CHAPTER 7

DEVELOPMENT OF KNOWLEDGE-BASED LOW VOLUME AUTOMOTIVE MANUFACTURING (KBLVAM) MODEL: STAGE 2 (DESIGN)

7.1 Introduction

This chapter focuses on the detailed development of the KBLVAM Model for the Stage 2 (Design) as shown in Figure 7.1. It explains all levels in the Design Stage (Operational Level) of the structure of the KBLVAM System as described in Chapter 5.

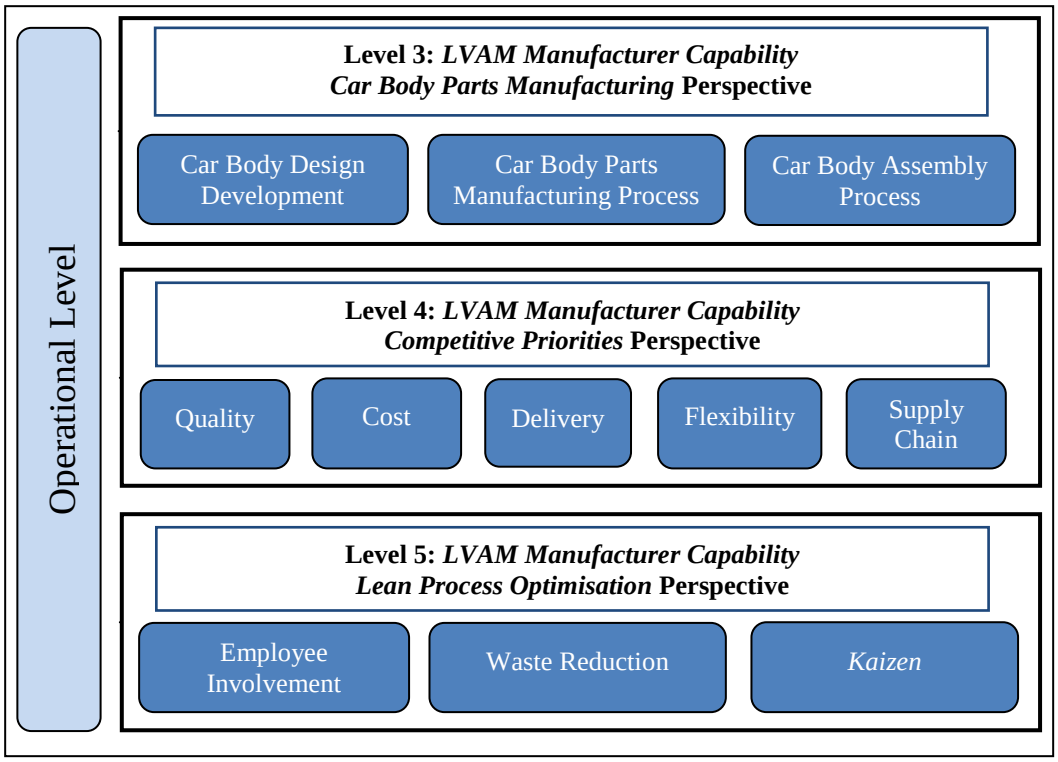

Figure 7.1: Structure of KBLVAM system – Stage 2

This chapter discusses the details contained within modules, including the production rules and process flow of the system. There are three levels of

perspectives covered in Stage 2 that include *LVAM Manufacturer Capability - Car Body Parts Manufacturing (Level 3)*, *LVAM Manufacturer Capability - Competitive Priorities (Level 4)* and *LVAM Manufacturer Capability - Lean Process Optimisation (Level 5)*. This chapter discusses 11 modules covering 1450 KB rules. Each of the perspectives will be explained in the following sections from Level 3 to Level 5 in the KBLVAM structure.

7.2 Level 3 - *LVAM Manufacturer Capability - Car Body Parts Manufacturing* Perspective

The *LVAM Manufacturer Capability - Car Body Parts Manufacturing* Perspective in the strategic level of KBLVAM System is structured into three modules as discussed in Chapter 5, *Car Body Design Development*, *Car Body Parts Manufacturing Process* and *Car Body Assembly Process*. The main focus for these modules is to determine the current manufacturer's condition towards LVAM manufacturing perspective. This is done by assessing the important automotive manufacturing environment which related to the three modules. The detailed KBLVAM structure of this perspective is shown in Figure 7.2.

There are three sub-modules under the *Car Body Design Development* module and two sub-modules each for *Car Body Parts Manufacturing Process* and *Car Body Assembly Process* modules. Each of the three modules consists of activities such as *Car Body Design concept*, *Conceptual Design* Analysis and *Car Body Design Development Assessment* (*Car Body Design Development* module); *Design of Dies and Checking Fixtures* and *Design of Manufacturing Process* (*Car Body Parts Manufacturing Process* module); and *Design of Assembly Tools* and *Design of Assembly Process* (*Car Body Assembly Process* module).

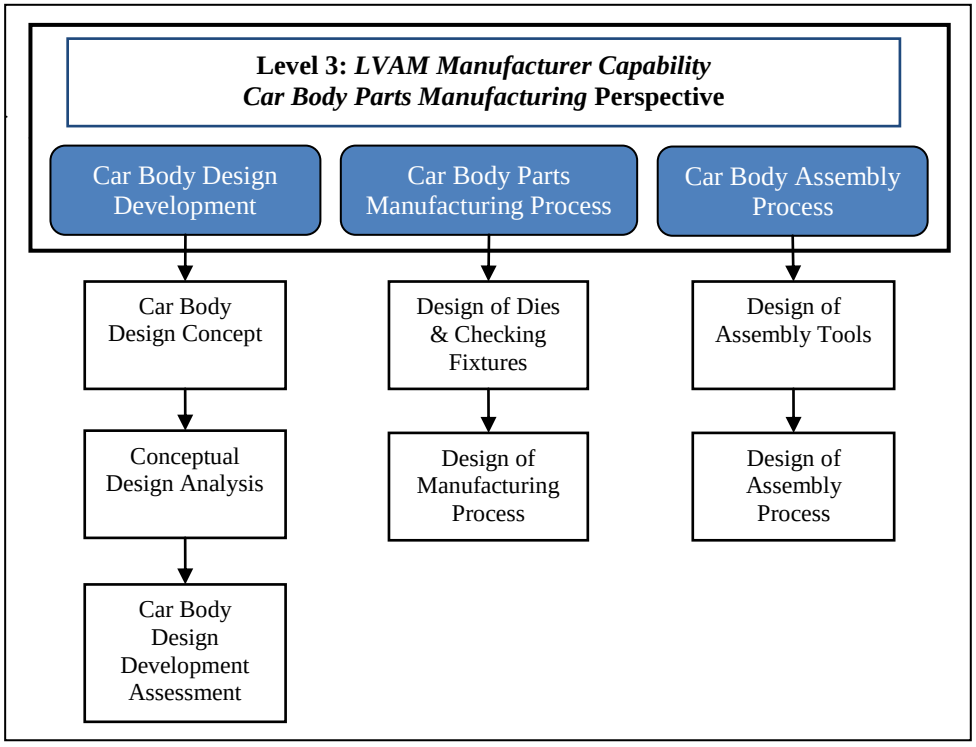

Figure 7.2: LVAM manufacturer capability – *Car Body Parts Manufacturing* perspective

Referring to Figure 7.2, the assessment process begins with the execution of the *Car Body Design Development* module, followed by the *Car Body Parts Manufacturing Process* and *Car Body Assembly Process* modules. The specific assessment for all the three modules is explained in the following sections.

7.2.1 *Car Body Design Development* Module

Referring to the flowchart of this module, as shown in Figure 7.3, KBLVAM considers multifunctional teams from marketing, engineering, manufacturing, and quality staffs to be involved as early as possible in the product design stage (Mohamed et al., 2005). Product development of an automotive program begins with conceptual design stage, which integrates the market demands and business strategy. It is the work of the design team which can be either internal or outsourced. The

process visualises the current needs and business perspective into a product concept sketch (Kumar et al., 2006).

