CHAPTER 4

CONCEPTUAL MODEL OF KNOWLEDGE BASED COLLABORATIVE LEAN MANUFACTURING MANAGEMENT (KBCLMM) SYSTEM

4.0 Introduction

This chapter describes the conceptual model of Knowledge Based Collaborative Lean Manufacturing Management (KBCLMM) System. Since there is presently no solid framework for developing KBCLMM, this research attempts to solve the problem by providing a generic framework of KBCLMM, supported by the use of Knowledge Base (KB) capability. It also includes description of the KBCLMM structure and types of assessment that can be conducted during the verification and validation process.

4.1 Knowledge Based System (KBS) Applications in Manufacturing Management

The applications of Knowledge Based System (KBS) in manufacturing management have become a field of research since 1980s, along with the emergence of the intelligent manufacturing system concepts [Proudlove *et. al.* (1998)]. By using this application, organisations have made improvements in their operations, ranging from the product and process design to the functional and strategic levels of the organisation [Khan and Day (2002), Udin *et. al.* (2006), Hung *et. al.* (2008)]. In the Supply Chain Management (SCM) System for manufacturing, information system applications are amongst the tools that have been utilised to improve organisation competitiveness [Udin (2004)].

Applications such as automatic component replenishment, forecasting and scheduling have been used widely in enhancing the quality of the management decision making process [Stank *et. al.* (1999), Helms *et. al.* (2000), Udin (2004)].

In the current era of dynamic competition, the need for a new approach in the CLMM will be able to provide a detailed response to customers, reduce lead time, eliminate wastes, improve customer satisfaction and reduce cost of production can be achieved through a collaborative environment. The collaboration of three powerful techniques and systems, i.e. JIT, MRP II, and TQM (described in Chapter 2), has inspired the development of conceptual model which integrates these approaches.

In addition to this need, there are many previous relevant KBS systems which are developed for the planning and design manufacturing improvement initiatives which include Master Production Scheduling [Khan (1996)], Pull and Push Manufacturing Planning and Control [Razmi (1998)], Sequencing and Scheduling in Cellular Manufacturing [Momin (1999)], Performance Measurement System [Wibisono (2003)], and Collaborative Supply Chain Management [Udin (2004)]. However, the need for KBS with special attention to CLMM has not been developed before. As a result, KBCLMM is developed to meet this need. The detail of this framework is discussed in the following section.

4.2 Framework of the Conceptual Model

Chapter 2 has surveyed essential elements of CLMM, which covered JIT, MRP II, and TQM. The information gathered from the literature review was interpreted and "translated" into a KB. This KB will be used as the main

foundation of the conceptual model framework. Concurrently, other general elements of any manufacturers, such as organisation environment, market, finance, and supply chain will also be reviewed in this section as part of the conceptual model development.

In order to develop the conceptual model, some of general approaches of IDEFØ modelling technique were adapted. IDEFØ is a systematic method used to model the actions, activities, and decisions of an organisation or system [IDEF0 (1993)]. IDEFØ modelling concepts are described in Appendix D. The conceptual model emphasises three stages: Planning, Design and Implementation.

In Stage 1 (Planning Stage), there are two major sets of information that need to be considered: *Collaborative Business* and *Lean Manufacturing* perspectives. Profile of organisation is the first component needed in the *Collaborative Business* perspective. This component is used to gather the general information of the organisation environment, and much related to the organisation's financial status and market share [Udin *et. al.* (2006)]. These financial and market components need to be analysed to evaluate the strength of the organisation in planning the strategy for CLMM achievement. For that reason, the inter-related elements of *Organisation Environment*, *Financial Analysis* and *Market Analysis* are identified to be assessed in the *Collaborative Business* perspective of the model as shown in Figure 4.1.

As operations are the heart of any manufacturing organisation, a component to gather the strategy of the organisation towards CLMM is needed. This component, *Lean Manufacturing* perspective is needed to gather the

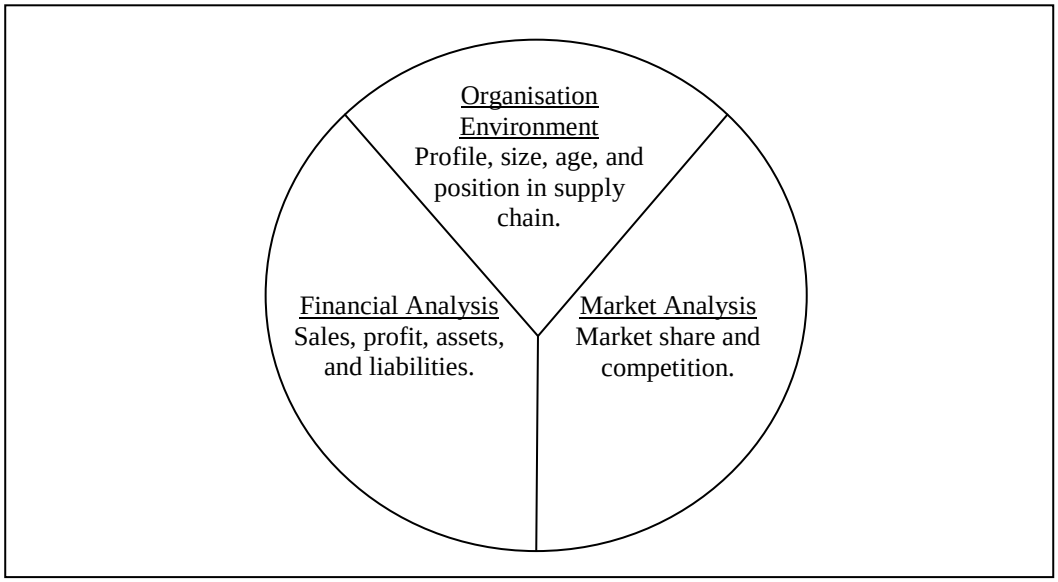

Figure 4.1: *Collaborative Business* Perspective [based on Udin *et. al.* (2006)]

information on how lean the organisation in term of product design, production, internal relationship, and external relationships with suppliers and customers [Nawawi *et. al.* (2007)]. For that reason, three elements are identified to be assessed: *Product Design for Manufacture*, *Internal Lean Chain*, and *External Lean Chain* which is linked to *Collaborative Business* perspective as shown in Figure 4.2.

