CHAPTER 5

DEVELOPMENT OF KNOWLEDGE-BASED COLLABORATIVE LEAN MANUFACTURING MANAGEMENT (KBCLMM) MODEL: STAGE 1 (PLANNING)

5.0 Introduction

This chapter focuses on the detailed development of the KBCLMM Model for the Stage 1 as shown in Figure 5.1. It explains all levels and perspectives of the model based on the structure of the KBCLMM System as described in Chapter 4. All components and elements are referred as modules and sub-modules as developed in the KBCLMM System.

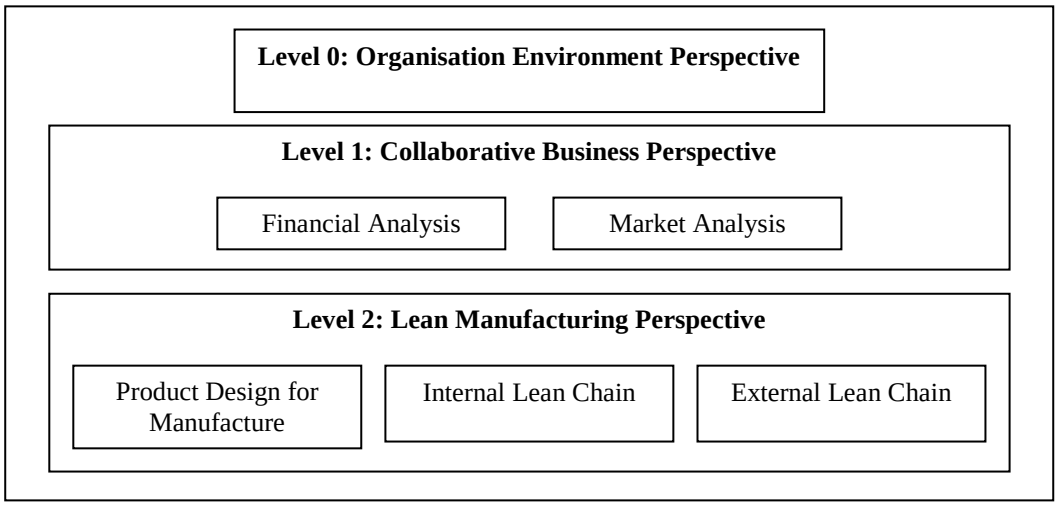

Figure 5.1: Structure of KBCLMM System – Stage 1

This discussion covers the details contained within modules, including the production rules and process flow of the system. Each of the perspectives will be described in Sections 5.2, 5.3 and 5.4 according to their corresponding

level in the structure of the KBCLMM System. Prior to this, the mechanism of KBCLMM will be discussed in the following section.

5.1 Mechanism of KBCLMM

The assessment of organisation performance in the KBCLMM System is conducted through a series of questions that measure both qualitative and quantitative information on the current situation of organisation in each level through a Gauging Absences of Pre-requisites (GAP) analysis that is embedded in the system. The Analytic Hierarchy Process (AHP) is then implemented to determine the priorities and identify factors from every perspective for improvement purposes towards KBCLMM development. Prior to that, the knowledge elicitation and production rules' construction will be discussed.

5.1.1 Knowledge Acquisition and Production Rules Construction

In the developing KBCLMM, most of the knowledge was acquired from the published materials as reviewed in Chapters 2 and 4, and from the discussions and interviews with domain experts, especially the academic supervisors. Knowledge, data and information found in these materials and discussions were then interpreted into the production rules structure. The knowledge engineer, i.e. the researcher then presented the prototype rules to the domain experts, as part of initial verification and refinement. The processes of rules' construction, modification, verification and refinement were repeated several times until the rules achieved the domain experts' satisfaction in terms of consistency, accuracy, reliability, and validity.

5.1.2 Interactive Questions

A series of interactive questions are developed for users to answer in a stepwise manner. All questions were written in simple clear English sentences, to prevent the user from misunderstanding the issues of the questions. In addition, to enhance the user-interface capability, a good combination of background and foreground colour is used to make the question windows looks interesting. Based on the user responses and question issues, those questions may have sub-questions in the sub-windows.

5.1.3 Explanation Facility

Even though all questions are phrased as unambiguously as possible to avoid misinterpretation, certain questions may include terminology the user may not readily understand or be familiar with. This could lead to an incorrect answer and would finally affect the advice given by the system. There are many techniques which have been developed for handling these kinds of uncertainty in the rule-base which include Fuzzy Logic (as discussed in Chapter 3) and Bayesian Inference [Darlington (1997), Swinburne (2002)].

However in this research, the uncertainty is overcome by an *explanation facility* built in the system. The *explanation facility* in essence, contains additional knowledge base to overcome uncertainty. Through the *explanation facility* in KBCLMM, additional knowledge is given if the user needs further clarification on any particular question. This explanation ensures the user fully understands the issues of the question, the consequences from the issues, and to avoid uncertainty in answering the questions. The explanation also provides an indication of good practice that should be implemented in the organisation.

Figure 5.2 shows an example of a question and its explanation facility for *Internal Lean Chain* module if the KBCLMM user clicks the *Explanation* toolbar.

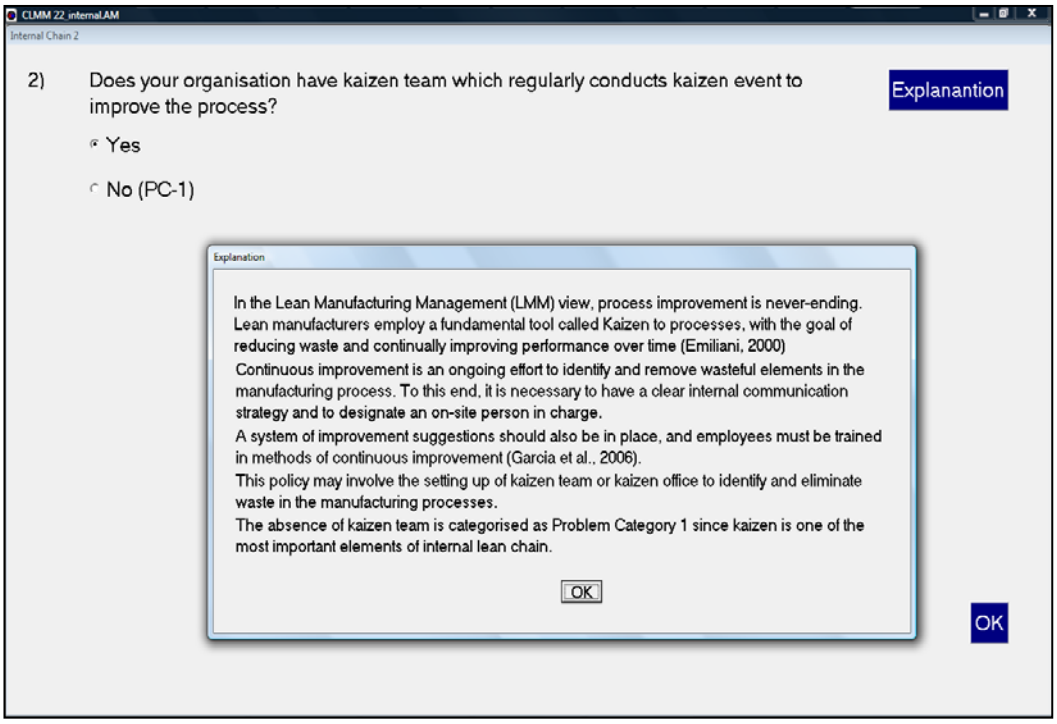

Figure 5.2: An Illustration of Question with *Explanation Facility* Contained within KBCLMM

5.1.4 Facility Answer

Depending on the content and context, a question can be answered with graphical user interface (GUI) controls (widgets) such as *check box*, *toggle button*, *radio button* (to answer *Yes*, *No*, *Do not know*, etc), or a number (percentage, range of number or scales) response. During interactive mode, the possible responses are displayed and the user is asked to enter the correct response.

5.1.5 Inference Mechanism and Search Strategies

Chapter 3 has explored the inference mechanism which includes forward and backward chaining. The AM for Windows shell support both types of chaining. However in the KBCLMM development, due to the nature of the KBCLMM which gather data and information from interviews and published reports, forward chaining approach was used to control the inference mechanism and draw conclusion.

An example of the forward chaining approach in the production rules of the *Internal Waste Elimination* sub-module is shown below.

IF *the organisation continuously attempts to reduce overproduction*
AND *the organisation continuously attempts to reduce transportation times*
AND *the organisation continuously attempts to reduce part waiting times*
AND *the organisation continuously attempts to reduce inventories*
AND *the organisation continuously attempts to reduce worker motion*
AND *the organisation continuously attempts to reduce over processing*
AND *the organisation continuously attempts to reduce idle time of workers*
THEN *the organisation has commitment to the waste elimination programme*
ELSE *the organisation needs to improve the waste elimination activities*

From the above rules, based on the input data which were tested to the rule-base contained in the KBCLMM and the answer is *Yes* for all questions, the organisation is concluded as having a commitment to the waste elimination programme. If at least one of the answers is *No*, then conclusion is drawn that the organisation needs to improve the waste elimination activities.

