174	18
			3	Risk management	[QULT 3]	0.073	33	0.0075	28
5	Information systems + Technology [INFO]	0.113	1	Information accessability	[INFO 1]	0.561	11	0.0634	6
			2	Information technology	[INFO 2]	0.273	14	0.0308	11
			3	Storage technology	[INFO 3]	0.113	30	0.0128	22
			4	Transportation technology	[INFO 4]	0.053	39	0.0060	31
6	Fleibility & Reputation[FLEX]	0.109	1	Customer satisfaction	[FLEX 1]	0.727	5	0.0792	2
			2	Ability to meet future requirement	[FLEX 2]	0.273	14	0.0298	12
7	Delivery [DELR]	0.067	1	On time delivery/shipment	[DELR 1]	0.594	10	0.0398	8
			2	Lead time	[DELR 2]	0.217	22	0.0145	20
			3	Accuaracy of delivery time	[DELR 3]	0.132	27	0.0088	25
			4	Reduction in time & raw material consumption	[DELR 4]	0.057	38	0.0038	36
8	Professionalism [PROF]	0.045	1	Punctuality	[PROF 1]	0.705	6	0.0317	10
			2	Expertise	[PROF 2]	0.226	20	0.0102	24
			3	Experience	[PROF 3]	0.069	36	0.0031	38
9	finiancial position [FINC]	0.037	1	Upgrading of equipments & services	[FINC 1]	0.879	1	0.0325	9
			2	Improved process efficiency	[FINC 2]	0.121	29	0.0045	34
10	locations [LOCT]	0.032	1	Geographyical specialization & coverage	[LOCT 1]	0.851	3	0.0272	15
			2	International scope	[LOCT 2]	0.149	24	0.0048	33
11	Regulatory & policy [REGL]	0.027	1	Govt. legislation & support	[REGL 1]	0.875	2	0.0236	16
			2	Tax benefits & related policy	[REGL 2]	0.125	28	0.0034	37
12	Competitiveness [COMP]	0.021	1	Competition among firm	[COMP 1]	0.694	8	0.0146	19
			2	Benchmarking standards	[COMP 2]	0.234	19	0.0049	32
			3	Adopting sustainability	[COMP 3]	0.072	34	0.0015	40
13	Supply chain factor [SCFT]	0.016	1	Role of stakeholder & supports	[SCFT 1]	0.496	13	0.0079	27
			2	Top management support	[SCFT 2]	0.257	16	0.0041	35
			3	Skilled human forces	[SCFT 3]	0.137	26	0.0022	39
			4	Social responsibility	[SCFT 4]	0.072	34	0.0012	41
			5	Customer Environmental Awareness	[SCFT 5]	0.038	41	0.0006	42

5. Case study

5.1 Introduction to problem

Anson's Electro Mechanical Works is a well-known submersible pump manufacturing company having a pan-India presence. There are more than 350 Anson employees currently working in India. The plant provides direct and indirect employment to more than 600 people. Anson started their first manufacturing plant in 1967 in Jogeshwari, a suburb of Mumbai, then in 1989 established another manufacturing unit in Palghar, Thane District.

Anson has steadily grown over the years and their brands, Anson's and Anco, have become the hallmark of quality, reliability, and endurance. Anson's manufactures horizontal and vertical open-well submersible pumps and monobloc pumps. They also manufacture ATEX certified flameproof motors that are used in petrol and diesel dispensing units. Anco Motors manufactures 6" and 4" submersible pumps, monobloc Ganga pumps, and self-priming Saraswati and Triveni models.

The main advantages of localization are:

- Reduction in cost of components, resulting in a lower final price of the pumps. Localization is undertaken in the situation where the cost benefit comes to more than 40% compared to imported goods.
- Better service is expected, as local companies are easily accessible.
- Reduction in delivery time. The time required to import any material is generally greater than 2 weeks, which also results in an increase in company overhead costs.
- Better coordination between vendors and Anson's.

The purpose of this case study is to select 3PL for Anson's Electro Mechanical Works in Palghar for the purchase of cast iron components for manufacturing "6" submersible motor pumps for bore wells XRF B2 Series 4-12".