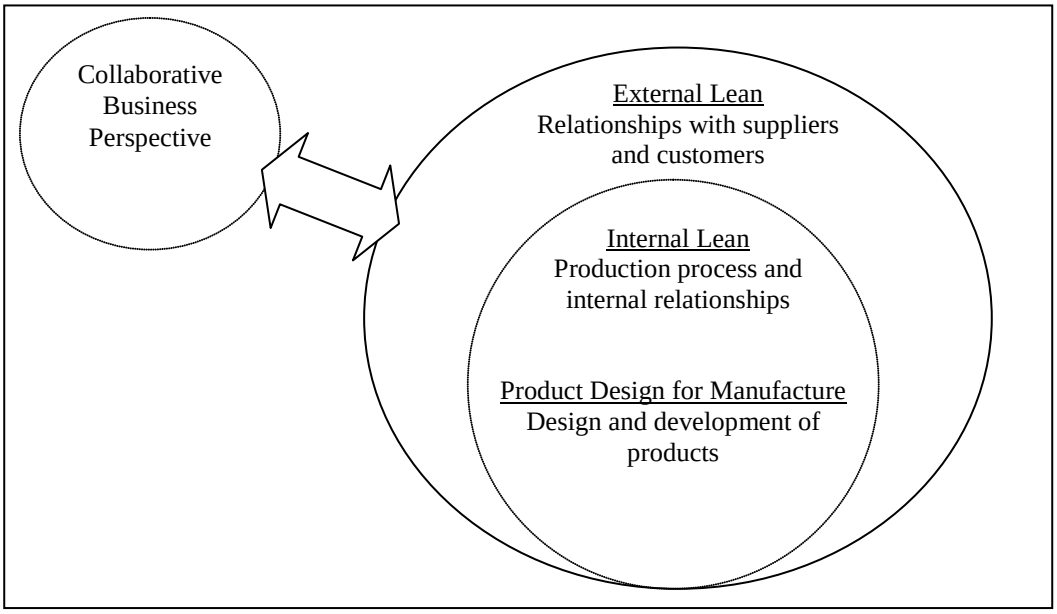

Figure 4.2: *Lean Manufacturing* Perspective [based on Nawawi *et. al.* (2007)]

From Figures 4.1 and 4.2, it can be seen that the Stage 1 involves planning elements of the organisation's strategy. This strategy then needs to be designed accordingly to successfully achieve CLMM, and contained in Stage 2.

In Stage 2 (Design Stage), there are two major sets of information that need to be considered. The capability of the organisation to compete in the business is the first component that needs to be evaluated. This element, *Organisation CLMM Capability* is assessed based on the organisation capabilities in terms of quality, time, flexibility, value (cost), and supply chain [Nawawi *et. al.* (2008)]. At the same time, the organisation's resource capabilities of human, technology, and finance which play important roles to achieve CLMM need to be identified. Figure 4.3 shows these capability elements which can be grouped into *Competitive Priorities* and *Resources Priorities*.

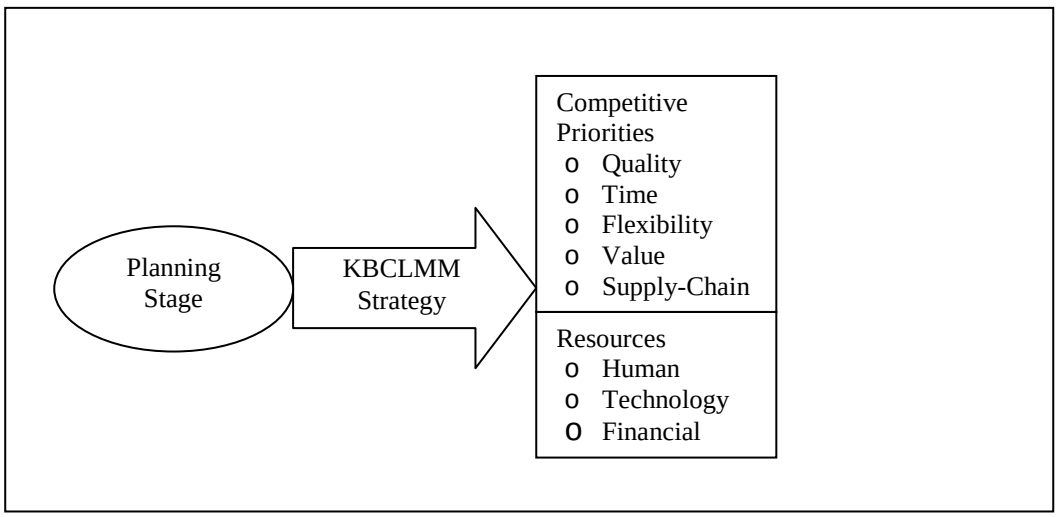

Figure 4.3: *Organisation CLMM Capability* Perspective [based on Nawawi *et. al.* (2008)]

Since business success mainly depends on customers, the organisation's efforts on the operational processes need to be aligned to acquire and satisfy the customers. The involvement of all employees, identifying and elimination non-

value adding activities, and continuously improve the manufacturing process are the elements identified to ensure the customers loyal to the organisation.