5.1.6 GAP Analysis

From the answers given by the user, the computer-based GAP analysis is used to determine the disparity between the essential or desirable pre-requisites and what actually exists in an organisation. This analysis is to identify likely problem areas, which must be addressed by the management if an effective implementation is to be achieved. The problems highlighted for each negative reply is categorised into five problem categories which have been discussed in Chapter 4.

5.1.7 AHP Technique

In order to select the most important improvement initiative, the development of a tool to address both qualitative and quantitative parameters is required. As the GAP Analysis identifies the absences of pre-requisites elements in each module and sub-module, AHP prioritises what module or sub-module to focus for action and improvement. The application of the AHP not only provides the quantitative tool to weight the criteria of each module, but also confirms the correctness and integrity of the comparison of the factors made by the user [Khan and Wibisono (2008)].

As discussed in Chapter 3, AHP has been applied to several decision problems that relate to POM, particularly in the production control [Sharma and Agrawal (2008)], plant batch design [Aguilar-Lasserre *et. al.* (2008)], and supply chain [Udin (2004), Rabelo *et. al.* (2007)]. However, to the researcher's knowledge so far, there is no such application of the AHP either for development or implementation of collaborative LMM.

Referring to the structure of KBCLMM System, as illustrated in (Chapter 4), the AHP pair-wise comparisons start from the Level 2. In Level 2 for example, the AHP decides which one of these alternatives (*Product Design for Manufacture*, *Internal Lean Chain*, and *External Lean Chain*) should be in priority of improvement to increase organisation competitiveness for collaborative business perspective. To illustrate this, the AHP structure for Level 2 of *Lean Manufacturing Perspective* is shown in the Figure 5.3.

Based on Figure 5.3, Layer 1 is the focus which sets the objective of the structure, which is to prioritise and select the most needed improvement program for the *Lean Manufacturing Perspective* activities. Layer 2 of the hierarchy consists of *Quality*, *Time*, *Flexibility*, *Value* and *Supply Chain* which are the factors or criteria that influence the selection of the improvement programs. Finally in Layer 3, there are alternatives that should be prioritised and improved within the organisation to reflect the readiness of the organisation to implement the improvement programs for *Lean Manufacturing Perspective*. This layer consists of *Product Design for Manufacture*, *Internal Lean Chain*, and *External Lean Chain*.

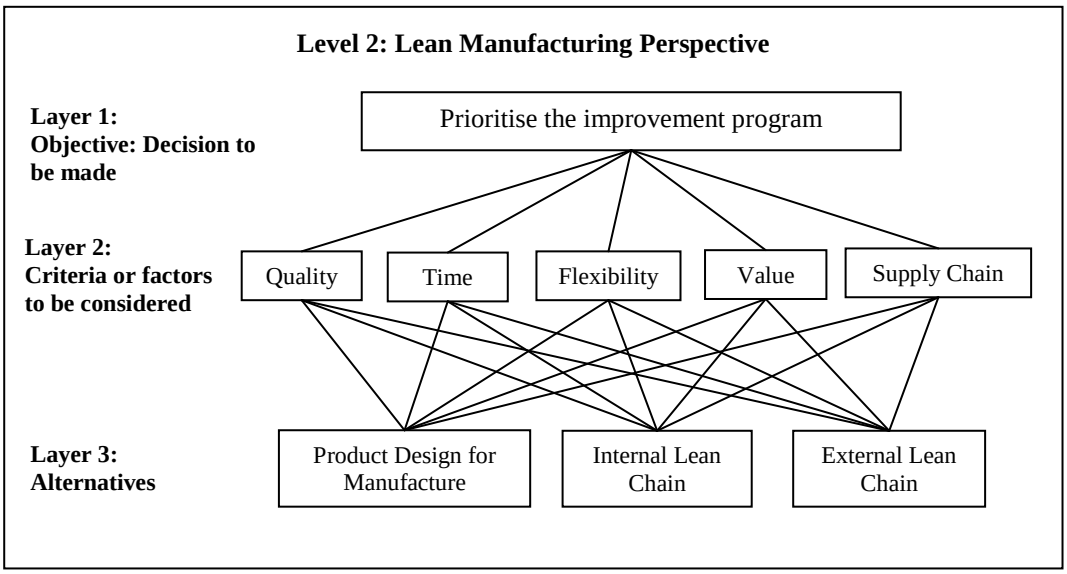

Figure 5.3: The AHP Structure for *Lean Manufacturing Perspective* of KBCLMM

The needs for these alternatives are assessed based on the criteria in Layer 2 through series of questions in KBCLMM, and the data for these comparisons are transferred directly from the process of GAP Analysis embedded in the KBCLMM System. The transferred process of scale from GAP Analysis to AHP Technique is described in detail in Chapter 3 and Appendix C.

5.2 Level 0 - Organisation Environment Perspective

The *Organisation Environment Perspective* is the first module used to gather the information that relates to general information and background of the organisation. The function of this module is to understand and identify the existing condition of the organisation and its environment.

Figure 5.4 shows the process flowchart of this module. The module consists of a series of questions that relate to organisation general information which include age of the organisation, number of employees, number of suppliers and customers, and collaborative lean manufacturing management investment activities.

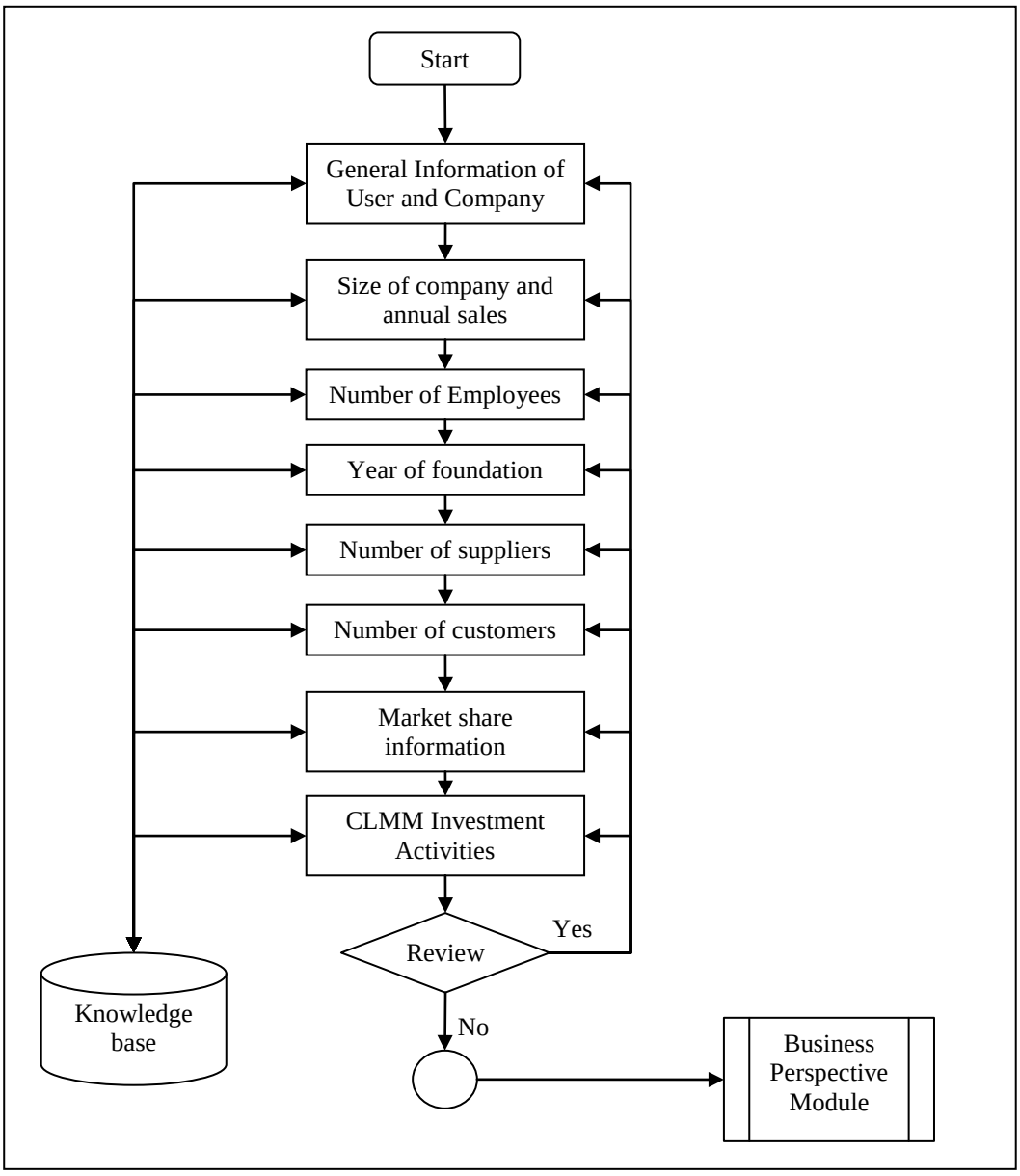

Figure 5.4: Flowchart of *Organisation Environment Perspective* Module

This information is gathered through a series of questions retrieved from the knowledge base (KB). The KB also can provide explanation for the questions, should the user need further clarification. From the user responses to the questions, the KB system analyses the answers through a series of knowledge rules, shown below as an example:

IF *the company annual sales turnover is more than £3.68 million*
OR *the number of full time employees is more than 150*
THEN *the company is classified as a large size company*
OR *the company annual sales turnover is between £1.47 million and £3.68 million*

AND *the number of full time employees is 150 or less*
THEN *the company is classified as a medium size company*
OR *the company annual sales turnover is between £36,800 and £1.47 million*
AND *the number of full time employees is at least 5*
THEN *the company is classified as a small size company*
OR *the company is classified as a micro size company*

In this module, users need to input the general information such as name of the user, job designation, and address of the organisation. Then, the users need to input the annual sales and number of employees, which reflect the size of the organisation. The data related to the age of organisation is needed to assess the duration of the organisations competing in the industry. The rest of the questions are related to the number of suppliers and customers, to identify the strength of their relationship and the CLMM investment activities, which could indicate the focus of the organisation towards CLMM. An example of user responses is shown in Table 5.1.

Table 5.1: Example of User Responses in *Organisation Environment Perspective* Module

Variables Description	**Data**		
Name of user (the interviewee)	Zulkifli Abu Hassan		
Post	Head of Department		
Department	Dies Engineering		
Organisation	PHN Industry Sdn. Bhd.		
Address of Organisation	Lot PT 75-77, Jalan 26/6, Kawasan Perindustrian HICOM, Seksyen 26, 40710 Shah Alam, Selangor Darul Ehsan.		
Annual Sales	> £3.68 million		
Number of Employees	> 150		
Position in Automotive Industry	1st tier supplier		
Products	Dies		
Age of Organisation	17 years (1991)		
	Age of Relationship		
	< 5 years	**5 – 10 years**	**> 10 years**
Number of Suppliers	8	10	15
Number of Customers	0	0	4
	Last Year	**2 Years Ago**	**3 Years Ago**
CLMM Investment Activities:			
Just-In-Time (JIT)	Yes	Yes	No
Manufacturing Resources Planning (MRP II)	Yes	Yes	No
Total Quality Management (TQM)	Yes	Yes	No

Based on the data shown in the table, the KB-system rules classifies the organisation depending on the variables that are already defined, such as position in automotive industry, products manufactured, size of organisations, and CLMM investment activities.

The use of rules is not only a core of the KB system, but could also support in simplifying and improving the process involved in producing the results. An example of rules used in classifying the organisation in this module is shown below.

IF *the age of organisation is more than 15 years*
AND *the relationship with most of the suppliers is more than 10 years*
AND *the relationship with most of the customers is more than 10 years*
AND *in the last 2 years, the organisation continuously invested in improving JIT system*
AND *in the last 2 years, the organisation continuously invested in improving MRPII system*
AND *in the last 2 years, the organisation continuously invested in enhancing TQM*
THEN *the organisation is classified as in the harvest stage of the business cycle*
AND *the organisation has good relationship with suppliers*
AND *the organisation has good relationship with customers*
AND *the organisation has focused its investment in CLMM in the last 2 years*

The KBCLMM uses its inference engine to process the information given and deduce the results, e.g. the organisation is in harvest stage of business cycle [Kaplan and Norton (1996)] based on its age and the organisation has good relationship with suppliers since most of them are supplying materials to the organisation for more than 10 years. The information gathered in this module is then stored in the KBCLMM and can be loaded to the other modules.

5.3 Level 1 - Collaborative Business Perspective

The *Collaborative Business Perspective* in the Level 1 of KBCLMM System structure consists of two modules, which are *Market Analysis* and *Financial Analysis*. The function of these modules is to ascertain the current

organisation position, which is based on the analysis of market share and financial performance.

The detailed KB structure of this perspective is shown in Figure 5.5 with two modules used to analyse the current financial and market performance.

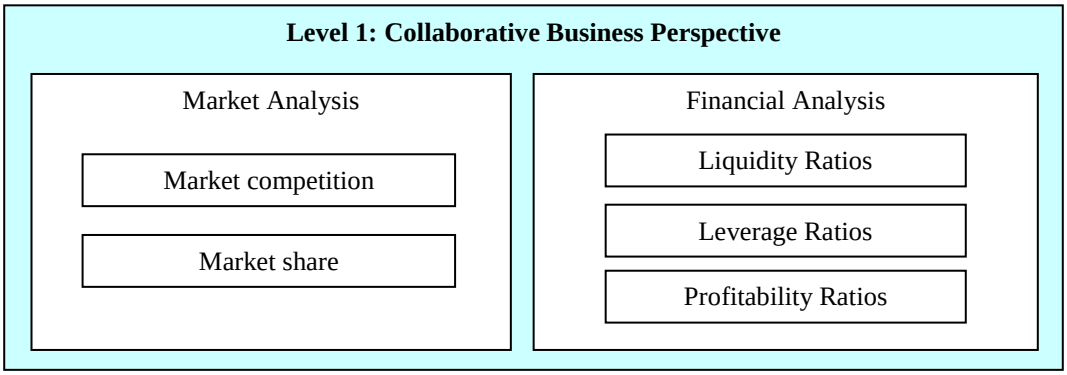

Figure 5.5: *Collaborative Business Perspective*

Each of these modules consists of sub-modules of aspects or activities such as *Market Competition* and *Market Share* in the *Market Analysis* module, and financial ratios such as *Liquidity*, *Leverage*, and *Profitability* in the *Financial Analysis* module. The process begins with the execution of the *Market Analysis* module and followed by the *Financial Analysis* module. Each of these modules is described in the corresponding sections.

5.3.1 Market Analysis Module

In the KBCLMM System, the market analysis is divided into two categories of measurement, *Market Competition* and *Market Share* analysis. In *Market Competition* analysis, the user needs to provide basic data about the number of other similar organisations that compete in the automotive industry. This information covers markets locally, regionally, and globally. Meanwhile,

for *Market Share* analysis, the percentage of business received from customers is used as a market share measurement.

Market Share is the stage of analysing how products win orders in the market place and what the customers demand [Hill (2000)]. It is therefore crucial to measure an organisation's market share relative to its competitors in the current situation. Any organisation that does not have any measurement for its market share is categorised under PC1, based on GAP Analysis Problem Category scales. The flowchart of this module is shown in Figure 5.6.

A typical example of user responses to questions in the *Market Analysis* sub-module is shown in Table 5.2.

Table 5.2 Example of User Responses in *Market Analysis* Module

Main Product: **Passenger Cars**			
Market Competition	**2007**	**2006**	**2005**
Local	5-20 companies	5-20 companies	5-20 companies
Regional	5-20 companies	5-20 companies	5-20 companies
Global	> 20 companies	> 20 companies	> 20 companies
Market Share	**2007**	**2006**	**2005**
Local	30-40%	30-40%	30-40%
Regional	Unknown	Unknown	Unknown
Global	Unknown	Unknown	Unknown

The rules in *Market Analysis* module used for deducing these inputs are listed as follows.

IF *the market competition locally is 5 to 20 companies*
AND *the market competition regionally is 5 to 20 companies*
AND *the market competition globally is more than 20 companies*
AND *its domestic market share 3 years ago is 30% to 40%*
AND *its domestic market share 2 years ago is 30% to 40%*
AND *its domestic market share last year is over 30% to 40%*
AND *its regional market share is unknown* (**Yes**: GP; **No**: BP, **PC1**)
AND *its global market share is unknown* (**Yes**: GP; **No**: BP, **PC1**)
THEN *this organisation has medium competition locally and regionally in the last three years*
AND *this organisation has high competition globally in the last three years*

AND *this organisation has steady domestic market share for in the last three years*
AND *this organisation needs to measure regional and global market share*

