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Knowledge Based System Implementation for Lean Process in Low Volume Automotive Manufacturing (LVAM) with Reference to Process Manufacturing

N.M.Z.N. Mohamed and M. K. Khan

Abstract

Global manufacturing industry mostly depends on new product development and processes to become competitive. The product development process for automotive industry is normally complicated, lengthy, expensive, and risky. Hence, a study of lean manufacturing processes for low volume manufacturing in automotive industry is proposed to overcome this issue by eliminating all wastes in the lengthy process. This paper presents a conceptual design approach to the development of a hybrid Knowledge Based (KB) system for lean process in Low Volume Automotive Manufacturing (LVAM). The research concentrates on the low volume processes by using a hybrid KB system, which is a blend of KB system and Gauging Absences of Pre-requisites (GAP). The hybrid KB/GAP system identifies all potential waste elements of low volume process manufacturing. The KB system analyses the difference between the existing and the benchmark standards for lean process for an effective implementation through the GAP analysis technique. The proposed model explores three major lean process components, namely Employee Involvement, Waste Elimination, and Kaizen (continuous improvement). These three components provide valuable information in order for decision makers to design and implement an optimised low volume manufacturing process, but which can be applied in all process manufacturing, including chemical processing.

KEYWORDS: low volume automotive manufacturing (LVAM), knowledge based system, gauging absences of pre-requisites (GAP), lean process optimisation

1 Introduction

Most manufacturing involve sequential processes from the design stage until the product launch (Gao et al., 2000). Taskforces from multi-functional discipline teams comprising of management staff, marketeers, designers, engineers and supporting staff ensure the smooth implementation of manufacturing processes to tight deadline. According to Nobelius (2004), the manufacturing processes involve stages of design concepts, product development, process validation and production which are obviously complicated, lengthy, expensive, and risky.

One method deployed to increase the effectiveness of the manufacturing process is by implementing elements of lean manufacturing process. The oil crisis in North America in 1973 generated great concern for Japanese manufacturing, especially Toyota Motor Company which pioneered the lean manufacturing process (Shah and Ward, 2007). Lean manufacturing process optimisation is a thorough assessment of each activity of a company with the aim of reducing wastes at all levels. Through the lean manufacturing process, the efficiency and effectiveness of each operation is studied including machines, equipment, layouts and personnel. Lean manufacturing analyses the non-value adding activities (value chain) comprehensively in order to eliminate waste.

According to Melton (2005), waste is defined as any activity in a process which does not add value to it and, is usually about 60% to 70% for most manufacturing process operations. The priority to eliminate waste in manufacturing environment represents a huge benefit in terms of manufacturing improvements. The main goals of lean manufacturing process are speed of delivery, flexibility and quality, which can be achieved through dynamic partnerships, rich information sharing and the coordination of physical flows without rigid investments, in order to allow rapid reconfiguration (Cagliano et al., 2004). However, the key factor in achieving all the above elements of lean manufacturing is the human one.

2 Research background

The automotive sector is one of the most important economic catalysts in every country (Orsato and Wells, 2007). It creates direct and indirect industry covering almost all products of steel, rubber, plastics and electronics. A typical automotive project would require direct and indirect human resources from many functional organizations and facilities such as workers, suppliers, consultants and partners spread across the country and throughout the world. According to Hallgren and Olhager (2009), increased competition, global markets, and more challenging customers are all contributing factors that should be the main focus of today's business environment.

Low Volume Automotive Manufacturing (LVAM) is one of the strategies required to sustain the market choices for this sector. Niche vehicle model such as luxury, sports and special purpose vehicles are an example of LVAM that require high customisation (Meichsner, 2009). According to Laudanski (2008), low volume manufacturing process performs manufacturing based on order from clients.

To achieve this strategy, the concept of lean process related to employee involvement, waste elimination and *Kaizen* (continuous improvement) is studied in the LVAM environment. It is necessary to have a systematic tool for generic design, such as Knowledge Based Systems, in order to achieve the manufacturing process optimisation and the high standards of manufacturing quality.

2.1 Expert Systems (ES) / Knowledge Based System (KBS)

Intelligence is the ability to learn, understand, solve problems and to make decisions (Negnevitsky, 2002). In reaching this level, the human thought process has started from data, information and knowledge. Data is unprocessed facts and when assembled together will become information. The interpretation of this information will become knowledge and adding experience to it will make the process intelligent.

According to Udin (2004), Artificial Intelligence (AI) is a field of knowledge in computer application development that imitates the human behavior in completing tasks. According to Cui et al. (2008), AI has emerged as a computer science discipline and has produced a number of powerful tools, many of which are of practical use in engineering to solve difficult problems normally associated with human intelligence.

Teti and Kumara (1997) categorised AI into its functions, techniques and manufacturing sector as shown in Table 1. It is clearly shown that the applications of AI are widely used for various usages in manufacturing environment. Among popular AI techniques are Genetic Algorithms (GA), Artificial Neural Networks (ANN), Fuzzy Logic (FL), Simulated Annealing (SA), Case Based Reasoning (CBR), Frame Based System (FBS) and Expert System (ES)/ Knowledge Based Systems (KBS).

Knowledge Based System (KBS) is usually defined as computer programs that help solve problems which would normally be done by a human expert. This Expert System commonly consists of knowledge core, knowledge exploration and ability to show results. The acquired knowledge of the KBS is the input from various sources such as human experts, research papers, and books (Benavides and Prado, 2002).

