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A multi attribute decision making method for selection of optimal assembly line

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A B S T R A C T

With globalization, sweeping technological development, and increasing competition, customers are placing greater demands on manufacturers to increase quality, flexibility, on time delivery of product and less cost. Therefore, manufacturers must develop and maintain a high degree of coherence among competitive priorities, order winning criteria and improvement activities. Thus, the production managers are making an attempt to transform their organization by adopting familiar and beneficial management philosophies like cellular manufacturing (CM), lean manufacturing (LM), green manufacturing (GM), total quality management (TQM), agile manufacturing (AM), and just in time manufacturing (JIT). The main objective of this paper is to propose an optimal assembly method for an engine manufacturer's assembly line in India. Currently, the Indian manufacturer is following traditional assembly method where the raw materials for assembly are kept along the sideways of conveyor line. It consumes more floor space, more work in process inventory, more operator's walking time and more operator's walking distance per day. In order to reduce the above mentioned wastes, lean kitting assembly is suggested by some managers. Another group of managers suggest JIT assembly as it consumes very less inventory cost compared to other types of assembly processes. Hence, a Multi-attribute decision making model namely analytical hierarchy process (AHP) is applied to analyse the alternative assembly methods based on various important factors.

1. Introduction

The present globalization and rapid technological developments leads organizations to meet high competition in the global market. To face the difficulties like varying customer demand, different product design and requirement of perfect quality with exact delivery time, many people attempt to implement new and beneficial management philosophies like lean manufacturing, world class manufacturing, green manufacturing, total quality management, and agile manufacturing (Ben et al. 1999, Luis et al., 2001). In this paper, an engine manufacturing assembly line is considered as a case organization. Presently, traditional assembly system is implemented for assembling engines which means that raw materials and components for assembly are kept along the side of the conveyor line. The floor space required, work in process inventory, operator walking time and operator walking

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distance per day are high in traditional assembly. In order to reduce the above said wastes, lean kitting assembly is suggested by some managers in the company. Another group of managers suggest JIT assembly since it consumes less inventory cost compared to other types of assembly processes. The important question here is how to make a decision for the optimal assembly method and how to convince the top management for the changes in the manufacturing methodologies. Therefore, in this paper, an attempt has been made to select and suggest an optimal assembly method among traditional, lean kitting and JIT assembly. To recommend the suitable assembly method, we may use a number of multi-attribute decision making (MADM) models such as analytic hierarchy process (AHP), analytic network process (ANP), fuzzy inference system (FIS), and goal programming (GP). In this paper, AHP is applied to analyse the alternative assembly methods based on the impact of various important factors affecting the production.

2. Literature Review

Tamaki and Nof (1991) described the design method of robotics kitting systems, as an alternative part entry process, which contributes to reduction of overall assembly cost. Robot improves productivity, flexibility and part flow control in parts kitting operations. Bozer and McGinnis (1992) developed a descriptive model which can be used to quantify the trade off in material handling, space requirement and WIP between kitting and line stocking for an assembly of stationary fitness cycle. Brynzor and Johansson (1995) focused on design of kitting system in terms of location of the order picking activity, work organization, picking method, information systems and equipment. Some design aspects and performances from case studies are discussed. In kitting system, results shows that picking efficiency and accuracy can be improved by making better use of the product structure. Gunther et al. (1996) analyzed the component kitting problem in semi automated printed circuit board assembly. The main objective is to minimize total operator time. In this work, they described the component kitting problem faced by an electronic component manufacture. A heuristic solution procedure was developed, which was computationally very efficient even for large-scale problems encountered in industries. De Toni and Tonchia (1996) explained that a good organizational change required by lean production leads to a management by process organization, and that management by process influences the performance measurement system (PMS). Rao Tummala et al. (1997) examined and evaluated strategic and operational level success factors, benefits and costs to develop strategies of implementing concurrent engineering (CE). First several success factors to implement CE were identified based on literature review. Then, the AHP model was formulated and used to assess the success factors, benefits and costs in order to develop strategies to implement CE in Hong Kong electronics products manufacturing companies. Also, the same model was used to determine the benefits/cost ratios and to decide whether or not to implement CE in the Hong Kong electronics industry. Par Ahlstrom (1998) examined whether any sequence of manufacturing changes initiates improvement in manufacturing performance. This finding groups the principles of lean production into four different categories, depending on when management devoted effort and resources to the principles. Woo Lee et al. (2000) presented a methodology using ANP and zero-one goal programming for information system projects selection problems that have multiple criteria and interdependence property. Chrisrmansson and Medbo (2002) discussed a material kitting case study using alternative methods like picker to material principle and material to picker principle. The material kitting was video recorded and picker physical exposures were assessed. The material kitting showed improved productivity as compared with other kitting methods.