The three main vendors of cast iron components are:

- V1. Consolidated Eutectics, 33, M.I.D.C., Shiroli, Kolhapur- 416 122.
- V2. NSVP Industrial Casting Pvt. Ltd., Plot No: -B-200, Functional Estate, Udyog Nagar, Udhana, Surat-394 210.
- V3. John T. Hardaker Pvt. Ltd., 51, A. B. Government Industrial Estate, Charkop, Kandivali (W), Mumbai – 400 067.

This study focuses on cast iron components from three vendors V1, V2 and V3, which have been preselected from a list of approved vendors. The goal is to find the best vendor among the three and then, to place an order for a large quantity among them based on their ranking.

5.2 AHP calculations

As mentioned earlier, we must follow the steps for AHP calculations. First, we collected data using questionnaires on the three vendors from personnel at Anson's Pvt ltd. Twenty questionnaires were mailed to superiors at Anson Pvt Ltd and seven questionnaires were received at the end of four months, representing a response rate of 35%. Due to time

constraints, we began analysis of the seven responses. The response rate of 35% is acceptable for analysis; a response rate of more than 20% is considered acceptable for data analysis (Malhotra & Grover, 1998).

Since we have already performed the calculations for our key factors and their sub-factors, we followed the same AHP steps again. First, we collected the data in the form of the pairwise comparisons, and then normalized the matrix of the data. Next, we collected the pairwise comparison data for the sub-factors. To confirm the accuracy and acceptability of our work, we checked each sub-factor's consistency ratio to make sure that (CR) calculated < (CR) recommended. We concluded that if the level of consistency is good, that is, CR ≤ 10%, then it is acceptable.

Table 7
Consistency ratio for sub factors with w.r.t vendors

LEVEL	ELEMENTS OF THE MATRIX	WITH RESPECT TO		CONSISTENCY RATIO (C.R.)
LEVEL 3	VENDOR 1 VENDOR 2 VENDOR 3	1	Cost reduction	0.0963
		2	Operation cost	0.0907
		3	Warehousing cost	0.0888
		4	Cost saving	0.0821
		5	Economic benefits	0.0772
		6	3PL opportunistic behavior	0.0664
		7	Reliability	0.0866
		8	Truth & trust	0.0746
		9	Integration & Co-ordination	0.0775
		10	Breadth of services	0.0673
		11	Pre-sale / post-sale services	0.0189
		12	Value added services	0.0164
		13	Continuous improvement	0.0447
		14	Environmental issues	0.0152
		15	Risk management	0.0838
		16	Information accessibility	0.0770
		17	Information technology	0.0943
		18	Storage technology	0.0683
		19	Transportation technology	0.0656
		20	Customer satisfaction	0.0914
		21	Ability to meet future requirement	0.0883
		22	On time delivery/shipment	0.0398
		23	Lead time	0.0731
		24	Accuracy of delivery time	0.0723
		25	Reduction in time of raw material consumption	0.0758
		26	Punctuality	0.0347
		27	Expertise	0.0953
		28	Experience	0.0621
		29	Upgrading of equipment & services	0.0961
		30	Improved process efficiency	0.0754
		31	Geographical specialization & coverage	0.0650
		32	International scope	0.0574
		33	Govt. legislation & support	0.0938
		34	Tax benefits & related policy	0.0966
		35	Competition among firms	0.0873
		36	Benchmarking standards	0.0535
		37	Adopting sustainability	0.0304
		38	Role of stakeholder & supports	0.0970
		39	Top management support	0.0970
		40	Skilled human forces	0.0740
		41	Social responsibility	0.0945
		42	Customer environmental awareness	0.0953

From Table 7, we confirmed that the pairwise comparison matrices in level three used for rating the vendors are consistently good, i.e., CR < 0.1, and the AHP synthesizing process can be used to calculate the priorities of the 3PL vendors to determine an overall outcome.

5.3 Calculation of overall weights

In the model above, the overall weights of each vendor were calculated by first multiplying each sub-factor by the weight of its respective major factor and the vendor rating associated with it. The values obtained from each of the 42 sub-factors were added to give the final weight for each vendor.

For example, for any vendor, say V1, the weights are calculated as follows for the weight of V1:

$$\text{V1} = \sum_{S=1}^{42}(s * m * r)$$

Where:
s = sub-criteria, of which there are 42 in total in this study.
m = number of main criteria.
r = rating of vendor V1 associated with that sub-criteria

The above formula was applied in Microsoft Excel 2007 to obtain the results given in Table 8.