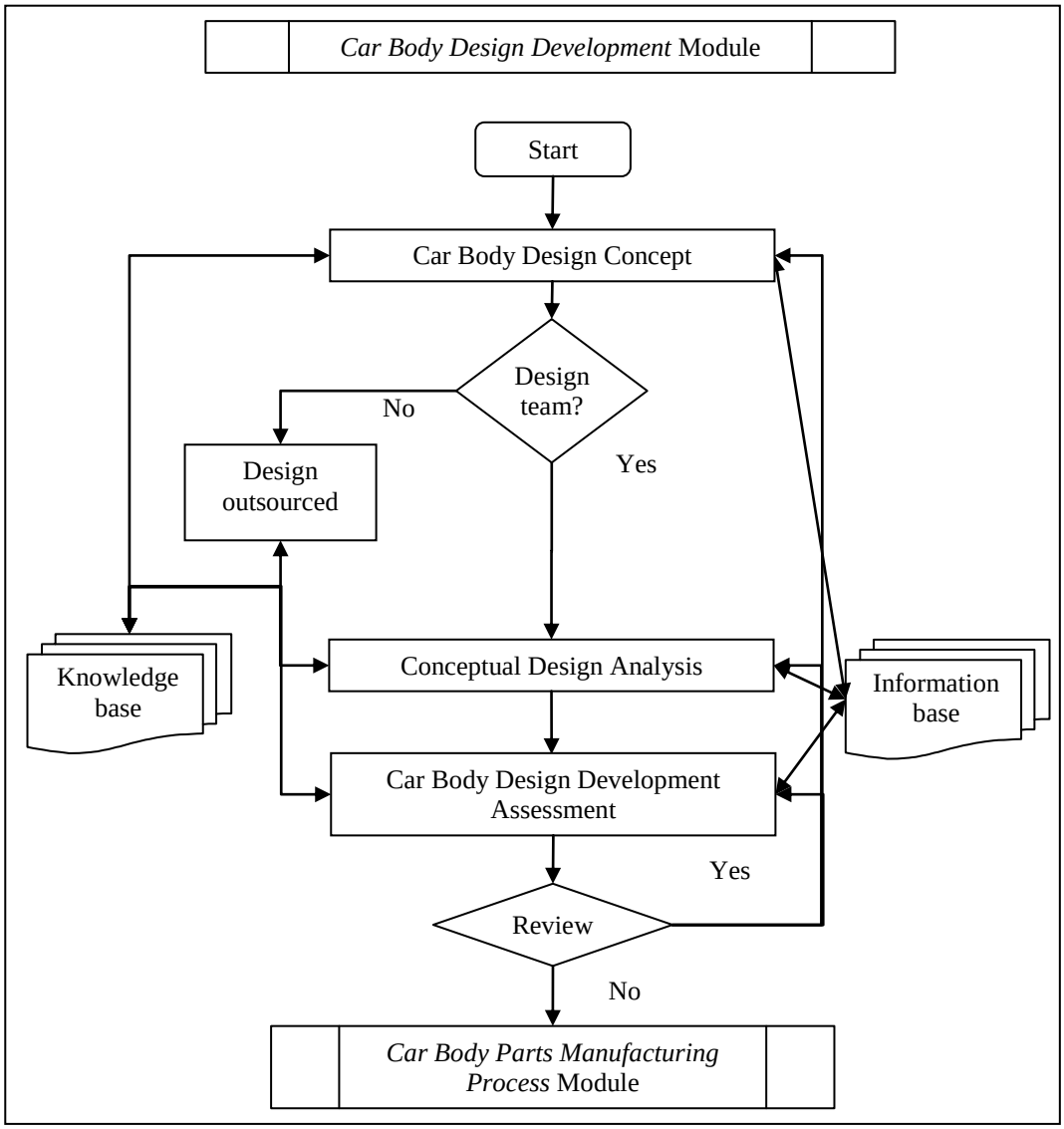

Figure 7.3: Flowchart of *Car Body Design Development* module

The concept should consider the fundamental characteristics of the automotive model which include physical dimensions, target market, image, options, material selections and performance specifications. From the sketches, the clay modellers or computer simulation engineers use this information to design detailed interior and exterior model of the vehicle. Later, the physical model or the virtual reality model will be carefully studied by other development team members from

body design, equipment design, manufacturing, quality control, purchasing and suppliers.

This concurrent engineering activity gives responses to all team members on the feasibility and limitations of manufacturing the model and provide suggestions for improvement. After a series of refinement processes are completed, the clay or simulated models will be digitized for the purpose of detailed product design and prototype build. These activities are very important in LVAM assessment because without the evidence of involvement of the related parties will result in Problem Category 1 (PC-1) in the KBLVAM system.

The elements in *Car Body Design concept*, *Conceptual Design Analysis* and *Car Body Design Development Assessment* activities will be discussed in the following sub-sections.

7.2.1.1 *Car Body Design Concept* Sub-Module

Referring to Figure 7.2, *Car Body Design Concept* is the first stage of the *Car Body Design Development* module, which is very important in linking the design concept of the new product and the manufacturer's strategy and vision (Hallgren and Olhager, 2009). These inter-related series of activities consider every aspect of market demands and business strategy and transform them into prototype build. The *Car Body Design Concept* sub-module, is developed to assess these activities which include product sketches, involvement of multi-functional team, and benchmarking of own and competitors' products (Yang et al., 2007).

Referring to Figure 7.3, the first question to be asked by KB System in *Car Body Design Concept* sub-module is whether the LVAM manufacturer has the

evidence of design team involvement in the car body design stage or not. The early involvement of multifunctional team is very important to determine the success of the product. Therefore, KBLVAM considers multifunctional teams from marketing, engineering, manufacturing, and quality staffs to be involved as early as possible in the product design stage. The questions in KBLVAM System will determine the level of involvement from multifunctional teams with corresponding scores specified in the particular rules. After completing the questions in this module, KB system will categorise whether the company is a multifunctional company or the activities under this module are done separately. The example of a rule - base for this sub-module used for deducing this condition is listed as follows:

IF *the marketing team involved in the car body design* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the engineering team involved in the car body design* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturing team involved in the car body design* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the quality team involved in the car body design* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the purchasing team involved in the car body design* (**Yes**: GP; **No**: BP, **PC-5**)
AND *the potential supplier team involved in the car body design* (**Yes**: GP; **No**: BP, **PC-5**)
IF *the manufacturer rates the car body design in terms of technology and innovation as* (**Excellent**: GP; **Good**: BP, **PC-4**, **Average**: BP, **PC-5**, **Poor**: BP, **PC-1**)
AND *the manufacturer rates the car body design in term of quality as* (**Excellent**: GP; **Good**: BP, **PC-7**, **Average**: BP, **PC-5**, **Poor**: BP, **PC-1**)
AND *the manufacturer rates the car body design in term of reliability as* (**Excellent**: GP; **Good**: BP, **PC-7**, **Average**: BP, **PC-5**, **Poor**: BP, **PC-1**)
AND *the manufacturer rates the car body design in term of safety as* (**Excellent**: GP; **Good**: BP, **PC-7**, **Average**: BP, **PC-5**, **Poor**: BP, **PC-1**)
AND *the manufacturer rates the car body concept in terms of features and design as* (**Excellent**: GP; **Good**: BP, **PC-7**, **Average**: BP, **PC-5**, **Poor**: BP, **PC-1**)
AND *the manufacturer rates the products in term of price as* (**Excellent**: GP; **Good**: BP, **PC-7**, **Average**: BP, **PC-5**, **Poor**: BP, **PC-1**)
THEN *the car body design and development team is multifunctional and the manufacturer design and development activity is good*
OR *the car body design and development team is separated and the manufacturer design activity is poor*

As an example of the above rules, KBLVAM provides options for the user to answer *Yes*, *No* questions as well as to give a rating *Excellent (GP), Good (PC-7), Average (PC-5)* or *Poor* (PC-1) on the selected questions. Lack of involvement of these teams will result in the system categories it as a serious problem of PC-1. By

having a weak teamwork in the LVAM, the manufacturer cannot make a significant internal performance improvement as well as the loss of opportunity will increase.

7.2.1.2 *Conceptual Design Analysis* Sub-Module

In the next stage of the *Car Body Design Development* module, KB System assesses the LVAM manufacturer on how it analyses the design concept. This *Conceptual Design Analysis* sub-module assesses on the application of design tools such as *Failure Mode and Effect Analysis* (FMEA) in the product development activities (Johnson and Khan, 2003). The example of a rule - base for *FMEA* aspects of this sub-module used for deducing concept analysis condition is listed as follows:

IF *the manufacturer has ensured clear definition of FMEA to the car body design team* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer has trained car body design team on FMEA programme* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body design team develop a rating chart combined with a table to assign severity of potential failures* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body design team develops a rating chart combined with a table to assign likelihood of potential failure occurring* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body design team develops a rating chart combined with a table to assign the chance of detection within the design process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body design team analyses the design of the products to determine the critical major modes* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body design team analyses the design of the products to determine the effect of failure modes* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body design team documents all the FMEA during design process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body design team upgrades the documentation system whenever a recent FMEA has been documented out* (**Yes**: GP; **No**: BP, **PC-1**)
THEN *the FMEA has been implemented in the car body design activities*
OR *the FMEA needs to be implemented or improved in the car body design activities*

The KBLVAM System uses the above rules to gauge the level of FMEA's implementation in the manufacturer's design analysis. This *Conceptual Design Analysis* sub-module starts with the manufacturer's commitment towards the implementation of FMEA among the product designers. This is to ensure that the designers are trained and aware the importance of FMEA in design analysis. Then,

the system evaluates the use of FMEA throughout the design analysis process so that it is followed and documented properly. Failure to follow the FMEA procedure is considered as a serious problem of PC-1 because it will affect the quality of concept analysis.

7.2.1.3 *Car Body Design Development Assessment* Sub-Module

Based on Figure 7.3, in the *Car Body Design Development Assessment* sub-module, KB System assesses the manufacturer's capability in developing a new car model. It includes how many numbers of new models, total development time to reach the market, and what types of activities involved in the car development process (Hallgren and Olhager, 2009). The activities will include interior and exterior body parts design, number of processes, car body assembly method, material selection, and manufacturing adaptability study. The example of a rule - base for *Car Body Design Development Assessment s*ub-module used for deducing this condition is listed as follows:

IF *the average time to market for this year is less than last year* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the average time to market for this year is less than last 2 years* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the customers are involved in the idea generation and car body design conceptualisation* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturing adaptability is considered during the interior car body part design* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturing adaptability is considered during the exterior car body part design* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the potential suppliers are involved in determining car body part material selection* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the potential suppliers are involved in developing car body part specification and performance range* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the potential suppliers are involved in the car body part quality targets* (**Yes**: GP; **No**: BP, **PC-1**)
THEN *the company continuously improve time to market in the car body part development process*
OR *the company need to reduce the time to market, adopt concurrent engineering technique and improve the car body part development process*

Based on user responses, KBLVAM uses the above rules to evaluate the level of problems occurred in this sub-module. There are very serious problems of PC-1 if

the *average time to market* for the year is more than the previous year, *potential suppliers* are not involved in determining material selection and *potential suppliers* are not involved in product quality targets. From the rules, the involvement of customers and suppliers in the product development process are very important in order to have direct input to the project.

7.2.2 *Car Body Parts Manufacturing Process* Module

Referring to Figure 7.2, the next module under the *LVAM Car Body Parts Manufacturing Perspective* is the *Car Body Parts Manufacturing Process* module. The corresponding flowchart of this module is shown in Figure 7.4.