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Table 1. AI Functions and Techniques in Manufacturing (Teti and Kumara, 1997)

Artificial Intelligence in Manufacturing		
AI functions	***AI techniques***	***Manufacturing Sector***
Learning Knowledge Reasoning Goal-seeking Pattern recognition Decision Making Advice Communication Control Self-improvement Self-maintenance Self-organisation	Genetic algorithms Neural networks Fuzzy logic Neuro-Fuzzy Simulated Annealing Expert Systems Knowledge Based Systems Hybrid systems Multi Agents	Design Planning Production Scheduling Systems Assembly Monitoring Chemical Process Control Chemical Process Systems Inspection Maintenance

The application of KBS provides the opportunity to interact with users, assist in the decision making process and can also be used as a learning device for all members in the manufacturing organisation (Khan and Wibisono, 2008). The final goal of the KBS is to have all the best experts' experience into a single knowledge base (Chapman and Pinfold, 2001). As the KBS applications are widely used in decision making, design and implementation processes which are suitable for LVAM; therefore this method has been selected for this work. In achieving this goal, commitments from all related parties are required during the development stage so that the KB system represents the actual knowledge requirements in solving problems for lean process optimisation.

3 A Knowledge Based framework for LVAM development

This paper focuses on solving the lean process optimisation problem by proposing a generic framework for Knowledge Based Low Volume Automotive Manufacturing (KBLVAM). The implementations of KBS in manufacturing management has been a field of research since the 1980s, along with the introduction of the intelligent manufacturing system concepts (Nawawi, 2009). The need for a new approach in LVAM will offer a detailed response to manufacturer's desire to tackle the issues of lean process, especially when related to employee involvement, waste elimination and *Kaizen* (continuous improvement).

Since presently there is no solid framework for developing the KBS with special attention to lean processes in LVAM, the development of KBLVAM has been undertaken to overcome this limitation. The standard elements from the various reviews of lean manufacturing process being practiced by the global automotive industry will be the basis for the development of the KBLVAM model. The gathered data, information, and knowledge from literature and human experts on employee involvement, waste elimination and *Kaizen* will be "translated" into a KB, through a proposed conceptual model developed to represent the operational components of an actual automotive manufacturer environment. The developed KBLVAM has been integrated with Gauging Absences of Pre-requisites (GAP) analysis technique, which analyses the difference between the actual condition and the ideal case (benchmarking) before the final decision is made.

3.1 Gauging Absences of Pre-requisites (GAP) analysis technique

Nawawi (2009) described GAP analysis as a method to assess the gap between the manufacturer's necessary pre-requisites for effective (benchmark) implementation compared to its status quo, and which should be done in a structured and hierarchical format. There are three main objectives of GAP analysis in developing the KBLVAM lean process optimisation for this research. The first objective is to identify the main requirement for the effective lean process implementation of LVAM in automotive industry. The second objective is to compare the current lean process status with the benchmark standards by means of providing a quantitative basis for analysis. The final objective is to identify the strengths and weaknesses of current lean process practices in LVAM environment by aligning to the new LVAM proposed model.

The GAP analysis in the research is prepared through the knowledge responses from the users to the KBLVAM System's designed rule-based questions. The responses from the users prompt the System on the possible problems faced by the users. The problems are then sorted as negative replies. Each negative reply captured in the System is classified into nine categories, which are classified in descending order of importance. The Problem Category (PC) is ranked from 1 to 9, with the code PC-1 being the worst state and PC-9 being the least critical state (see Appendix). Based on the GAP process optimisation methodology, only the Bad Points are categorised into Problem Categories in order to identify the necessary pre-requisites that are required to achieve the LVAM accomplishment.

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3.2 LVAM manufacturer capability – *Lean Process Optimisation* perspective

Lean Process Optimisation Perspective in the KBLVAM System structure consists of three modules, which are *Employee Involvement*, *Waste Elimination* and *Kaizen as* shown in Figure 1.

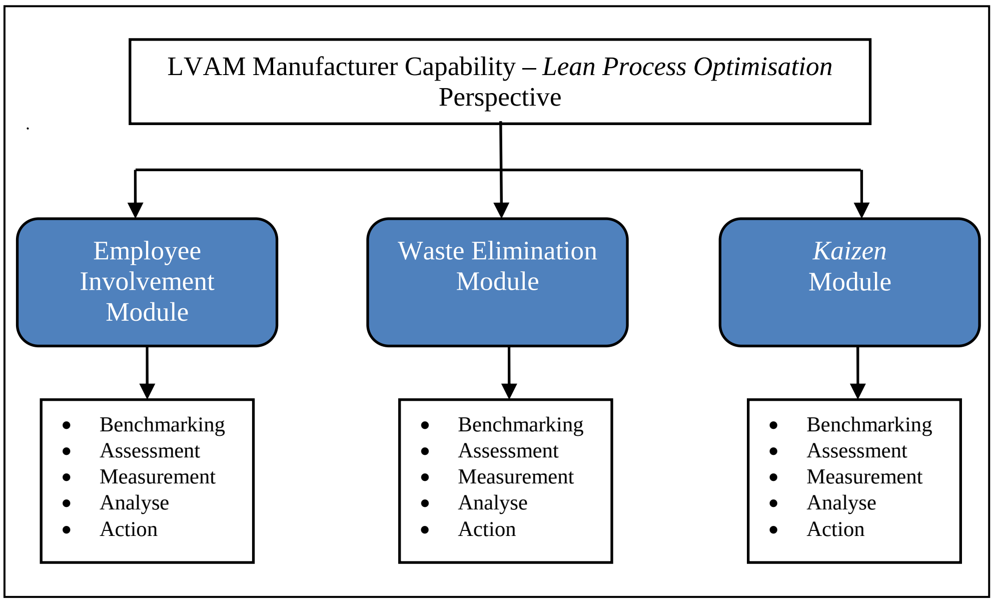

Figure 1. LVAM Manufacturer Capability – *Lean Process Optimisation* Perspective

The implementation levels of these lean processes are identified in how the LVAM manufacturer benchmarks, assesses, measures, analyses and plans an action to these three optimisation processes as shown in Table 2. The evaluation process includes the levels of team building, training and re-training, target setting, and specific areas for lean process optimisation. This KBLVAM System provides series of KB questions that are particularly related to lean processes for low volume automotive manufacturer.