Ertugurul Karsak et al. (2002) use a combined ANP and zero-one goal programming approach to incorporate the customer needs and the product technical requirements systematically into the product design phase in quality function deployment. The existing dependencies in the QFD process are taken into considered using the ANP approach and a goal programming model was constructed to determine the set of PTRs that will be taken into account in the product design phase. Joshi et al. (2002) discussed the problems at kitting stage of a printed circuit board (PCB) assembly process and the use of simulation to improve the process. It provided detailed information of the kitting process followed at the manufacturing facility at which this research was conducted. It was observed from historical data, that 10% of the kits at assembly setup had discrepancies. The main objective of this research was to reduce these kitting discrepancies by at least 50%. The sub-objectives were to implement a continuous flow system, improve operational performance, ensure the on-time delivery of kits, and implement a closed loop feedback system for better kitting accuracy. Oliver, et al. (2002) studied lean production and manufacturing performance improvement in Japan and compared the lean production with other popular production methods.

Lars Medbo (2003) explored on material kit functionality, usefulness of the materials kit in respect of operator's handling of materials. The analysis indicated that the assembly works proved to be almost the same when there are no technical differences between the layouts. Galantucci et al. (2004) proposed the implementation of hybrid fuzzy logic-genetic algorithm (GA) methodology to plan the automatic assembly and disassembly sequence of products. The GA-Fuzzy logic approach was implemented onto two levels. The primary level of hybridization consists of a fuzzy controller method for the parameters of an assembly or disassembly planner based on GAs. The secondary level is the identification of the optimal assembly or disassembly sequence by a fuzzy function, in order to obtain a closer control of the technological knowledge of the assembly/disassembly process. Abdulmaleh and Rajagopal (2006) described a case where lean principles were adopted for the process sector for application in a large integrated steel mill. Value stream mapping is the main tool used to identify the opportunity for various lean techniques. A simulation model was developed to contrast "before" and "after" scenarios in detail. Houshmand and Jamshidnehhad (2006) presented an axiomatic modelling of lean production systems design, using process variables. Here an attempt is made to introduce performance variables (PVs) in production system design. In production system authors interpret PVs as the tools, methods and resources required for implementing a lean production system. Karthik (2006) proposed an integrated supplier selection methodology for designing robust supply chains. Sullivan et al. (2007) illustrated a road map of how value stream mapping can be an important tool to define, analyze, and quantify waste such as excess WIP and defects. Salomon et al. (2007) used multiple decision making for supplier selection of assembly line equipments in an automotive industry Kull and Tallurai (2008) proposed a combination of AHP and goal programming as a decision tool for supplier selection in the presence of risk measures and product life cycle considerations. The efficiency of the model is tested at a mid-sized, second-tier automotive supplier. Scherrer Rathje et al. (2009) identified the major criteria and conditions that lead to either lean success or failure. They found the sources to failure like the lack of senior management commitment, lack of interest and low acceptability of workers for changes. The sources of success are employee autonomy to make decisions, information transparency, etc.

