Key Performance Indicators Prioritization in Whole Business Process: A Case of Manufacturing Industry

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Abstract: The Dynamic and rapidly changing business environment offers challenges to manufacturing industries that demands timely related and right strategic decisions in order to compete in the marketplace. In this research, analytical hierarchal process (AHP) at strategic decision making is used. In manufacturing environment at strategic level, whole business process is involved and includes activities like marketing, production planning and control, finance, shop floor control, quality assurance, capacity planning, product development, supply chain management, inventory management, packaging, human resource management, maintenance management and sales/dispatch. Three manufacturing strategies are 'defensive strategies' corresponding to low cost, 'offensive strategies' corresponding to more agile and 'innovative strategies' corresponding to product differentiator. A questionnaire based survey has been conducted in manufacturing organizations and it has been found that production planning and control is the most important for 'protector players', whereas quality assurance activity and rapid product development is the most important for 'offensive and innovative players'. Interestingly, it has been found that marketing, and shop floor control is least important for protector and offensive manufacturers.
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1. Introduction

The Dynamic and rapidly changing business environment offers challenges to manufacturing industries which demands timely related and right strategic decisions in order to compete in the marketplace. At strategic level whole business process is involved which includes activities like marketing, production planning and control, finance etc. Analytical Hierarchal Process (AHP) at strategic decision making is used for prioritizing the importance of departments in automobile parts producing sector. A brief overview about strategic decision making process is described followed by introduction to AHP and justification for it use. The final strategic hierarchy is presented in last section.

Strategy is defined by Farjoun (2002) as "the planned or actual co-ordination of the firm's major goals and actions, in time and space that continuously co-align the firm with its environment". This definition encapsulates three interrelated points: behavior, co-ordination and adaptation. In practice, the essence of strategy is the improvement of competitiveness. This is probably one of the most challenging tasks facing any firm, given the increasingly volatile business environment. To survive and gain competitive advantage, organizations of all sizes increasingly need to pursue well developed and clear cut strategies (Christopher. Bartlett and Ghoshal, 1990; Powell, 1992). Yet small firms are often stated to be 'naive about planning and the development of strategy' (Deakins and Freel, 1998). The number of ways that small firms tend to respond to change exemplifies this. Firstly, they tend to look inward rather than outwards and ignore change (focused only at tactical decision making). Secondly, some continue to rely on efficiency based measures as their 'strategic plan' for the future. Thirdly, some firms believe that, as they are part of a localized supply chain, they are immune to any external influences (focusing only on services). In research world, many approaches have been developed for coping with strategic level decisions. At that level, the focus is to identify key performance factors and prioritize them in whole business settings. Therefore, AHP as a tool is selected which aid in prioritizing key activities in whole business process. Much research work has been carried out over the last few decades of using AHP as a multi criteria decision making tool. The most significant work in this regard is: AHP for facility layout (Jiaqan 1997), AHP study of TQM (W. G. Lewis, 2005), multi criteria supplier selection using AHP (Cengiz, 2003), prioritization of key performance indicators using AHP (Arash 2006), AHP in FMS decision making (Ozden 2004). In our case the main focus is to conduct a survey of automobile sector to identify type of manufacturers and then apply AHP as a tool to identify the main department which should be paid attention by the manufacturer at strategic level. In

prioritizing whole business process, main departments selected include marketing (MKT), production planning and control (PPC), finance/accounts (FIN), shop floor control (SFC)/assembly, quality assurance (QA), capacity planning (CP), product development (PD), supply chain management (SCM), inventory management (IM), packaging(PKG), human resource management (HRM), maintenance management (MMT) and sales/dispatch (S&D). AHP has been used in a wide variety of complex decision-making problems, such as the strategic planning of organizational resources (Saaty, 1990), the evaluation of strategic alternatives (Tavana and Banerjee, 1995), and the justification of new manufacturing technology (Albayrakoglu, 1996). The work carried out by (Jahanzaib. E, 2008) and (Mirza Jahanzaib 2013) is significant in this regard. In order to minimize the risks involved in goal setting, the prioritization of whole business process should be viewed as a multi-criteria, decision-making problem. Analytical hierarchy process (AHP) can be used for multi-criteria decision making. It is evident from our discussion that AHP is referred to as the most powerful and widely acceptable technique for decision making process which allows decision maker(s) to measure the consistency and stability of their decisions. AHP has also been proved to be useful in prioritizing alternative variables.