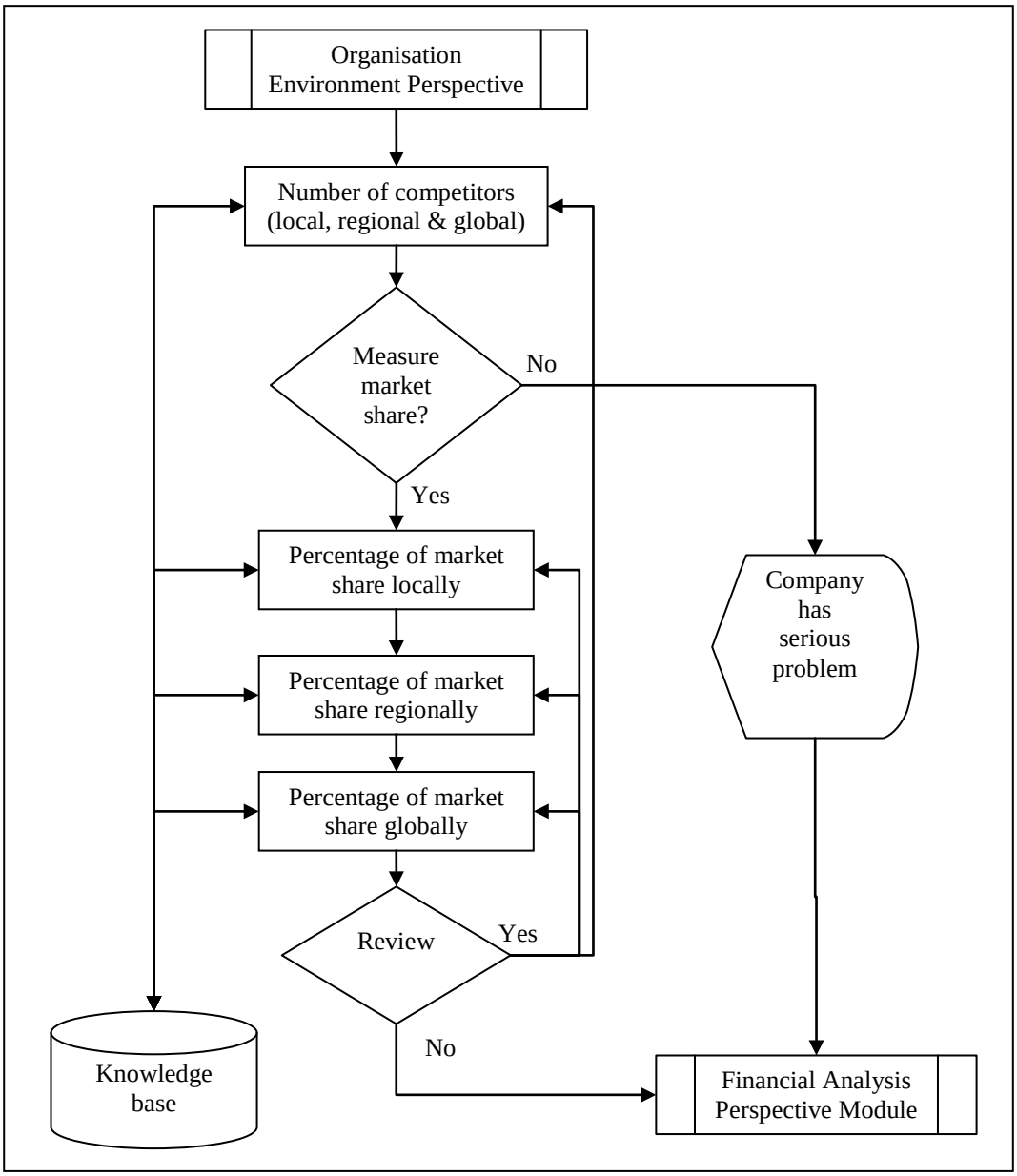

Figure 5.6: Flowchart of *Market Analysis* Module

Based on the user responses in Table 5.2, KBCLMM uses the above rules to classify the position of the organisation in term of market status. In this case, with between 5 and 20 companies in the business, the competition is considered as medium for domestic and regional market. However, it has high competition globally with more 20 companies in this business. Since the organisation did not

measure both regional and global market share, the KBCLMM categorised them as serious problems under PC1. The reason is because market share shows the position of the organisation relative to its competitors, and can be used as strategy to capture more market.

5.3.2 Financial Analysis Module

The *Financial Analysis* module relates to financial information of organisations. This module is based on the *Income Statements*, *Balance Sheet*, and *Cash Flow Statement* data of the organisation. The flowchart of this module is shown in Figure 5.7.

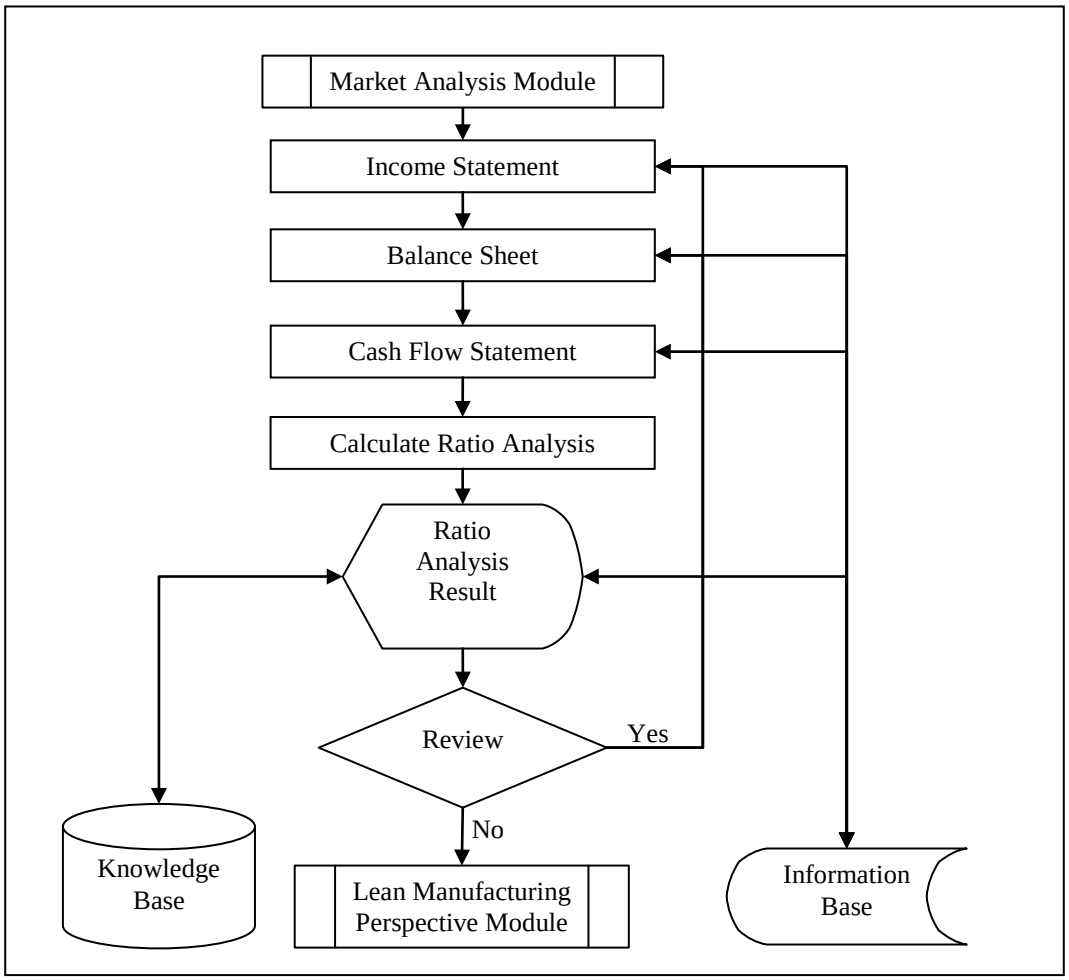

Figure 5.7: Flowchart of *Financial Analysis* Module

This information is used to calculate the organisation financial ratios. The ratios are produced and divided into three financial performance criteria of the organisation to be analysed: *Leverage ratios*, *Liquidity ratios*, and *Profitability ratios*. The *du Pont Model* [Mentzer (2001)] is also integrated to visualise these ratios, as shown in Figure 5.8.

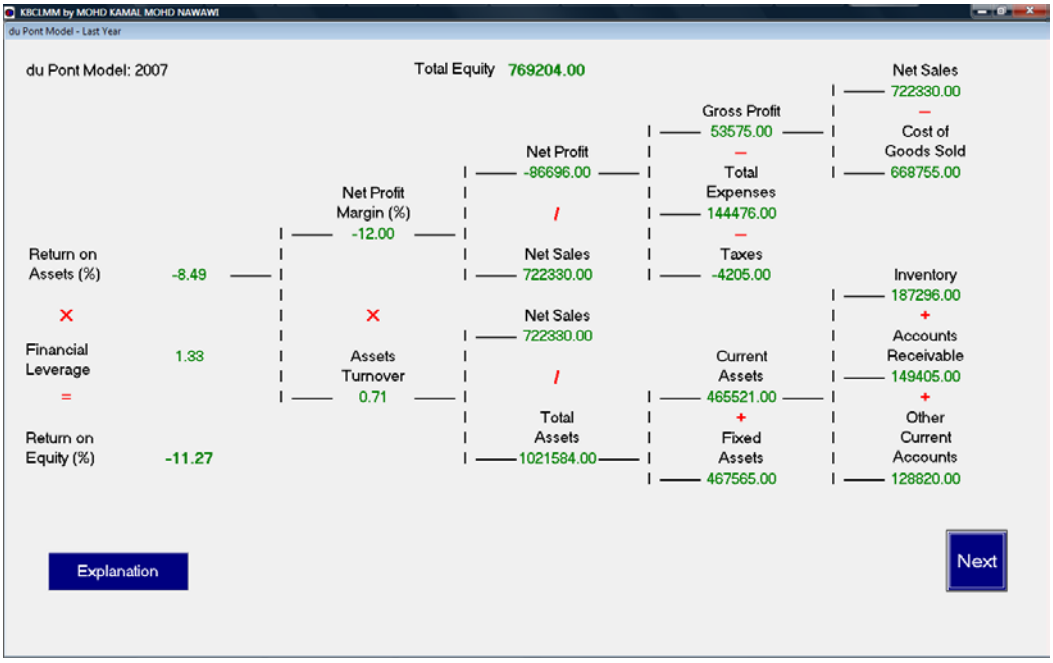

Figure 5.8: An Illustration of duPont Model from KBCLMM (based on Mentzer (2001))

From the organisation's three consecutive year data (2005 to 2007), the KBCLMM uses the rule-base to determine the financial performance of the organisation. The rules example for *Profitability ratio* in the *Financial Analysis* module is listed as follows.