In order to maximise use of the System, the user needs to give the relevant manufacturer's information related to the KB questions. If the user is not sure about some of the questions and needs clarification, the KBLVAM System will provide the explanation to the specific problems. The Explanation command, which is part of the KBLVAM System, offers guidance to the user in order to understand the questions and clarify the problems that may arise. This Explanation facility contains additional KB to overcome any fuzziness in the understanding of the KB questions and hence assists the user to reply accurately and effectively. This will then assist the KBLVAM in arriving at a realistic solution. The KBLVAM System will then analyse the answers from the user through a chain of knowledge rules.

Table 2. Sub-Modules Evaluation Elements

	Employee Involvement (EI) Module	Waste Elimination (WE) Module	*Kaizen* Module
Benchmark	- Vision of the company towards EI implementation - Benchmarking of EI with established companies - 3Cs implementation - Team building - Training and re-training - Target setting	- Vision of the company towards WE focus - Benchmarking of WE with established companies - Team involvement towards WE implementation - Training and awareness towards the importance of WE practice	- Vision of the company towards *Kaizen* realisation - Benchmarking of *Kaizen* practice with successful companies - *Kaizen* team formation - *Kaizen* training - Rewards for successful *Kaizen's* proposal
Assessment	Assessment of aspects such as employee empowerment, job enrichment, job rotation, specialisation, and job enlargement	Assessment of aspects such as 5S *(Sort, Set in order, Shine, Standardise, Sustain)*	Assessment of aspects such as Total Productive Maintenance (TPM), set-up time reduction, process scheduling, and tool maintenance,
Measurement	- Methods of EI measurement - Records of EI measurement data - EI feedback form/suggestions	- Record of WE data based on target areas. - Types of waste, number and percentage of defects. - Types of trainings provided	- Record of *Kaizen* proposals - Types of *Kaizen*, number and percentage of successful *Kaizen* recorded
Analyse	Analysis of target achievement/failure for EI setting.	Analysis of WE programme against the vision/target/company's benefit.	Analyse of target achievement/failure for *Kaizen*'s proposals
Action	-Reset target/focus -Re-training -Motivation -Rewards	-WE awareness campaign -Team improvement -Layout improvement -Process improvement	-Improve *Kaizen*'s proposal process/procedures. -Improve rewarding system

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In *Lean Process Optimisation* Perspective, although the modules are parallel activities (see Figure 1), the KBLVAM System is designed to start the questions in sequential flow from *Employee Involvement*, *Waste Elimination* and *Kaizen* modules. Each of the three modules of the KBLVAM System is described in the following sections.

3.2.1 *Employee Involvement* module

The main purpose of developing the *Employee Involvement* module is to assess the existing status of manufacturer's commitment to designing and implementing LVAM through its involvement of human resources. *Employee Involvement* element is recognised as a key essential in most manufacturing proposals like LVAM, TQM and Six-Sigma (Tarí and Sabater, 2004). Every employee is expected to have a high degree of personal responsibility and possession of the job.

Most manufacturers are very aware of costs they incur, such as wages and rent, however many are unaware of the hidden costs associated with under-performing staff. Manufacturer's effort to improve the management system through *Employee Involvement* module ensures that the system is developed, implemented and continuously improved. In achieving this level, manufacturers need to have vision, teamwork, training programmes, and a rewarding system. According to Nawawi (2009), the overall activities under *Employee Involvement* are stimulated and motivated through the 3Cs (Culture, Communication, and Commitment).

Culture plays a vital role in determining whether manufacturers are successful or not with their *Employee Involvement* methods. The developed and implemented culture within the company should include high values and ethics to support the creation of *Employee Involvement* module (Liker and Hoseus, 2008). The developed culture focuses on creativity, innovation, and learning programmes which are implemented through actions and behaviours.

Good communications in the manufacturing environment play an enormous role to the manufacturer's success. Communications among the management and workers should be stimulated and encouraged. The vision, values, mission, policies and strategies are clearly communicated and accessible to every level of staff. This is to avoid communications breakdown among the staff, especially during changes, which will result in productivity lost.

The emphasis on commitment is also important to ensure the implementation of *Employee Involvement* module. The commitment is required from everyone in the company including the senior management. High levels of commitment in any manufacturing organisations require people to be involved and will be of value to manufacturers.

Benefits can include increased job satisfaction for employees and increased commitment to the manufacturer and significant improvement in productivity (Herron and Hicks, 2008). It also results in a cost saving to the company, due to the reduced number of management levels in the company. The process flow of *Employee Involvement* module is shown in Figure 2.

