Conference Paper

Development of a FAHP Algorithm Based Performance Measurement System for Lean Manufacturing Company

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Abstract

For companies that implement Lean Manufacturing, it is essential to measure the extent of success in terms of the achievements of optimum performances. This paper describes the development of a Fuzzy Analytical Hierarchy Process (FAHP) algorithm based Performance Measurement System (PMS) application software for lean companies. The PMS software, which was developed using the C++ language, was designed as a decision making system to aid lean manufacturing companies. The software allows decision making analysis based FAHP facilitating data input, pairwise comparisons, weight calculation and lean company scores. A case study of a lean manufacturing is presented to illustrate the theoretical and practical aspects of the PMS software. The case study demonstrated the software tool can assent to a lean company to implement PMS in a much easier manner yielding more accurate and consistent results that include a list of recommended actions to address issues identified. Therefore, it can improve the company performance.

Keywords: Fuzzy AHP based Algorithm, Lean Manufacturing, Performance Measurement

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1. Introduction

Developing a Performance Measurement System (PMS) which fosters continuous improvement and is based on a company's strategy and characteristics of its processes can be challenging due to, amongst other factors, the diversity of criteria, activities and companies' strategic preferences. The traditional approaches to PMS, which is based purely on financial measures, may not be adequate to measure the performance of lean companies due to the relatively wide range of financial and non-financial characteristics and specific lean related tools and techniques which they employ in their activities.

Ohno [1] from Toyota Production System (TPS) defined lean manufacturing as activities that involve value-added work, continuously removing waste and non-value added work. The characteristics of lean manufacturing were identified by Shah and Ward [2] as continuous improvement, waste elimination, quality improvement, low inventories, short cycle times, process control, supplier development, pull system, continuous flow, quick changeover, preventive maintenance, statistical process control, employee and customer involvement. Womack *et al* [3]; Ferdousi & Ahmed [4] identified lean characteristics such as value stream mapping, just-in-time production, 5S, error proofing, work standardized, kanban and automation.

By clearly identifying the lean characteristics, it is then possible to design a PMS that effectively measures performances in companies that implement lean systems. The extent to which a company implements lean systems and the success factors depend on a set of consistent lean characteristics that are linked with the PMS. Therefore, a clear definition of lean characteristics is an important pre-requisite in the measurement and monitoring of a company's performance with respect to lean manufacturing activities.

This paper makes use of accepted lean manufacturing characteristics as the basis for the development of a PMS. In terms of its underpinning theory, the widely accepted Fuzzy Analytical Hierarchy Process (FAHP) is adopted so as to handle the inherent vagueness and Multiple Criteria Decision Making (MCDM) nature of lean performance measurement. The FAHP method, which is a result of combining AHP (Analytical Hierarchy Process) with the fuzzy concept, has been applied to many areas since being introduced by Laarhoven & Pedrycz [5] followed by several other authors [6-10]. Noci & Toletti [6] applied FAHP to identify quality based priorities. The FAHP was also applied in the selection of suppliers based on the most satisfaction criteria for the decision maker [7]. Kabir & Hasin [8] stated that the FAHP was more balance scale of judgment and it was not containing subjective judgment in terms of selection and preference of decision-makers. Regarding Lee *et al*. [9], the FAHP can obtain the relative importance in real practice where an uncertain pairwise comparison environment exists. Furthermore, according Tan *et al.* [10], it can be used to account for variations in degrees of confidence, such as nuances/traces.

In terms of the AHP method, algorithm program applications are available, such as the "Expert Choice" to solve the AHP implementation problems (Expert Choice, 2012) [11]. However, to the author's knowledge, the FAHP commercial algorithm program is not available. Therefore, this paper developed the algorithm program for lean manufacturing PMS. The PMS is implemented as a software tool developed using the C++ language so that practitioners can apply this PMS without having to perform the tedious and complicated computations associated with FAHP.