These three elements: *Employee Involvement*, *Waste Elimination* and *Continuous Improvement*, which form the second component in Stage 2, *Organisation CLMM Alignment* is shown in Figure 4.4.

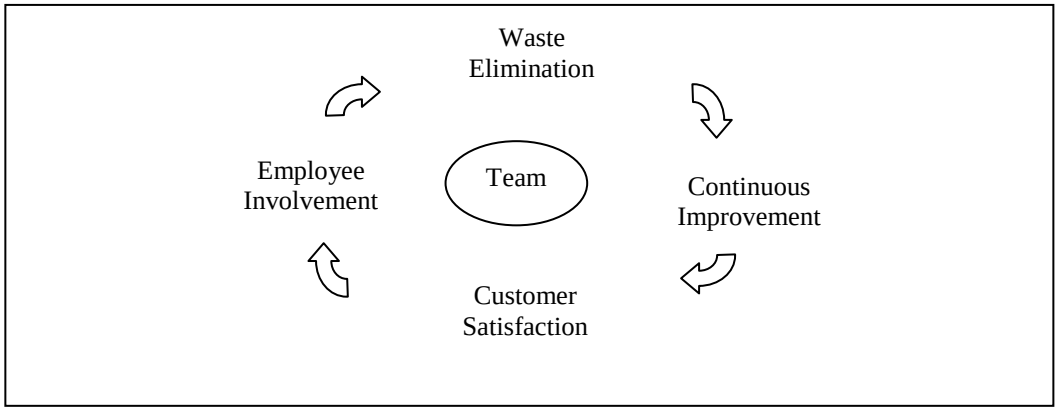

Figure 4.4: *Organisation CLMM Alignment* Perspective [based on Nawawi *et. al.* (2008)]

In Stage 3 (Implementation Stage), the mechanism of CLMM implementation needs to be assessed. The mechanism consists of five main sequential team-base approach steps: *Performance Measurement*, *Benchmarking*, *Evaluation*, *Diagnosis* and *Action Plan* as shown in Figure 4.5.

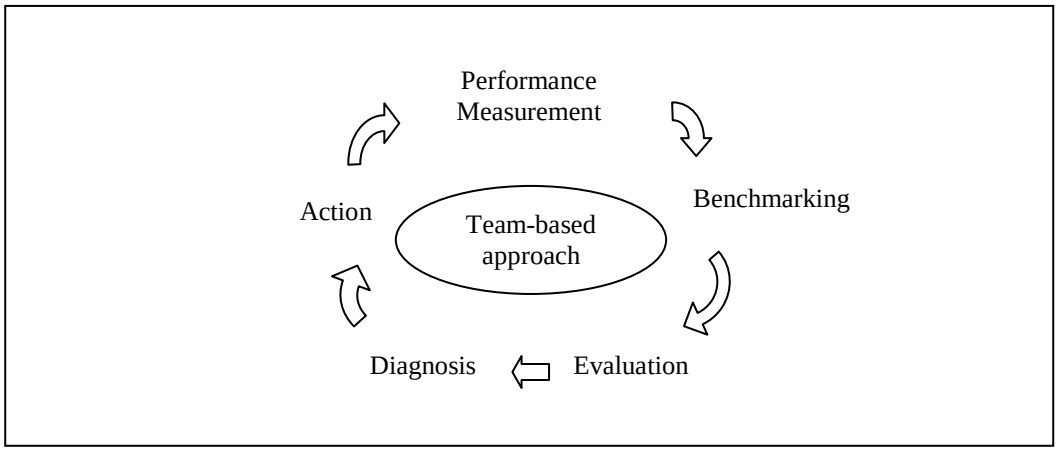

Figure 4.5: *Mechanism of CLMM Implementation* Perspective [based on Nawawi *et. al.* (2008)]

These steps are used to determine the achievement of the organisation implementation towards CLMM.

In essence, all elements in Stage 1, Stage 2, and Stage 3 are inter-related and can be integrated as shown in Figure 4.6.