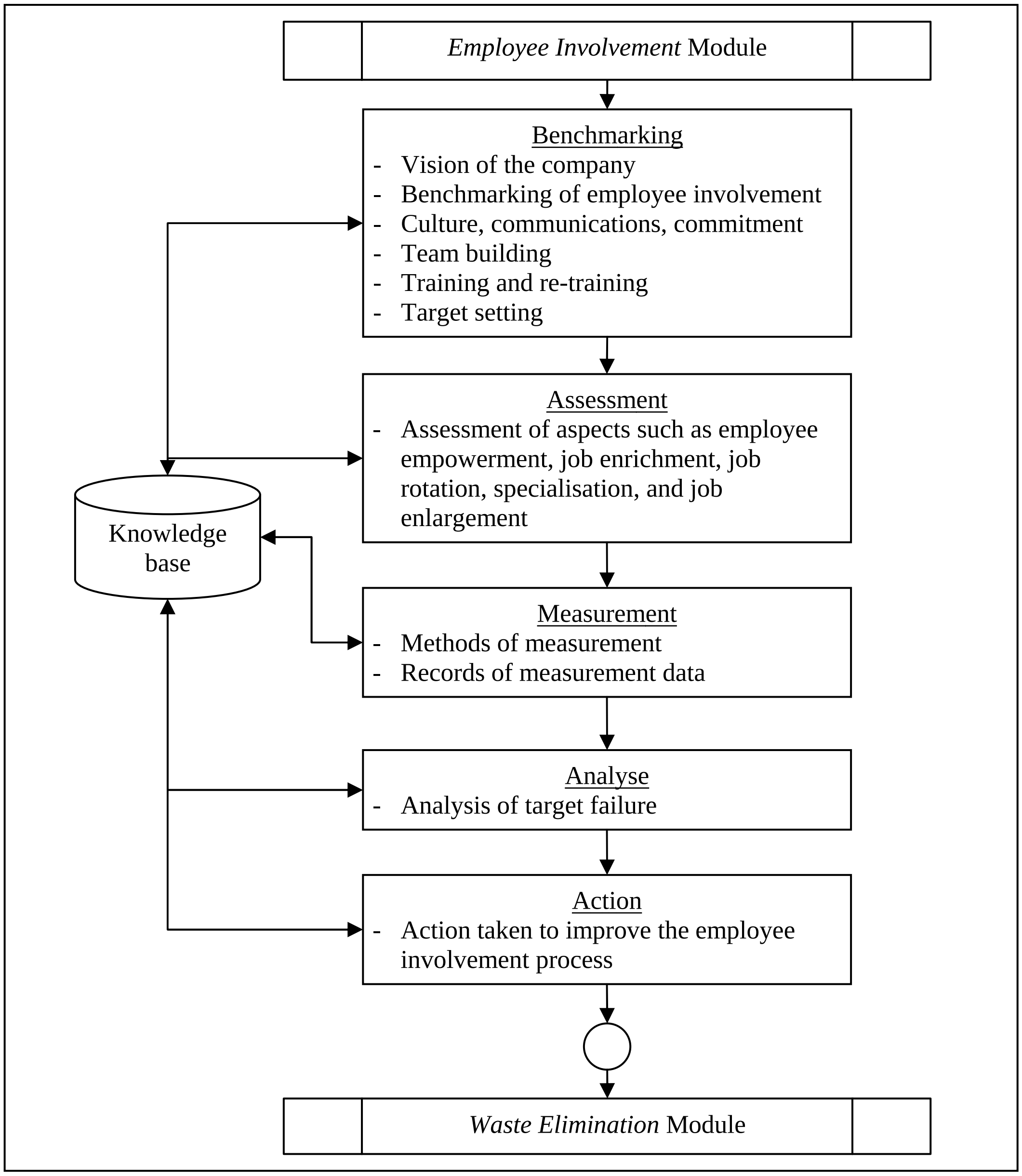

Figure 2. Flowchart of *Employee Involvement* Module

Given below are brief examples of KB rules that relate to *Employee Involvement* module:

IF *the LVAM manufacturer has identified the vision and benchmark for the employee involvement* (**Yes**: GP; **No**: BP, **PC-3**)
AND *the LVAM manufacturer has identified the culture for the employee involvement (**Yes**: GP; **No**: BP, **PC-1**)*
AND *the LVAM manufacturer has identified the communications route for the employee involvement (**Yes**: GP; **No**: BP, **PC-1**)*
AND *the LVAM manufacturer has identified the commitment elements for the employee involvement (**Yes**: GP; **No**: BP, **PC-1**)*
AND *the LVAM manufacturer stresses teamwork parallel to employee involvement* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the LVAM manufacturer employs job specialisation in the manufacturing processes* (**Yes**: GP; **No**: BP, **PC-7**)
AND *the LVAM manufacturer employs job enlargement in the manufacturing processes* (**Yes**: GP; **No**: BP, **PC-5**)
AND *the LVAM manufacturer employs job enrichment in the manufacturing processes* (**Yes**: GP; **No**: BP, **PC-3**)
AND *the LVAM manufacturer employs job rotation in the manufacturing processes* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the LVAM manufacturer employs employee empowerment in the manufacturing processes* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the LVAM manufacturer has a system to measure the employee involvement* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the LVAM manufacturer has the records of employee involvement* (**Yes**: GP; **No**: BP, **PC-1**)
THEN *the LVAM manufacturer element of employee involvement is good and competent to achieve LVAM manufacturer capability*
OR *the LVAM manufacturer needs to reconsider its employee involvement process to achieve LVAM manufacturer capability*

In this module, the questions start with an assessment to identify the existence of employee involvement programmes in the manufacturer. The first level of questions involves the benchmarking elements to gauge the difference between the existing and the standard practices. Among the important elements in benchmarking sub-module are vision, culture, communications, commitment and teamwork. Benchmarking sub-module is very important as failure to have these elements in place will result in PC-1. The System then evaluates the performance of employee involvement aspects such as job specialisation, job enlargement, job enrichment, job rotation, and employee empowerment. The lack of job specialisation and job enlargement are not considered as serious problems, since the focus should be put more on job rotation and employee empowerment to achieve LVAM.

The measurement methods and records for the process of employee involvement show the evidence that the manufacturer knows and understands the importance of these elements. However, if there is no measurement method and record being practised, this means that the manufacturer has no clear idea of how to align the employee involvement process in achieving lean process optimisation. Thus, it is deemed as a serious problem of PC-1. All the elements in this module need to be analysed and require actions to be taken to improve the employee involvement process.

Although the KBLVAM System is designed particularly for LVAM environment, the *Employee Involvement* module is also applicable for other manufacturing sectors such as chemical manufacturing. In chemical process and chemical control, the elements of 3Cs are very important especially when it involves the human factor. The human factor is critical to the success of all organisations. This is more the case for chemical process manufacturing where cost and safety aspects are crucial, and primarily based on decisions made by humans.

Good communications are also important in chemical manufacturing, as communications breakdown could result in major failures and impacting costs, safety and environment. Therefore, the policies, procedures, and strategies must be clearly communicated to all levels of staff. Finally the element of commitment towards the assigned jobs is also required by all levels in the chemical manufacturing process industry. By having a comprehensive employee involvement programme in the chemical plant, it will help to improve the efficiency of the process as well as to avoid problems cited earlier.

Therefore the KBLVAM System is not only applicable for LVAM environment but also can be adapted and used in the chemical manufacturing and other manufacturing sectors in order to assess the level of human aspect's implementation in the overall manufacturing processes.

