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A Fuzzy-AHP Multi-Criteria Decision Making Model for Procurement Process

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Abstract

The purpose of this study is to develop a fuzzy-AHP multi-criteria decision making model for procurement process. It aims to measure the procurement performance in the automotive industry. As such measurement of procurement will enable competitive advantage and provide a model for continuous improvement. The rapid growth in the market and the level of competition in the global economy transformed procurement as a strategic issue; which is broader in scope and responsibilities as compared to purchasing. This study reviews the existing literature in procurement performance measurement to identify the key areas of measurement and a hierarchical model is developed with a set of generic measures. In addition, a questionnaire is developed for pair-wise comparison and to collect opinion from practitioners, researchers, managers etc. The relative importance of the measurement criteria are assessed using Analytical Hierarchy Process (AHP) and fuzzy-AHP. The validity of the model is confirmed with the results obtained.

Keywords: Multi-criteria decision making, fuzzy-AHP, procurement performance measurement.

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1. Introduction

Procurement is a core function in every organization. Traditionally the focus of procurement was limited to efficient purchasing activities or was just considered as a clerical job. Reducing cost of purchasing was considered as the main function of procurement. Globalization and dynamic market environment transformed procurement as a strategic issue. These drives all organization to be more innovative and improving their services towards meeting rapidly changing customer requirement (Paul & He, 2012). In addition, it is a key area to focus for the firms to become cost effective and competitive in an environment characterised by increasing globally challenging and declining profit margins (Barratt and Barratt, 2011).

Most importantly, in some industries such as automotive, textile and electronics, procurement covers 80% of the overall cost (Tsang et al., 2013). The role of procurement has become ever more demanding to provide savings, to support wider sustainable development, diversity and to improve service delivery (Loader, 2010) .According to (Gioconda et al., 2010) procurement is the most critical function in supply chain. This gives rise to prioritise procurement as a primary function and its importance in measuring its performance.

Moreover, agile manufacturing and changing customer's perception as a part of globalisation shortened the product lifecycle. Purchasing is the primary function in the supply chain and crucial for the performance of supply chain specification (Pani and Kar, 2011). Procurement became a strategic priority for firms in order to achieve competitive advantages. In today's dynamic business environment procurement is positioned as critical business process focusing on long term value creation from traditional concept of short term cost minimization (Hong and Kwon, 2012).

1.1. Procurement in Automotive Industry

Automotive industries are in a path of streamlining their production line in reducing waste. Thus procurement became a complex strategy for them. Automotive industry contributes 4% to 8% of Gross Domestic Product (GDP) of a country and is one of the largest industrial sectors in the world (Afsharipour et al., 2006).

Due to a large number of raw materials and component parts used for assembly, there is a need of managing suppliers. Most of the manufacturers in last two decades reduced their supplier base from thousands to hundreds and in some case to several tens of suppliers. Rationalization is based on Japanese experience (Golinska and Kosacka, 2012).

Nowadays, most of the manufactures purchasing their sub-assemblies like; door, electronics etc. from the suppliers. This lead to a change in the infrastructure to support the design, procurement and logistics processes of the manufacturers (Benko et al., 2003). Most importantly, the major part of automotive production happens at the supplier level (Maurer et al., 2004). This has led to a change from traditional automotive industry practices to supplier integration and customer involvement.

Increased customization is a new trend in the automotive industry. The customers can also be in a part of the manufacturing, to the extend where they can decide what they want and how they want it. As a result, procurement becomes a significant matter where innovation and development of the products and products offering have become a continuous process (Afsharipour et al., 2006). As an impact of the development of these sectors, the transactions across the business are steadily transforming to electronic platform and the lead time has been reduced (Kangogo and Gakure, 2013). In addition, Outsourcing helped car assemblers to reduce their cost with increased flexibility, improve quality, save space and reduce development time (Giancarlo et al., 2011)

1.2. Procurement Performance Measurement

Procurement is worse than any other business function at measuring its performance in an objective, truthful and credible manner (Smith, 2012). Monitoring procurement system performance provides managers with the information they need to evaluate how well the system is functioning and to identify areas where additional measures may be required to improve the overall procurement performance. As an impact, industries have to monitor their procurement process and measure the procurement performance to achieve competitiveness in the market. Prioritising the criteria for measurement according to their relative importance is also a critical issue. Purchasing departments are acting in a state of various multiple requirements. The criteria used for the overall performance of a purchasing department will change overtime.

According to Van Weele (2010), purchasing performance consists of two elements; efficiency and effectiveness. Efficiency means "doing the things right" and effectiveness means "doing the right things"(CIPS, 2005).

To achieve the aim of this study, two methodologies are used for pairwise comparison and prioritisation of criteria; classical AHP and fuzzy AHP. A comparison between the results from classical AHP and fuzzy AHP is shown in result and discussion part. The proposed multi-criteria decision making model might be beneficial for decision makers to focus on the most critical criteria towards procurement performance.

Section 2 describes the methodologies used for this study and the steps to follow. In Section 4, criteria used to develop the model are explained in detail. The model is represented in a hierarchical structure. Section 5, explains the validation of the proposed model by two methodologies. Results obtained from both classical AHP and fuzzy AHP is shown in Section 6. The last part of this paper gives the overall conclusion of this study.

2. AHP Methodology

AHP is the finest solution for multi-criteria decision making proposed by Saaty (1980). The main highlight of the AHP methodology is that, it considers the various phases of the process and presents an efficient outcome. AHP breaks down a complex problem in to measurable criteria in a hierarchical structure. AHP determines the weights of both qualitative and quantitative criteria (Mendoza, 2008). The decision maker creates pairwise comparison matrix for every pairwise item assessed (Hadad & Hanani, 2011). Following are the main steps:

1. 1. Constructing the hierarchical model: First, the problem is structured as hierarchical model with different level of evaluating the alternatives. The highest level is the overall goal followed by main-criteria, and sub-criteria in the subsequent levels. The criteria for the performance evaluation for each dimension should be mutually independent (Saaty, 1980).

2. Pairwise comparison of criteria and alternatives for development of judgment matrices: The next step is to make the pair-wise comparison to find the comparative weights among the attribute of the decision element. Each of the pair wise comparison matrices should pass the consistent test. The outcome of this step is the ranked priorities for the decision alternative under each criterion. Saaty introduced a scale for the pair-wise comparison based on a standard evaluation scheme.

3. Calculating local priorities: Once pair-wise comparison is completed, the next step is to calculate the local priorities from the judgment matrices. Eigen value method (EVM), the logarithmic least squares method (LLSM), the weighted least squares method (WLSM), the goal programming method (GPM) and the fuzzy programming method (FPM), these are the main calculation methods summarised by (Mikhailov, 2000).

4. Alternatives Ranking: The final step is to obtain the final ranking or global ranking by considering all local priorities obtained from the previous step with the application of simple weighted sum. This determines the final ranking of the alternatives (Wang et al., 2007)

Once the weights have been allocated for each criterion and recorded, a consistency check has to be performed. (Saaty, 1980) suggested the consistency index to measure the degree of consistency by the following equation:-

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

In general, a value of CI less than 0.1 is satisfactory. Then the consistency ratio (CR) has employed the comparison value CI and R1 (CR=CI/R1). CR≤0.1 can be taken as sufficiently consistent.