3. Analysis of existing assembly system in the case organization

Presently, the case organization produces six varieties of engine and it uses traditional assembly, in which the components and subassemblies for the assembly are kept along the conveyor line. It suffers from many disadvantages such as requiring more space, high work in process inventory, more operator walking time, more searching time and more walking distance. Also it reduces flexibility, less shop floor control and availability of small components, and hence it is not suitable for multi product single conveyor production system. An alternative replacement is to use lean kitting assembly where the components for assembly are supplied with kits of components.

3.1 Proposed Methodology: Lean Kitting Assembly

3.1.1. Lean Manufacturing

International motor vehicle programme defines lean manufacturing as a concept which leads to consume less of everything. Lean (Panizzolo, 1998; Azim, 1999; Barker, 1999; Bicheno, 2001; Grajo, 1996) is a set of tools for achieving the following goals like reduced cycle and non value adding time, reduced inventory levels, increased productivity and output and reducing defects and wastages. Lean is predicted to maximize the value added to each of the company's activities by eliminating unnecessary resources. These unnecessary resources are also known as wastes or muda. Lean enterprises research centre (LERC) divides the manufacturing companies' activities into three divisions:

i. Value-added activity – 5%
ii. Non-value added activity – 60%
iii. Necessary non-value added activity – 35%

All manufacturers mainly aim to reduce the 60% non value added activities in their plant, which are in the form of wastes. In a manufacturing system, the practice of delivering components and sub-assemblies to the shop floor in predetermined quantities and placing them together in specific containers is known as Kitting. Kitting represents the assembly with the supplement of kits of components. The parts are sorted according to the assembly objectives.

- The flow model for a Lean kitting assembly is shown in Fig.1.