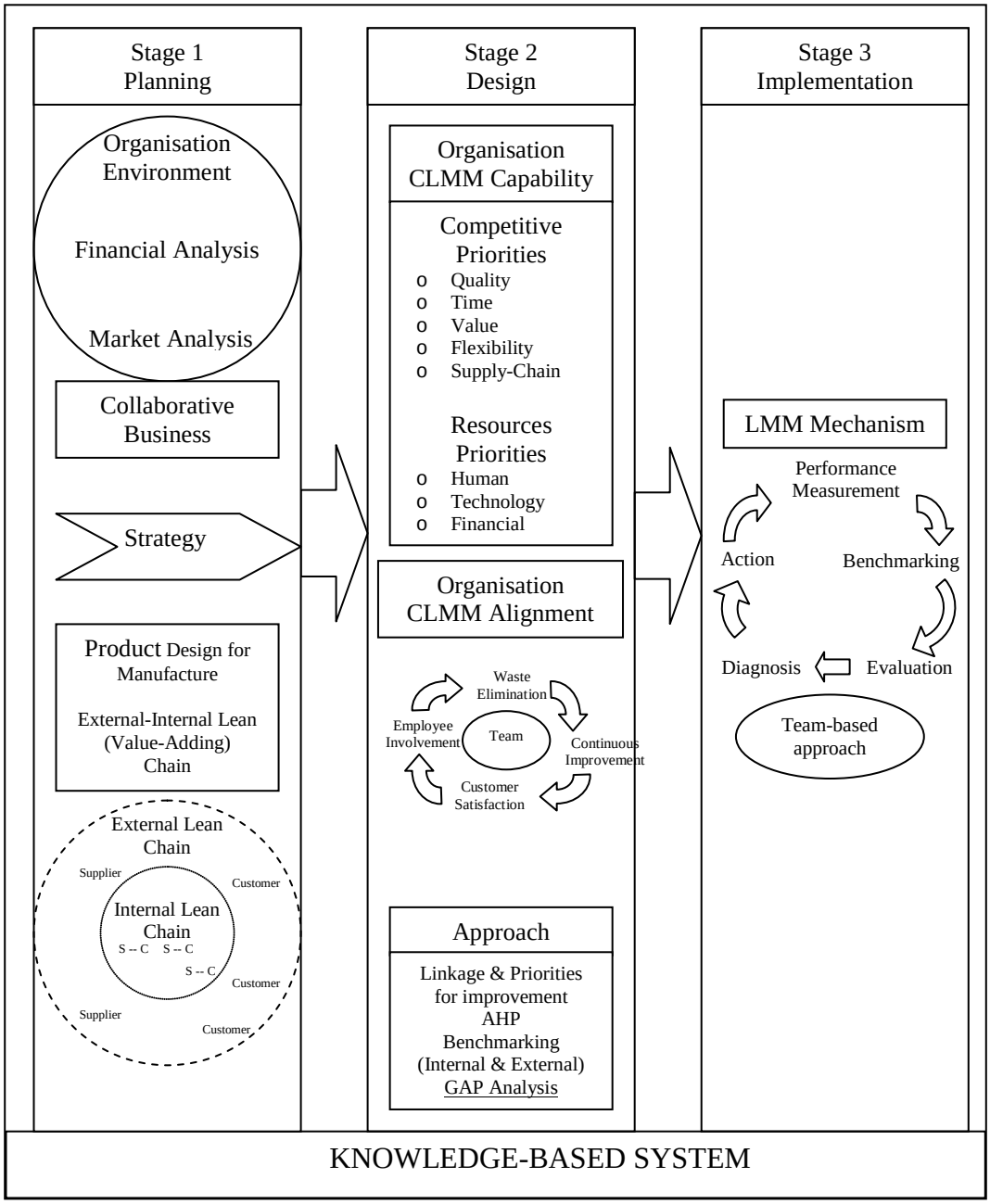

Figure 4.6: Conceptual Model for KBCLMM (Source: Nawawi *et. al.* (2008))

Within the three stages, the KBS is used as the foundation of the model. The conceptual model also consist the design approach which shows how the GAP and AHP techniques are embedded in the KB system. The conceptual model provides a broad idea and key parameters which will then be translated into a much more detailed and specific KB structure. The following sections will describe each of the interrelated elements in detail.

4.2.1 Organisation Environment

Organisation Environment component determines the particular environment the organisation is operating in. General information and background of the organisation under study are gathered. The information includes size of organisation, annual sales turnover, foundation year, its position in automotive supply chain, its competitors, suppliers and customers, and investment in collaborative lean manufacturing management (CLMM) activities.

Based on the organisation annual sales turnover and number of employees, the size of manufacturing and manufacturing related services company can be determined. For example, in Malaysia, there are divided into four categories; micro, small, medium and large. The detail of the categories in accordance to is shown in Table 4.1.

The classification is done for the reason that different sizes of organisations have different environment and capabilities, which influence the strategy in developing and implementing CLMM. For example, limited financial capability and lack of expertise in small size organisation will affect the management decision to implement lean manufacturing [Achanga *et. al.* (2006)].

Table 4.1: Categories of organisation size in Malaysia (Source: Small and Medium Enterprise Development Corporation, Malaysia [SMIDEC (2007)])

Size	**Description**
Micro	Sales turnover of less than RM250,000 (approx. £36,765) OR full time employees less than 5
Small	Sales turnover between RM250,000 (approx. £36,765) and less than RM10 million (approx. £1.47 million) OR full time employees between 5 and 50
Medium	Sales turnover between RM10 million (approx. £1.47 million) and RM25 million (approx. £3.68 million) OR full time employees between 51 and 150
Large	Sales turnover more than RM25 million (approx. £3.68 million) OR full time employees more than 150

From the data of number of employee, various measures can be calculated which give insight the competitiveness level of the organisation. The measures include labour productivity (sales/employee), financial performance (profit/employee), labour turnover, and labour qualification which reflect the organisation performance [Guest *et. al.* (2003), Wibisono (2003)].

In collaborative environment, position of the organisation in the automotive supply chain is required to determine its role and relationship with its suppliers, customers and competitors. This is due to collaborative lean aspect that emphasises not only internally within the organisation, but also externally between organisations [Womack and Jones (2003)].

The age of organisation, calculated from the organisation's founding year is an indicator whether the organisation is in the growth, sustain or harvest stage of business life cycle [Kaplan and Norton (1996)]. Based on this, the organisation can be categorised as in one of three stages; growth, sustain and harvest [Wibisono (2003) and Udin (2004)]. In this study, the organisation that

in the business less than 5 years is in the stage of growth, 5-15 years is in the stage of sustain, and more than 15 years is in the harvest stage.