3.2.2 *Waste Elimination* module

This module is developed to gauge the existing status of manufacturer's commitment to reducing and eliminating waste in achieving LVAM. The process flow of *Waste Elimination* module is shown in Figure 3. In the manufacturing environment it is necessary to provide only the necessary quality products, in the right quantity, at the right time and place, while using a minimum of facilities, equipment, materials and human resources through waste elimination. Lean manufacturing process has identified the following seven wastes: waste from over production, waste of waiting time, transportation waste, processing waste, waste of motion, waste from product defects and inventory waste (Holweg, 2007).

According to Schroer (2004), the highest value of products is achieved by reducing and eliminating waste as much as possible for non value adding activities which significantly increase productivity, shorter delivery times, cost reduction, improved quality, increased customer satisfaction and higher profit. The activities for *Waste Elimination* module work as inter-related system that includes *Kaizen* (continuous improvement), *Kanban* (Just In Time (JIT)) system, setup time reduction, uniform plant loading, and cellular manufacturing.

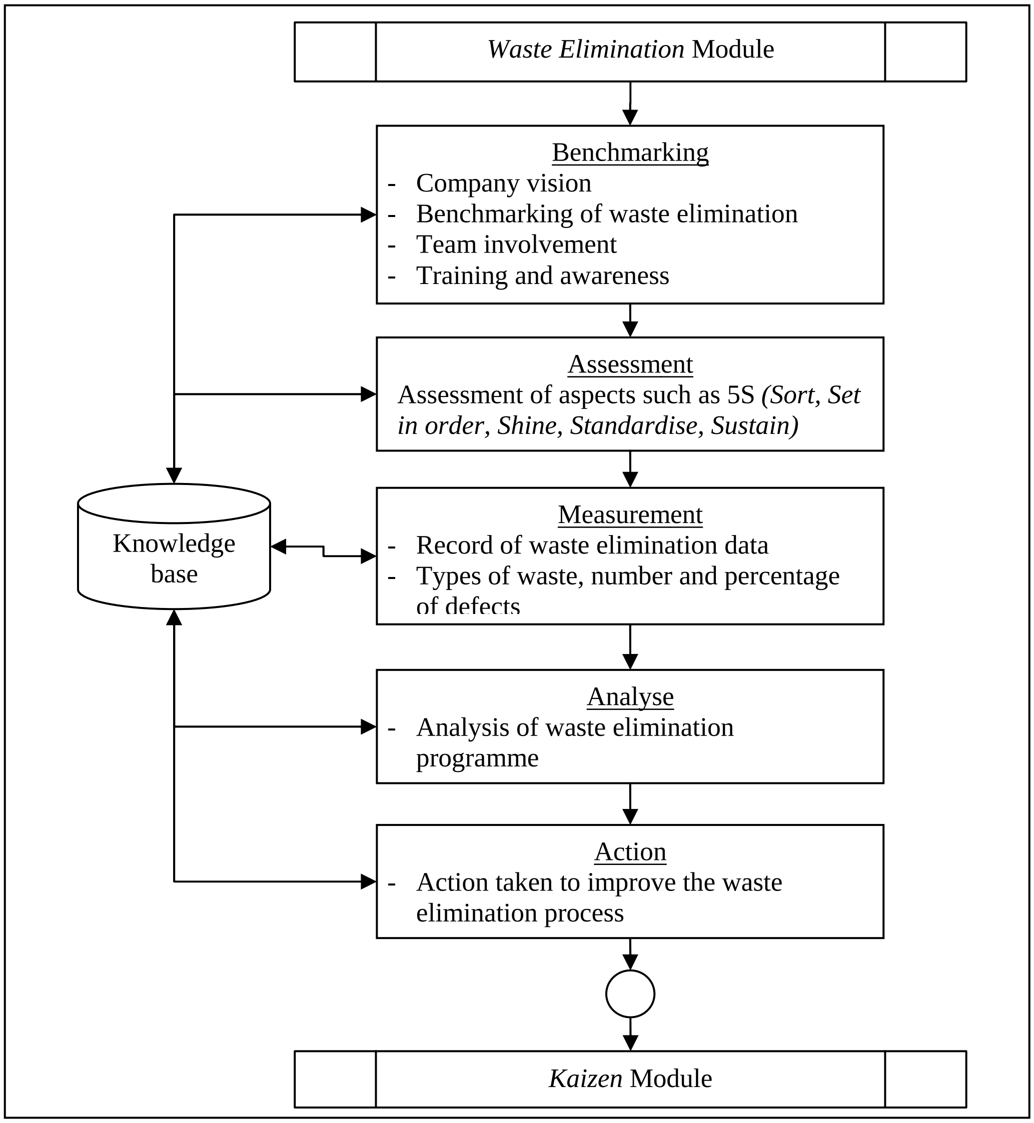

Figure 3. Flowchart of *Waste Elimination* Module

Furthermore, the elements of focused factory, job standardisation, and total productive maintenance (TPM) are also considered under *Waste Elimination* module (Hokoma, 2007). For this module, benchmarking, assessment, measurement, analysis and action plan are needed to ascertain that the manufacturer is committed to this process. The example of KB rules implemented in this module is briefly shown as follows:

IF	*the LVAM manufacturer has identified the best practice of waste elimination (benchmark)* (**Yes**: GP; **No**: BP, **PC-1**)
AND	*the LVAM manufacturer has assessed the aspects of 5S (Sort, Set in order, Shine, Standardise, Sustain)* (**Yes**: GP; **No**: BP, **PC-1**)
AND	*the LVAM manufacturer has measurement records of waste elimination process* (**Yes**: GP; **No**: BP, **PC-1**)
AND	*the LVAM manufacturer has records of number and percentage of out of quality* (**Yes**: GP; **No**: BP, **PC-1**)
AND	*the LVAM manufacturer has records of number and percentage of overproduction* (**Yes**: GP; **No**: BP, **PC-1**)
AND	*the LVAM manufacturer has records of number and percentage of throughput time* (**Yes**: GP; **No**: BP, **PC-5**)
AND	*the LVAM manufacturer has records of average percentage of value-added time* (**Yes**: GP; **No**: BP, **PC-3**)
AND	*the LVAM manufacturer consistently analyses the waste elimination process* (**Yes**: GP; **No**: BP, **PC-1**)
AND	*the LVAM manufacturer consistently evaluates the waste elimination process* (**Yes**: GP; **No**: BP, **PC-3**)
AND	*the LVAM manufacturer consistently takes action to improve the waste elimination process* (**Yes**: GP; **No**: BP, **PC-1**)
THEN	*the LVAM manufacturer element of waste elimination is good and capable to achieve LVAM alignment*
OR	*the LVAM manufacturer needs to reconsider its waste elimination process to align the LVAM*