IF *the Net Profit Margin in 2007 > 2006* (**Yes**: GP; **No**: BP, **PC2**)
AND *the Net Profit Margin in 2006 > 2005* (**Yes**: GP; **No**: BP, **PC2**)
AND *the value of Net Profit Margin in 2007 is positive* (**Yes**: GP; **No**: BP, **PC1**)
AND *the value of Net Profit Margin in 2006 is positive* (**Yes**: GP; **No**: BP, **PC1**)
AND *the value of Net Profit Margin in 2005 is positive* (**Yes**: GP; **No**: BP, **PC1**)
AND *the Sales to Total Assets (STA) in 2007 > 2006* (**Yes**: GP; **No**: BP, **PC2**)
AND *the Sales to Total Assets (STA) in 2006 > 2005* (**Yes**: GP; **No**: BP, **PC2**)
AND *the Inventory Turnover (IT) in 2007 > 2006* (**Yes**: GP; **No**: BP, **PC2**)
AND *the Inventory Turnover (IT) in 2006 > 2005* (**Yes**: GP; **No**: BP, **PC2**)
AND *the Return on Total Assets (ROA) in 2007 > 2006* (**Yes**: GP; **No**: BP, **PC2**)
AND *the Return on Total Assets (ROA) in 2006 > 2005* (**Yes**: GP; **No**: BP, **PC2**)

AND *the Return on Equity (ROE) in 2007 > 2006* (**Yes**: GP; **No**: BP, **PC2**)
AND *the Return on Equity (ROE) in 2006 > 2005* (**Yes**: GP; **No**: BP, **PC2**)
THEN *the organisation STA has increased in three consecutive years*
AND *the organisation IT has increased in three consecutive years*
AND *the organisation ROA has increased in three consecutive years*
AND *the organisation ROE has increased in three consecutive years*

From the above rules, it can be seen that for example the KBCLMM categories it as a serious problem if the *Net Profit Margin* for the year is less than the previous year. This case is also the same for other ratios including *Sales to Total Assets*, Inventory Turnover, *Return on Total Assets*, and *Return on Equity*. The System also categorises it as a serious problem of PC1 if the value of *Profit Margin* in any year is negative (i.e. the organisation make financial loss instead of profit). The relation between financial performance and the collaborative lean manufacturing decision can also be seen from the situation, for example, if the organisation reducing average inventory levels, this action will reduce inventory expenses, which directly improves the lean manufacturing practice and indirectly the *Net Profit Margin*, and influence the improvement in the organisation *Return on Equity (ROE)*, which shows a good reputation in the organisation's financial position.

5.4 Level 2 - Lean Manufacturing Perspective

The *Lean Manufacturing Perspective* in Level 2 of KBCLMM System structure consists of three modules, *Product Design for Manufacture*, *Internal Lean Chain*, and *External Lean Chain*. The goal of these modules is to determine the current organisation position towards Collaborative Lean Manufacturing Management, which is based on the product design, and internal-external integration. This is done by assessing several variables such as programmes, commitment, leadership, trust and relationship in product design

and development, internal and external lean chain. The detailed KB structure of this perspective is shown in Figure 5.9 with three sub-modules used to assess the product design activities, and two sub-modules each for internal and external lean chains.

Each of these modules consists of aspects or activities such as *Conceptual Design, Design Tools for Analysis,* and *Product Development* in the *Product Design for Manufacture* module, *Internal Process Control* and *Internal Continuous Improvement* in the *Internal Lean Chain* module, *Supplier Integration* and *Customer Integration* in the *External Lean Chain* module. The process begins with the execution of the *Product Design for Manufacture* module, followed by the *Internal Lean Chain* module before *External Lean Chain* module begins to execute. Each of these modules is described in the corresponding sections.

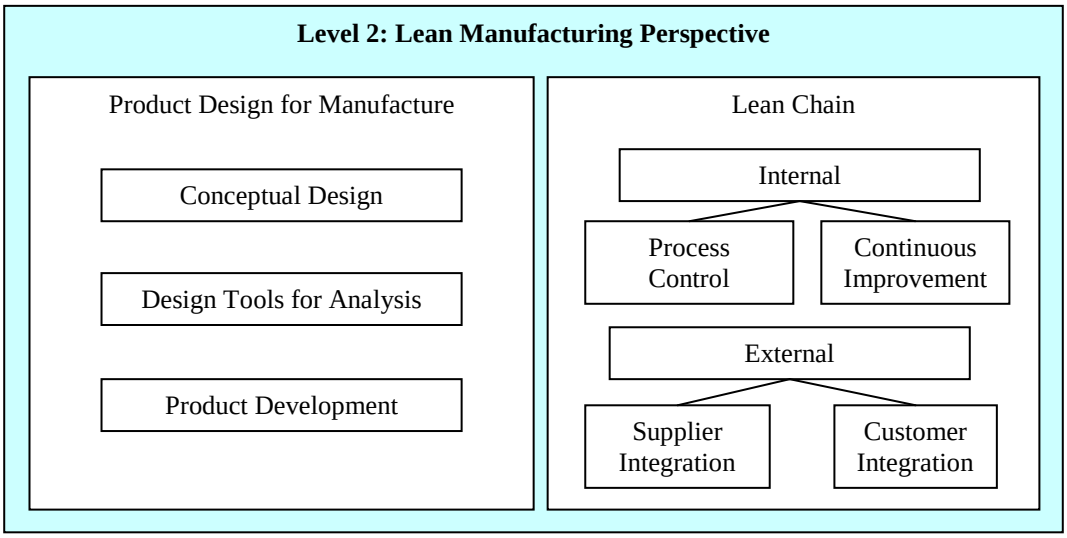

Figure 5.9: *Lean Manufacturing Perspective* Structure

5.4.1 Product Design for Manufacture Module

The *Product Design for Manufacture* module is developed with objectives of gathering product design information and analysing the product

design process which covers from the conceptual design to the full launch of new products.

It is important in CLMM to measure the involvement of supplier and customer (external collaboration). For example, having no internal and external collaboration in the product design and development process are categorised as PC1 since in the product design and development, everybody involvement are really important for total improvement in CLMM. The flowchart of this module is shown in Figure 5.10.