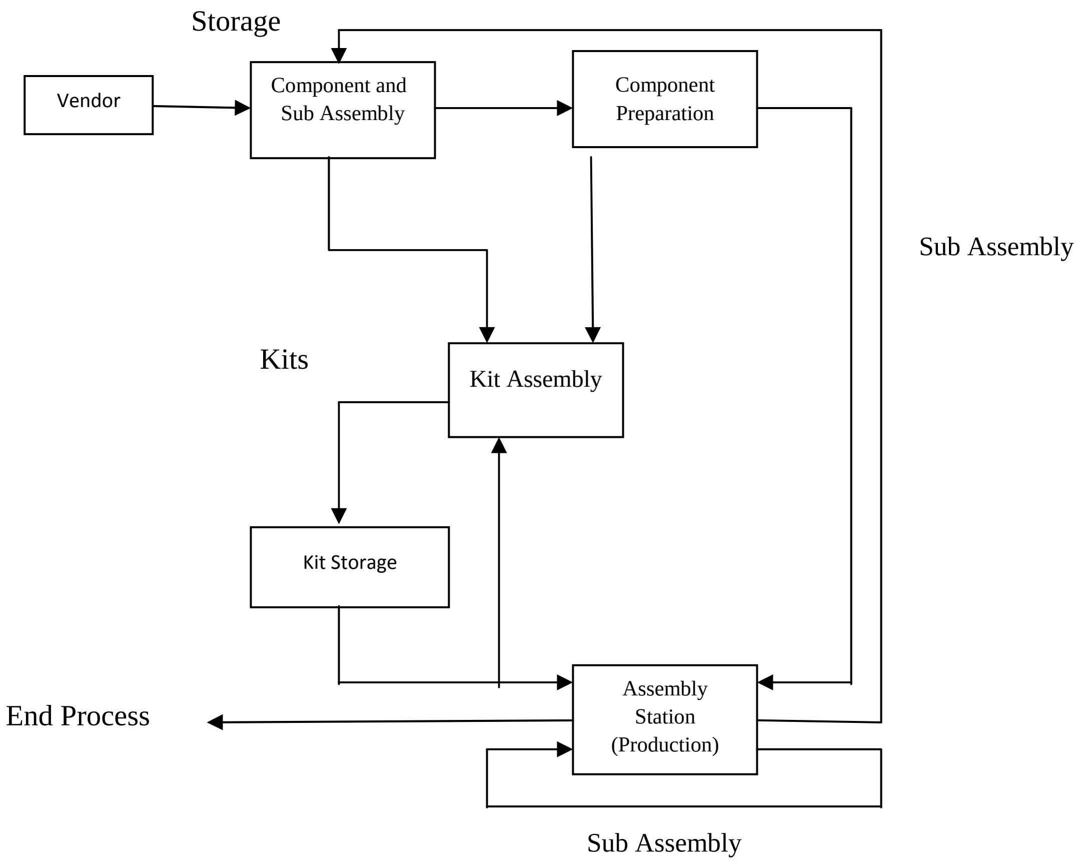

Fig. 1. Flow of kits in lean kitting assembly

The Fig.1 shows the flow of kits in a lean kitting assembly environment. The components from vendor enters store and then taken to component preparation area. After preparation, they are taken to kit assembly where the kits are getting prepared. After preparing the kits, they are sent to kit storage and then they are delivered to the assembly line. Sometimes, the kits may be directly sent to assembly station after kit assembly. From the assembly station, either the assembly is delivered to the customer or it may be again given as input for the assembly station.

3.2 Justifying the selection of an assembly system

There are different methods for assembly systems. But the selection of an optimal assembly method requires detailed analysis from multiple perspectives to justify the selected system. The use of MADM model for selection of assembly method supports the decision making process. In this paper, MADM model is used in which the selection is based on different important factors affecting the assembly processes. The important factors are as follows: Operator distance travelled, floor space required, work in process inventory and operator walking time. Here, AHP is carried out among lean-kitting, traditional and JIT assembly to find optimal assembly method.

3.3 Analytical Hierarch Process

AHP is one of MCDM methods originally developed by Saaty (1999, 2008). The basic framework of AHP is based on the innate human ability to make sound judgment for small problems. Also, AHP is a structured technique for helping people deal with complex decisions. Instead of prescribing a correct decision, the AHP helps us determine the priorities. Based on mathematics and human psychology, it was developed and it was extensively studied and refined since the introduction time. The general purpose of multi attribute decision making (MADM) model like AHP is to help as an aid for thinking and decision making, but not to take decision. It is used in different branches of sciences such as chemistry, business, industry, healthcare, finance, etc as decision making approach. In this paper, the AHP is applied by considering various important factors like operator distance travelled, floor space required, work in process inventory and operator walking time. The inputs for AHP are obtained from senior people in the case organization with good experience of more than three decades in the fields like production, assembly, materials, marketing and quality control. After obtaining data, the AHP is applied. By using AHP, the decision making will become easy and the decision makers will gain confidence for the selection of suitable assembly method for their company.

3.4 AHP algorithm

The step by step procedure to carryout AHP is given below:

Step 1: Setting up hierarchy

To begin with, the problem must be structured into a hierarchy. The first level denotes the overall goal of the decision-maker. The second level consists of several different factors that contribute to this goal.