2. Methodology

The PMS for lean company can be developed based on the characteristics of lean such as discussed in Introduction. This paper employed a set of lean company characteristics based on lean manufacturing performance in Susilawati *et al* [12] and [13]. The PMS for lean manufacturing companies is based on a MCDM method, the FAHP. The FAHP method is a systematic approach using the concepts of fuzzy set theory and hierarchical structure analysis, which makes it more effective than conventional Analytical Hierarchy Process (AHP) in real implementation when choice, ranking and decision problems are encountered. An algorithm in the form of a FAHP program is developed using the C++ language. The flowchart of the design steps of algorithm PMS using FAHP is shown in Fig. 1. The steps for FAHP used in this paper: establish a decision group, members of the decision groups make a judgment on the importance of the lean manufacturing activities, aggregate judgments of the decision maker, check consistence, and calculate the weight.

The members of the decision group make a judgment of relative preference and importance of one lean practice parameter over another with a pairwise comparison. Due to the vagueness of the judgment, the score awarded to the pairwise lean practice does not exactly represent the real condition. The crisp score awarded by a member of the decision group is then transformed into a fuzzy number, in order to capture the vagueness. Because the decision maker cannot reach 100% confidence in their judgment, this degree of confidence should be captured in the FAHP method. Next, the fuzzy pairwise comparison from several decision makers is combined to form an overall group decision then aggregated. The decision makers can revise and make right the decision-maker/assessor inconsistency when making pairwise comparisons, which are checked by the Consistency Ratio (CR). The CR is a comparison between Consistency Index (CI) and Random Index (RI) [14]. The CR can reflect the decision maker/assessor understanding on his/her own preferences. If the CR is >0.10, the decision-maker should re-evaluate his/her pairwise comparisons [14]. Finally, the weight of lean practices is calculated. By inputting the information and data of current state of lean activities and establishing the base line and target improvement lean activities are then revealed as the final score of lean company. These performance scores will give the managers and decision makers some real insights into the lean company's activities and their company's performance.

3. Tool Evaluation

The lean manufacturing PMS's algorithm program has been applied as a case study for an automotive company in the Indonesian manufacturing industry. The company needed to measure and to improve the company's overall performance by achieving the company's strategic goals, which use six specific perspectives: financial perspectives, supplier issues customer issues, process, people and future (Fig. 2). Fig. 3 presents the pairwise comparisons and degree of confidence for the assessors. The scores of performance of the company are presented in Fig. 4.

Fig. 4 demonstrates the competitive business priority on a company performance and in this instance is defined based on the financial perspectives and customer issues (the computer software has been designed with complete flexibility to allow companies to tailor the performance based on their needs). The current lean score is 0.208 for the financial perspectives and 0.023 for supplier issues. The optimum lean score target, which can be achieved for next year is 0.297 for the financial perspectives and 0.262 for customer issues. The current overall score for the lean activities in the perspectives performance impact with regards to overall performance scores is 0.574.

It can be seen that last year's achievements are used as a baseline score for every lean activity. In this case, due to the lean manufacturing PMS started in this current