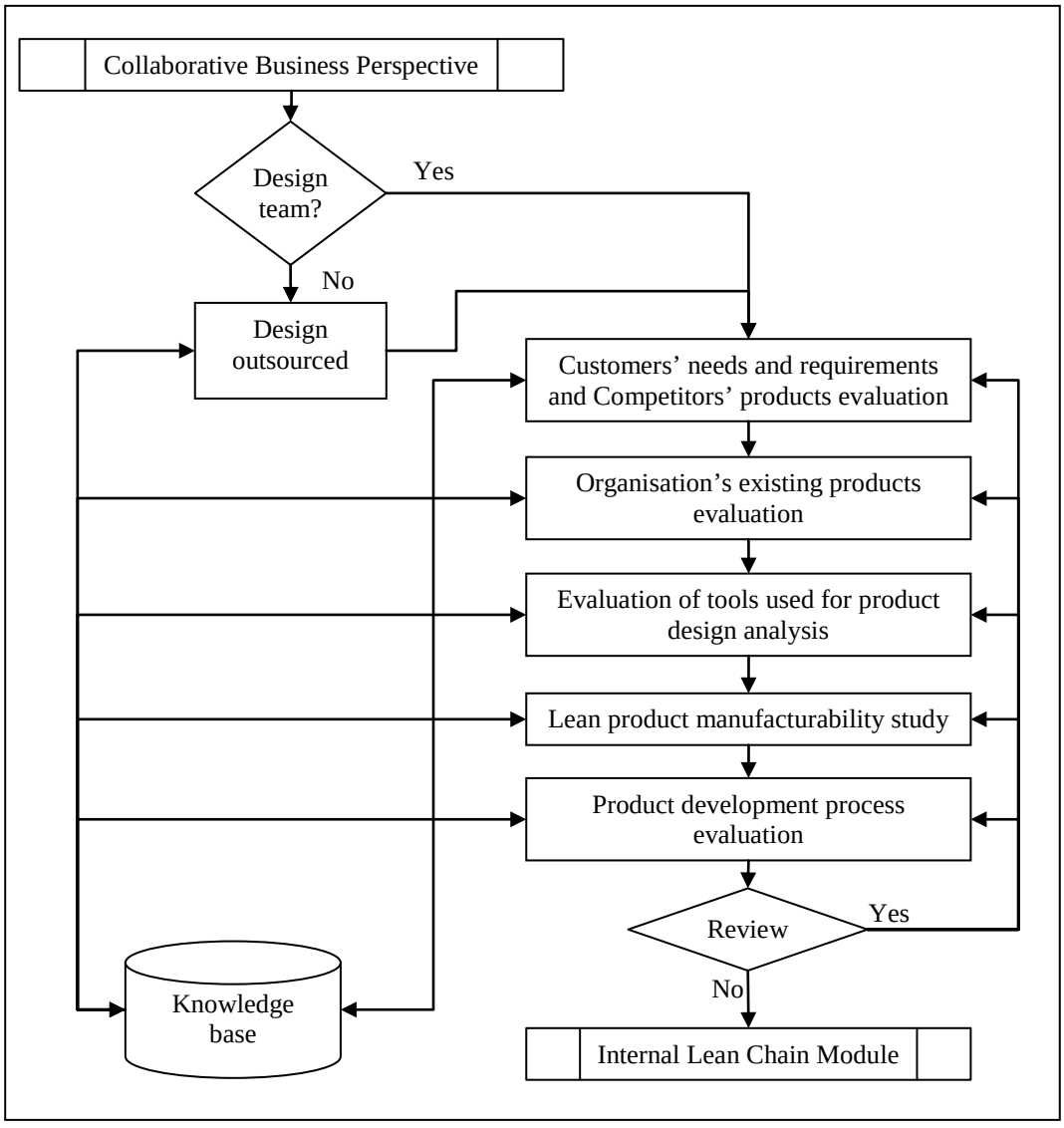

Figure 5.10: Flowchart of *Product Design for Manufacture* Module

Conceptual Design, *Design Tools for Analysis*, and *Product Development* are three elements in the *Product Design for Manufacture* activities and will be discussed in the following sub-sections.

5.4.1(a) Conceptual Design Sub-Module

Conceptual Design, the first stage of *Product Design for Manufacture* is crucial because it links the creation of new products to the organisation's strategy [Krajewski and Ritzman (2005)]. It is a series of activities that transforms the customer needs to prototype design. The *Conceptual Design* sub-module is developed to assess these activities which include idea generation, involvement of multi functional team, and evaluations of own and competitors' products. The example of rule-base for *Conceptual Design* sub-module used for deducing this condition is listed as follows.

IF *the marketing team involved in the product design* (**Yes**: GP; **No**: BP, **PC1**)
AND *the engineering team involved in the product design* (**Yes**: GP; **No**: BP, **PC1**)
AND *the operations team involved in the product design* (**Yes**: GP; **No**: BP, **PC1**)
AND *the quality team involved in the product design* (**Yes**: GP; **No**: BP, **PC1**)
AND *the purchasing team involved in the product design* (**Yes**: GP; **No**: BP, **PC3**)
IF *the organisation rates the products in terms of technology and innovation as* (**Excellent**: GP; **Good**: BP, **PC4**, **Average**: BP, **PC3**, **Poor**: BP, **PC1**)
AND *the organisation rates the products in term of quality as* (**Excellent**: GP; **Good**: BP, **PC4**, **Average**: BP, **PC3**, **Poor**: BP, **PC1**)
AND *the organisation rates the products in term of reliability as* (**Excellent**: GP; **Good**: BP, **PC4**, **Average**: BP, **PC3**, **Poor**: BP, **PC1**)
AND *the organisation rates the products in term of safety as* (**Excellent**: GP; **Good**: BP, **PC4**, **Average**: BP, **PC3**, **Poor**: BP, **PC1**)
AND *the organisation rates the products in terms of features and design as* (**Excellent**: GP; **Good**: BP, **PC4**, **Average**: BP, **PC3**, **Poor**: BP, **PC1**)
AND *the organisation rates the products in term of price as* (**Excellent**: GP; **Good**: BP, **PC4**, **Average**: BP, **PC3**, **Poor**: BP, **PC1**)
THEN *the product design and development team is multifunctional and the organisation design and development activity is good*
OR *the product design and development team is isolated and the company design activity is poor*

Since CLMM stresses the importance of multifunctional team in product design, the KBCLMM (as shown in the above rules) categories it as a serious problem of PC1 if the product design team does not include marketing,

engineering, operations, and quality staff. It should also be pointed out that the KBCLMM does not only give options of *Yes* and *No*, but also could give the user many options to answer the questions. As an example from the above rules, the user has the options to answer *Excellent*, *Good*, *Average* or *Poor* for the question "*How the organisation rates the products in term of quality?*" If the user rated the products as *Poor* in term of quality, then the System categorises it as PC1, *Average* as PC3, *Good* as PC4, and *Excellent* as GP.

5.4.1(b) Design Tools for Analysis Sub-Module

In this second stage of *Product Design for Manufacture*, the organisation is assessed on the application of design tools such as *Failure Mode and Effect Analysis* (FMEA), *Experimental Design* and *Taguchi Methods* in the product design activities. These tools were explained in detail in Chapter 2. The example of rule-base for *FMEA* aspect in *Design Tools for Analysis* Sub-Module used for deducing this condition is listed as follows.

IF *the organisation has ensured clear definition of FMEA to product design team* (**Yes**: GP; **No**: BP, **PC1**)
AND *the organisation has trained product design team on FMEA programme* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design team develop a rating chart combined with a table to assign severity of potential failures* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design team develops a rating chart combined with a table to assign likelihood of potential failure occurring* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design team develops a rating chart combined with a table to assign the chance of detection within the design process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design team analyses the design of the products to determine the critical major modes* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design team analyses the design of the products to determine the effect of failure modes* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design team documents the FMEA carried out* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design team upgrades the documentation system whenever a recent FMEA has been documented out* (**Yes**: GP; **No**: BP, **PC1**)
THEN *the FMEA has been implemented in the product design activities*
OR *the FMEA needs to be implemented or improved in the product design activities*

Based on the user responses, the KBCLMM uses the above rules to identify the level of FMEA in the organisation's product design. In this sub-

module, the System firstly evaluates the commitment of the organisation to ensure the clear definition and give training in FMEA. Then, the use of FMEA through the product design process is assessed. An absence of any elements in the FMEA is considered as a serious problem since it will affect the overall product design analysis.

5.4.1(c) Product Development Sub-Module

In the *Product Development* sub-module, assessment includes the number of new products launched, time-to-market for new products, and also the actual product development activities after the design analysis has been done. The activities consist of a number of processes, e.g. part and assembly design, component sizing and selection, layout study, and ergonomics study.

The example of rule-base for *Product Development* Sub-Module used for deducing this condition is listed as follows.

IF *the average time to market for year 2007 is less than 2006* (**Yes**: GP; **No**: BP, **PC1**)
AND *the average time to market for year 2006 is less than 2005* (**Yes**: GP; **No**: BP, **PC1**)
AND *the number of new products launched in 2007 is less than 2006* (**Yes**: GP; **No**: BP, **PC2**)
AND *the number of new products launched in 2006 is less than 2005* (**Yes**: GP; **No**: BP, **PC2**)
AND *the customers are involved in the idea generation and product conceptualisation* (**Yes**: GP; **No**: BP, **PC1**)
AND *the suppliers are involved in the idea generation and product conceptualisation* (**Yes**: GP; **No**: BP, **PC2**)
AND *the suppliers are involved in the business assessment and reviewing product sales forecasts* (**Yes**: GP; **No**: BP, **PC1**)
AND *the suppliers are involved in determining product material requirements* (**Yes**: GP; **No**: BP, **PC1**)
AND *the suppliers are involved in developing product specification and product performance range* (**Yes**: GP; **No**: BP, **PC1**)
AND *the suppliers are involved in the product quality targets* (**Yes**: GP; **No**: BP, **PC1**)
AND *the suppliers are involved in determining packaging design* (**Yes**: GP; **No**: BP, **PC3**)
THEN *the company continuously improve time to market in the product development process*
OR *the company need to reduce the time to market, adopt concurrent engineering technique and improve the product development process*

From the above rules, it can be seen that the KBCLMM categories it as a serious problem with PC1 if the *average time to market* for the year is less than

the previous year. This case is also similar with PC2 if *the number of new products launched* for the year is less than the previous year. The KBCLMM also assess the involvement of customers and suppliers in the product development activities. For example, the absence of customer involvement in idea generation of the product is considered as a serious problem of PC1 since customers are the ones who will use and pay the products.

5.4.2 Internal Lean Chain Module

The *Internal Lean Chain* module consists of two sub-modules: *Internal Continuous Improvement* and *Internal Process Control*. These two elements will be discussed in the following sub-sections. The flowchart of this module is shown in Figure 5.11.