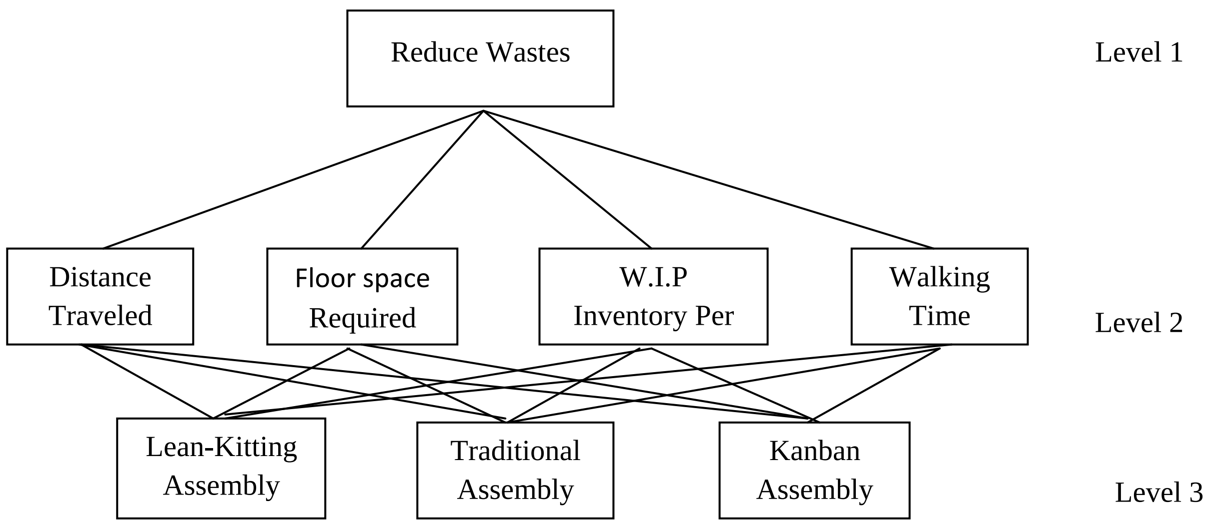

Fig. 2. Hierarchical structure of AHP model

Step 2: Pair wise comparison of characteristics

In this step the factors from the second level of the hierarchy are compared with each other in order to determine the relative importance of each factor in the accomplishing the overall goal. The easiest and visually most structured way of doing this is to prepare a matrix with the factors.

Step 3: Establish priority vector

In this step the decision-maker uses the numbers from the matrix to get an overall priority value for each factor.

Step 4: Comparison of alternatives

Now the decision-maker moves from level 2 to level 3 of the hierarchy and does a pair wise comparison of the three alternatives.

Step 5: Calculate priority vector for alternatives (for various factors considered)

This follows the same procedure as in Steps 3, 4, and 5.

Step 6: Obtain the overall priority vector

The last step in AHP is to obtain the overall ranking of the three alternatives by mathematically combining the three priority matrices. Table 1 is the summary of AHP computations on four attributes given in level 2 which are distance travelled, floor space required, operator walking time and WIP inventory. As we can observe, floor space is the most important item, WIP is the second important item, distance travelled comes in the thirst level of importance and waling time comes last. The consistency ratio is less than 10 percent which there is enough evidence to accept the results.

Table 1
AHP scores for four different attributes

Attributes	Distance Travelled	Floor space	WIP /day	Walking Time
AHP Score (CI=9.09%)	19.67%	52.42%	21.67%	6.23%

The next step is to define the relative preference for three alternative choices and finally combine them based on the weights obtained from Table 1. From Table 2, it is observed that the overall priority vector for lean kitting with almost 60% is higher than other two other assembly systems. Therefore, lean kitting can be recommended as a suitable alternative among traditional and JIT assembly for the timing gear CAM sub assembly.

Table 2
Timing gear CAM sub assembly overall priority vector

	Distance travelled	Floor space required	WIP/day	Operator walking time	Priority Vector	Overall Priority Vector
Lean Kitting assembly	65.55%	54.55%	64.34%	72.35%	0.1967	59.9%
Traditional assembly	26.48%	37.00%	7.38%	8.33%	0.5242	26.9%
JIT assembly	7.96%	8.45%	28.28%	19.32%	0.2167	13.2%
CI Score	4.21%	9.77%	8.34%	9.61%	0.0623	100%

4. Conclusions

We study an Indian assembly case study where it uses traditional method to assemble parts. However, the management team of this company plan to reduce the wastages like excess work in process inventory, operator walking distance, floor space required and idle time like operator walking time associated in their production and assembly processes. A study performed to determine the number of alternative replacements for traditional assembly and, using the art of AHP, they are ranked using AHP method. The results of this survey indicate that lean kitting is mostly recommended by the experts and it could be suitable replacement for traditional one.