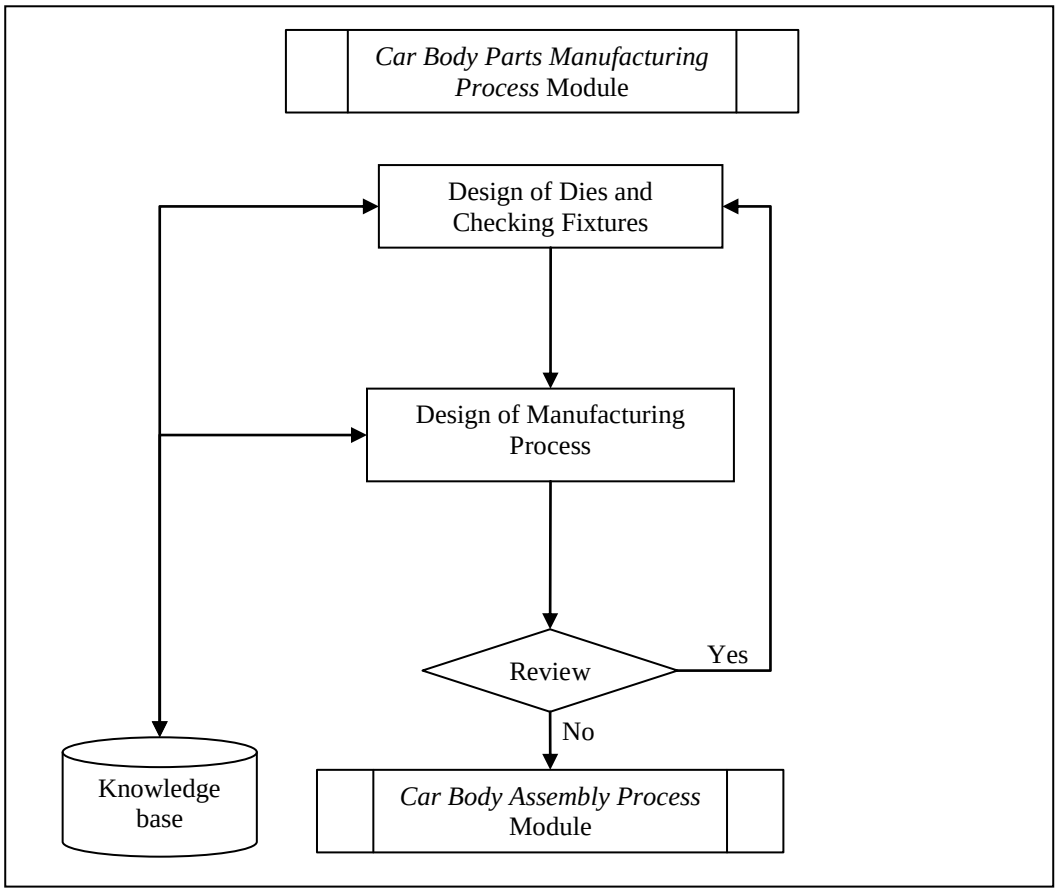

Figure 7.4: Flowchart of *Car Body Parts Manufacturing Process* module

The KB questions in this module will determine the level of dies and checking fixture designs, and manufacturing process design. The KBLVAM will begin the process by analysing the Process Planning that determines how many processes are involved in producing a certain body part. It consists of two sub-modules: *Design of Dies and Checking Fixtures* and *Design of Manufacturing Process* that will be discussed in details in the following sub-sections.

7.2.2.1 *Design of Dies and Checking Fixtures* Sub-Module

The KB questions in this sub-module will determine the level of dies and checking fixture designs. The KBLVAM will begin the process by analysing the Process Planning that determines how many processes are involved in producing a certain body part. For example the normal sequential stamping processes in Front Door Outer in a typical car model requires four sets of dies before it becomes a complete part. However for LVAM, the consistent use of high flexibility manufacturing enables these processes to be reduced as far as possible (Williamson, 2006). As such, only one die is required to be designed for the part and the remaining processes are done by laser cutting and manual bending. Responses from the user on these processes will determine the Problem Category of KBLVAM. The next stage, KBLVAM will check the implementation of simulation software to simulate the draw process in order to check the problems with the design so that early rectification can be done in the dies and checking fixtures design stage. The simulation software can show material movement simulation so that every interference and mismatching can be detected as well as the cross sectional views for the critical areas. Another advantage of simulation software is to give initial result

for a certain part such as crack, wrinkle and overlap. The KBLVAM System will categorise it as PC-1 if these elements are absent during the analysis.

Checking fixtures design is required in the automotive parts manufacturing specifically to check the accuracy of the produced part is according to the parts drawing design. It is important that KBLVAM assesses the checking fixtures design process so that the accuracies and tolerances of critical points and areas of the part which match with other parts during the assembly process are kept within the limit. The example of a rule-base for the *Design of Dies and Checking Fixtures* sub-module used for deducing this condition is listed as follows:

IF *the minimum number of process has been studied among the die designers and die design experts during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the die design standard is followed to ensure all the specifications are considered during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the design check sheet is applied to control the design according to specifications during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the die design is followed the allocated press specifications during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the die design conceptual check is done by the experts during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the die design detailing check (dimensional check) is done by the experts during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the die design hours is monitored and controlled in order to keep the overall schedule during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the design is checked and approved by the experts during the die design stage* (**Yes**: GP; **No**: BP, **PC-1**)
THEN *the die design processes of the manufacturer are good*
OR *the Manufacturer's needs to improve the die design processes by implementing the missing tools*

The above rules show that the KBLVAM categorises it as a very serious problem with PC-1 if there is any absence of die design process control tools to achieve LVAM. Lack of these tools, the KBLVAM system suggests the Manufacturer's to improve the die design process control activities by implementing the missing tools.

7.2.2.2 *Design of Manufacturing Process* Sub-Module

Referring to Figure 7.2 and Figure 7.4, the next stage of the *Car Body Parts Manufacturing Process* module is to design the manufacturing process. The KB System begins to assess whether the manufacturing process is based on the dies and checking fixtures planning and design input. It is a process that will transform the dies and checking fixtures design into actual parts. The KBLVAM also identifies the manufacturing process of a die starting from the construction of Full Model Casting (FMC) pattern which should be based on the die design, and the casting of the pattern to become a die by using the material specified in the die drawing (Mohamed et al., 2005). The number of dies is also assesses by the KB System which should follow the process planning as mentioned in the *Design of Dies and Checking Fixtures* sub-module.

Once the die is casted, the next process is called machining; a process that uses Computer Numerical Control (CNC) data from the part drawing to machine the surface of the die. The KB System identifies whether the CNC machines use the CNC data prepared by the machine programmer and machine the die accordingly. The next stage in the die manufacturing process is the finishing process which is to polish the surface of the die so that the blank sheet material will be drawn smoothly during the stamping process. At this stage, the KB System also assesses the assembly process of die accessories such as springs, lifters, stoppers and lifting hooks are fitted to the die as specified in the die drawing.

Finally, the KB System assesses the final stage of the die manufacturing process, which is the try-out process by using try-out press in order to check the functions of the die as well as the quality of the part produced during the trials (Kim,

2007). The quality of the part is determined by using the checking fixture. Any problem detected by the checking fixture will require adjustments to the die and several stamping trials are required until the problem is rectified. Checking fixture is a tool that checks the part for quality confirmation based on the part drawing. It is normally fabricated by using soft material such as resin which is directly machined from the part drawing. The same source of CNC part drawing data is used for both die and checking fixtures fabrication. By following this procedure, KB System ensures the part produced from stamping process is according to the design intent. The example of a rule - base for *Design of Manufacturing Process* sub-module used for deducing this condition is listed as follows:

IF *the manufacturing process planning is applied to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the check sheet is applied to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the press simulation data is applied to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body part drawing is used to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the dies and checking fixtures drawings are used to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the purchased parts data is applied to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the general dimensions and tolerance (GD&T) is applied to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the press specification is applied to monitor and control the dies and checking fixtures manufacturing process* (**Yes**: GP; **No**: BP, **PC-1**)
THEN *the dies and checking fixtures manufacturing process control activities of the manufacturer are good*
OR *the manufacturer needs to improve the internal process control activities by implementing the missing tools*

It can be seen from the above rules that the KBLVAM considers a very serious problem of category PC-1 if there is any absence of process control tools in implementing the *Dies and Checking Fixtures Manufacturing Process*. Without these tools, the System suggests the Manufacturer's to improve the manufacturing process control activities by implementing the missing tools.

7.2.3 *Car Body Assembly Process* Module

The *Car Body Assembly Process* module consists of two sub-modules: *Design of Assembly Tools* and *Design of Assembly Process*. The flowchart of this module is shown in Figure 7.5.