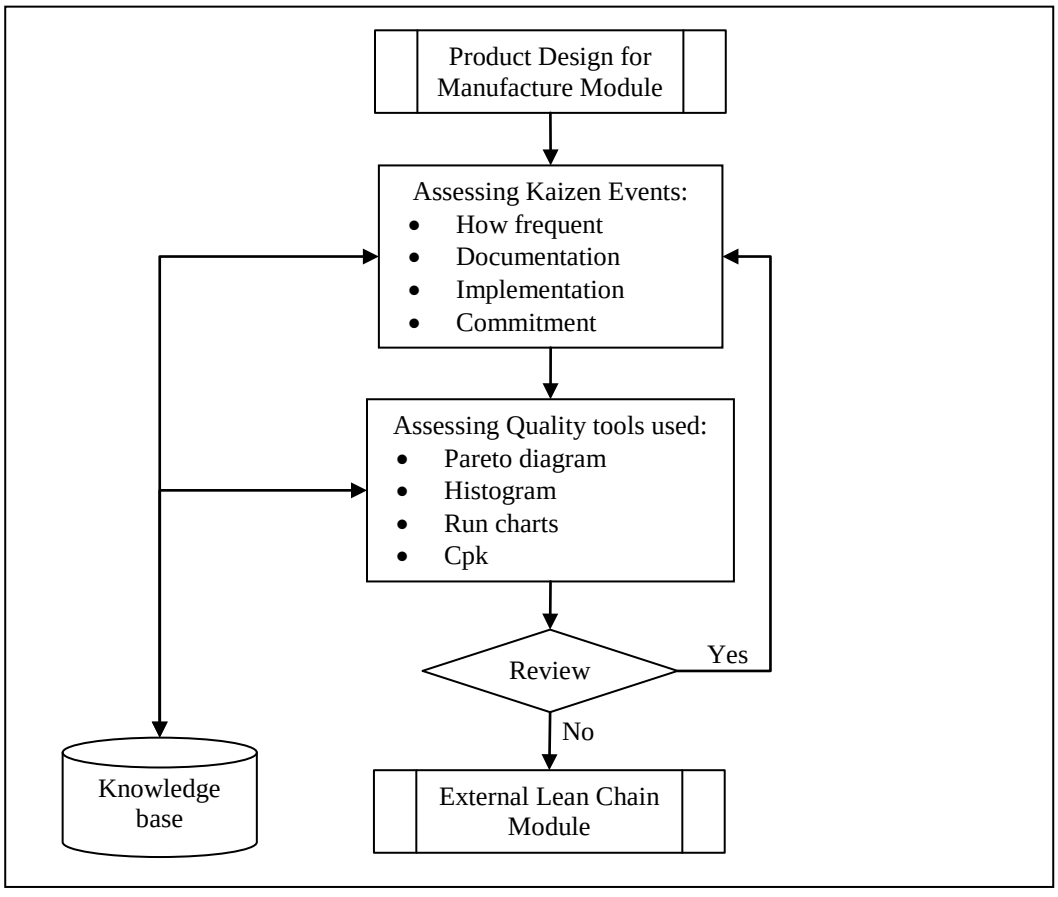

Figure 5.11: Flowchart of *Internal Lean Chain* Module

5.4.2(a) Internal Continuous Improvement Sub-Module

In the Lean Manufacturing Management view, process improvement is never-ending. Lean manufacturers employ a fundamental tool called *Kaizen* to processes, with the goal of reducing waste and continually improving performance over time [Emiliani (2000)]. Continuous improvement is an ongoing effort to identify and remove wasteful elements in the manufacturing process. To this end, it is necessary to have a clear internal communication strategy and to designate an on-site person in charge. A system of improvement suggestions should also be in place, and employees must be trained in methods of continuous improvement [Garcia *et. al.* (2006)].

The application of *Kaizen* is supported by numerous process analysis and improvement tools which include 5S, visual factory, total productive maintenance, set-up reduction, mistake-proofing, standard work, one-piece flow, and *kanban* [Emiliani (2000)]. Questions about the other important metrics such as dock-to-dock time and lean rate [Domingo *et. al.* (2007)] records for the last three years were also asked to assess the improvement achieved. The example of rule-base for *Internal Continuous Improvement* sub-module used for deducing this condition is listed as follows.

IF *the organisation have kaizen team which regularly conduct kaizen event to improve the process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the kaizen event is always documented* (**Yes**: GP; **No**: BP, **PC1**)
AND *the kaizen event is documented and presented to top management* (**Yes**: GP; **No**: BP, **PC1**)
AND *the kaizen event is always presented to staff of operations* (**Yes**: GP; **No**: BP, **PC1**)
AND *the kaizen event is always presented to staff of planning* (**Yes**: GP; **No**: BP, **PC3**)
AND *the kaizen event is always presented to staff of purchasing* (**Yes**: GP; **No**: BP, **PC4**)
AND *the kaizen event is always presented to staff of financial* (**Yes**: GP; **No**: BP, **PC4**)
AND *the kaizen event is always presented to staff of administration* (**Yes**: GP; **No**: BP, **PC1**)
AND *the organisation implements cellular layout as part of internal continuous improvement* (**Yes**: GP; **No**: BP, **PC1**)
AND *the organisation implements pull production as part of internal continuous improvement* (**Yes**: GP; **No**: BP, **PC1**)

AND *the organisation implements kanban control as part of internal continuous improvement* (**Yes**: GP; **No**: BP, **PC1**)
AND *the organisation implements set-up time reduction as part of internal continuous improvement* (**Yes**: GP; **No**: BP, **PC1**)
THEN *the organisation has commitment to kaizen events and internal continuous improvement is good*
OR *the organisation needs to improve the kaizen event and internal continuous improvement activities*

Since *kaizen* team is essential for any organisation achieving CLMM, the KBCLMM (as shown in the above rules) identifies whether the organisation has the team which regularly conduct events to improve processes. The System categories it as a serious problem of PC1 if there is no *kaizen* team, or there is no documentation for the events conducted, and so forth. The KBCLMM also clarifies whether elements of continuous improvement aspects are practised in the organisation such as cellular layout, set-up reduction, pull production and so on. As an example from the above rules: if there is no *kanban* control in the production, then the System categorises it as PC1 since *kanban* control is one of the key elements of CLMM as discussed in Chapter 2.

5.4.2(b) Internal Process Control Sub-Module

It is very important for supplier to satisfy the customer. Suppliers must provide zero-defect parts or technically conform to the specifications. Statistical Process Control (SPC) is a collection of tools used to determine whether a process is delivering parts which meet the specifications [Krajewski and Ritzman (2005)]. From the CLMM view, these quality tools are mostly used to identify and eliminate defects i.e. one of the seven wastes listed by many lean experts [Ohno (1988), Monden (1998), Womack and Jones (2003)].

There are some common quality tools used at the manufacturing process such as flowcharts, run charts, Pareto charts, check sheets, cause-and-effect

diagrams, opportunity flow diagram, and control charts [Oakland (2003), Chase *et. al.* (2006)]. Through these tools, the precision and accuracy of particular process can be visualised. One of the important metrics recorded and measured is Process Capability Index (Cp_k) which represents the accuracy (mean) and precision (variation) of the measurement. The example of rule-base for *Internal Process Control* sub-module used for deducing this condition is listed as follows.

IF *the process flow chart is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the check sheet is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the histogram is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the Pareto Analysis is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the cause-and-effect diagram is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the scatter diagram is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the opportunity flow diagram is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
AND *the control chart is applied to monitor and control the internal quality process* (**Yes**: GP; **No**: BP, **PC1**)
THEN *the internal process control activities of the organisations are good*
OR *the organisation needs to improve the internal process control activities by implementing the missing tools*

It can be seen from the above rules that the KBCLMM categories it as a serious problem with PC1 if there is any absence of statistical process control tools in implementing internal process control to achieve CLMM. Without these tools, the System suggests the organisation to improve the internal process control activities by implementing the missing tools.

5.4.3 External Lean Chain Module

The *External Lean Chain* module consists of two sub-modules: *Integration with Suppliers* and *Integration with Customers*. These two elements will be discussed in the following sub-sections. The flowchart of this module is shown in Figure 5.12.