From the above rules, the KBLVAM classes it as a serious problem of PC-1 if the LVAM manufacturer does not identify the best practice of waste elimination (benchmark) since it is an essential element of LVAM. The System also accesses the aspects of 5S (Sort, Set in order, Shine, Standardise, and Sustain). It is important to have the 5S activities in order to eliminate wastes; failure to have these elements in place will result in PC-1.

The manufacturer also needs to have records on the waste elimination process such as number of defects and overproduction, which need to be reduced. Furthermore, questions about the analysis of waste elimination programme, and action taken to improve the waste elimination process are then asked by the KBLVAM System. For instance, if there is no action taken to improve the waste elimination process, the KBLVAM System will conclude it as a serious problem of PC-1. The aspects of waste elimination covered in this module can again be modified to be implemented in any manufacturing process, including process manufacturing.

3.2.3 *Kaizen* (continuous improvement) module

The *Kaizen* module is developed to assess the current status of manufacturer's commitment to continuously improve the manufacturing culture in achieving LVAM. Continuous improvement is a major success to a company if implemented properly and will require a cultural change. *Kaizen* is a philosophy of continuous improvement of all the employees in a manufacturer, in order for them to perform better each day (Herron and Hicks, 2008). The process flow of *Kaizen* module is shown in Figure 4.

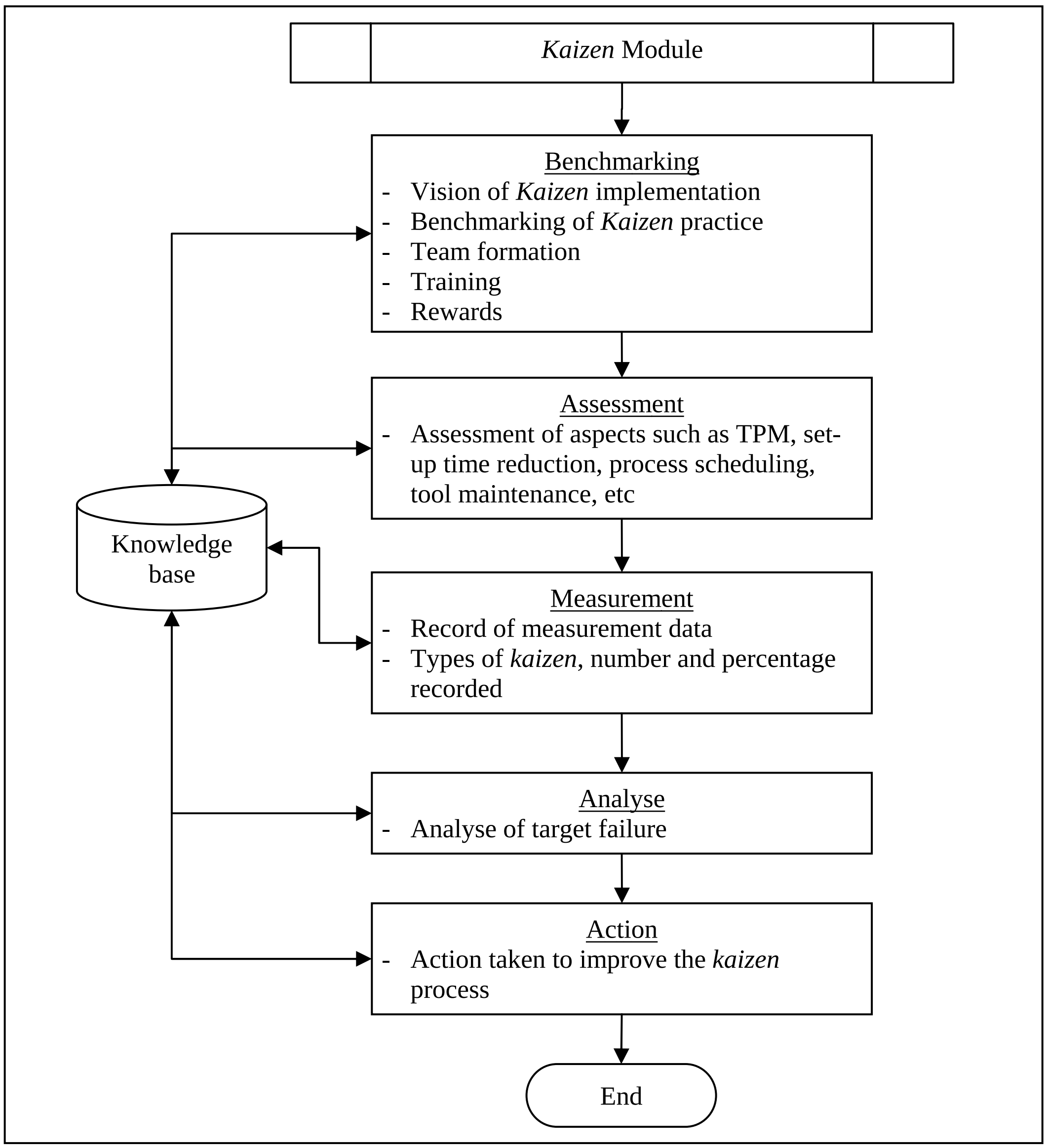

Figure 4. Flowchart of *Kaizen* Module

Employees are given full freedom to express their ideas toward the improvement process, which may subsequently be implemented in the company. This approach enables them to participate, and encourages everyone to make improvements. This idea of team participation is called *Kaizen Teian* in the Japanese system, and has proven to be remarkably effective in the process of improvement.