Decision makers often face uncertainty when prioritizing one criterion over another with AHP method. A fuzzy logic is integrated with AHP method to overcome this uncertainty (Wang et al., 2007)

3. Fuzzy-AHP Methodology

AHP method is similar to human thinking. AHP breaks down a complex decision making process in to simple comparisons. However, it doesn't consider cognitive factors of human's judgement (Ahmad et al., 2012). It is difficult to determine the ratios on classical AHP method. Fuzzy AHP is the extension of Saaty’s theory and many researchers have provided that fuzzy AHP shows more sufficient description in decision making process compared to the classical AHP methods (Mithun and Song, 2014). Because of its popularity TFNs is used in this work. Figure 1 represents the membership function of each set of numbers. As shown in the figure the membership functions are that the sets overlap each other.

AHP is a participation oriented methodology that helps coordination and synthesis of multiple evaluators in the organizational hierarchy. Participation improves the quality of decision making process by using a scale of 1-9. The uncertainty inherent with using crisp values in translating the judgments emphasise the importance of using fuzzy logic to deal with the uncertainty or imprecision in the judgement due to incomplete or imperfect knowledge by considering all possible values in the membership function to attain the crisp decision (Sharma and Yu, 2014).

In summary, the purpose of fuzzy AHP is to deal with a complex decision making problems by decomposition of theses problems in to a hierarchy with main goal (criterion) on the top, criteria and sub-criteria below that and possible alternatives at the bottom level. All the elements are compared in pairs to assess its relative importance in the level and the level above that. The method computes eigenvectors until the composite final vector is obtained. The final vector of weights (global weight) shows the relative importance of each alternative towards the main goal (Sharma and Yu, 2014).

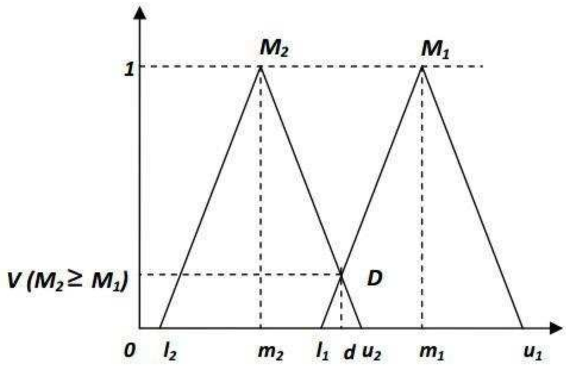

Figure1. The Intersection between TFNs

The membership function of TFNs can be described by the following equation

$$\mu_M(x) = \begin{cases} \frac{x}{m-l} - \frac{l}{m-l}, & x \in [l,m] \\ \frac{x}{m-u} - \frac{u}{m-u}, & x \in [m,u] \\ 0, & otherwise \end{cases}$$

The TFN M is often represented as (l, m, u). Where l, is the lower bound value, m is the middle bound and u is the upper bound value.

Fuzzy can always be given by its corresponding left and right representation as in the equation below;

$\widetilde{M} = M^{l(y)}$,

$$M^{l(y)} = [l + (m-l)y, u + (m-u)y], y \in [0,1]$$

Where $l(y)$ and $r(y)$ represents left side and right side of fuzzy numbers.

TFNs have various operations. Only important ones are used in this study. Two fuzzy numbers $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ have been given as follows

$$(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

$(l_1, m_1, u_1) \ominus (l_2, m_2, u_2) = (l_1 - l_2, m_1 - m_2, u_1 - u_2)$

$(l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 * l_2, m_1 * m_2, u_1 * u_2)$

$(l_1, m_1, u_1) \oslash (l_2, m_2, u_2) = (l_1/l_2, m_1/m_2, u_1/u_2)$

As shown in table 1 fuzzy AHP is a range of values in order to deal with uncertainties for decision makers.

Table 1. Fuzzy Conversion Scale

Importance Intensity	Triangular Fuzzy Scale	Importance Intensity	Triangular Fuzzy Scale
1	(1,1,1,)	1/1	(1/1,1/1,1/1)
2	(1,2,4)	1/2	(1/4,1/2,1/1)
3	(1,3,5)	1/3	(1/5,1/3.1/1)
5	(3,5,7)	1/5	(1/7,1/5,1/3)
7	(5,7,9)	1/7	(1/9,1/7,1/5)
9	(7,9,11)	1/9	(1/11,1/9,1/7)

The scale is adopted from (Prakash, 2003) fuzzy prioritization approach.

Suppose a triangular fuzzy number A= $a_{ij}$is expressed as $[l_{ij}, m_{ij}, u_{ij}]$, i and j = 1,2…….n, where l_{ij}, m_{ij}, u_{ij} are lower bound, the mean bound and upper bound of the triangular fuzzy set. In addition, we assume that $l_{ij} < m_{ij} < u_{ij}$when$i \neq j$.

If $i = j$, then $a_{ij} = a_{ii}$=(1,1,1). Therefore, an exact priority vector $w = (w_1, w_2, \dots \dots \dots . w_n)^T$derived from the judgement matrix must satisfy the inequalities.

Chang et al (1996) provided the following formula to calculate the synthetic value:

$$a_{ij}^t = [a_{ij}^t, a_{ij}^t, a_{ij}^t],\ i,j = 1,2,\dots,n_k,\ t = 1,2, \quad (1)$$

'T' is a TFN given by the t^{th} expert, by the formulak^{th}

$$M_{ij}^k = \frac{1}{T} \otimes (a_{ij}^1 + a_{ij}^2 + \dots + a_{ij}^T) \quad (2)$$

The synthetic TFN of the k^{th} layer can be derived and the synthetic judgement matrix of the layer total factors towards the h^{th} factor of the $(k-i)^{th}$ layer can also be obtained.

Using the following formula can get synthetic degree value.

$$S_j^k = \sum_{j=1}^{n} M_{ij}^k \otimes \left(\sum_{i=1}^{n_k} \sum_{j=1}^{n_k} M_{ij}^k \right)^{-1}, \quad i = 1,2,\dots,n_k \quad (3)$$

The output of this sum $(\sum_{j=1}^{n} M_{ij)}^k$ is the fuzzy additional operation of n extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{n} M_{ij}^k = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right) \quad (4)$$

The total some of these $[(\sum_{i=1}^{n_k} \sum_{j=1}^{n_k} M_{ij}^k)^{-1}]$, will lead to the fuzzy addition operation of $N_{ij}^k (j = 1,2,\dots,n)$ values such that, the inverse of the vector in equation (3) can be shown as follows,

$$\left(\sum_{i=1}^{n_k} \sum_{j=1}^{n_k} M_{ij}^k \right)^{-1} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right)^{-1} \quad (5)$$

$$\left(\sum_{i=1}^{n_k} \sum_{j=1}^{n_k} M_{ij}^k \right)^{-1} = \left(\frac{1}{\sum_{j=1}^{n} u_{ij}}, \frac{1}{\sum_{j=1}^{n} m_{ij}}, \frac{1}{\sum_{j=1}^{n} l_{ij}}\right) \quad (6)$$

Once synthetic value is determined, the degree of possibility on one fuzzy number/synthetic value obtained to be greater than other is obtained is determined as follows;

$$V(M_1 \geq M_2) = sup_{x \geq y}\left(\min(\mu_{M_1}(x), \mu_{M_2}(y)\right) \quad (7)$$

$$V(M_1 \geq M_2) = 1 \ if \ m_1 \geq m_2 \quad (8)$$

$$V(M_2 \geq M_1) = hgt\ (M_1 \cap M_2) = \mu_{M_1}(d)$$

$$V(M_2 \geq M_1) = hgt\ (M_1 \cap M_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \quad (9)$$

Chang further added, the degree of possibility of ith factor to be greater than others is as follows (Ahmad et al., 2012).

$$V(M \geq M_1, M_2, \dots, M_k) = V(M \geq M_1)\ and\ (M \geq M_2) and \dots and\ (M \geq M_k) = min\, V(M \geq M_i),\ i = 1,2,\dots,k \quad (10)$$

Let

$$d'(S_i) = \min V(S_i \geq S_k) \quad (11)$$

Hence the Weight Vector given by

$$W' = (d'(S_1), d'(S_2) \dots \dots . . d'(S_n)\ )^T$$

Where $S_i(i = 1,2, \dots . . n)$ are n elements of the matrix. The elements of each column are divided by the sum of that column and the elements in each resulting row are added and this sum is divided by the number of elements in the row), the normalized weight vectors are obtained as follows (Percin, 2008):

$$W = (\ \ d(S_1), d(S_2), \dots, d(S_n)\ )^T, \qquad (12)$$

The final weight or global weight of each criterion is obtained by multiplying the criteria with the matrix obtained by calculating each alternative with respect of each criterion.