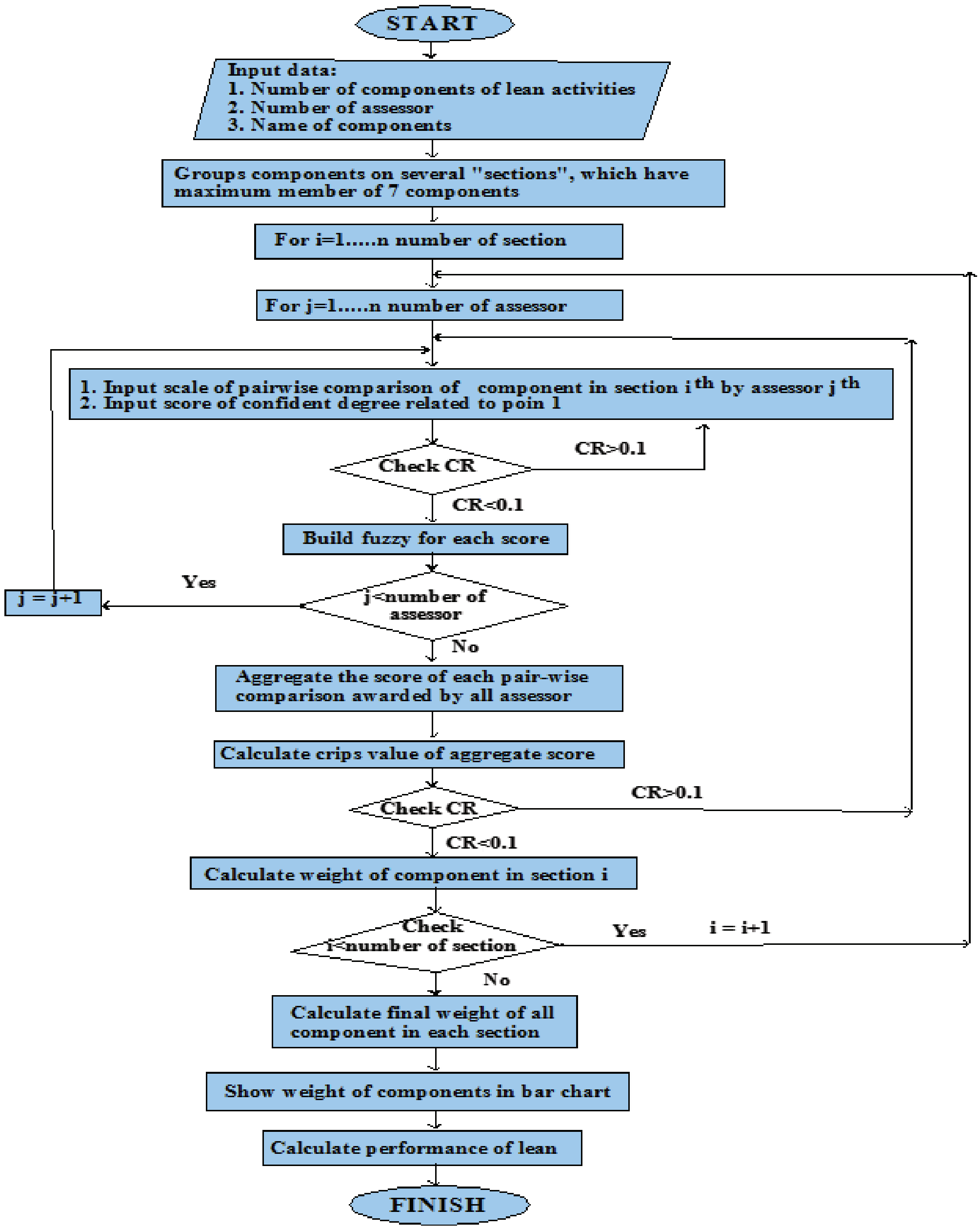

Figure 1: Flowchart to develop the FAHP algorithm program for lean manufacturing PMS.

year, the baselines were set to zero. The target improvement is the change needed to achieve the company's future state. This was obtained from the differences between the current results and the base lines. The current results were collected from the company's data, which is the difference in the current year's state and last year's state. The lean score for the current condition was calculated as a real achievement (current results) divided by target improvement and multiplied by the weight of the lean activities for a given time period. In this case, the period of time is 1 year. Future-state is at 100%, due to the fact that it was established as an optimum, in order to achieve improvement.

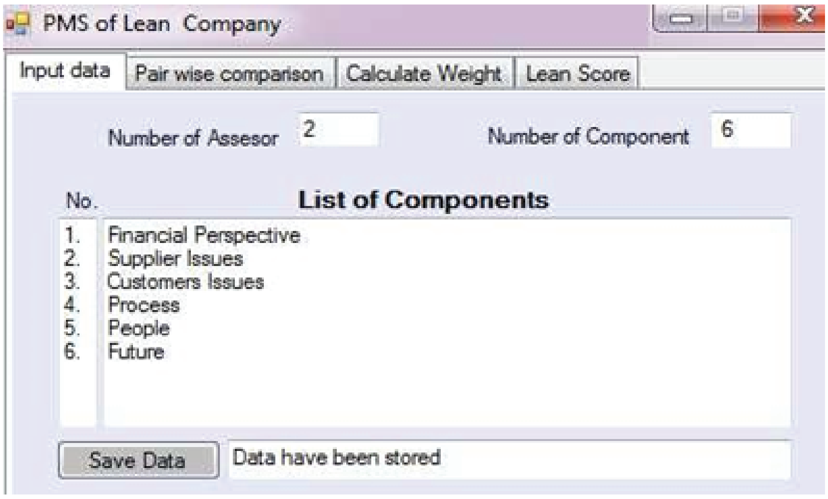

Figure 2: Input data by assessors for components of the lean performance perspectives.