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References

Azim, A. (1999). Using simulation to design a lean material delivery system in an automotive body shop. *SAE Technical paper series*, 1999-01-1643, 1-5.

Barker, R. C. (1999). Production systems without MRP: A lean time based design. *International Journal of Management Science*, 22(4), 349-360.

Bicheno J., Holweg M. & Niessmann J. (2001). Constraint batch sizing in a lean environment. *International Journal of Production Economics*, 73, 41-49.

Ben Naylor, Nair, M. & Berry, D. (1999). Integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics*, 62, 107-118.

Brynzor, H., & Johansson, M. I. (1995). Design and performance of kitting and order picking system. *International Journal of Production Economics*, 4, 115- 125.

Chrisrmansson, M. & Medbo, L. (2002). A case study of principally new way of materials kitting an evaluation of time consumption and physical work load. *International Journal of Industrial Ergonomics,30*, 49-65.

Frank, C. & Garcia, (2000). Using value stream mapping as a strategic planning and implementation tool. *European Management Journal*, 16, 327-224.

Grajo, S. (1996). Strategic layout planning and simulation for lean manufacturing - A layout tutorial. *Proceedings of the 1996 Winter Simulation Conference*, 561-568.

Gunther, H.O., Gronalt, M. & Piller, F. (1996). Compact kitting in semi-automated printed circuit board assembly. *International Journal of Production Economics*, 43, 213-226.

Karthik, V.N. (2006). An integrated supplier selection methodology for designing robust supply chains. *IEEE International conference on Management of Innovation and Technology*, 906-910.

Tamaki, K., & Nof, Y. (1991). Design method of robot kitting system for flexible assembly. *Robotics and Autonomous Systems*, 8, 255 – 273.

Kull J. & Talluri S. (2008). A supply risk reduction model using integrated multi criteria decision making. *IEEE Transactions on Engineering Management*, 2008, 55(3), 409-419.

Luis, M., Sanche, Z. & Nagi, R., (2001). A review of agile manufacturing system. *International Journal of production Research*, 39(16),3651-3600.

Houshmand, M. & Jamshidnezhad, B. (2006). An Extended Model of design process of lean production systems by means of process variables. *Robotics and computer Integrated Manufacturing*, 22, 1-16.

Medbo, L. (2003). Assembly work execution and materials kit functionality in parallel flow assembly systems. *International Journal of Industrial Ergonomics*, 31, 263 - 281.

Oliver, N., Delbridge, R. & Barton, H. (2002). Lean production and manufacturing performance improvement in Japan, The UK and US. *ESRC Business Research*, University of Cambridge.

Panizzolo. R. (1998) Applying the lessons learned from 27 lean manufacturers, the relevance of relationship management. *International Journal of Production Economics*, 55, 223-240.

Rao Tummala, V.M., Chin, K.S. & Ho, S.H. (1997). Assessing success factors for implementing CE: A case study in Hong Kong electronics industry by AHP. *International Journal of Production Economics*, 49, 265-283.

Saaty, L. (1999). Fundamentals of the Analytic Network process. *ISAHP*, 1-14.

Saaty, L. (2008). Decision making with the analytic hierarchy process. *International Journal of Services Sciences*, 1(1), 83-98.

Salomon A. P., Marins A. S. & Duduch A. (2007). Multiple decision making applied to the supplier selection for assembly line equipments in an automotive Industry. *ISAHP*, 1-5.

Sullivan, G., McDonald, N. & Aken, E. V., (2007). Equipment replacement decisions and lean manufacturing. *Robotics and Computer Integrated Manufacturing*, 18, 255-265.