4. Development of the proposed model

This section explains the component of the hierarchical proposed model. The proposed model is developed based on reviewing different research papers and also the authors' industrial experience. The model is classified in to four levels for pair-wise comparison.

First level sates the goal of the overall model. Second level (Efficiency and Effectiveness) states the main-criteria to achieve the goal and the third and fourth criteria are sub-criteria and sub-sub-criteria towards the overall goal. Figure 2 indicates the proposed multi-criteria decision making model for procurement process.

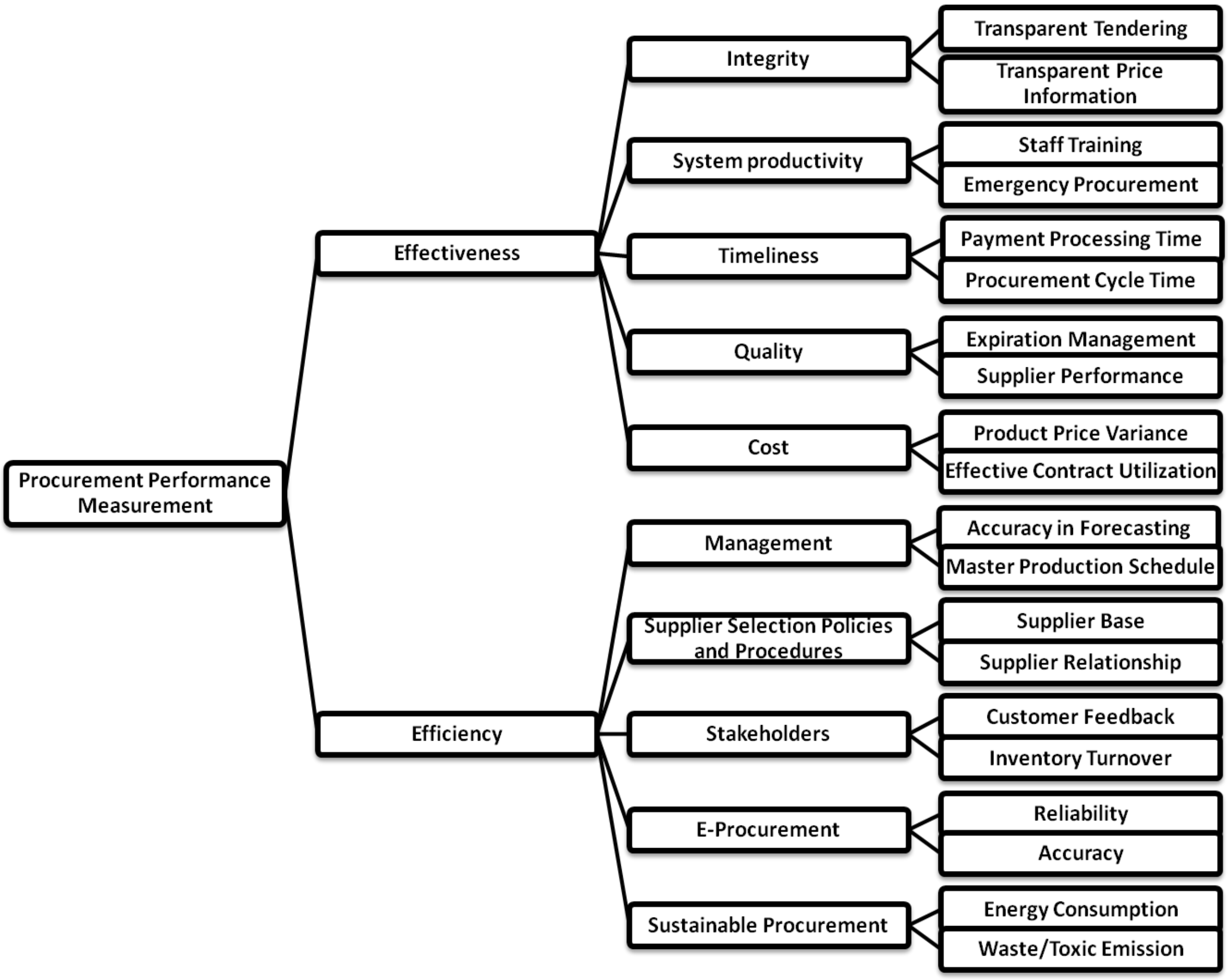

Figure2. The Proposed Multi Criteria Decision Making Model for Procurement Process

A questionnaire is designed for data collection from academics and industrialists. The questionnaire is developed based on the criteria and levels in the AHP model. Experts have been asked to make pair-wise comparisons between two factors/ criterion at a time, decide which factor is more important and then specify the degree of importance on a scale between 1 (equal importance) and 9 (absolutely more important) to the more important factor/criteria.

In total 52 people responded for the questionnaire survey and among that 29 were academics and 23 were industrialists. All the responders agreed about the model and shown positive response towards procurement performance measurement and its necessity.

4.1. Efficiency

Efficiency is defined as the relationship between planned and actual sacrifices made in order to realise a goal is previously upon (Weele, 2010).Procurement performance is critical to the success of every firm. Superior performance leads to competitiveness. Thus it became vital to check the efficiency of the procurement process. Efficiency means the organization is "doing things right". Measuring performance on the basis of efficiency will improve the quality of service. On the other hand, the absence of performance measures or wrong measures will create adverse results (CIPS, 2005).

Achieving procurement efficiency is a strategic issue now. As requirements of automotive industry increases, the need for measuring performance also increases. Following are the sub-criteria come under strategic issue of the procurement process and in measuring efficiency towards the procurement performance.

4.1.1. Sustainable procurement

Procuring sustainably helps organisations to eliminate waste as well as become more energy efficient and save money (CIPS, 2005). Sustainable procurement can be defined as "using procurement to deliver long term social, economic and environmental benefits" (Action Sustainability, 2012). (Crespin-Martin and Dontenwill, 2012) states two main reasons that drive firms towards social and environmental stakes; internal and external. Personnel commitment from managers and investors to implement green supply chain as well as desire to reduce cost by elimination of the waste, as internal factors. Apart from that, the new government rules and regulations as well as a desire to achieve competitive advantage as external factors. Efficiency of the sustainable procurement can be assessed on two main indicators (waste emission and energy consumption). Sustainable procurement means, doing procurement in a way that supports the environment eco-friendly.

Especially in automotive industries sustainability can be developed by adopting manufacturing methodologies like Lean and Just-in-time (JIT) technique. Lean methodology will contribute to the waste elimination process by identifying the wastes or non-value added actions in a process. At the same time, just-in-time technique helps to order goods only when it demands.