2. Analytical Hierarchal Process

The analytical hierarchal process (AHP) is a powerful and flexible decision-making tool that helps people set priorities and make decision when both quantitative and qualitative aspects of a decision need to be considered. This is done by reducing complex decisions to a series of pair wise comparisons, computing Eigen values and then synthesizing results. AHP not only helps in decision makers arrive at the best decision, but also provides a clear rationale for the decision. The decision maker judges the importance of each criterion in pair-wise comparisons. The outcome of AHP is a prioritized ranking or weighting of each decision alternative. The AHP consists of following five steps:

1. Decide upon the criteria for selection
2. Rate the relative importance of these criteria using pair-wise comparisons
3. Rate each potential choice relative to each other choice on the basis of each selection criterion – this is achieved by performing pair-wise comparisons of the choices
4. Combine the ratings derived in steps 2 and 3 to obtain an overall relative rating for each potential choice as

$$a_{ij} = \sum_i (w_i k_{ij})$$

Where; aj = overall relative rating for method j; w_j = average normalized weight for criterion I; k_{ij} = average normalized rating for method j w.r.t. criterion i.

5. Synthesis of priorities and the measurement of consistency

i) Calculate the eigenvector or relative weights and for each matrix

ii) Compute consistency index (CI) for each matrix of order n by the formula:

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

iii) The consistency ratio (CR) is then calculated using the formulae:

$$CR = \frac{CI}{RI}$$

Where; RI is a known random consistency index obtained from a large number of simulations runs and varies depending upon the matrix size. For example; 0.05 value is for 3x3 matrix, 0.08 for 4x4 and 0.1~0.2 for all other matrices. AHP weights with level of importance information are given in table 1:

Table 1 Weight in AHP

Preference weights/ level of importance	Definitions	Explanation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately preferred	Experience & judgment slightly favor one activity over another
5	Strongly preferred	Experience & judgment slightly favor one activity over another
7	Very strongly preferred	An activity is strongly favored over another and its dominance demonstrated in practice
9	Extremely preferred	The evidence favoring one activity over another is of the highest degree possible of affirmation
2,4,6,8	Intermediate preferred	Used to represent compromise between the preferences listed above
Reciprocals	Reciprocals for inverse comparison	

3. Methodology

A comprehensive survey was designed for identifying the role of main departments in whole business process using AHP. A number of questionnaires related to usage of AHP were also reviewed before designing questions (this work is only focused on strategic level decision making). A survey of automobile discrete parts industry was conducted (complete survey cannot be explained; interested readers can contact with author in this

regard). Personal visits to some companies were also made to get first hand information and questionnaire validated by sample questions from CEOs/Business executives/Managers. Based on the feedback of practicing managers and discussions with EDB sector development professionals, final version of questionnaire was sent to the companies. Out of 180 questionnaires mailed to CEO/MDs/Managers, 66 responses were received out of which 60 were found useful. This gives a response rate of 33.4% which is considered adequate for this type of survey in fragmented discrete parts manufacturing industry. Frohlich M (2002) suggested ways to improve response rate, which is also considered in designing of questionnaire.

The complete survey is beyond the scope of this paper. From the survey responses three types of manufacturers have been identified which are '*protector'* corresponding to low cost, '*offensive*' corresponding to customer focused with high quality and '*innovative*' corresponding to outperforming competition with product differentiation. The manufacturing strategy for each manufacturer's type is devised. '*Protector Strategies'* are the set of decisions as a result of which organizations achieves low cost producer status for protector manufacturers. Using traditional approaches like line balancing, world load control; line is balanced which help to reduce cost by minimizing waste time/operations hence reducing cost. The word *'protector'* is used as a defensive approach for manufacturers to produce at lowest cost using traditional approaches so as to become low cost producers. *'Offensive strategies'* are derived from the set of decisions which results in the production with high quality, flexibility and customer focused. *Technology Driven Strategy (TDS)* framework as an offensive strategy has been devised for analyzing the means of improving productivity by improved manufacturing systems and increased automation (Jahanzaib Mirza et al 2007). The focus is to find out the impact of costs when manufacturing organizations replace manual work with automation. Automation does not allow poorly designed products and inefficient processes to exist (Russell and Taylor, 1998). *'Innovative strategies'* are derived from the set of decisions which results in the organization undergoing value adding changes with high customer service so as to become market differentiators with an emphasis on outperforming the competition. In innovative strategy, the work of (Mirza Jahanzaib 2013) related to the automated system is also helpful to understand the operational performance in innovative production system. Over the last decade or so, there appear to be a clear grouping of work in terms of three types of strategies: Hayes and Wheelwright (1979a, 1984), Hill (1993, 2000), Safizadeh (1996), Ahmad (2002), Ariss S (2002), Voss C (2005), and Johansson P et al (2006).