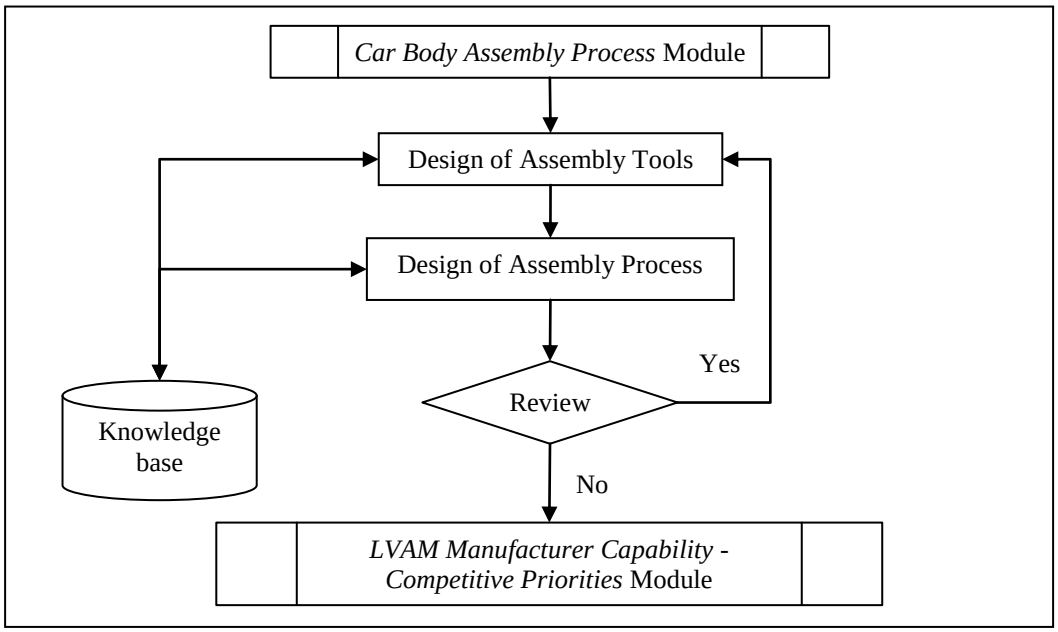

Figure 7.5: Flowchart of *Car Body Assembly Process* module

In this module, the KB System assesses the car body assembly lines, assembly jigs, welding robots, welding guns and hemming jigs. It is important for LVAM environment that various assembly tools must be considered to minimise the cost, including the application of adhesive and fasteners (Chen et al., 2006). Failure to have these elements in the body assembly processes will result in lower scores in the KB System. These two elements will be discussed in the following sub-sections.

7.2.3.1 *Design of Assembly Tools* Sub-Module

In the *Design of Assembly Tools* sub-module, KBLVAM Model will assess the LVAM manufacturer on the design of the car body assembly tools process. The assessment will focus on what type of assembly tools are designed at body assembly lines; such as assembly jigs, welding robots, welding guns or hemming jigs for closure parts such as doors, hood and trunk lid (Thuillier et al., 2008). The KB System then assesses the manual assembly tool is aimed for sub-assembled parts with less critical matching tolerance. At the main assembly line, the KB System expects that all the sub-assembled parts are designed to be assembled together by using robots for accuracy and uniformity control. An excellent integration of assembly tools during the design of car body assembly tool stage is very important in LVAM. This integration involves the processes during the body parts assembly which related to people, machines, method and material (Mohamed et al., 2005). All these considerations must be considered during the assembly of the design tools stage that need to be assessed by KBLVAM. The example of a rule - base for *the Design of Assembly Tools* sub-module used for deducing this condition is listed as follows:

IF *the manufacturer have a design policy for assembly tools development* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the assembly tools design activities involve key personnel* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the assembly tools design activities involve key material suppliers* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the assembly tools design activities consider minimising assembly process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the assembly tools design activities consider sub-contracting to potential supplier* (**Yes**: GP; **No**: BP, **PC-3**)
AND *the suppliers are allowed to access and use common resources* (**Yes**: GP; **No**: BP, **PC-3**)
THEN *the assembly tools design activities of the manufacturer are good*
OR *the Manufacturer's needs to improve assembly tools design activities*

As shown in the rules above, the KBLVAM identifies whether the manufacturer has a design policy for assembly tools development. This is an

important aspect in the design of assembly tools because the policy is the manufacturer's commitment to design quality cars and the KBLVAM categorises it as a very serious problem of PC-1 if there is no policy involved. The collaboration with the suppliers and sub-contractors also important in LVAM environment in car body assembly design stage. The collaboration will expedite the design process and reduce the overall project timing. Lack of suppliers and sub-contractors' involvement will result in a major problem of PC-3, which is considered as part of the strategic decision.

7.2.3.2 *Design of Assembly Process* Sub-Module

Referring to Figure 7.5, the next stage of the *Car Body Assembly Process* module is to design the assembly process. In the *Design of Assembly Process* for car body parts, KB System assesses the manufacturer on how to assemble the parts, components, and sub-components to become a complete car body. It is important that the design of assembly process is based on the easiest assembly method (Meichsner, 2009). The KB System also assesses whether the manual assembly line is used for less critical assembly requirement (inner body parts) and the automatic assembly line for high quality requirement (outer body parts). In the *Design of Assembly Process*, the arrangement of parts supply (parts, components, and sub-components) to the assembly line is also important to be considered. KB System identifies the handling and palleting of parts and completed car body in the LVAM environment in order to optimise the process control. All these considerations must be considered during the design of assembly stage that needs to be assessed by the

KB System. The example of a rule - base for the *Design of Assembly Process* sub-module used for deducing this condition is listed as follows:

IF *the car body manufacturing team involved in the design of assembly process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the car body quality team involved in the design of assembly process* (**Yes**: GP; **No**: BP, **PC-1**)
AND *assembly jigs drawings are based on Assembly Operation Sheet (AOS)* (**Yes**: GP; **No**: BP, **PC-1**)
AND *involves various methods considerations* (**Yes**: GP; **No**: BP, **PC-1**)
THEN *the design of assembly process is practising good planning for body assembly process activities*
OR *design of assembly process for body assembly process activities is poor*

From the above rules, it can be seen that the KBLVAM categorises it as a very serious problem of PC-1 if the manufacturer does not consider the team involvement as one of the most important aspect in the design of the assembly process. The KB System also assesses the activities related to car body assembly which should consider various methods. For example, if there is no consideration to use various methods for body assembly process, the KBLVAM categories it as a very serious problem of PC-1 since methods might be different for different types of car body structures.

7.3 Level 4 – *LVAM Manufacturer Capability - Competitive Priority* Perspective

The LVAM *Manufacturer's Capability – Competitive Priorities Perspective* consists of five modules: *Quality, Cost, Delivery, Flexibility* and *Supply Chain*. The function of these modules is to discover the current Manufacturer's capability towards LVAM in terms of these five competitive priorities as discussed in Chapter 5. The detailed structure of this perspective is shown in Figure 7.6 with five modules used to evaluate the respective competitive priorities.

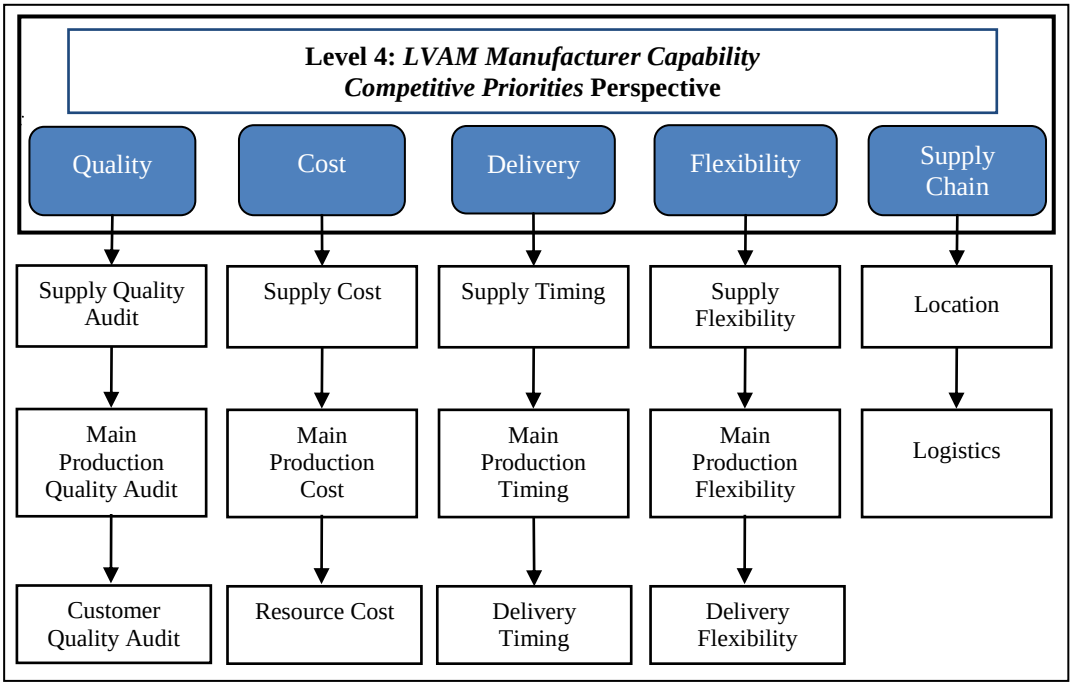

Figure 7.6: Detailed structure of KBLVAM- Level 4

Each of these modules consists of sub-modules that are related to supplier, manufacturer's main production, and customer. For *Supply-Chain* module, *Location* and *Logistics* are the main focus of the KB System evaluation. The activities related to these sub-modules are described and explained in the corresponding sections.

7.3.1 *Quality* Module

Quality is the first module in LVAM Manufacturer Capability – *Competitive Priority* Perspective, developed in the KBLVAM to assess the quality from upstream to downstream of the low volume automotive manufacturing processes. In order to produce a high quality car model to market, the manufacturer needs to have clear quality procedures for incoming parts supply, main line production and delivery of the finished car. The quality of parts supplies needs to be monitored and controlled by the manufacturer especially when related to specifications and standards. The

quality teams also play an important role in the main line production and delivery point. The KB System ensures the quality of the cars is controlled in order to meet customer satisfaction. The related sub-modules that are studied involve *Supply Quality Audit*, *Main Production Quality Audit* and *Customer Quality Audit*. The flowchart of this module is shown in Figure 7.7.