4.1.2. E-Procurement

Automotive industry's procurement processes are in a transformation as an impact of globalization. In order to achieve the competitiveness automation of the process is adopted by many of the industries. "E-procurement is an important step towards development of the extend enterprise where the supply chain becomes a continuous, uninterrupted process extending from buyer through selling partners" (Afsharipour et al., 2006). E-procurement system supports the strategic procurement functions and reduces operation functions. Automotive industry faces increasing pressure to improve efficiency, reduce cost, quickly identify and respond to changing demands.

E-procurement solutions arise from all these needs with an ability to collaborate suppliers, original equipment manufacturers (OEMs) and third party logistics providers. Efficiency of the e-procurement thus became a challenge for the organizations and performance of the e-procurement solutions can be measured on two main indicators; Accuracy and Reliability.

4.1.3. Stakeholders

Every business runs with an objective of meeting or exceeding stakeholder's requirements. Stakeholders can be internal or external to the organization. Internal stakeholders will be shareholders, management and employee. External stakeholders are customers, suppliers etc. Stakeholders see business in different perspective. Internal stakeholders look the procurement department's performance in terms of inventory turnover. While, external stakeholders look from value for money perspective and their satisfaction can be measured by customer feedback.

Prioritising individual stakeholders and their needs in the beginning of the process help smooth functioning and efficiency can be achieved. Prioritising should be based on their influence in the process or business (Sharma, 2008). Stakeholders are very sensitive in order to understand their feelings organizations have to view business in stakeholder's shoe.

4.1.4. Supplier Selection Policies and Procedures (SSPP)

In contemporary supply chain management, the performance of potential supplier is evaluated against multiple criteria rather than considering a single factor. In most of cases a single supplier cannot satisfy all the requirements. Therefore, supplier selection is a multi- criteria decision making problem in which firms need to prioritise selecting the best supplier on its working style and the industry type (Agarwal et al., 2010).

The main objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser, and develop long-term relationship between buyer and suppliers (Tahiriri et al., 2008). Moreover, the usage of methodologies like Total Quality Management (TQM) and Just-In-Time (JIT) has made the supplier selection process extremely important (Petroni, 2000).

The efficiency of the selection procedures can be measured on the basis of number of suppliers (supplier base) and consolidating suppliers contracts and involving them in strategic procurement planning process and maintain long-term relationship (supplier relationship). Maintaining supplier relationship and determination of supply base is a strategic issue. As suppliers play a vital role in quality and cost contribution. For PM, the screening process of suppliers should be monitored based on strategic decisions.

4.1.5. Management

Getting things done by others requires proper leadership and communication skills. Support of management is necessary for every strategies success. Efficient participation and action plans by the management should be measured towards PM. Materials requirement and resource planning is the main part of management function in procurement process. Over Production leads to obsolete goods and under production leads to not meeting the customer requirements. So there will be a balance between these two. Proper forecasting techniques should be used for this purpose.

Management efficiency can be measured on the basis of these factors; master production schedule and accuracy in forecasting. The Planning process is a continuous function. Efficient management and planning reduces cost and at the same time maximum profit with better utilization of available resources.

4.2. Effectiveness

Effectiveness is another dimension of procurement performance measurement (PPM). Weele (2010) defined purchasing effectiveness as the extent to which, by choosing a certain course of action, a previously established goal or standard being met. Purchasing effectiveness relates to the degree to which previously established goal and objectives have been met. A strategy or activity is either effective or not: a goal is reached or not. However, the goal can be expressed in terms of aspiration levels; the strategy or action that realizes a higher level may then be considered as more effective than another (Weele, 2010).

Effectiveness of the procurement process is related to goal or objective of obtaining right material in right quality, at right time and right place. The process should contribute to the innovation and reduce the company's supply risk. So effectiveness measures and criteria to assess the effectiveness of the procurement performance and its indicators are added in to the model and are explained as follows.

4.2.1. Cost

Finance is the life blood of every business and it is scarce resource as well. Effective utilization is required otherwise it will be like throwing our own money. Procurement process plays a prominent role in cost saving of the organization. Most of the companies cost arises from purchase of materials. A slight variation in percent can make a huge difference in overall outcome.

Cost reduction should not be based on sourcing cheap price products. In that case, we have to compromise the quality. Budget is limited and effective contract utilization can reduce cost. (USAID, 2013) proposed effective contract utilization and product price variance as the two main areas of cost related measurement towards PPM.

4.2.2. Quality

Quality is one of the core areas for PM. Especially automotive industries are in a path of improving quality by eliminating waste. Suppliers also play a big role in contributing quality. Methodologies like TQM, Lean and J-I-T are widely used in automotive industries. The performance of supplier should be monitored to ensure the quality of products and services. Toyota is working with suppliers and measuring their performance to ensure the quality of their final products. Quality effectiveness can be measured on the basis of supplier performance and expiration management; measure in value the amount of expired products or obsolete goods that are produced and not used for the production (USAID, 2013).

4.2.3. Timeliness

Automotive industries are in a movement towards reducing lead time and cycle time towards achieving competitiveness. Timeliness can measured on the basis of procurement cycle time; identify the key transactions in procurement cycle such as, requisition, bidding process, approval. For better process, review previous 12 months data. Determine time required for each stage of transactions and take the average of that. Set standard time for each process. Another measurement area is procurement processing time; Check the payment system. Whether is there any delay in the processing of payments? Check supplier payments are on time or not according to the contract. This may help to negotiate more favourable price. Both of the measurement areas are proposed by (USAID, 2013).

4.2.4. System Productivity

The system productivity can be measured on the basis of emergency orders and staff training. Monitoring system productivity provides managers with the information of how well the system is functioning. System productivity can be measured on the basis of emergency procurement; number of emergency orders issued among total purchase orders or contracts for a period of time. Historical data should be evaluated on the basis value and number or orders as well (USAID, 2013).

4.2.5. Integrity

Integrity of the system is one of the challenges for e-procurement. Corruption is easy to occur in procurement and sometimes it is not easy to detect. Weakness in execution and monitoring are common. Structural failure is a reason for procurement corruption. So the system should be evaluated. It can be done by; transparent price information; Measure is the procurement price information available to public. The price information for purchased unit should be transparent and easily accessible. It helps to scrutiny the procurement result. If information is not fully available check the reason and make necessary action to get it available. Transparent Tendering; Measure the competitiveness in the tendering process. Tendering process promote procurement process. Performance can be assessed by measuring total orders or contracts issued on competitive basis against total orders. Competitiveness creates effectiveness in the process (USAID, 2013).

5. Validation of the Proposed Model

This Section describes the validation of the proposed model using classical AHP and fuzzy AHP. The data collected from the questionnaire survey has converted in to geometric mean to measure the pair wise comparison of each criterion. Among the responses from the feedback, all the participants agreed with the model. As different participants have different opinion about each criterion. A geometrical mean method is used to convert the different Judgments in to one figure for each criteria and sub-criteria.

The following formula is used to calculate the geometric mean.

Geometric mean= $[(x_1)\ (x_2)\ (x_3)\ldots\ldots\ (x_n)]^{1/n}$

x = Individual weight of each judgement

n = Sample size (number of judgment)

AHP uses a scale indicating one element over another with respect to higher level element. The scale of relative importance is shown in table 2.

Table2. Scale of Relative Importance, Source (Saaty T. , 2008)

Intensity of Relative Importance	Definition
1	Equal importance
3	Moderate importance
5	Essential or Strong importance
7	Demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate values between the two adjacent judgements
Reciprocal of above non-zero numbers	If an activity has one of the above numbers compared with a second activity has the reciprocal value when compared to the first

The comparisons are performed for all elements in a level with respect to all elements in the level above. Following are the results obtained from pair-wise comparisons from AHP.