As stated above that whole business process activities have been used as key performance indicators affecting the business at strategic level. So these are used as a factor affecting the whole business settings so that important ones are identified and prioritized. The way in which we have used these indicators in AHP for prioritization is unique which is used to identify the relationship and importance of 'one indicator over the other using pair-wise comparison'. It is obvious that one who is involved in the process being asked to judge pair-wise relative importance of one indictor over the other may lead to inconsistence results. Therefore, CEOs/business executives/managers have been selected to fill the 'nxn' matrix who has been involved in operational and strategic decision making process in industry for many years. A questionnaire has been distributed in matrix form asking a simple question *'How much important is one indicator (department in our case) over the other'* using a scale of 0-9 for protector, offensive and innovative manufacturers respectively. This is because; sometimes-major investment is made without proper identification of key issues on functional departments. This may lead us to wrong decisions; therefore, relative comparisons of different alternatives of key indicators are very necessary. One logical argument is that the relative importance is different for person who is filling up the 'n x n' matrix. This is overcome as averaged values have been used for final prioritization calculations. Now, set up the 'n' requirement in the rows and columns of an 'n x n' matrix. Since, there are thirteen activities in whole business process; therefore the requirement matrix consists of thirteen rows and columns. The matrix is filled up above the diagonal (since the values below the diagonal are reciprocals for each corresponding indicator; cannot be reproduced due to lack of space). Then, perform the pair-wise comparison of all the requirements using the scale value as mentioned above. We have used Expert Choice® software for calculating importance ratings and Eigen value calculations. The judgments are recorded, 'n x n' values calculated and any inconsistencies shown in final results.

4. Results & Discussion

As stated in the previous section about types of manufacturers. The results, brief discussion for each type of manufacturer has been presented in the following section.

4.1. Prioritization for Protector Manufacturers

Figure1 and 2 showing both normal (w.r.t goals) and prioritized results in decreasing order of importance for 'Protector Manufacturers'.

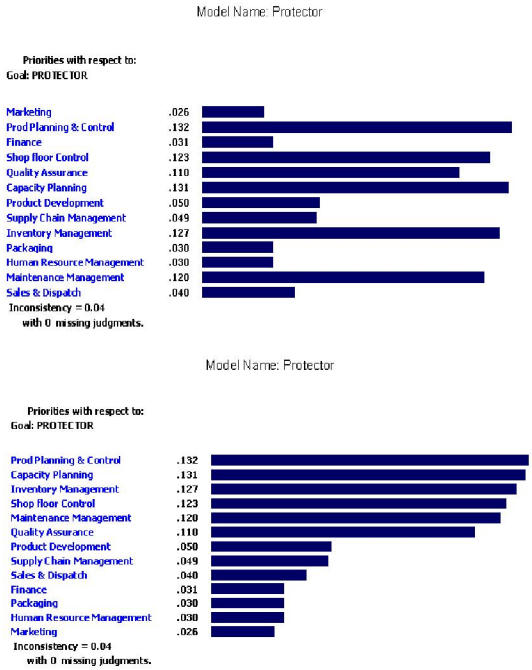

Fig 2 Decreasing order of Importance (Protector)

Production planning and control is the most important activity in prioritization. This is so as executives feel it utmost important at shop floor level followed by capacity and inventory management. Thus focusing on production planning and control can reduce cost per part and increase efficiency of system by minimizing waste times. Thus concentrating on these activities would capture the market so marketing has been identified to be the least sensitive rated by them at *'protector level'*. Therefore, it comes out that production planning and control followed by capacity planning; inventory management and shop floor control are the most sensitive activities in whole business settings for protector players as shown in figure 2. The prioritization for protector players in decreasing order of importance is, 1) Production Planning and Control 2) Capacity Planning, 3) Inventory Management, 4) Shop Floor Control, 5) Maintenance Management, 6) Quality Assurance, 7) Product Development, 8) Supply Chain Management, 9) Sales & Dispatch, 10) Finance, 11) Packaging, 12) Human Resource Management and 13) Marketing. Much attention should be placed on streamlining of operations, minimization of waste times from the processes using standard tools and methods of production planning and control, shop floor control etc.