Kaizen views improvements as a never-ending process which involves ongoing culture to identify and remove wasteful elements in the manufacturing process. It is necessary for the manufacturers to have visions and strategies on how to implement the *Kaizen* culture throughout company. The *Kaizen* programme should include a clear internal and external communication strategy so that any suggestions for improvements are structured and documented. The structured *Kaizen* method should consider the mechanism on how to propose, evaluate, reward and implement the suggestions (Garcia et al., 2006). The mechanism should include companywide trainings, awareness, communications and implementations.

The function of *Kaizen* is to continuously identify and study the areas in the manufacturing environment for improvement. This culture requires strong commitments for improvement from top management and all the staff by encouraging the *Kaizen* activities such as Quality Control Circle (QCC). In the QCC, groups of workers discuss and focus on areas that they need to study to eliminate waste actions and suggest for improvements. This activity requires active participation from group members and focuses on root cause to the problems.

A brief example of KB rules for *Kaizen* module is shown in the following:

IF *the LVAM manufacturer has identified the best practice of Kaizen (benchmark)* (**Yes**: GP; **No**: BP, **PC-1**)

AND *the LVAM manufacturer consistently assesses the process scheduling as part of Kaizen process* (**Yes**: GP; **No**: BP, **PC-1**)

AND *the LVAM manufacturer consistently assesses the total productive maintenance (TPM) as part of Kaizen process* (**Yes**: GP; **No**: BP, **PC-1**)

AND *the LVAM manufacturer consistently assesses the visual factory as part of Kaizen process* (**Yes**: GP; **No**: BP, **PC-1**)

AND *the LVAM manufacturer consistently assesses the mistake proofing technique (poka yoke) as part of Kaizen process* (**Yes**: GP; **No**: BP, **PC-1**)

AND *the LVAM manufacturer consistently assesses the work standardisation as part of Kaizen process* (**Yes**: GP; **No**: BP, **PC-1**)

AND *the LVAM manufacturer consistently assesses the tool maintenance as part of Kaizen process* (**Yes**: GP; **No**: BP, **PC-1**)

AND *the LVAM manufacturer has measurement records of Kaizen process* (**Yes**: GP; **No**: BP, **PC-1**)

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AND *the LVAM manufacturer consistently analyses the Kaizen process* (**Yes**: GP; **No**: BP, **PC-3**)
AND *the LVAM manufacturer consistently takes action to continuously improve the operations* (**Yes**: GP; **No**: BP, **PC-3**)
THEN *the LVAM manufacturer element of Kaizen is good and capable to achieve LVAM alignment*
OR *the LVAM manufacturer needs to reconsider its Kaizen process to align the LVAM*

The questions in this module begin with benchmarking the best practice of *Kaizen* in LVAM environment. This is an important aspect for the LVAM environment to achieve a world class standard and which has the vision for continuous improvement, teamwork, trainings and rewarding system. It is a serious problem of category PC-1 if there is no evidence for such activities in the company. The KBLVAM System then assesses the manufacturer's evaluation of elements of *Kaizen* such as total productive maintenance, visual factory, mistake's proofing technique (*poka yoke*), work standardisation, and tool maintenance. The absence of any of these elements is a serious problem of PC-1 because in achieving LVAM, implementation of all *Kaizen* elements is necessary.

Identifying the existence of measurement records for the *Kaizen* process is the next level of questions in KBLVAM System. The absence of measurement records shows that the manufacturer has no clear idea of how to align the *Kaizen* process that is used as an important part to achieve LVAM, and is therefore serious problem of PC-1. Finally the System will assess how the LVAM manufacturer analyses the Kaizen process and takes action to continuously improve the operations.

3.3 Results and analysis

In actual practice, in order for the KBLVAM System to assess the level of implementation of all the three modules, the representative of the LVAM's company must answer the designed questions accordingly. Based on the user's response, the System will identify the GAP between the existing practice and the benchmark practice. The KBLVAM will then suggest the detail elements that need to be improved. For this study, a simulated result for LVAM Manufacturer Capability - *Lean Process Optimisation* Perspective is shown in Table 3. A total number of 192 questions have been asked in this module which also contains the number of Good Points (GP), the number of Bad Points (BP), together with the Problem Categories (PC) of the BP. The GAP analysis optimisation technique suggests that only the BP is categorised into PC in order to identify the necessary pre-requisites that are required to achieve the LVAM. The KBLVAM System has identified, for each sub-module, the problem categories in a prioritised manner. Out of 192 questions, 104 have been categorised as GP whereas 88 have been considered as BP. The System concluded these 88 BP (13 PC-1, 7 PC-2, 12 PC-3, 8 PC-4, 16 PC-5, 11 PC-6, 10 PC-7, 6 PC-8, and 5 PC-9) need to be eliminated to achieve benchmark implementation of LVAM.

In the *Employee Involvement* module, the KBLVAM has identified major problem activities for all sub-modules of *Benchmark, Assessment, Measurement, Analyse,* and *Action.* The sub-module *Benchmark* is the most critical area that needs to be rectified because it has 2 PC-1 which indicates a very serious problem to the manufacturer. These 2 PC-1 problems are found to be related to culture and people. Therefore, it is the priority for the manufacturer to resolve the problems from category PC-1 (2 BP) before rectifying the other 6 BP (1 PC-3, 1 PC-5, 1 PC-6, 1 PC-7, 1 PC-8 and 1 PC-9). The second most critical area is *Action*, which has 1 BP, each in PC-1and PC-2. The other 2 BP are in PC-4 and PC-5. Although *Assessment* and *Analyse* sub-modules have more BP (14) compared to *Action* sub-module (4), 50% of the *Action* BP are in PC-1 and PC-2 which indicates serious problems in this sub-module. The manufacturer also needs to resolve the issue for *Measurement* sub-module, as one of the BP is from PC-1 category.