5.1. Efficiency and Effectiveness

Efficiency and effectiveness are the main two dimensions of PPM. Participants of the questionnaire were asked to give a weight among these two main criteria. The question asked was; while comparing these two main criteria towards main goal of procurement performance, what is the degree of importance between each criterion?

From the collected data, it is once again proved that strategic measures or efficiency measures are more important towards the goal of procurement PM.

Figure 3 and 4 show the relative importance of each sub-criterion under efficiency and effectiveness towards the PPM. It gives an understanding of the relative importance of each sub-criterion towards main criteria and towards the main goal.

Getting things done by others is not an easy process as management definition. It's a rising issue of procurement process to reduce inventory avoid non-value added activities. Proper planning by management can help to achieve the results. Supplier Selection Procedures and Policies ranked the second position in the efficiency measures.

The result shows the role or importance of suppliers in procurement process.

E-procurement system measurement ranked more than supplier selection policies and procedures. It illustrates that an accurate e-procurement solution simplifies the supplier selection criteria and management effort can be reduced through that. E-procurement can bring globalization to the business.

On the other hand, the quality is the most important factor under effectiveness. Automotive industries are in a movement towards improving quality; there cost has the least priority. The results states that a firm should not compromise on quality. Quality of service and product is important for procurement development, where system productivity ranked as second priority. Measuring employee's performance and monitoring them will enable smooth procurement process. Getting knows what to do and how to do requires proper training. Reducing lead time is a challenging issue in automotive industry, Timeliness measures thus ranked as third priority.

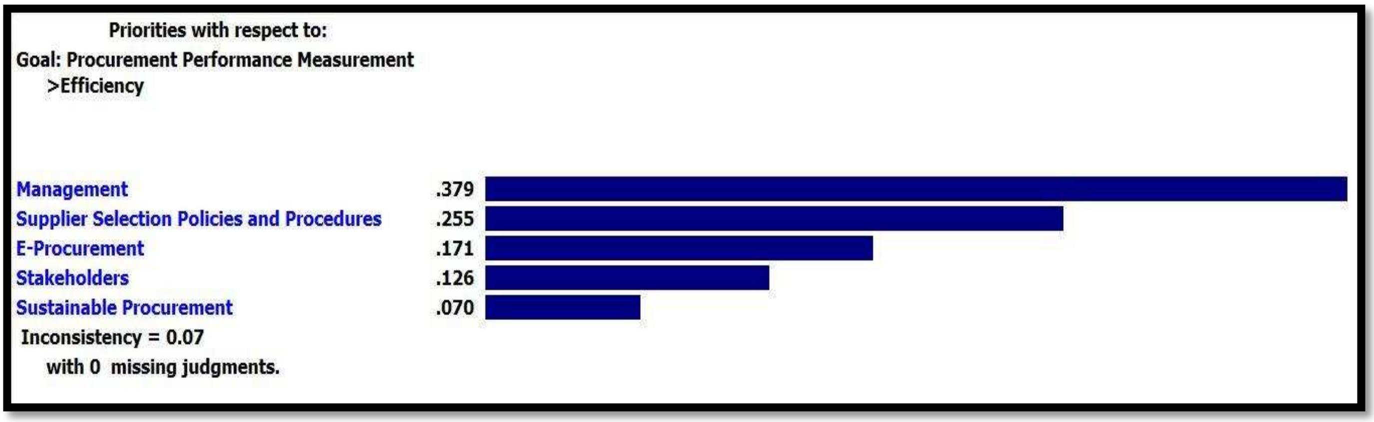

Figure3. Priority of Efficiency Measures with respect to: Goal: Procurement Performance Measurement

Figure4. Priority of Effectiveness Measures with respect to: Goal: Procurement Performance Measurement

5.2. Synthesis

A synthesis analysis has been done to understand the relative importance of all criteria towards the goal, PPM. The synthesis analysis not only shows the relative importance of the criteria. It also shows the consistency of the entire model. Figure 5 shows the summary of the criteria's priority with respect to the goal, PPM. The inconsistency measure is useful for identifying possible errors in judgements as well as inconsistencies in the judgment themselves. Inconsistency measures the logical inconsistency of the model.

The inconsistency ratio should be less than 0.1 or so to be considered reasonably consistent. The value of the ratio should be around 10 percent or less to be acceptable. In some cases 20 percent may be tolerated but never more (Sharma and Bhagwat, 2007).

The overall inconsistency is 0.06 that is 6%. According to Professor Saaty the inconsistency level is acceptable and the results show the high level of accuracy of the model. Moreover, this represents the level consistency in the comparisons and the validity of the model. Priorities are synthesized by multiplying local priorities by the priority of their corresponding criterion in the level above and adding them for each element in a level according to the criteria it affects.

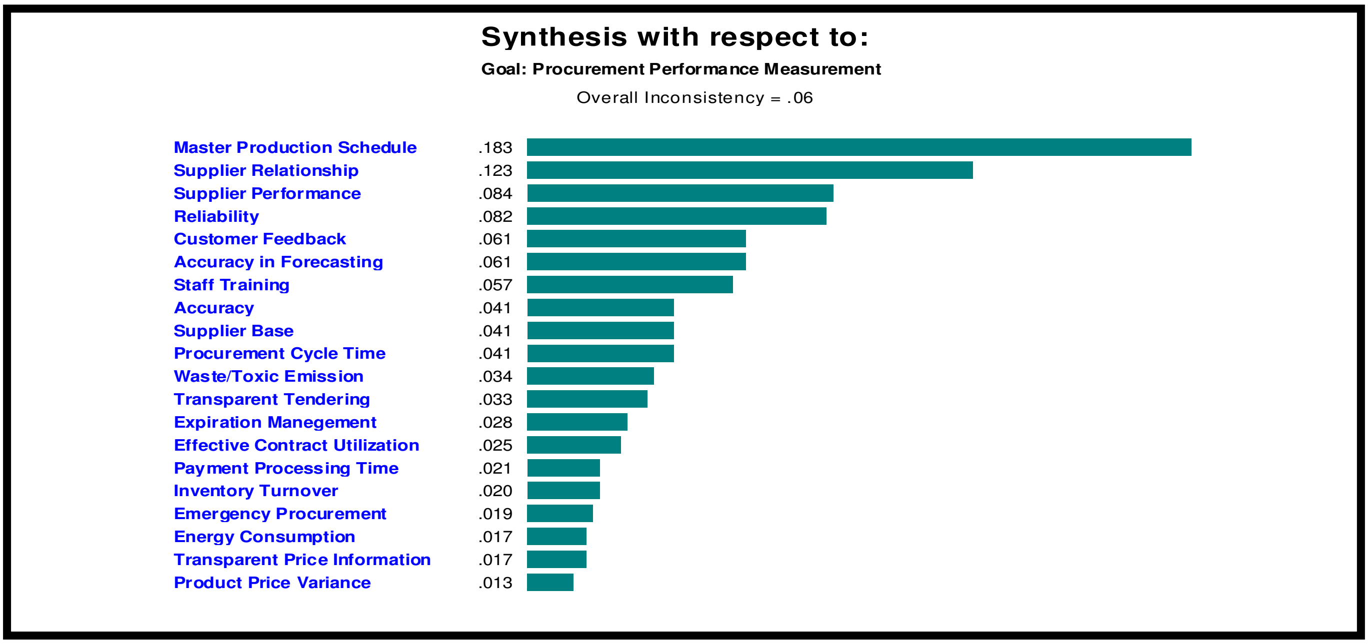

Figure5. Synthesis with respect to: Goal: Procurement Performance Measurement

5.3. Fuzzy AHP calculation

The triangular fuzzy scale represented in the methodology is used for the matrix creation. Once the matrix is prepared for comparison and consider if (l, m, u) is the importance of the sub-criteria Sustainable procurement over E-procurement then the importance of the sub-criteria E-Procurement over sustainable procurement will be $(l, m, u)^{-1}$ as shown in table 3. Table 3 shows conversion of all judgements under efficiency in to TFNs.