4.2.2 Market and Financial Analysis

The reason for considering organisation *Market Analysis* is that market performance indicates how good the organisations are in capturing customers through their products offered. This assessment shows how competitive the price of the products offered in the market are [Udin *et. al.* (2006)]. Hill (2000) emphasised that market share assessment is the first stage in evaluating customer demand and analysing the product characteristics in order to capture the market. It has been proven that the structure of the lean chain plays an important factor in improving organisation's competitiveness to win larger market share [Womack and Jones (2003)].

The *Financial Analysis* indicates how the organisation is presently being run in terms of efficiency and effectiveness. The *Financial Analysis* is based on the *Income Statements*, *Balance Sheet* and *Cash Flow Statement* of the organisation. From the *Income Statements* input, two important financial performances are assessed, *Gross Profit* and *Net Profit*. *Gross Profit* represents the profit remaining after deducting the cost of goods sold from the sales turnover while *Net Profit* reflects the profit attributed to operating activities after deducting operating expenses, tax and any financial items. Based on the *Balance Sheet*, three financial performance criteria of the organisation could be analysed which includes *Leverage, Liquidity*, and *Profitability*. Finally from the *Cash Flow Statement*, net increase (or decrease) in cash of the organisation could be assessed from operating, investing and financing activities of the organisation.

All of these financial performance measures could be determined and compared to the World Class Manufacturing (WCM) standard companies. A company is rated as a WCM if it achieves global standard in terms of manufacturing performances and capabilities [Sunnapwar and Kodali (2006)]. As an example, Toyota is recognised by many sources [Spear and Bowen (1999), Womack and Jones (2003), Spear (2004), and Holweg (2007)] as a WCM organisation in automotive manufacturing.

4.2.3 Product Design for Manufacture

Product design is one of the main activities of any manufacturing organisation, beside physical production and order taking process [Womack and Jones (2003)]. In this assessment, information about the product design activities, which covers from the conceptual product design stage to the full launch of the new product, is gathered. The product design process can be divided into four sequential stages: Conceptual Design, Prototype Design and Analysis, Product Development, and Full Launch [Krajewski and Ritzman (2005)]. In CLMM, it is necessary for a multifunctional team (staff from marketing, engineers skilled in several specialties, purchasing, quality, maintenance, and operation) to work together in designing and developing a new product.

In the first stage of product design, marketing staff plays an important role in defining market segment, customers' needs, wants, requirements and target groups. The leanness of the product design team then is evaluated based on the company efforts in the elements of identification of customers, identification

of customers' requirements, needs and wants, and market segment of the products.

The involvement of customers and marketing needs can be determined. Questions related to how the company lists the target customers group, ranks the customers requirements and so on can be used to determine whether the concept of Quality Function Deployment (QFD) is practised [Cohen (1995), Chakraborty and Dey (2007)]. QFD is also considered as a major element of Lean Product Development (LPD) [ETI (2005)].

Many new products and services fail because of a lack of customer focus, which can be overcome by QFD [Anonymous (2003)]. QFD provides a careful routine to incorporate both customer and market perspectives into the conceptualisation phase of the innovation process, and forces companies to aim their innovation efforts at real customers instead of an impersonal market [Anonymous (2003)]. According to Zairi (1993) and supported by Chan and Wu (2002), QFD amplifies the voice of customer to all levels of the organisation and educate people to think about doing what the customer wants rather than doing things for the customer.

4.2.4 Internal and External Lean

These two components are interrelated in term of lean chain, which refers to connections between value-adding activities inside and across organisations. Activity in any process can be allocated as value-adding or non-value adding. In CLMM, non-value adding activity is considered as a waste and must be eliminated, as shown in Figure 4.7.

In the *Internal Lean Chain*, operators of two adjacent processes are considered as internal supplier and internal customer. The supplier is committed to supply material or parts which are good in quality at the right time, right quantity and at the right place in order to satisfy the customer. Supplier commitment and customer satisfaction are interrelated factors which contribute to the success of the internal lean chain. *Internal Continuous Improvement* and *Internal Process Control* are the two elements identified to achieve these factors.

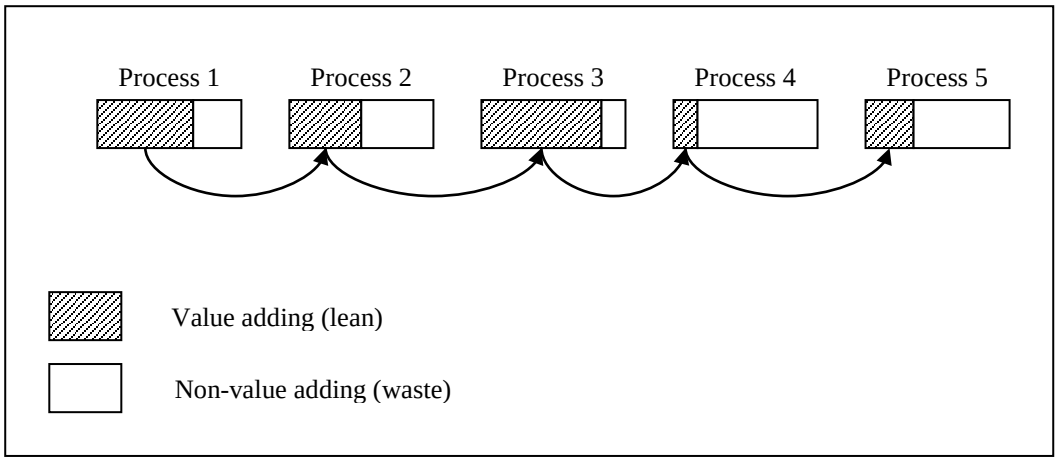

Figure 4.7: Lean flow of production processes

According to Dolcemascolo (2006), conversion from mass production to lean production for any company starts with the implementation of lean concepts internally. If the company has an integrated facilities, i.e. make most of the parts itself instead of outsourcing, then the company need to give greater emphasise on internal lean [Dolcemascolo (2006)].