Table 8
Final weights and rank of the three vendors

Sr. No.	Vendor	Final Weights	Ranking
1	V1	0.5618	1
2	V2	0.2798	2
3	V3	0.1585	3

The results show that the AHP model can handle many tangible and intangible criteria as it has 42 sub-criteria and 13 main criteria that are easily managed.

Vendor 1 (V1) is the top-ranked choice using the AHP method, and hence V1 is the best choice of vendor in the case study.

5.4 Order allocation under capacity constraints

In the case study we conducted, the order quantity was relatively large with a 600-unit monthly requirement. The quantity is too large to be satisfied by any single supplier. It is, however, subject to fluctuations, depending on the market demand. Keeping the fluctuating demand situation in mind, it was decided to allocate orders to different vendors. The proportion of the order quantity was influenced by the vendor weights. This decision to distribute orders among vendors is advantageous as it also promotes healthy competition and reduces the risk of production stoppage if any one vendor is unable to fulfill the order due to unforeseen circumstances.

An AHP and linear programming approach was used in this study for order allocation. Ghodsypour and O'Brien (1998) presented the linear programming approach, where the objective function maximizes the total value of purchase (TVP). The data required for the solution are given below:

Order quantity = 600 units
Maximum permissible defect rate = 1200 ppm (parts per million)

Table 9
Capacity allotted to each vendor

Vendor	Capacity (Units)	Defect Rate(ppm)
V1	300	40
V2	250	50
V3	250	50

The above data are input into the general equations for a linear programming problem. The order quantities are:
X = Order Quantity for vendor V1
Y = Order Quantity for vendor V2
Z = Order Quantity for vendor V3

The objective function becomes maximize TVP = 0.5586X +0.2830Y + 0.1586Z
Subject to the quality constraints, $0.004X + 0.005Y + 0.005Z \leq 1200$.

The capacity constraints are:
$X + Y + Z = 700$
$X \leq 300$
$Y \leq 250$
$Z \leq 250$

The above linear programming problem is solved by using the "Wolfram Alpha Widget Linear Programming Calculator". The inputs and outputs are given below in Figures 3 and 4.

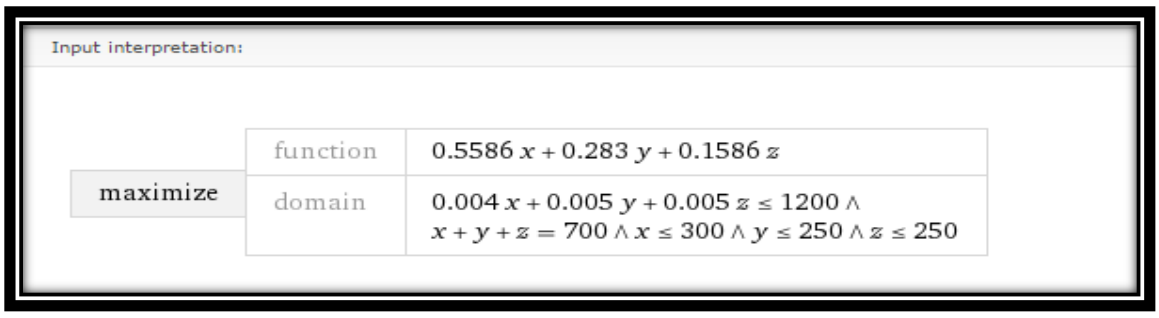

Figure 3 Input for linear programming problem

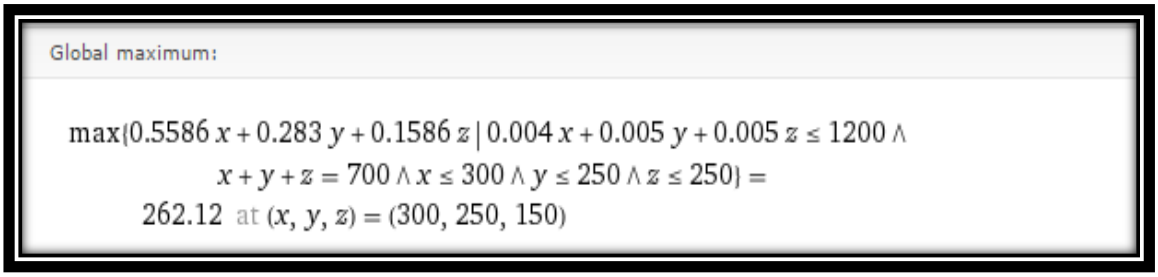

Figure 4 Output for linear programming problem

The results are summarized in Table 10.