Similar assessments by the KBLVAM System for the *Waste Elimination* and *Kaizen* modules have also highlighted major non-compliances in these modules. In the *Waste Elimination* module, *Benchmark* is the most problematic area with 8 BP (1 PC-1, 1PC-2 and 2 PC-4); *Measurement* with 6 BP (1 PC-1, 2 PC-3); *Analyse* with 5 BP (1 PC-1, 1 PC-3); *Assessment* with 6 BP (1 PC-2, 1 PC-3); and *Action* with 5 BP (1 PC-2 and 1 PC-4). This again shows key priorities needed to achieve benchmark implementation especially the culture, communications, commitment and people.

In the *Kaizen* module, again the *Benchmark* sub-module is the most problematic area with 9 BP (2 PC-1, 1PC-2, 1 PC-3 and 1 PC-4); followed by *Assessment* with 7 BP (1 PC-1, 1 PC-3, and 1 PC-4); *Measurement* with 5 BP (1 PC-1, 1 PC-3); *Action* with 4 BP (1 PC-1, 1 PC-3); and *Analyse* with 4 BP (1 PC-2 and 1 PC-4). The important areas need to be rectified for *Benchmark* sub-module are vision, culture, communications and people.

It seems that the KBLVAM System has identified three same areas of problems which are from the *Benchmarking* sub-module. The identified problem areas for all modules need to be resolved for a successful LVAM development. Priorities for rectification of the problems should focus on items from PC-1 to PC-4 and which are inter-linked across the three sub-modules (culture and people) because they are the main contributors to the manufacturing process. PC-5 to PC-9 indicate minor problems to the system and are not affecting the overall performance of the manufacturing activities. However, if these minor problems are resolved, they are likely to produce short term benefits to the system.

Table 3. Example of simulated results of the GAP analysis LVAM Manufacturer Capability - *Lean Process Optimisation* Perspective

Lean Process Optimisation Perspective	**No of Questions**	**GAP Analysis**										
		GP	BP	Problem Category (PC)								
				1	2	3	4	5	6	7	8	9
Employee Involvement												
Measurement	12	9	3	1	0	0	0	2	0	0	0	0
Benchmark	15	7	8	2	0	1	0	1	1	1	1	1
Assessment	10	4	6	0	1	1	1	2	1	0	0	0
Analyse	12	4	8	1	0	2	0	1	1	1	1	1
Action	12	8	4	1	1	0	1	1	0	0	0	0
Sub-total	**61**	**32**	**29**	**5**	**2**	**4**	**2**	**7**	**3**	**2**	**2**	**2**
Waste Elimination												
Measurement	13	7	6	1	0	2	0	1	0	1	0	1
Benchmark	14	6	8	1	1	0	2	0	2	1	1	0
Assessment	11	5	6	0	1	1	0	1	0	1	1	1
Analyse	10	5	5	1	0	1	0	1	1	1	0	0
Action	12	7	5	0	1	0	1	1	1	1	0	0
Sub-total	**60**	**30**	**30**	**3**	**3**	**4**	**3**	**4**	**4**	**5**	**2**	**2**
Kaizen												
Measurement	13	8	5	1	0	1	0	1	1	1	0	0
Benchmark	17	8	9	2	1	1	1	1	1	0	1	1
Assessment	16	9	7	1	0	1	1	2	0	2	0	0
Analyse	11	7	4	0	1	0	1	0	1	0	1	0
Action	14	10	4	1	0	1	0	1	1	0	0	0
Sub-total	**71**	**42**	**29**	**5**	**2**	**4**	**3**	**5**	**4**	**3**	**2**	**1**
Grand Total	**192**	**104**	**88**	**13**	**7**	**12**	**8**	**16**	**11**	**10**	**6**	**5**

4 Conclusion

This paper has summarised the importance of lean process implementation for low volume automotive manufacturers through implementing KBLVAM System. The development of KBLVAM System for the lean process has covered the important issues related to LVAM environment at the strategic and operational level. There are three main modules of the KBLVAM System that identify the gap between the existing condition and the industry benchmark of low volume automotive manufacturers. The *Employee Involvement* is the first module used to identify the level of employee involvement programmes in the manufacturer. The second module is the *Waste Elimination* which is used to gather data on the existing status of a manufacturer’s commitment to reducing and eliminating waste in achieving LVAM. The third module of KBLVAP System is *Kaizen* which is used to gauge the level of continuous improvement culture currently existing in the LVAM environment culture. As shown, the KBLVAM can provide the decision makers with qualitative and quantitative information, and guidance for promoting the implementation of lean manufacturing philosophy in order to achieve process optimisation. The technique can be extended to any manufacturing environment, including chemical process industries.

5 Appendix: Problem Categories and Description of GAP Analysis Technique

Category	Code	Description
1	PC-1	This indicates a very serious problem, which should and can be resolved in the short term and the result of the problem is quite likely to provide a real short-term benefits.
2	PC-2	This indicates a serious problem, which involves pre-requisites to the system and requires appropriate and logical improvement and implementation plan.
3	PC-3	This indicates a major problem, which is likely to have pre-requisites and is better dealt with as part of an appropriate and logical improvement and implementation plan.
4	PC-4	This is quite a major problem and can be dealt with now. If resolved, it is likely to produce short-term benefits.
5	PC-5	This indicates a problem to the system and can be dealt with now. If resolved, it is likely to produce short-term benefits.
6	PC-6	This indicates a minor problem and can be dealt with now. If resolved, it is likely to produce short-term benefits.
7	PC-7	This is not a serious problem. Although it could be dealt with now, it is unlikely to produce short-term benefits. Therefore, it should only be dealt with if it is a pre-requisite for other things.
8	PC-8	This is not really a problem, However it is important to consider certain situations as future improvement.
9	PC-9	This is not really a Good or Bad point itself. The questions associated with this category are primarily asked to identify certain situations in the environment, which upon subsequent probing by succeeding questions may well reveal problems.

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