In the *External Lean Chain*, suppliers are considered as partners [Monden (1998), Phelps *et. al.* (2004), Mitra and Singhal (2008)] instead of outsiders. Suppliers are well informed about the demand and planning of the organisation and sometimes invited to involve in the product development and process design. As a result, suppliers can design and plan their own process to meet the

customer's demand with high quality products. At the other end, customers are satisfied and loyal. So, in this component; integration with suppliers and integration with customers are two major elements from the external lean perspective.

4.2.5 Competitive Priorities Capability

According to Bank (2000) the capability of any organisation largely based on quality and defines quality as "*fully satisfying agreed customer requirements at the lowest internal cost*". Oakland (2003) expands this capability by mentioning that reputation of any organisation is based on four competitive priorities, i.e. quality, reliability, price and delivery, and quality is recognised as the most important. In the more recent literature, Krajewski and Ritzman (2005) highlighted these capabilities as time, quality, flexibility and cost.

In addition to these metrics, organisations with the direction of collaborative initiatives need to consider the supply chain factor, since suppliers and customers play important roles to ensure the success of lean manufacturing. These operational metrics are used by organisations to manage activities within and between their organisations in order to improve their CLMM and hence the organisation's competitiveness. In essence, the competitive priorities identified are quality, time, flexibility, value, and supply chain and will be discussed in detail in Chapter 6.

4.2.6 Resources Capability

Resources Capability includes all of those resources which could influence the capability of an organisation's CLMM integration. The resources

identified are human, technology and financial resources. These three resources are dependant to each other and must exist in parallel in the whole operations and activities in the lean manufacturing.

Human resource focus is one of the most important criteria to winning competition [Mentzer *et. al.* (2000)]; it is therefore a critical point to be assessed in the CLMM development. The basis of this is to develop the good relationship internally and externally of the organisations, which is based on trust and willingness to share amongst each other. Human resources capabilities also have a strong influence on the success of the productivity improvement initiatives. This argument is confirmed by [Gowen and Tallon (2003), Vonderembse *et. al.* (2006)] who found the impact of human resources factors, such as training and management commitment which support the success of the organisation.

At the same time, technology resource is one of the important operating principles to beat competition in manufacturing. The use of technology is believed to encourage the effectiveness of CLMM operation. Mentzer *et. al.* (2000) reveal the influence of technology factors, such as the unique and future technological capability; for example a supplier selection process. They emphasise that the technology capability is among the important enablers in successful collaboration work.

Financial resource capability is a crucial factor in the determination of any successful implementation programmes. According to Achanga *et. al.* (2006), this is due to the fact that finance covers the possibilities through which other useful provisions like training and consultancy could be made. Many companies especially in the SME (Small and Medium Enterprise) category are

financially inept and harbour poor financing arrangements [Achanga *et. al.* (2006)]. Inadequacy of financial resource is thus a major hindrance to the successful lean manufacturing adoption and subsequent implementation [Achanga *et. al.* (2006)].

4.2.7 Organisation CLMM Alignment

Organisation CLMM Alignment is the component that relates to processes in the functional areas and lean manufacturing activities of organisations. This is in line with Slack *et. al.* (2007) who define lean philosophies into these three functions, as articulated in [Krajewski and Ritzman (2005)], who define TQM as "*a philosophy that stresses three principles for achieving high levels of process performance and quality: customer satisfaction, employee involvement, and continuous improvement in performance*."

The first process, *Employee Involvement* is recognised as one of the important elements in any improvement initiatives, e.g. TQM, Six Sigma and Lean Manufacturing. As the employee is the back bone of any organisation, it is important to develop a program which measures, benchmarks, evaluates, diagnoses, and improves the employee involvement process in the organisation. The program may include job specialisation, job enrichment, job enlargement, job rotation, employee empowerment, organisational cultural change and teamwork encouragement [Krajewski and Ritzman (2005), Chase *et. al.* (2006)].

The level of employee involvement can be evaluated based on Slack *et. al.* (2007), who categorise it into three degrees of empowerment based on the level of authority given. The three levels are shown in Table 4.2.

This *Employee Involvement* process is linked to the second process of CLMM Alignment, *Waste Elimination*. Waste in lean manufacturing management is defined as anything that not required by customers or any activity which is not adding value to the part produced. There are seven wastes mentioned in many literatures [Emiliani (1998), Monden (1998), Womack and Jones (2003), Dolcemascolo (2006)]. The wastes are defect, overproduction, transportation, waiting, inventory, motion, and over processing. Womack and Jones (2003) add underutilisation of employee as the eight waste of manufacturing. In CLMM, the focus on elimination of these forms of wastes is one of the most significant parts [Slack *et. al.* (2007)].