Table 10
Quantity ordered from each vendor

Vendor	Order Quantity
V1	300
V2	250
V3	150

From the results, it is observed that the vendor with the highest weight, i.e., vendor V1, is given more preference and receives a larger order quantity. The order quantity allocated to the vendor with the highest weight is limited only by the production capacity, although the final decision usually lies with the purchaser. In this case study, the defect rate had no serious impact on the order quantity, as the values were similar for all the vendors.

5.5 Sensitivity analysis

A sensitivity analysis identified the impact of changes in the priority of the criteria on the suppliers' performance and the order quantities. In this study, a sensitivity analysis was conducted by varying one parameter, cost, to study its impact on order quantity, impact of varying cost parameter on suppliers' performance and order quantity.

Cost is one of the parameters considered for vendor selection. Out of the 13 major criteria considered, cost is one parameter, which fluctuates the most due to the competitive business environment, and hence it was investigated using a sensitivity analysis. Variations in the cost priority affect the suppliers' ratings, which in turn are the parameters of the objective function in linear programming, thus variations in cost have an impact on the order quantity.

Ghodsypour and O'Brien (1998) state that a sensitivity analysis cannot be performed on general packages of LP such as LINDO or SOLVER (a function of Microsoft Excel) as they consider the variation of one coefficient while others are constant, while the change in a parameter will change all the coefficients of the objective function. This study proposes the use of Microsoft Excel 2007, by using various formulae to bypass this

problem. Microsoft Excel is used to determine the change in the remaining criteria with the changes in the cost parameter.

The new criteria weights are input into an Excel worksheet shown in Table 11 applying the AHP (Saaty) to find new vendor ratings. These ratings are then fed into an Excel worksheet to find the optimum order quantities. The approach however can only be applied to those models whose weights are utilized in a crisp form during calculation. Figure 6 shows the approach adopted for the sensitivity analysis.

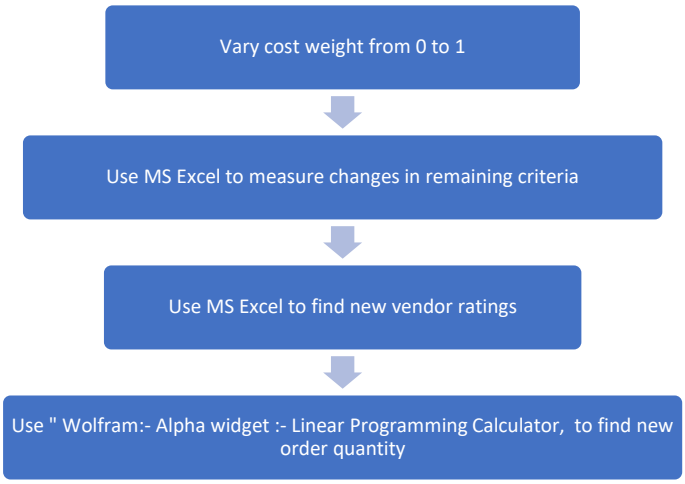

Figure 5 Approach adopted for sensitivity analysis

Table 11
Criteria weights by varying cost

Criteria Weights												
[COST]	[RELT]	[SERV]	[QULT]	[INFO]	[FLEX]	[DELR]	[PROF]	[FINC]	[LOCT]	[REGL]	[COMP]	[SCFT]
0	0.1522	0.1308	0.1296	0.1421	0.1371	0.0843	0.0566	0.0465	0.0403	0.0340	0.0264	0.0201
0.1	0.1370	0.1177	0.1166	0.1279	0.1234	0.0758	0.0509	0.0419	0.0362	0.0306	0.0238	0.0181
0.2	0.1218	0.1047	0.1036	0.1137	0.1097	0.0674	0.0453	0.0372	0.0322	0.0272	0.0211	0.0161
0.3	0.1065	0.0916	0.0907	0.0995	0.0960	0.0590	0.0396	0.0326	0.0282	0.0238	0.0185	0.0141
0.4	0.0913	0.0785	0.0777	0.0853	0.0823	0.0506	0.0340	0.0279	0.0242	0.0204	0.0158	0.0121
0.5	0.0761	0.0654	0.0648	0.0711	0.0686	0.0421	0.0283	0.0233	0.0201	0.0170	0.0132	0.0101
0.6	0.0609	0.0523	0.0518	0.0569	0.0548	0.0337	0.0226	0.0186	0.0161	0.0136	0.0106	0.0081
0.7	0.0457	0.0392	0.0389	0.0426	0.0411	0.0253	0.0170	0.0140	0.0121	0.0102	0.0079	0.0060
0.8	0.0304	0.0262	0.0259	0.0284	0.0274	0.0169	0.0113	0.0093	0.0081	0.0068	0.0053	0.0040
0.9	0.0152	0.0131	0.0130	0.0142	0.0137	0.0084	0.0057	0.0047	0.0040	0.0034	0.0026	0.0020
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