4.2. Prioritization for Offensive Manufacturers

Figure 3 and 4 show normal (w.r.t goals) and prioritized results for offensive manufacturers. As offensive manufacturers objective is to satisfy customized requirements by enhancing variety (to delight customers), so they are termed external focused. Quality assurance, product development is rated as the most important activities in whole business settings for offensive manufacturers.

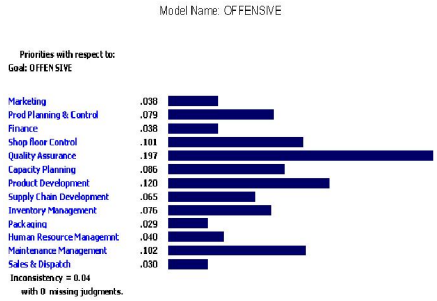

Fig 3 Offensive Manufacturers w.r.t goal

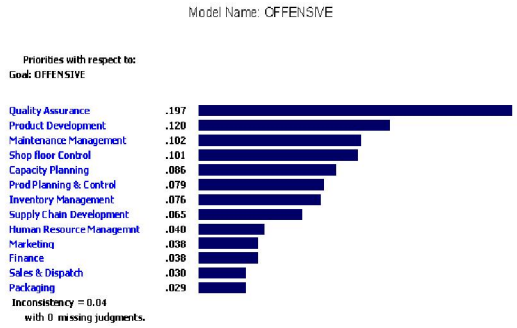

Fig 4 Decreasing order of Importance (Offensive)

This means that executives/managers are quite aware that this is the most important stage and turning point to become competitive. Therefore, much attention should be paid in quality assurance and product development activities by introducing advanced manufacturing systems and increasing quality level at shop floor (by means of automated systems). The prioritization in decreasing order of importance is, 1) Quality Assurance, 2) Product Development, 3) Maintenance Management, 4) Shop Floor Control, 5) Capacity Planning, 6) Production Planning and Control, 7) Inventory Management, 8) Supply Chain Management, 9) Human Resource Management, 10) Marketing, 11) Finance, 12) Sales and Dispatch, and 13) Packaging. It is pertinent to note that at offensive stage, quality assurance and product development are the most sensitive activities which affect the whole business setting.

4.3. Prioritization for Innovative Manufacturers

Figure 5 show prioritized results for innovative manufacturers. It is interesting to note that quality assurance, product development and maintenance management are rated to be the most sensitive activities in whole business settings for

innovative manufacturers.

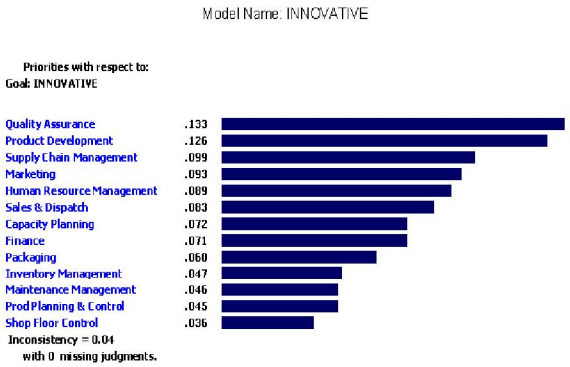

Figure 5 Innovative Manufacturers priorities in decreasing order of importance

The prioritization in decreasing order of importance is given below, 1) Quality Assurance, 2) Product Development, 3) Supply Chain Management, 4) Marketing, 5) Human Resource Management, 6) Sales & Dispatch, 7) Capacity Planning, 8) Finance, 9) Packaging, 10) Inventory Management, 11) Maintenance Management, 12) Production Planning and Control, 13) Shop Floor Control. It is found that quality assurance, product development and supply chain management are the most important activities in whole business settings. One similarity lies here between *offensive and innovative manufacturers* is quality assurance and product development come out most important for both type of manufacturers. This is because at medium to high variety, new product development and quality offer challenges to manufacturers for achieving highest degree of reliability and innovation as demanded by domestic and international customers. Value Analysis (VA) is the systematic application which is used to identify the function of a product or service, establish a monetary value for the function and provide the necessary function reliably at the lowest cost. Value can be increased either by increasing the importance for the same cost or by decreasing the cost for the same utility. Let; I = Importance; C = Cost Therefore; Value = I / C. The information collected is on the basis of importance versus cost out of hundred percent (%). Importance at operation 1, 2, ..,n is I_1, I_2,…, I_{13} respectively**.** Similarly related cost at operation 1, 2, …, n is C_1, C_2,… C_{13} respectively. There are thirteen departments/activities engaged for the manufacturing of automobile parts. Department's importance and corresponding cost is shown in figure 6.