Table 4.2 Level of employee empowerment

Suggestion involvement	- Lowest level of empowerment - Staff to contribute through suggestions for the operation might be improved - No autonomy for staff to implement changes to their jobs - To prevent dilution of organisations standardized task methods, especially for high-volume operations
Job involvement	- Empower staff to redesign their jobs - There must be some limits to the way each individual makes changes which could impact on other staff and on performance of the operations as a whole
High involvement	- Includes all staff in the strategic direction and performance of the whole organisation

To facilitate waste identification and elimination, 5S is a methodology that has been used by many lean manufacturers [Emiliani (1998), Slack *et. al.* (2007)]. Originally, the five Ss are from Japanese words; *Seiri*, *Seiton*, *Seiso*, *Seiketsu* and *Shitsuke*. However, many literatures [Chapman (2005), Slack *et. al.* (2007)] in western countries translate them into English as follows:

- Sort (Seiri): Employee keeps items that are needed. Unneeded items are eliminated.
- Straighten or Simplify (Seiton): Items are positioned in such a way that they can be easily reached whenever they are needed.
- Shine (Seiso): Everything is kept clean and tidy.
- Standardize (Seiketsu): Operation is in a consistent and standardized fashion.
- Sustain (Shitsuke): Commitment and pride in keeping to standards are developed.

In the CLMM view, improvement process is never-ending. Also known as *kaizen, Continuous Improvement* (the third process in CLMM Alignment) is an ongoing effort to identify and remove wasteful elements in the manufacturing process. It is necessary to have a clear internal and external communication strategy, and a system of improvement suggestions should also be in place, and employees must be trained in methods of continuous improvement [Delbridge and Barton (2002), Garcia *et. al.* (2006)].

4.2.8 Mechanism of CLMM Implementation

Stage 3 (Implementation) relates the mechanism of implementing the CLMM. The mechanism starts with measurement of performance of the organisations and followed by benchmarking, evaluation, diagnosis and action plan.

Performance Measurement is an initial point for further analysis [Wibisono (2003)], whereas *Benchmarking* is to compare the measurement against other organisation, normally the best in the same industry and is

recognised as an essential tool for quality improvement of quality [Dattakumar and Jagadeesh (2003)]. Then, *Performance Evaluation* is the assessment of a possible situation in comparison with plans and or standards previously set as a target [Wibisono (2003)] while P*erformance Diagnosis* is the process of finding the root causes of performance problems [Najmi *et. al.* (2005)]. Lastly, *Action* is concerned with action that has been done and also the action planned to be implemented.

The goal of this mechanism is to evaluate the achieved performance, which means that the actual performance is compared with performance targets [Stoop and Bertrand (1997)]. After a diagnosis which explains how the actual performance has been established, one can start appropriate actions for performance improvements [Stoop and Bertrand (1997)]. This process of measurement, benchmarking, evaluation, diagnosis, and action is regarded as a closed loop process continuously leading to performance improvements, and is comparable to the plan-do-check-act (P-D-C-A) cycle [Stoop and Bertrand (1997), Lee (2002)]. In all three *Organisation CLMM Alignment - Process* Perspective modules, the factors are related to measurement, benchmarking, evaluation, diagnosis and action plan.

4.2.9 Structure of KBCLMM System

As clearly stated in the second objective of this research, the need to develop a KB system requires the conceptual model shown in Figure 4.6 to be converted into a structured model. Strategic issues in the conceptual model are contained in the planning stage (Stage 1) of the model, while tactical and

operational issues are more relevant to the design stage (Stage 2) and implementation stage (Stage 3) of the model.

To enable the conceptual model to be developed into KB system, clear KBCLMM Model needs to be clearly structured in hierarchical levels from most strategic issue to the most operational issues as shown in Figure 4.8, reflecting in a way, the hierarchical strategic and operational issues of the organisation. The KBCLMM Structure reflects the potential of detailed KBCLMM System which will be developed and discussed in the following two chapters.

For this reason, Stage 1 is divided into three levels (Level 0 to Level 2). *Organisation Environment* is identified as the most strategic issue and placed in Level 0 to gather the basic profile of the organisation for the purpose of identification and reference. As market and financial status are much related to the strength of the organisation business, Level 1 contains *Market Analysis* and *Financial Analysis*. Other strategic issues which related to the organisation operations are placed in Level 2, which includes *Product Design for Manufacture, Internal Lean Chain,* and *External Lean Chain*.

For the tactical and operational issues, five competitive priorities of *Quality, Time, Flexibility, Value* and *Supply Chain* are transferred to Level 3. While Level 3 contains the competitive priorities capability, Level 4 consists of the capabilities of the organisation's resources: *Human, Technology* and *Financial*. The most operational issues, i.e. the identified processes to align the CLMM to achieve customer satisfaction are located in Level 5, which includes *Employee Involvement*, *Waste Elimination* and *Continuous Improvement*. Finally, the mechanism steps of implementation in Stage 3 are linked to each of