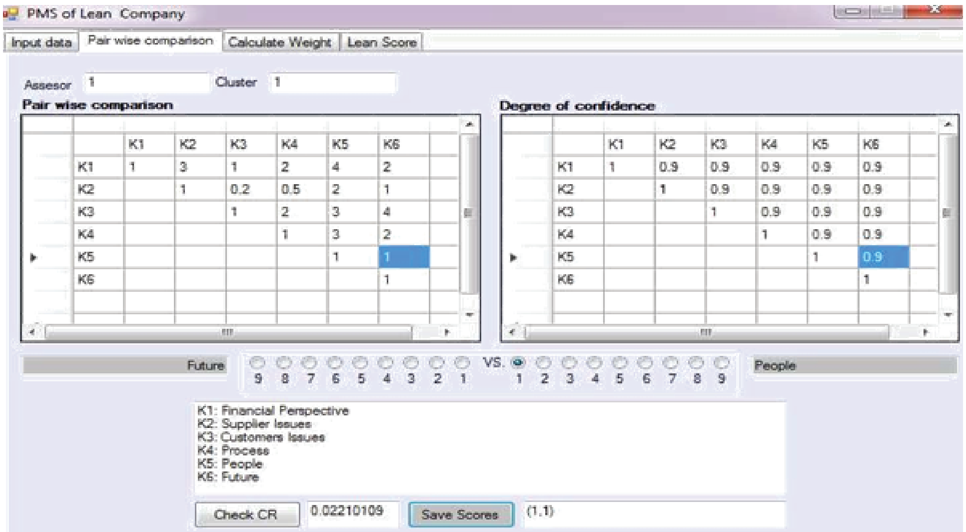

Figure 3: Pairwise comparisons by a member of group decision maker for the lean performance perspectives and its degree of confidence.

4. Summary

This paper describes a PMS model for lean company in the form of computer software tool. The software tool is flexible and practical, allowing practitioners to apply PMS in companies that vary in size and system, within a range of industries and can help a company to measure its progress toward its goals and enable decisions to be made on its strategies and activities for continuous improvement. The case study revealed that the software tool easily implemented and work well with a number of advantages: data obtained from the assessment have better accuracy considering the vagueness and degree of confidence of assessors in the scores that they provided; data analysis can be done more easily and accurately so that the companies could facilitate the process of planning activities of lean manufacturing in the future.

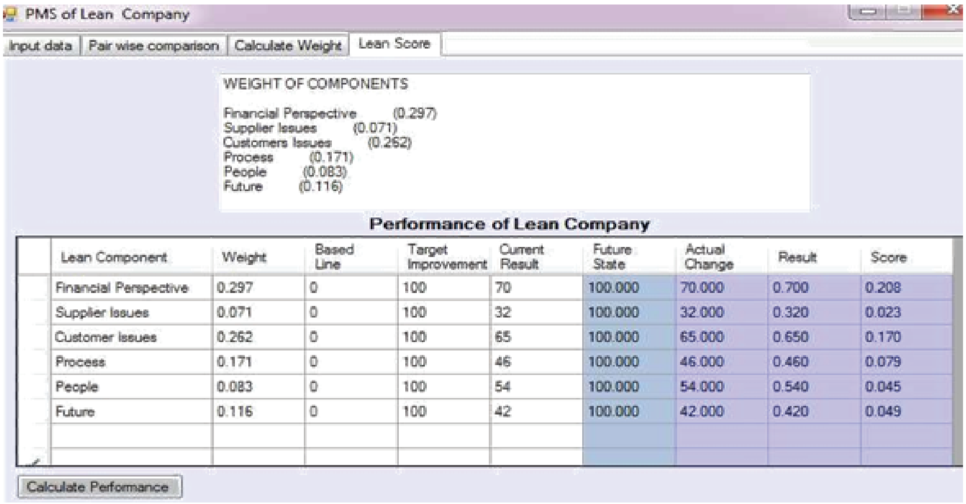

Figure 4: The performance scores of the lean company.

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