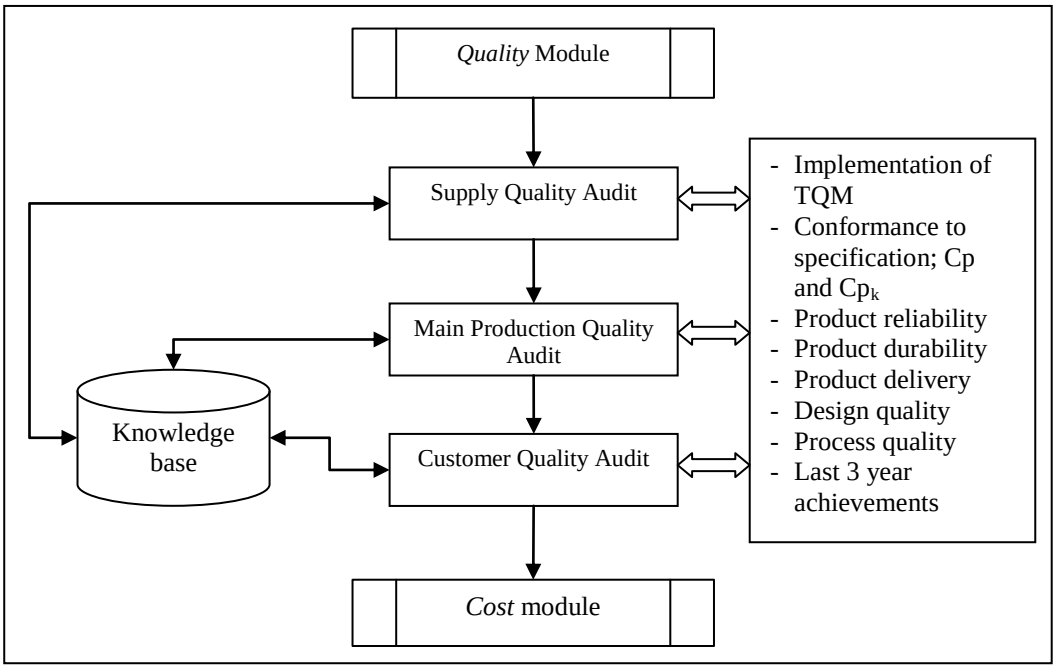

Figure 7.7: Flowchart of *Competitive Priorities* - *Quality* module

It is important that quality concerns for LVAM are identified at the source of the problems and try to eliminate them by using quality concepts such as Advance Product Quality Planning (APQP). The strategy involves a cross-functional team which focuses on up-front quality planning, customer's satisfaction and continuous improvement and being practiced by General Motors, Ford and Chrysler as part of their TS16949 certification standard (Sroufe and Curkovic, 2008). APQP stresses that the counter-measures to the current problems are compiled, so that similar problems can be avoided in the future models and to help early identification of required changes (Bobrek and Sokovic, 2005). As a result, the APQP strategy will

avoid late design changes and provide a quality product on time at the lowest cost. Below are some of the examples of rules that related to *Quality* module:

IF *the management team considered TQM is important and to be implemented in LVAM* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the management team committed to improve the level of customer satisfaction in LVAM environment* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the management team prioritised the necessary resources to implement TQM in LVAM* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the management team and all employees mutually shared the same vision of fulfilling TQM implementation in LVAM* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the management team established clear visionary goals for TQM realisation in LVAM* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the management team strategised a comprehensive implementation plan for TQM in LVAM* (**Yes**: GP; **No**: BP, **PC-2**)
AND *the management team ensured a clear definition of TQM in LVAM shared among all employees involved* (**Yes**: GP; **No**: BP, **PC-3**)
THEN *the management team has developed necessary programs to ensure the TQM is applied successfully in LVAM*
OR *the implementation of TQM is poor and requires management team full commitment to ensure TQM is implemented properly in LVAM environment.*

Based on these rules, it is essential that the management team of the LVAM manufacturer is committed to implement TQM in accomplishing LVAM. Hence, in the KBLVAM, the lack of commitment from the management team to improve such as the level of customer satisfaction, prioritise resources, and share mutual vision with all employees, indicate that the manufacturer has serious problems in the *Quality* module.

7.3.2 *Cost* Module

In this module, the KB System assesses the manufacturer's concern on LVAM competitive priorities in terms of cost. It is very important for the LVAM manufacturer to monitor costs for all processes from supply to the finish line (Kim, 2003). Cost controls will make sure the manufacturers to maximise profit from their car models. Three criteria are considered in this module; *Supply Cost*, *Main Production Cost*, and *Resources Cost.*

This module assesses the manufacturer's concern on LVAM Manufacturer Capability - *Competitive Priorities* in terms of cost as shown in Figure 7.8

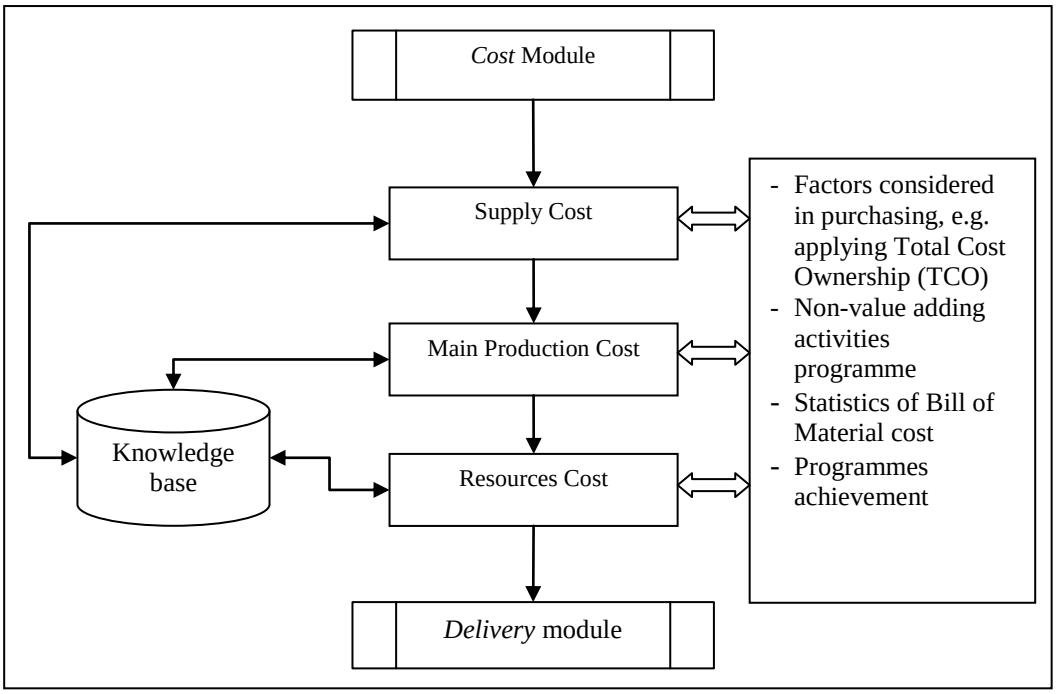

Figure 7.8: Flowchart of *Competitive Priorities* - *Cost* module

In order to maximise profit, manufacturing activities such as LVAM need to have a proper cost control from the purchasing of the material, in-house production, and until the delivery of the cars to customers. The cost of producing LVAM body parts from raw material, stampings, and assemblies must be tracked so that non-value adding activities are minimised. There are three criteria considered in this module; *Supply Cost*, *Main Production Cost*, and *Resources Cost*. The example of a rule – base that implemented for *Main Production Cost* in this module is briefly shown as follows.

IF *the manufacturer emphasises to reduce non value adding activities in production* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer emphasises to improve value adding activities in production* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer develops Bill of Material cost to help control costs and boost cash inflow* (**Yes**: GP; **No:** BP**, PC-2**)
AND *the manufacturer has a dedicated department such as Cost Management Unit* (**Yes**: GP; **No:** BP**, PC-5**)

AND *the manufacturer's Cost Management Unit calculate each LVAM car parts to make sure it make profit* (**Yes**: GP; **No**: BP, **PC-2**)
AND *the manufacturer considers maintenance cost for dies/moulds* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers maintenance cost for assembly jigs* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers maintenance cost for hemming machines* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers cost for safety (Personal Protective Equipment)* (**Yes**: GP; **No**: BP, **PC-2**)
THEN *the manufacturer achievement in assessing the competitive priority of main production cost is good*
OR *the manufacturer needs to review the competitive priority of main production cost to identify the problem*

In this module, LVAM focuses the importance of reducing the non-value adding activities. The KBLVAM ascertains whether the manufacturer has reduced non-value adding and improved value adding activities in the LVAM's car body parts manufacturing. The System categorises it as a very serious problem of PC-1 if there is no emphasis to these activities. In addition, the KBLVAM also considers that the Bill of Material cost is measured in ensuring the manufacturer could make a profit. The absence of this activity is also considered as a serious problem of PC-2. Finally, the KBLVAM will conclude that the manufacturer achievement in assessing the *Cost* module is good if all the above rules are satisfied by the user's feedback.

7.3.3 *Delivery* Module

Timing for each activity is very important in LVAM because it involves three different levels. In this module, KB System assesses the timing that involves suppliers, manufacturer's main production, and delivery to customers. The sub-modules that relate to this module are *Supply Timing*, *Main Production Timing*, and *Delivery Timing.* This module will assess each level based on the punctuality of system towards LVAM implementation. The corresponding flowchart of this process in the KBLVAM System is shown in Figure 7.9.