Once the entire matrix is created based on the TFN, the next step is to calculate the sum of each rows and columns to find out the synthetic value of each criterion. Following equation is used to calculate the sum of each rows and columns $(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$.

Once the sum of each rows and columns is obtained, the next step is to find out the synthetic value extend. The sum of all rows and columns of all criteria is shown in Table 4. The synthetic extend of all criteria can be obtained by dividing lower bound of every row with the higher bound of sum of columns sum, middle bound of row with sum of columns sum and higher bound of the rows sum by lower bound of the sum of column sum.

Table3. Fuzzy Comparisons Matrices at Sub-criteria level (Efficiency)

Sub-criteria (Efficiency level)	Sustainable Procurement	E-Procurement	Stakeholders	Supplier Selection Policies and Procedures	Management
Sustainable Procurement	(1,1,1)	(1/5,1/3,1/1)	(1/4,1/2,1/1)	(1/5,1/3,1/1)	(1/6,1/4,1/2)
E-Procurement	(1,3,5)	(1,1,1)	(1,2,4)	(1/5,1/3,1/1)	(1/4,1/2,1/1)
Stakeholders	(1,2,4)	(1/4,1/2,1/1)	(1,1,1)	(1/4,1/2,1/1)	(1/4,1/2,1/1)
Supplier Selection Policies and Procedures	(1,3,5)	(1,3,5)	(1,2,4)	(1,1,1)	(1/5,1/3,1/1)
Management	(2,4,6)	(1,2,4)	(1,2,4)	(1,3,5)	(1,1,1)

Table4. Sum of Rows and Columns based on different Criteria

Criteria	Rows Sum	Column Sum
Sustainable Procurement (Sus-P)	(1.81 , 2.41 , 4.5)	(6,13,21)
E-Procurement (E-Pro)	(3.45,6.83,12)	(3.45,6.83,12)
Stakeholders (Stake-H)	(2.7,4.5,8)	(4.25,7.5,14)
Supplier Selection (Sup-S)	(4.2,9.33,16)	(2.65,5.16,9)
Management (Man)	(6,12,20)	(1.86,2.58,4.5)
Sum of Column Sum		(18.21,35.07,60.5)

Once synthetic extend is determined the degree of possibility of fuzzy number/synthetic value obtained to be greater than other can determined by following equations (7-10).

Synthetic value obtained for all sub-criteria are shown below.

Synthesis

$$S_{\text{Sustainable procurement}} \left[\frac{1.81}{60.5}, \frac{2.41}{35.07}, \frac{4.5}{18.21}\right]$$

$$= (0.0299, 0.0687, 0.2471)$$

$$S_{\text{E- procurement}} = \left[\frac{3.45}{60.5}, \frac{6.83}{35.07}, \frac{12}{18.21}\right] (0.0570, 0.1947, 0.6589)$$

$$S_{\text{Stakeholders}} = \left[\frac{2.7}{60.5}, \frac{4.5}{35.07}, \frac{8}{18.21}\right] (0.0446, 0.1283, 0.4393)$$

$$S_{\text{Supplier Selection}} = \left[\frac{4.2}{60.5}, \frac{9.33}{35.07}, \frac{16}{18.21}\right] (0.0694, 0.2660, 0.8786)$$

$$S_{\text{Management}} = \left[\frac{6}{60.5}, \frac{12}{35.07}, \frac{20}{18.21}\right] (0.0991, 0.3421, 1.0982)$$

Comparison of $S_{\text{Sustainable Procurement}}$ with other synthetic values;

$$V(S_{\text{Sustainable Procurement}} \geq S_{\text{E-Procurement}})$$

Mean value of Sustainable procurement is not greater than mean value of E-Procurement and lower bound of E-Procurement is not greater than upper bound of Sustainable procurement then,

$$V(S_{\text{Sustainable}} \geq S_{\text{E-Procurement}})$$

$$\frac{(l_{E-Pro} - u_{Sus-P})}{(m_{Sus-P} - u_{Sus-P}) - (m_{E-Pro} - l_{E-Pro})}$$

$$V(S_{\text{Sustinable}} \geq S_{\text{E-Procurement}})$$

$$= \frac{(0.0570 - 0.2471)}{(0.0687 - 0.2471) - (0.1947 - 0.0570)}$$

$$= 0.60$$

$$V(S_{\text{Sustainable Procurement}} \geq S_{\text{Stakeholders}})$$

Mean value of Sustainable procurement is not greater than mean value of Stakeholders and lower bound of Stakeholders is not greater than upper bound of Sustainable procurement then,

$$V(S_{\text{Sustainable}} \geq S_{\text{Stakeholders}})$$

$$= \frac{(l_{\text{Stake-H}} - u_{Sus-P})}{(m_{Sus-P} - u_{Sus-P}) - (m_{\text{Stake-H}} - l_{\text{Stake-H}})}$$

$$= \frac{(0.0446 - 0.2471)}{(0.0687 - 0.2471) - (0.1283 - 0.0446)}$$

$$= 0.77$$

$$V\left(S_{\text{Sustainable}} \geq S_{\text{Supplier Selection}}\right)$$

Mean value of Sustainable procurement is not greater than mean value of Supplier Selection Policies and Procedures and lower bound of Supplier Selection Policies and Procedures is not greater than upper bound of Sustainable procurement then,

$$\frac{(l_{\text{Sup-S}} - u_{Sus-P})}{(m_{Sus-P} - u_{Sus-P}) - (m_{\text{Sup- S}} - l_{\text{Sup- S}})}$$

$$\frac{(0.0694 - 0.2471)}{(0.0687 - 0.2471) - (0.2660 - 0.0694)}$$

$$= 0.47$$

$$V\left(S_{\text{Sustainable}} \geq S_{\text{Management}}\right)$$

Mean value of Sustainable procurement is not greater than mean value of Management and lower bound of Management is not greater than upper bound of Sustainable procurement then,

$$V\left(S_{\text{Sustainable}} \geq S_{\text{Management}}\right)$$

$$= \frac{(l_{\text{Man}} - u_{Sus-P})}{(m_{Sus-P} - u_{Sus-P}) - (m_{\text{Man}} - l_{\text{Man}})}$$

$$\frac{(0.0991 - 0.2471)}{(0.0687 - 0.2471) - (0.3421 - 0.0991)}$$

$$= 0.35$$

Compare all the synthesis values under efficiency. Here the minimum value of each element is taken in to account and the sum of each element are divided by the sum of the column will give the priority of that element in the level. Then the normalized value can be obtained as per equation (12).

Most importantly the sum of all elements in level should be one. Weight vector is based on the above equation.

$$W^{'} = (\ 0.35\ , 0.79\ , 0.61\ , 0.91\ , 1\ )^{T}$$

As per equation (12) by normalizing the above value the weights can obtain as follows

$$W_{Sustainable} = 0.35/3.66$$

$$= 0.09$$

$$W_{E-Procurement} = 0.22$$

$$W_{Stakeholders} = 0.17$$

$$W_{Supplier\ Selection} = 0.25$$

$$W_{Management} = 0.27$$

$$W_{Efficiency} = (\ 0.09, 0.22, 0.17, 0.25, 0.27\ )^{T}$$

By following the same step the weights of each criterion can be obtained.