When the cost is zero, the other criteria are normalized to determine their new weights. For other values of cost, the following formula is applied:

$$N = O - \left(\frac{(NC - OC) * O}{1 - OC} \right)$$

N = new criteria weight
O = original criteria weight
NC = new cost weight
OC = original cost weight

After obtaining, the new criteria weights, the new vendor ratings obtained through Excel for each of the new scenarios are shown in Table 12. For the first step, Table 12 shows the Microsoft Excel results for the variation in the other parameters with the variation in cost weight from zero to one.

The weights of the three vendors do not vary much as shown in Table 12. Individual criteria do not have much influence because of the large number of criteria (42 total parameters). The order quantity in each case remained the same when solved with Excel. The only option available for vendors to obtain a greater share of the orders is to improve their performance for many criteria to improve their overall ratings. The model included in the study thus promotes an effort towards improving the overall efficiency of the vendors.

Table 12
Variations in vendor weights with changes in cost weight

Vendor	**Final Weight**	**Ranking**	**Vendor**	**Final Weight**	**Ranking**
Cost = 0			Cost = 0.6		
V1	0.5551	1	V1	0.5748	1
V2	0.2854	2	V2	0.2691	2
V3	0.1597	3	V3	0.1563	3
Cost = 0.1			Cost = 0.7		
V1	0.5583	1	V1	0.5781	1
V2	0.2827	2	V2	0.2664	2
V3	0.1591	3	V3	0.1557	3
Cost = 0.2			Cost = 0.8		
V1	0.5617	1	V1	0.5814	1
V2	0.2800	2	V2	0.2637	2
V3	0.1586	3	V3	0.1551	3
Cost = 0.3			Cost = 0.9		
V1	0.5650	1	V1	0.5847	1
V2	0.2773	2	V2	0.2610	2
V3	0.1580	3	V3	0.1545	3
Cost = 0.4			Cost = 1		
V1	0.5683	1	V1	0.5879	1
V2	0.2746	2	V2	0.2583	2
V3	0.1574	3	V3	0.154	3
Cost = 0.5					
V1	0.5716	1			
V2	0.2719	2			
V3	0.1568	3			