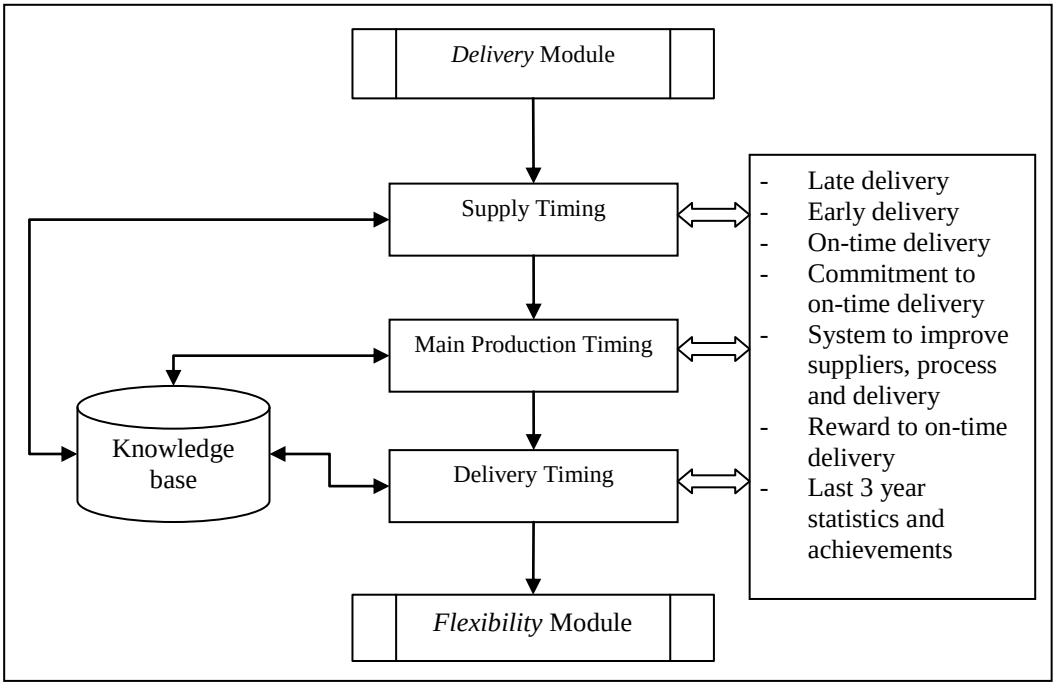

Figure 7.9: Flowchart of *Competitive Priorities - Time* module

In order to assess the time from the upstream to downstream of the LVAM cycle, three levels that correspond to the time are evaluated, and these are *Supply*, *Main Production* and *Delivery*. For every sub-module, there are three factors of time to be considered in this module; on-time, late, and early. The rules are used to deduce the data from the user in assessing aspects such as the importance of timely delivery, rewards and commitment of the manufacturer (Kost and Zdanowicz, 2005). An example of a rule - base implemented in this module to deduce the achievement in *Delivery Timing* is shown in the following section.

IF *the manufacturer emphasises the importance of on-time delivery to meet your customers' requirement* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer has been penalised by the customers for late delivery* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer has a system to eliminate or avoid late delivery to the customers* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer has been rewarded from the customers for on-time delivery* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer has a system to adjust the early delivery to the customers* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the average number of on-time delivery from your company to customers for last year is < 80%* (**Yes**: BP, **PC-1**)
THEN *the manufacturer achievements in the on-time delivery is good and capable to improve competitiveness*

OR *the manufacturer needs to review its achievement in the delivery timing to customers for further improvement*

Based on these rules, it can be seen that the LVAM manufacturer needs to emphasise the importance of on-time delivery to the customers. The absence of commitment to deliver the customers on-time is considered as a serious problem. For example, in the above rules, KBLVAM categorises it as PC-1 if the manufacturer has no proper system to improve the delivery to customers, then they have problems with late delivery.

7.3.4 *Flexibility* Module

Flexibility in manufacturing is another *Competitive Priorities* that need to be evaluated. The flowchart of this process in the KBLVAM System is shown in Figure 7.10.

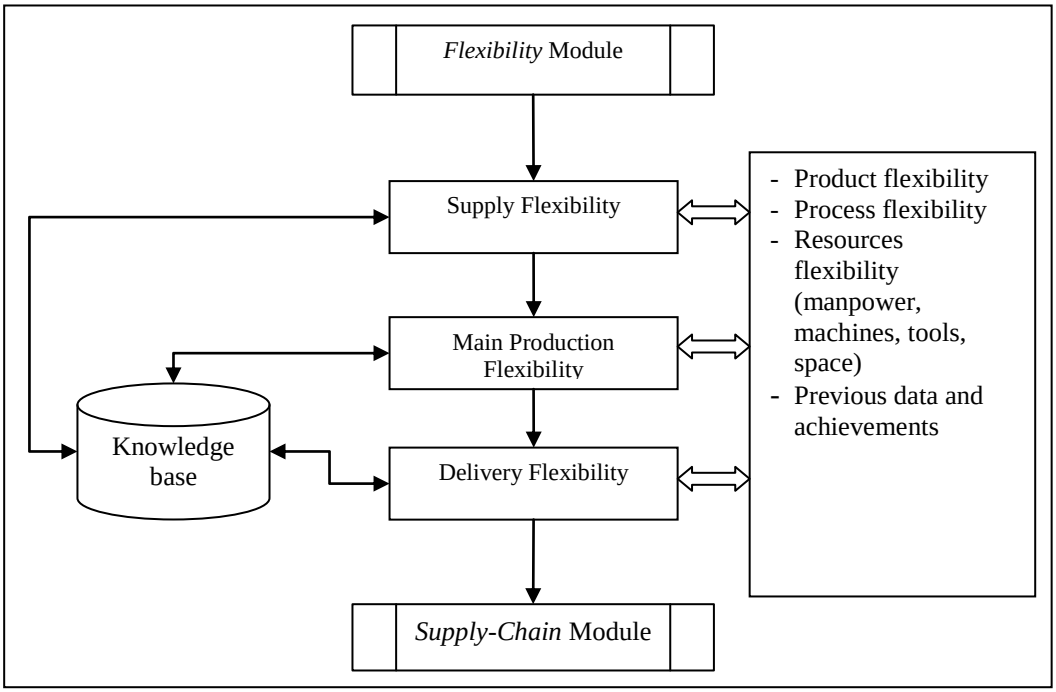

Figure 7.10: Flowchart of *Competitive Priorities* - *Flexibility* module

In LVAM environment, flexibility plays an important role as it is the ability of the manufacturer to cope with the demand changes from suppliers, in-house manufacturing, and customers in order to avoid inefficiencies (Cagliano et al., 2004). For these reasons, three areas that correspond to dimensions of flexibility are assessed by the KB System, and these are *Flexibility in Supply*, *Flexibility in Main Production* and *Flexibility in Delivery.* An example of a rule - base implemented in this module is briefly shown as follows:

IF *the manufacturer stresses the importance of LVAM model flexibility to the suppliers* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the suppliers flexible enough to meet your LVAM model requirement* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer stresses the importance of production flexibility to the suppliers* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer has a collaborative programme with the suppliers to improve their LVAM's model flexibility* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer has a collaborative programme with the suppliers to improve their resources flexibility* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the suppliers can cope with flexible production hours to meet your urgent delivery* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the suppliers can cope with flexible delivery hours to meet your urgent delivery* (**Yes**: GP; **No:** BP**, PC-1**)
THEN *the manufacturer's achievements in assessing the competitive priority flexibility perspective module is good*
OR *the manufacturer's needs to review the competitive priority flexibility to identify the problem*

From the above rules, it can be seen that the KBLVAM categorises it as a very serious problem of PC-1, if the manufacturer ignores the importance of the LVAM model requirement, production, and engineering changes flexibilities within the manufacturer and also to the suppliers. Furthermore, the collaborative programme designed for manufacturer and suppliers is vital in order to improve these flexibilities.

The flexibility requirements are inter-related between suppliers, manufacturer and customers. These three parties must be flexible enough to meet each other's demands and order changes with short notice. The absence of any of these

requirements shows that the flexibility level is below the standard to achieve LVAM and considered as a very serious problem of PC-1.

7.3.5 *Supply Chain* Module

In this module, KB System assesses the manufacturer's concern on LVAM Manufacturing Competitive Priorities in terms of supply chain. The strategic location of LVAM's suppliers and customers is very essential in order to manage the supply chain and cost associated with it. Efficient logistics planning play important roles in improving the LVAM supply chain, which include warehousing, shipping and transportation (Sturgeon et al., 2008). These two criteria *Location* and *Logistics* are considered in this module and shown in Figure 7.11.

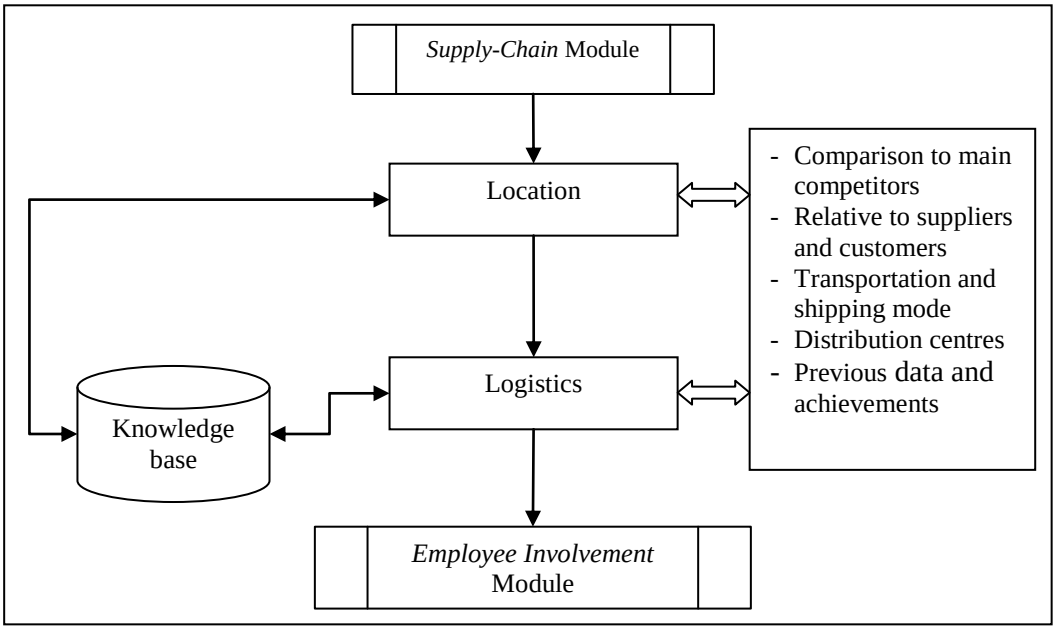

Figure 7.11: Flowchart of *Competitive Priorities Supply Chain* module

The example of a rule – base that implemented in this module is briefly shown as follows:

IF *the manufacturer emphasises the importance of good supply-chain to your suppliers* (**Yes**: GP; **No:** BP**, PC-1**)

AND *the manufacturer emphasises on supplier park to allow for competitive price* (**Yes**: GP; **No:** BP**, PC-3**)
AND *the manufacturer emphasises on synchronise delivery in consideration for location* (**Yes**: GP; **No:** BP**, PC-1**)
AND *the manufacturer considers distance in selecting your suppliers* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers geographical environment in selecting your suppliers* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers political issues in selecting the location of your suppliers* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers legal issues in selecting the location of your suppliers* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers regulatory environment issues in selecting the location of your suppliers* (**Yes**: GP; **No**: BP, **PC-1**)
AND *the manufacturer considers economic environment (e.g currency) issues in selecting the location of your suppliers* (**Yes**: GP; **No**: BP, **PC-1**)
THEN *the manufacturer's achievements in assessing the competitive priority of location and logistics is good*
OR *the manufacturer's needs to review the competitive priority of location and logistics to identify the problem*

Based on the above rules, the KBLVAM identifies the supply-chain effectiveness of the manufacturer in term of location and logistics. For example, if the manufacturer emphasises on the key suppliers to be in the supplier park to allow for competitive price, then, the KB System categorises these as *Good Point*s (GP). Otherwise, they are considered as a major problem of PC-3. It is also important that the manufacturer ensures that suppliers are able to perform synchronise delivery in consideration for location, distance, and geographical environment in selecting the suppliers. Failure to follow these requirements will result in serious problems of PC-1. Apart from the location, the related issues of political stability, legal, and environment are also essential aspects to be considered in this module.

7.4 Level 5 – *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 7.12.

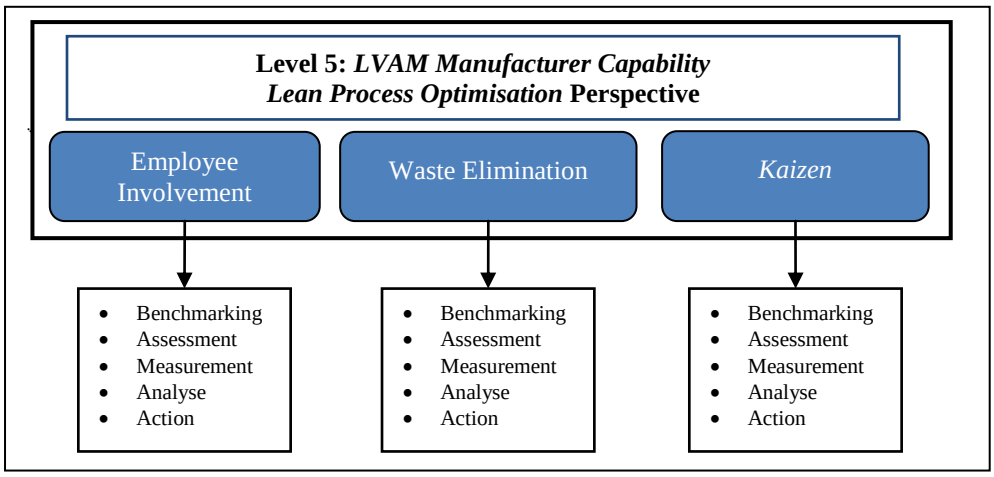

Figure 7.12: LVAM manufacturer capability – *Lean Process Optimisation* perspective

The implementation levels of these lean processes are identified by the KB System on how the LVAM manufacturer benchmarks, assesses, measures, analyses and plans an action to these three optimisation processes as shown in Table 7.1.

Table 7.1: *Lean Process Optimisation* 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

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 a series of KB questions that are particularly related to lean processes for LVAM manufacturer.

In *Lean Process Optimisation* Perspective, although the modules are parallel activities (see Figure 7.12), the KBLVAM System is designed to start the questions in a 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.

7.4.1 *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. The process flow of the *Employee Involvement* module is shown in Figure 7.13. The *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 the costs they incur, such as wages and rent, however many are unaware of the hidden costs associated with under-performing staff. Manufacturer's efforts 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 a 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.

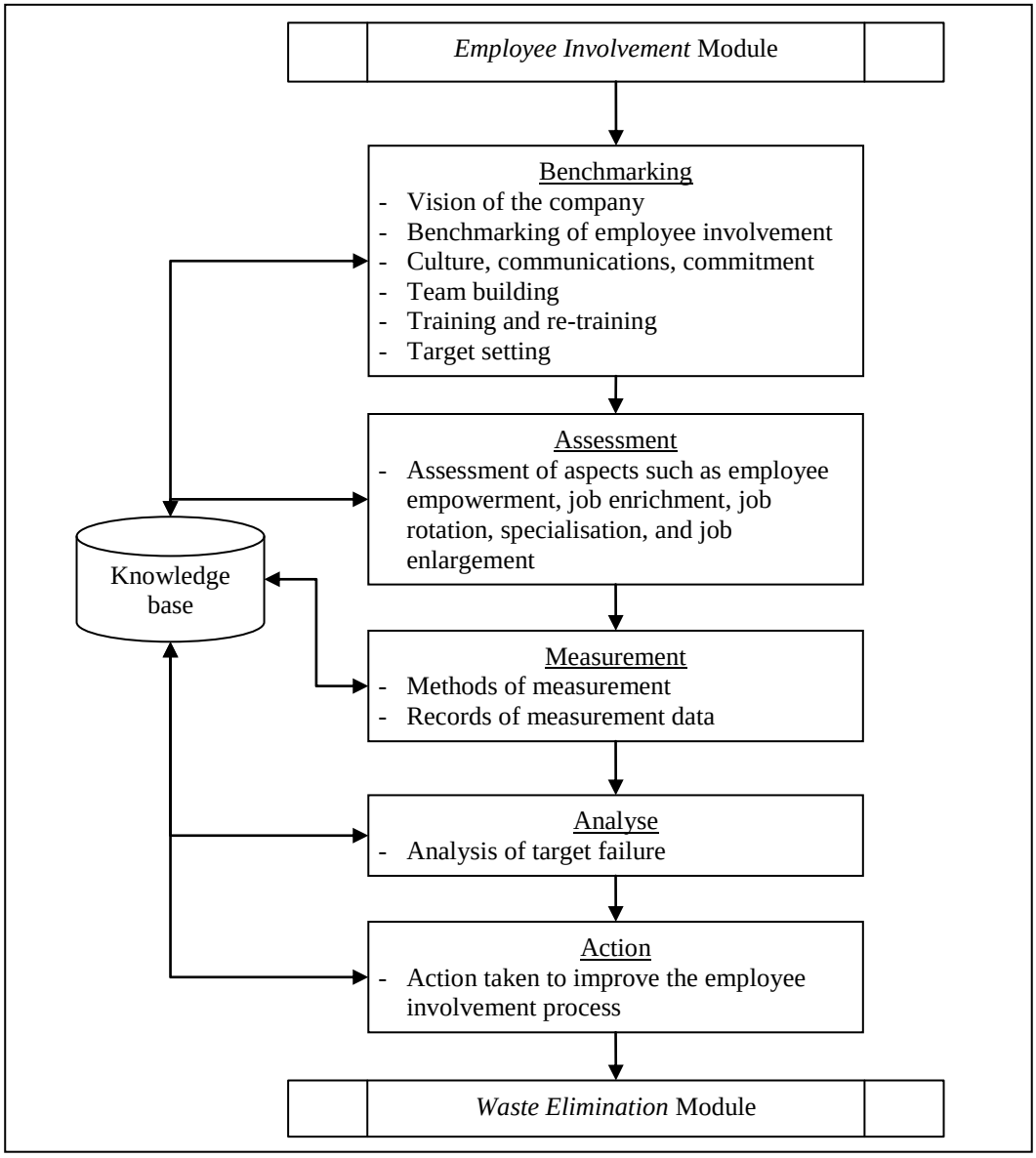

Figure 7.13: Flowchart of *Employee Involvement* module

Good communications in the manufacturing environment play an enormous role in the manufacturer's success. Communications between 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 a 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 the *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. Given below are brief examples of KB rules that relate to the *Employee Involvement* module:

IF *the LVAM manufacturer has identified the vision and benchmark for the employee involvement* (**Yes**: GP; **No**: BP, **PC-1**)
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. The 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 in 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 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 to 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 of the overall manufacturing processes.

7.4.2 *Waste Elimination* Module

In this module, the KB System 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 7.14. 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. A lean manufacturing process has identified the following seven wastes: waste from

over production, waste of waiting time, transportation waste, processing waste, the waste of motion, waste from product defects and inventory waste (Holweg, 2007).