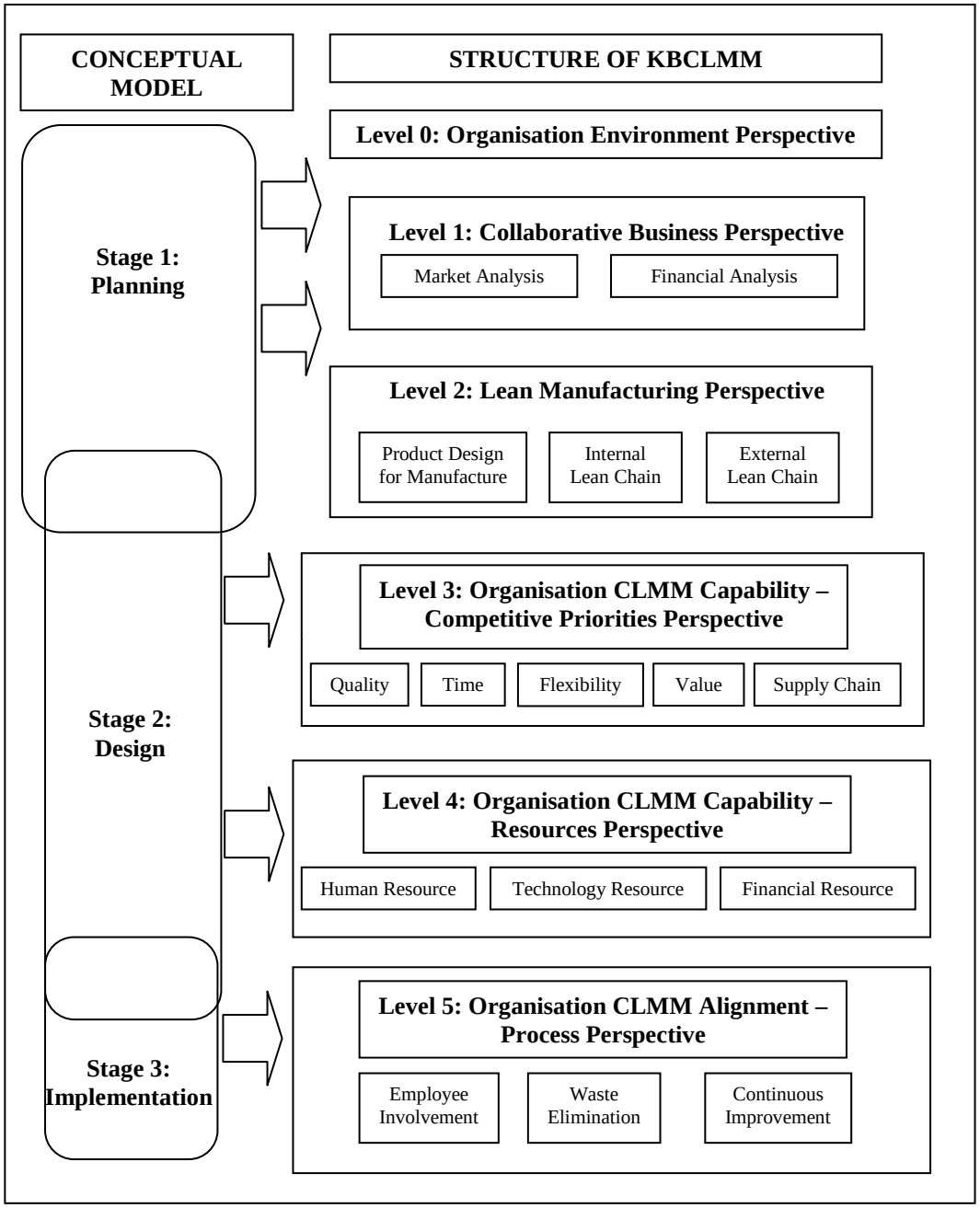

Figure 4.8: Conversion of Conceptual Model to Structure of KBCLMM System

the process in Level 5. These steps are *Performance Measurement*, *Benchmarking*, *Evaluation*, *Diagnosis* and *Action Plan*.

Based on this structure, a clear relationship is shown between conceptual components in the Stages 1, 2 and 3 of the model by dividing them into six CLMM perspectives. These perspectives were developed according to their

relevance to the CLMM development, based on the elements or variables that were derived from the previous lean manufacturing management literature discussed in Chapter 2. The KBCLMM Model is developed in the Knowledge-Based environment, based on the capability of the *AM for Windows* expert system shell.

In Figure 4.8, it is clearly shown that the KBCLMM System is developed on six interrelated levels (Level 0 down to Level 5). The core of the KBCLMM System extends from Level 1 to Level 5. From a strategic management point of view, both Levels 1 and 2 could be considered as corporate or strategic decision levels while the remaining Levels 3 to 5 are considered as functional or operational decision levels. This six-level structure of the KBCLMM System also reflects a typical functional hierarchy of most companies, leading to a very practical KB model. Each of these components (or modules, as viewed in the *AM for Windows* software) in every perspective will be discussed in detail level by level, in Chapters 5 and 6.

Since the KBCLMM Model is embedded with GAP analysis and AHP technique for improvement prioritisation, the assessment and evaluation of the organisation's current situation will be conducted through a series of questions that are contained in every module from Levels 0 to 5 in the System. These modules are considered as criteria, and based on the points gathered from these questions, the AHP technique will be used to prioritise every criterion.

4.3 Summary

This chapter has described the proposed KBCLMM Model by discussing three major stages, which are implemented in a Knowledge-Based System (the

foundation of the model) and supported by the combination of GAP analysis and AHP techniques in a hybrid model. The research has developed a model that has been divided into three major stages: Stages 1, 2, and 3. In Stage 1 (Planning stage), there are five major components, namely *Organisation Environment*, *Collaborative Business*, *Product Design for Manufacture*, *Internal Lean* and *External Lean*. In Stage 2 (Design stage), there are two major components, which are *Organisation CLMM Capability* and *Organisation CLMM Alignment*. Each component and element in both stages has been described. In Stage 3 (Implementation), there are five steps, performance measurement, benchmarking, evaluation, diagnosis and action.

For the purpose of information system development using KBS shell software, the proposed KBCLMM Model has been transformed into the structure of a KBCLMM System, which consists of six interrelated levels and five perspectives. These are *Organisation Environment*, *Collaborative Business Perspectives*, *Lean Manufacturing Perspectives*, *Competitive Priorities Perspectives*, *Resources Perspectives*, and *Process Perspectives*. Finally, the detailed design of the KBCLMM Model will be discussed in relation to the KBCLMM System by describing components and perspectives of Stages 1, 2, and 3 of the model in Chapters 5 and 6.