6. Results and discussions

Both the classical AHP and fuzzy-AHP results show efficiency measures are more important towards the goal, PPM. In the sub-criteria level, management (0.27) perceived to be the most important criterion followed by quality (0.26), supplier selection (0.25) and system productivity (0.23). It reveals that the performance measures related to management have been considered to be the most important. Whereas, the measures related to sustainable procurement have been related the least criterion. It is important that performance measures below efficiency (0.67) have been preferred over the same below effectiveness level. It shows that strategic decisions have more importance than operational decisions. It also suggests that customer feedback and supplier performance have an impact on turnover. The local weights of all sub-criteria as shown in figure 6 and 7 are obtained by multiplying the local weights of all sub-criteria with main criteria. According to global weights obtained from fuzzy AHP the final rankings are almost same as classical AHP. Fuzzy AHP helps to deal with uncertain judgement while classical AHP fails to deal with it. The results are justified, as the major objectives of the procurement process is to focus on the strategic decisions related to procurement more over operational issues. The results also gives a picture about a well accurate e-procurement solution can reduce supplier base by creating a strong relationship with existing suppliers and by measuring their performance.

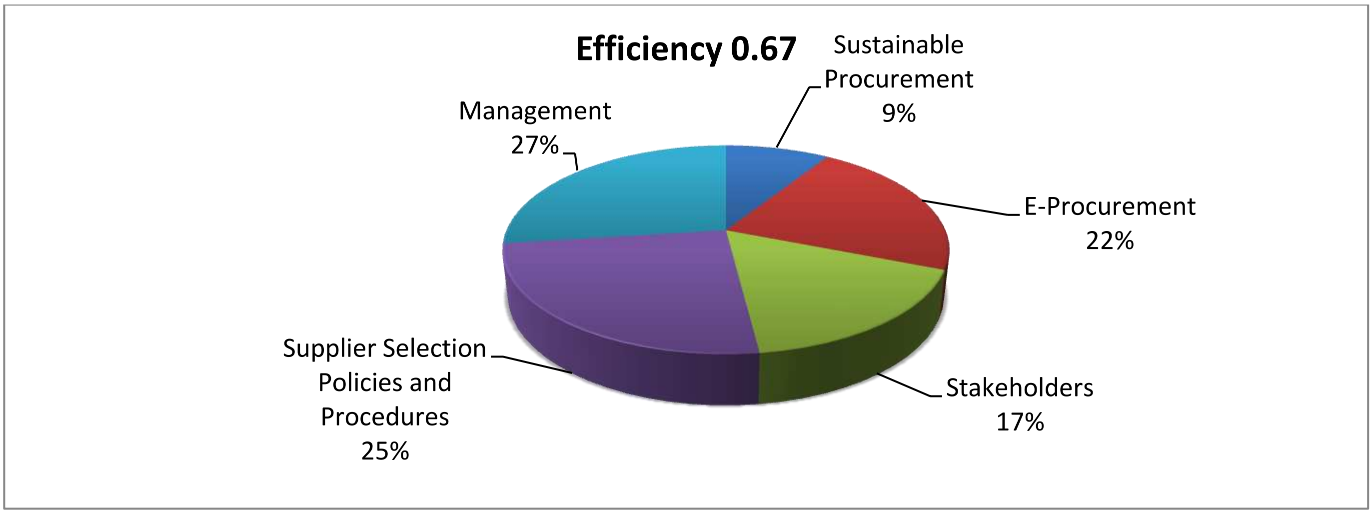

Figure6. Local weight of sub-criteria (Efficiency)

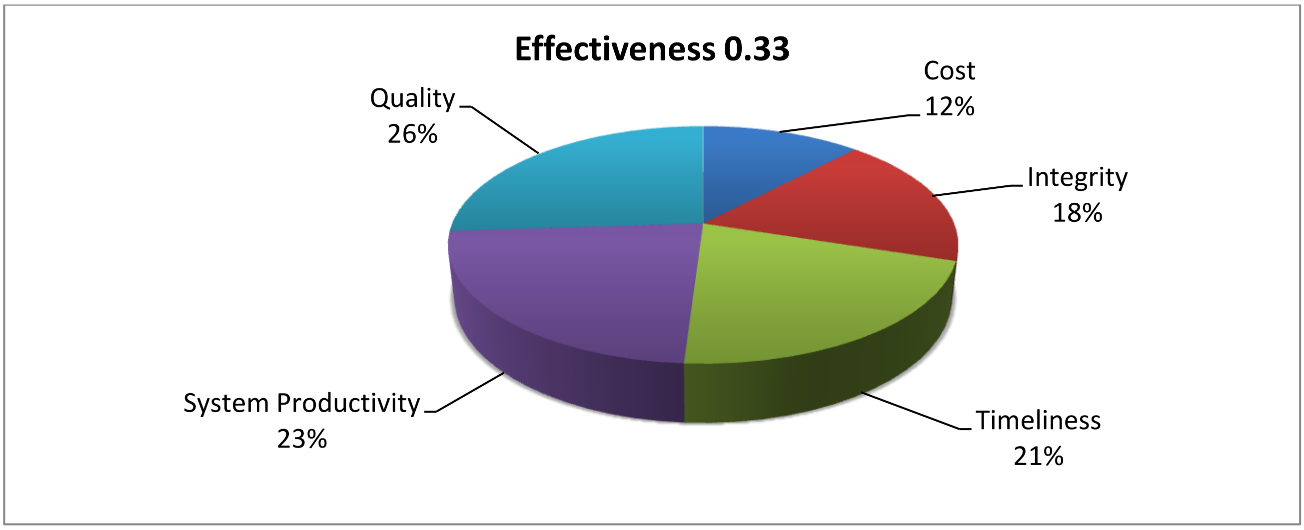

Figure7. Local weight of sub-criteria (Effectiveness)

So focusing on internal as well as external functions could be crucial for procurement process any in organization.

Pair-wise comparison values might vary based on the company situation and policies. For example some companies concentrate more on effectiveness measures than efficiency measures. Sensitivity analysis can be used to check how the priority of one factor related to another. By Sensitivity analysis, a decision maker can easily evaluate the changes.

Finally, there is a slight difference between classical AHP prioritization ratio and fuzzy AHP ratio. As fuzzy AHP taken in to account a set of value (TFN) rather than a single value, the prioritization will be more certain. It is noticeably that the global fuzzy weights (figure 8) shows that a slight difference in importance of elements in each criteria with respect to classical AHP.

Similarly table 5 shows the comparison between local weights derived each methodology. As per the tables efficiency is the most important main criteria and management is the most important criteria under efficiency level. Likewise quality is the most preferable measurement area under effectiveness.

6.1. Sensitivity Analysis

Sensitivity analysis helps a decision maker to understand the sensitivity of alternatives with respect to all objectives below the goal (Expert Choice, 2002). The importance or role of procurement varies from companies to companies and region to region. Implementation of sensitivity analysis to such decision making processes is essential to ensure the consistency of final decision and different scenarios can be visualized which are supportive to observe the impact of changing on criteria to final alternative rank (Syamsuddin, 2013). By this way the decision maker can observe how the priorities of alternatives would change.