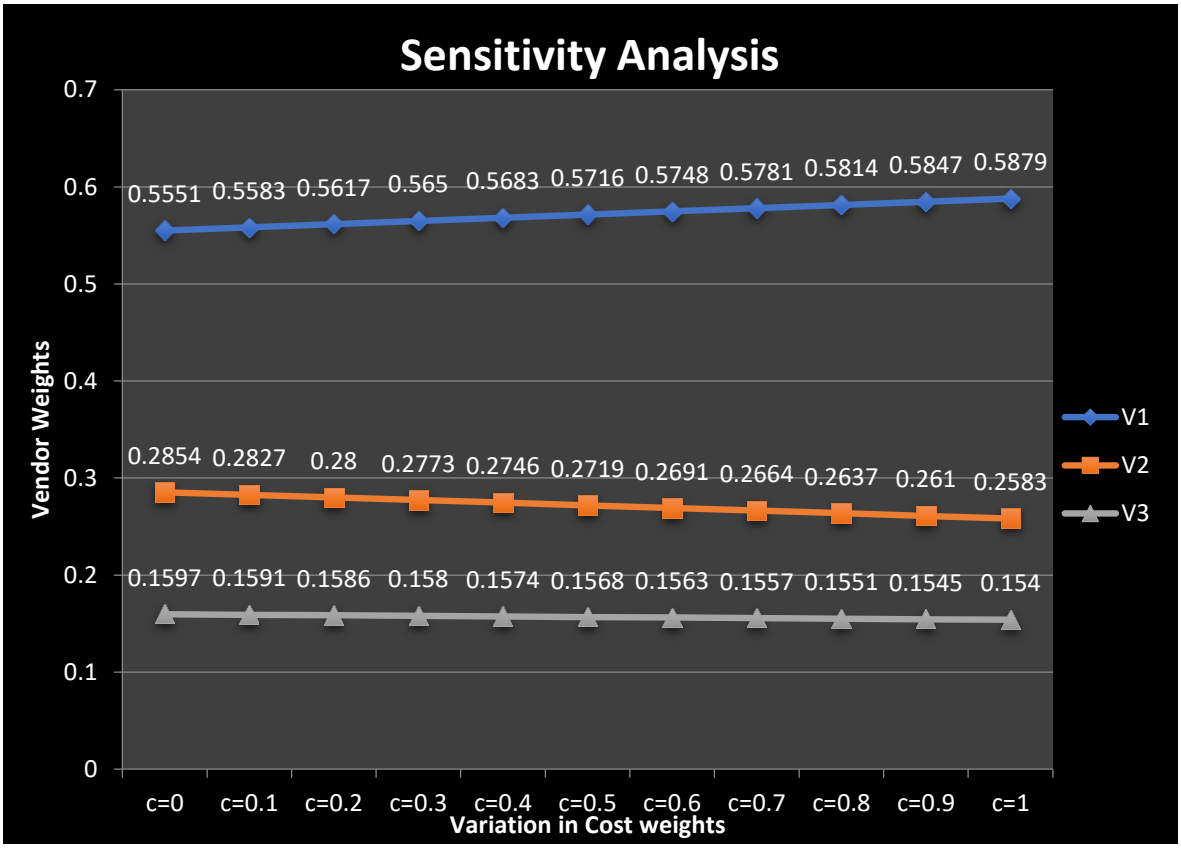

Figure 6 Variations in vendor weights with changes in cost weight
(Graphical Representation)

6. Conclusion

For the research objective of identifying criteria for 3PL in SCM, we conducted a literature review. Based on the literature review, 42 sub factors were identified and distributed among 13 key factors including cost, relationships, services, quality, information systems and technology, flexibility and reputation, delivery, professionalism, financial position, location, regulatory and policy, competitiveness and supply chain factors. With the help of this research, it was concluded that not all key factors have the same weightages in prioritizing 3PL vendors for SCM and not all key factors have the same intensity. From the perspective of Indian manufacturing industries, this study focused on finding the key factors for 3PL in SCM. This research ranked the key factors using an AHP-based approach. This research has provided a best industry solution for identifying key success factors and provided a benchmark for the implementation of best choice of 3PL in SCM.

With the help of our case study based on an Indian pump manufacturing industry, we used a sensitivity analysis to identify the impact of varying one parameter on order quantity. The sensitivity analysis indicated that due to the large number of criteria, the model is insensitive to changes in the priority of a single criterion. The order allocation in the study does not change with any change in the cost parameter.

In addition, this research found only 42 enablers, but researchers in future studies can work to find more or different enablers. To validate the enablers/drivers we found, other methods like the Analytical Network Process (ANP) and the Interpretive Ranking Process (IRP), fuzzy AHP, can be used to rank the factors.

The following are the major contributions of this study:
• This research recognizes the importance of multi-criteria decision making and identifies a large number of criteria, which play a role in vendor selection.
• The study identifies those criteria, which play a major role in the vendor selection process in the Indian manufacturing sector. The importance of each criterion is determined through an extensive survey conducted in the Indian manufacturing industry.
• As noted in the literature review, most papers on vendor selection consider only a few criteria for selecting a vendor. This study shows that many criteria can be successfully incorporated into a vendor selection model so that each parameter which can affect the selection process plays its part.
• The study demonstrates that AHP-based techniques can easily handle a large number of both tangible and intangible criteria and get consistent results.
• Microsoft Excel spreadsheets have been utilized at every stage of the vendor selection process. The use of Excel spreadsheets saves time, reduces human error during computation, and provides a real-time vendor selection framework.

For future research, we can employ various methodologies such as focus groups, in-depth interviews and brainstorming sessions with experts. Second, this case study was conducted specifically for the Indian manufacturing industry and may not be appropriate for other industries or other parts of the world. Third, only the AHP and a sensitivity analysis were considered for this study. Other significant methods like fuzzy AHP, ANP, etc. can be useful for further work.

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