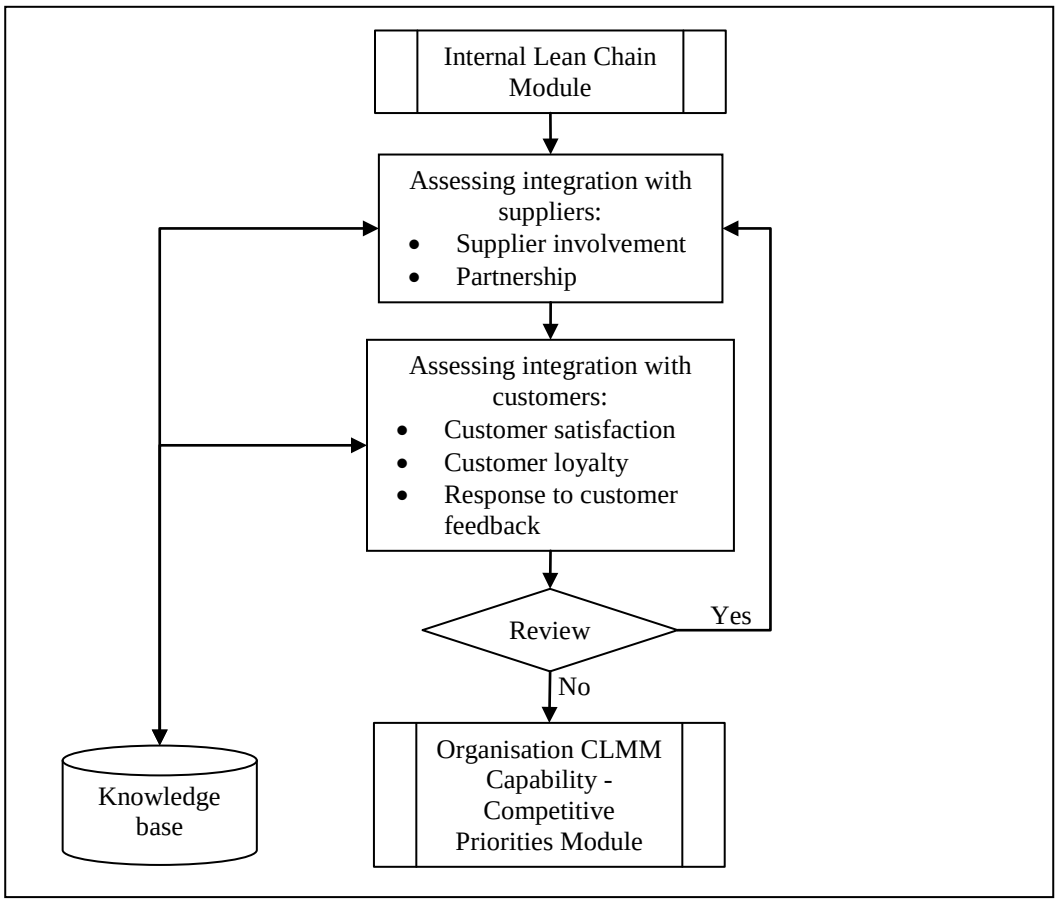

Figure 5.12: Flowchart of *External Lean Chain* Module

5.4.3(a) Integration with Suppliers Sub-Module

An excellent integration with suppliers is crucial in CLMM. This external integration refers to an organisation working closely with suppliers and judging the latter as an important element of lean supply chain [Narasimhan and Kim (2002)]. The degree of suppliers involvement and influence, and the level of partnership with suppliers are parameters that need to be assessed [Zailani and Rajagopal (2005)]. The example of rule-base for *Integration with Suppliers* sub-module used for deducing this condition is listed as follows.

IF *the organisation have a policy of supplier development* (**Yes**: GP; **No**: BP, **PC1**)
AND *the product design activities involve key suppliers* (**Yes**: GP; **No**: BP, **PC1**)
AND *the process design activities involve key suppliers* (**Yes**: GP; **No**: BP, **PC1**)
AND *the informal communication with suppliers to extend lean principle is established* (**Yes**: GP; **No**: BP, **PC3**)

AND *the communication network among suppliers to extend lean principle is developed* (**Yes**: GP; **No**: BP, **PC2**)
AND *the suppliers are allowed to access and use common resources* (**Yes**: GP; **No**: BP, **PC2**)
AND *the organisation is keep informed about suppliers' new developments* (**Yes**: GP; **No**: BP, **PC2**)
AND *the organisation is keep informed about suppliers' delivery problems* (**Yes**: GP; **No**: BP, **PC2**)
AND *the organisation is frequently visited by suppliers' sales personnel* (**Yes**: GP; **No**: BP, **PC3**)
AND *the organisation frequently discusses with suppliers about new opportunities* (**Yes**: GP; **No**: BP, **PC2**)
AND *the suppliers are well informed about the demand of the organisations* (**Yes**: GP; **No**: BP, **PC1**)
AND *the suppliers are well informed about the planning of the organisations* (**Yes**: GP; **No**: BP, **PC1**)
THEN *the activities of integration with suppliers of the organisations are good*
OR *the organisation needs to improve the integration with suppliers*

As shown in the above rules, the KBCLMM firstly identifies whether the organisation has a policy of supplier development. The System categories it as a serious problem of PC1 if there is no policy since suppliers are considered as partners in achieving CLMM. The KBCLMM then clarifies the involvement level of supplier by evaluating the elements of supplier involvement. As an example from the above rules, if the suppliers are not well informed about the demand and planning of the organisation, then the System categorises them as PC1.

5.4.3(b) Integration with Customers Sub-Module

Integration with customers refers to a company working closely with customers and viewing the latter as an important component of lean supply chain [Narasimhan and Kim (2002), Zailani and Rajagopal (2005)]. There are three elements that an organisation needs to focus on with respect to their customers: the importance of customer satisfaction, customer loyalty, and how the organisation deals with the feedback from customers [Wibisono (2003)]. The example of rule-base for *Integration with Customers* sub-module used for ascertaining this aspect is listed as follows.

IF *the management considered customer satisfaction as one of the most important Critical Success Factor* (**Yes**: GP; **No**: BP, **PC1**)
AND *the importance of customer satisfaction has been communicated to all employees* (**Yes**: GP; **No**: BP, **PC2**)
AND *the organisation has an incentive scheme to offer minimum price to dedicated customers* (**Yes**: GP; **No**: BP, **PC3**)
AND *the organisation has a scheme to offer resources and expertise to key customers* (**Yes**: GP; **No**: BP, **PC2**)
AND *the organisation has a scheme to offer delivery services to customers* (**Yes**: GP; **No**: BP, **PC2**)
AND *the organisation has a scheme to good credit period to customers* (**Yes**: GP; **No**: BP, **PC2**)
AND *the importance of customer loyalty has been communicated to all employees* (**Yes**: GP; **No**: BP, **PC2**)
AND *the organisation has programme to follow up after products delivered to customer* (**Yes**: GP; **No**: BP, **PC1)**
AND *the organisation has programme to invite customer on new product launching* (**Yes**: GP; **No**: BP, **PC1)**
AND *the organisation records both negative and positive feedback from existing customer* (**Yes**: GP; **No**: BP, **PC1)**
AND *the organisation takes action to deal with complaints and negative feedback from existing customer* (**Yes**: GP; **No**: BP, **PC1)**
THEN *the activities of integration with customers of the organisations are good*
OR *the organisation needs to improve the activities of integration with customers*

From the above rules, it can be seen that the KBCLMM categories it as a serious problem with PC1 if the management does not consider customer satisfaction as one of the most important Critical Success Factor. This case is also similar with PC2 if the importance of customer satisfaction has not been communicated to all employees. The System also assesses the activities that make the existing customers loyal the organisation's products. For example, if there is no action taken to deal with customer complaints, the KBCLMM categories it as a serious problem of PC1 since customer loyalty is very important and complaints need to be resolved to retain the customers.

5.5 Summary

This chapter has described in detail the development of Stage 1 in the Knowledge Based Collaborative Lean Manufacturing Management (KBCLMM) System. The development is based on the KBCLMM System structure shown in Figure 5.1. There are three levels in the KBCLMM System structure: Level 0 -

Organisation Environment Perspective, Level 1 – *Collaborative Business Perspective* and Level 2 – *Lean Manufacturing Perspective*. Prior to the detail description of each module, the mechanism of KBCLMM which consists of Interactive Questions, Explanation Facility, Facility Answer, GAP Analysis, and AHP Technique are explained.

The *Organisation Environment Perspective* module in Level 0 is the starting point of the KBCLMM System and is used to identify the general information of the organisation and its environment. The input of this module includes size of the organisation, number or employees, age of organisation, position in the automotive supply chain, information of suppliers and customers, and the CLMM investment activities. This information is used for identification purposes and status of the organisation in the automotive industry.

The *Collaborative Business Perspective* modules in Level 1 describe the organisation market analysis and financial analysis information. Market share and market competition are used to measure market share relative to its competitors in the domestic, regional and global market. Relating to financial performance, the *du Pont Model* are used to portray the financial position relative to the lean manufacturing operations, along with other financial ratios such as *Leverage*, *Liquidity*, and *Profitability* ratios.

In the *Lean Manufacturing Perspective* of Level 2, three modules: *Product Design for Manufacture*, *Internal Lean Chain* and *External Lean Chain* are described in detail, in which there are series of questions implemented. The process flowchart for each module and the examples of KB-system rule base procedures are also explained. Furthermore, the typical output from each

procedure that summarises the existing condition of the organisation has been presented by indicating the number of questions, along with the number of Problem Category items, which represent the key problem areas that need to be improved.

In brief, Chapter 5 has presented the detailed development of KBCLMM System in Stage 1 that consists of three levels: Levels 0, 1 and 2. The following Chapter 6 will present the Stage 2 of detail development, which consists of Levels 3, 4 and 5.