For example, as shown in figure 9, according to the actual results, management is the most important sub-criteria and master production schedule is the important sub-sub-criteria towards procurement performance measurement. The criteria or importance of factors are a function of time. Through sensitivity analysis a decision maker can check what-if sustainable procurement was the most important sub-criteria and how the priority of other factors would change. As shown in figure 10 waste/toxic emission and energy consumption reduction will be the most important sub-sub- criteria and stakeholders will be the least important sub-criteria. This will enable a decision maker to examine what if scenario and arrive to the best combination that suit the company's strategic objectives

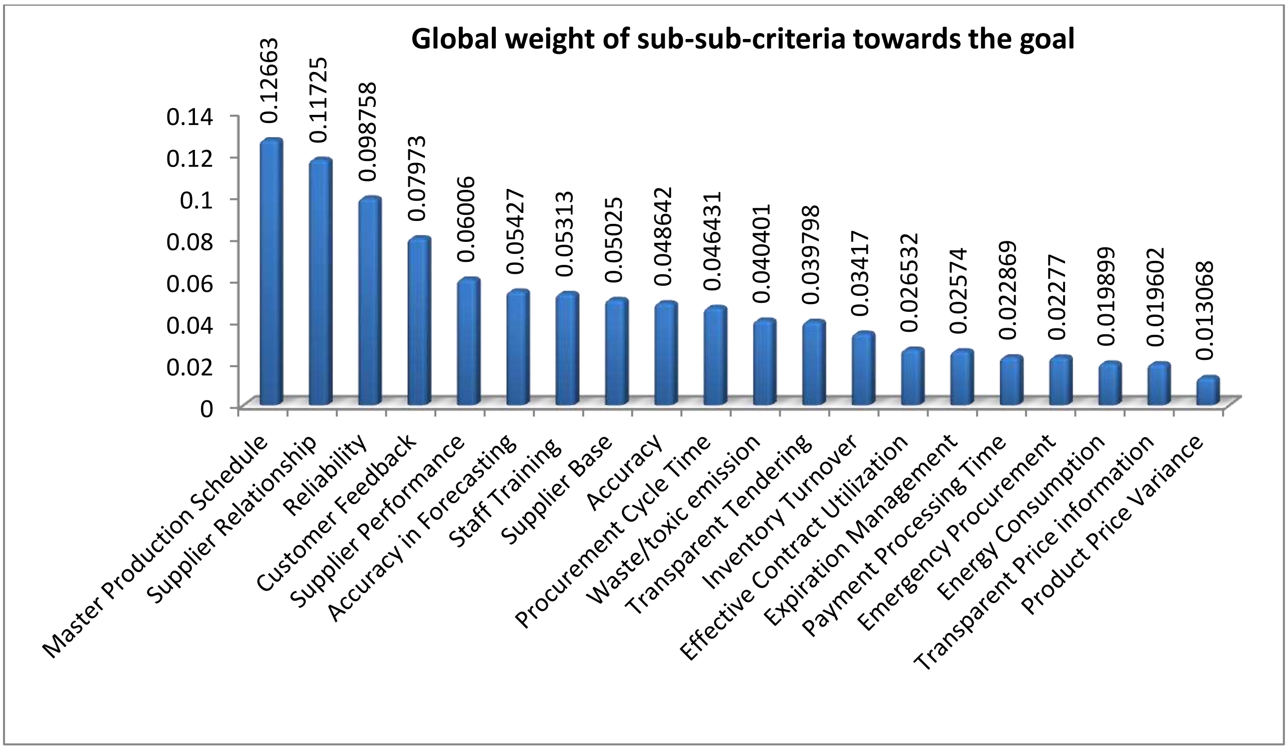

Figure8. Global weight of sub-sub-criteria towards the goal: Procurement Performance Measurement

Table5. Comparison between classical AHP and fuzzy AHP results

Main Criteria	Sub-Criteria	Fuzzy-AHP	Classical AHP
Efficiency	Sustainable Procurement	0.09	0.07
	E-Procurement	0.22	0.17
	Stakeholders	0.17	0.13
	Supplier Selection Policies and Procedures	0.25	0.25
	Management	0.27	0.38
Effectiveness	Cost	0.12	0.10
	Quality	0.26	0.35
	Timeliness	0.21	0.17
	System Productivity	0.23	0.24
	Integrity	0.18	0.14

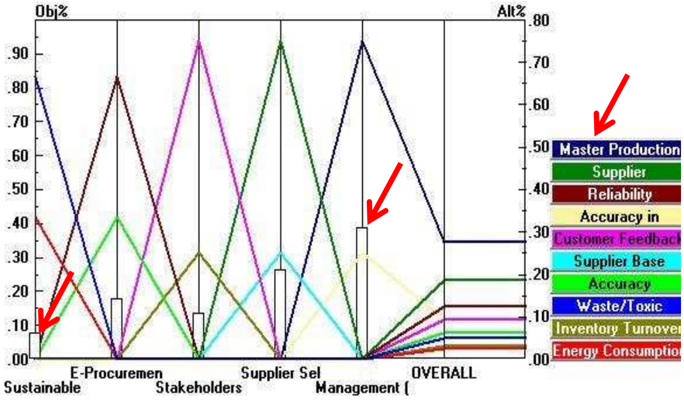

Figure 9 Sensitivity analysis actual results

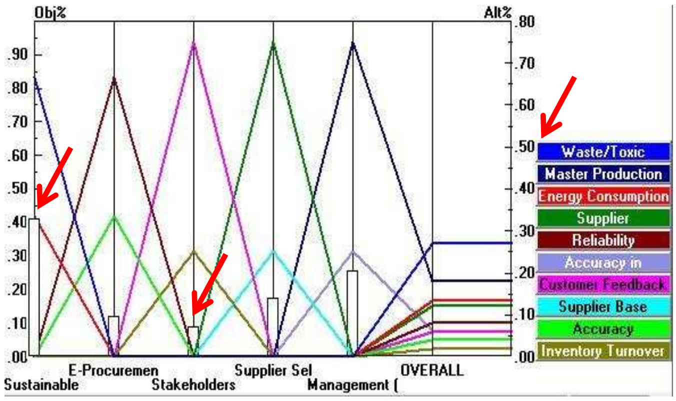

Figure 10 Sensitivity analysis new results

7. Conclusion, contribution to knowledge, limitations and further research

Measuring procurement performance is one of the challenging issues in today's competitive business scenario. An efficient and effective measurement can create improvement in the process and thus competitiveness can be achieved. In this study the criteria for procurement performance measurement have been decided based on current business scenario and expertise's judgments in this field. Considering the imprecise judgement facing by decision makers from classical AHP methodology a fuzzy AHP methodology also been used in this study to attain more crisp priority from each level of judgement for measurement depending on their criticality. The global ranking of the elements is performed by using FAHP and the validation is carried out by consistency check with AHP.

This study contributes to procurement performance measurement in automotive industry and manufacturing industry in general. The Proposed model is a comprehensible, comprehensive and balanced providing insights into prioritise criteria under efficiency and effectiveness level. The model highlights the relative importance of each element with respect to the upper level. The implementation of the proposed model would have significant positive impact on the future procurement practice in automotive industry by focusing on the most critical areas to attain competitive advantages.

FAHP sensitivity analysis helps to understand how the changes in priority of one criterion affect another. Through this the decision maker can make decisions according to changing situation. It needs lot of calculation and will consume more time. For that purpose this model can be integrated with programming language like Visual Basic. During the data collection and questionnaire stage, academics and industrialists were involved, and final model was developed based on their opinions collectively. However, it would be interesting in the future to take this study in to different direction and study the difference between both academics and industrialists opinion and explore what this might lead to in terms of criteria and sub-criteria and the structure of the model as a whole.

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