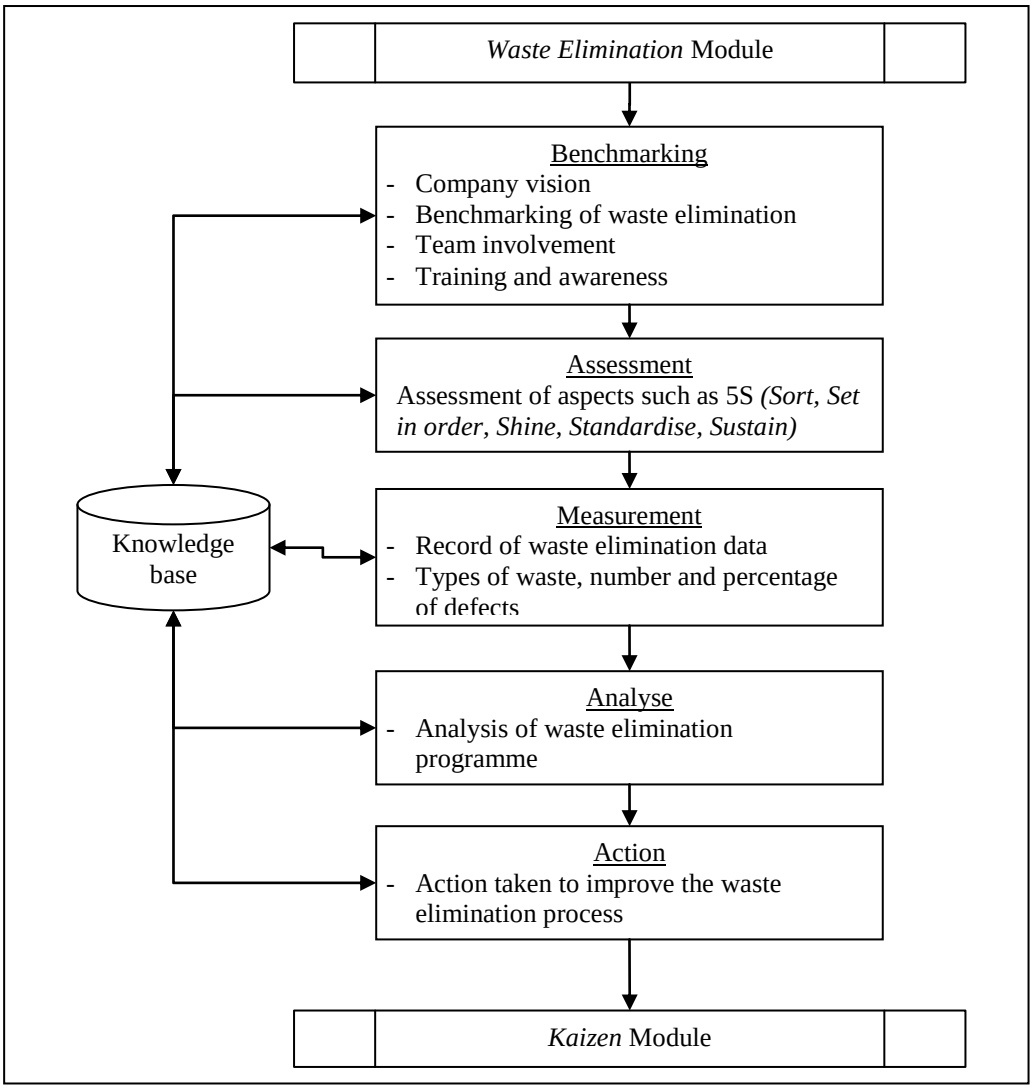

Figure 7.14: Flowchart of *Waste Elimination* module

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.

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 consistently analyses the waste elimination process* (**Yes**: GP; **No**: BP, **PC-1**)
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*

Based on 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 waste; failure to have these elements in place will result in PC-1.

The manufacturer also needs to have records of the waste elimination process such as number of defects and overproduction, which need to be reduced. Furthermore, questions about the analysis of the 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.

7.4.3 *Kaizen (continuous improvement)* Module

The *Kaizen* module is developed by the KB System to assess the current status of manufacturer's commitment to continuously improve the manufacturing culture in achieving LVAM. The process flow of *Kaizen* module is shown in Figure 7.15. 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 of a manufacturer, in order for them to perform better each day (Herron and Hicks, 2008). 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 on-going 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 the 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.

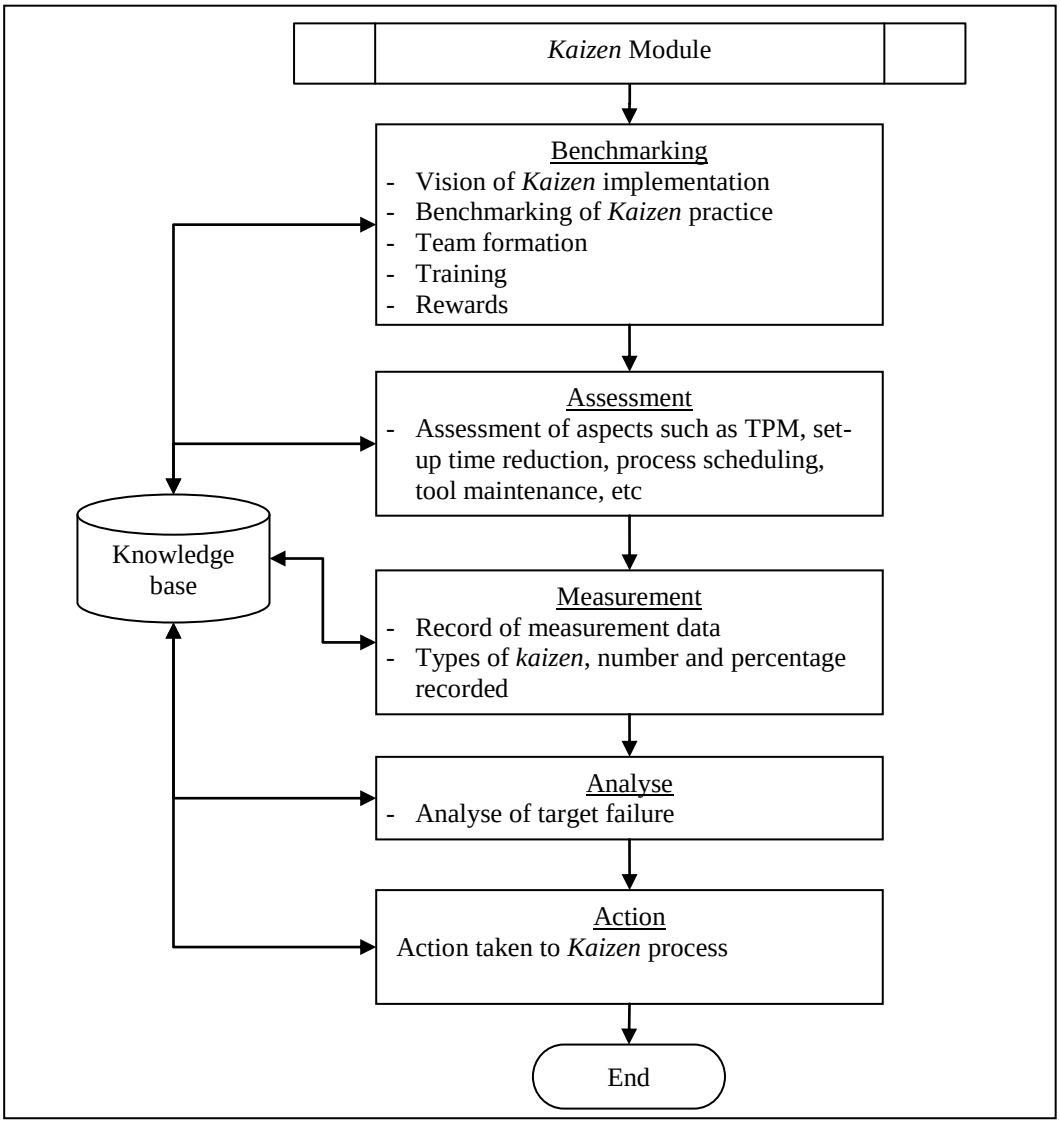

Figure 7.15: Flowchart of *Kaizen* module

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 of 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**)
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 of 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 in 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 a very serious problem of PC-1. Finally the KB System will assess how the LVAM manufacturer analyses the *Kaizen* process and takes action to continuously improve the operations.

7.5 Summary

This chapter described in detail the development of Stage 2 in the Knowledge Based Low Volume Automotive Manufacturing (KBLVAM) System. The Stage 2 development was based on the KBLVAM System structure as shown in Figure 7.1. There were three levels of the KBLVAM System structure, which started with Level 3 – *LVAM Manufacturer Capability – Car Body Parts Manufacturing* Perspective, Level 4 - *LVAM Manufacturer Capability – Competitive* Perspective, and Level 5 - *LVAM Manufacturer Capability – Lean Process Optimisation* Perspective.

In Level 3, the *LVAM Manufacturer Capability – Car Body Parts Manufacturing* Perspective, which consisted of three modules of strategic car body manufacturing process for LVAM, was discussed. Three modules involved were *Car Body Design Development, Car Body Parts Manufacturing Process* and *Car Body Assembly Process*. The assessment of these modules was based on several strategic aspects such as *Car Body Design Concept*, *Conceptual Design Analysis*, and *Car Body Design Development Assessment*; *Design of Dies & Checking Fixtures* and *Design of Manufacturing Process*; *Design of Assembly Tools* and *Design of Assembly Process.*

In Level 4, the *LVAM Manufacturers Capability – Competitive* Perspective, five modules were assessed, the *Quality, Cost, Delivery, Flexibility*, and *Supply-Chain*. There were three sub-modules in the *Quality* module, which were *Supply*

Quality Audit, *Main Production Quality Audit* and *Customer Quality Audit*; in the *Cost* module there were *Supply Cost*, *Main Production Cost*, and *Customer Cost*. For the *Delivery* module, there were sub-modules *Supply Timing*, *Main Production Timing*, and *Delivery Timing*; in the *Flexibility* module, there were three sub-modules, *Supply Flexibility*, *Main Production Flexibility*, and *Customer Flexibility*; whereas for *Supply-Chain* module, *Location* and *Logistics* were the sub-modules involved.

Finally, in Level 5, the *LVAM Manufacturer Capability – Lean Process Optimisation* Perspective, the *Employee Involvement* was the first module used to identify the level of employee involvement programmes in the manufacturer. The second module was the *Waste Elimination* which was 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 was *Kaizen*, which was used to gauge the level of continuous improvement 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.

Chapter 7 has discussed the detailed Stage 2 development of the KBLVAM System, which consists of Levels 3, 4 and 5. The following Chapter 8 will discuss the verification and validation of the KBLVAM model through the industrial and published case data.