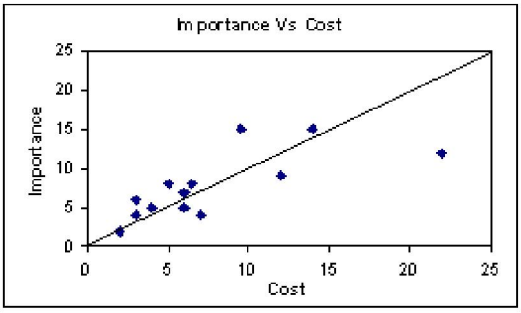

Figure 6 VA applied in innovative stage

Four departments which require consideration are shop floor control, product development, supply chain management and inventory management in which cost is more than importance as they lie below the line in figure 6. It is required to carry out detailed *VA analysis using tear down approach* for identifying causes and made remedial actions. By carrying out detailed analysis within the departments for innovative manufacturers can improve satisfaction level of customers at reduced cost.

5. Conclusion & Recommendations

- Based on prioritized results, there occur different levels of hierarchies i.e. most, moderately, and least important. The following conclusions have been drawn from the responses obtained from industries. Figure 7 show different levels of hierarchies based on the results. Production Planning and control is most important activity for protector manufacturers, whereas quality assurance is equally important for both offensive and innovative manufacturers respectively. This confirms that even executives are quite aware of their decisions at strategic level.
- Capacity planning is the second most important activity for protector whereas product development both for offensive and innovative manufacturers respectively. This comes out that attention be placed on capacity building for protector whereas emphasis should be placed on product development for offensive and innovative manufacturers.
- Much attention should be paid on inventory management, maintenance management and supply chain management by improving standards of forecasting data and using state of the art techniques like JIT, Kaizan, and 5S for material management.

Value Analysis (VA) as a tool assists innovative manufacturers to increase importance and reduce cost. It has been found that shop floor

control, product development, supply chain and inventory management is most costly-less important departments. Value analysis tear down approach should be implemented to find out less important and mostly costly activities. This help to improve product quality using VA activities. The following recommendations based on results as presented for protector, offensive and innovative manufacturers at strategic level are:

i. Production planning & Control and quality assurance issues are rated as most important at strategic level. It is evident that manufacturers should focus on production planning and quality assurance issues. This would be achieved using conventional approaches like work load control, line balancing algorithms and Kaizan, 5S etc at shop floor.

ii. Use of flexible systems lie CNC, NC and transfer machines not only mitigate capacity constraints issues on one side, but also help in product development with CAD/CAM integrated features. Other than above stated systems, quality related tools like gauging systems for mass production, control charting, acceptance sampling, total quality management, zero defects approaches should be used which can eliminate waste from system.

iii. In order to reduce lead and product development time, flexible processing and time compression technologies like rapid prototyping machines, 3-D scanner, and coordinate measuring machines should be used which provide fastest development time.

iv. Manufacturers should focus on manufacturing management systems for material management and supply chain management issues. This would be achieved by implementing MRP-I and II. To minimize new material and finished goods inventories, the reliability of vendors are important (zero defect stage) which will cut a lot of waste from the system.

Office automation tools and implementation of CAD/CAM in *ARIS architecture* should be understood in order to implement different hierarchies of ARIS within the organization.

v. Special attention should be paid on human resource development as it is found sensitive for innovative manufacturers. Simulation courses, off-line machine practice for new product development, making models in rapid product machines, learning of CAD software, training on advanced systems, seminars would help them to learn about latest tool/ techniques.

Figure 7 Hierarchical levels

Whole business process activities have been modeled and analyzed using AHP (Expert Choice software®). The necessary information needed in this regard is filled up in n x n matrix. The judgments are recorded and calculated as shown in figures 1 to 5 above. Production planning & control, quality assurance and product development are most important activities which affect business at each type of manufacturers. It is therefore imperative for manufacturers to keep special emphasis on production planning and control issues at protector, quality assurance at offensive and product development techniques at innovative stage.

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