CHAPTER 8

CONCLUSION

8.0 Introduction

This chapter highlights the summary of information presented in this thesis that includes discussions of research achievements, main findings, advantages and limitation of the developed system, and recommendations for future work that can be undertaken. The general goal of this research was to develop a Knowledge-Based (KB) approach model for planning and designing a Collaborative Lean Manufacturing Management (CLMM), by embedding Gauging Absences of Pre-Requisites (GAP) Analysis and Analytic Hierarchy Process (AHP) technique in the KB system. A summary of the research activities is illustrated in Figure 8.1. The achievement of research objectives and overall conclusions are presented, along with advantages and limitations of the proposed model. Finally, the contributions of this research, together with recommendations, are offered.

8.1 Achievement of Research Objectives

The objectives of this research listed in Chapter 1 have been achieved. This research provides a model for planning and designing a CLMM for a given automotive manufacturing environment. It offers a technique to assess organisation current situation through the GAP Analysis. In addition, it also provides an analytical tool in prioritising factors that need improvement through the AHP technique.

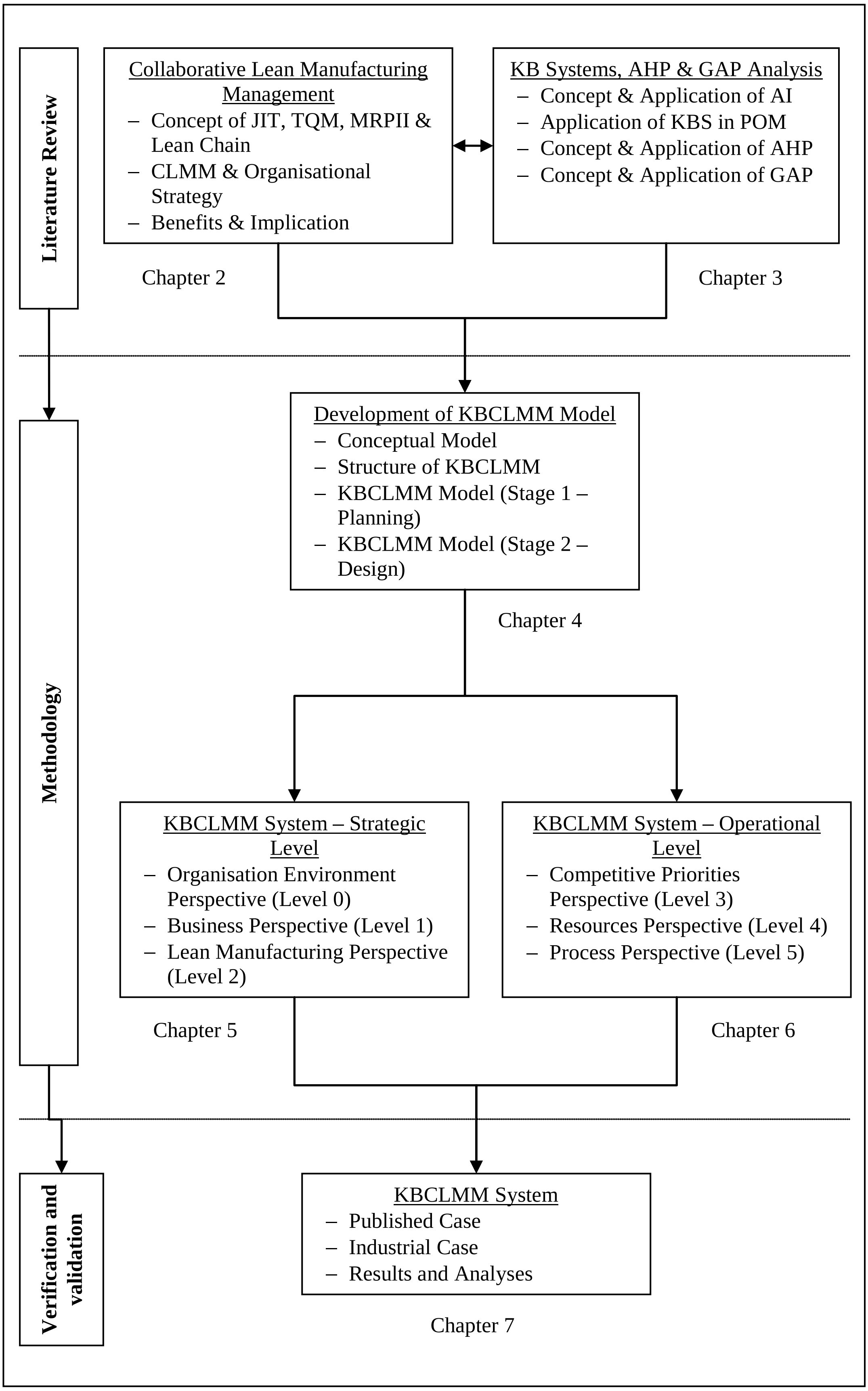


Figure 8.1: Summary of Research Activities

As the *Objective 1* of the research was to design a conceptual model of CLMM, extensive literatures of the subject of Lean Manufacturing Management (LMM) has been reviewed in Chapter 2. It was found that the LMM, which evolved from the Just-in-Time (JIT), Manufacturing Resources Planning (MRP II), and Total Quality Management (TQM) concepts, plays significant roles in capturing, maintaining and sustaining the competitive advantage of organisations. Based on the literatures, the KBCLMM Conceptual Model was developed and presented in Chapter 4, by describing each component in the model and its relationship.

Once the *Objective 1* has been achieved as presented in Chapter 4, the conceptual model was then converted into a hybrid KB/GAP/AHP System (*Objective 2*). In order to 'translate' the KB approach used to support the CLMM development, the KBCLMM Conceptual Model was transformed into the KBCLMM System Structure, consisting of six levels, as shown in Figure 4.8. The strategic level of the KBCLMM system was described in Chapter 5, whereas the operational level was covered in Chapter 6. The system was developed using the *AM for Windows* shell and through the production rules methods. Additional KB was contained in the detailed explanations for each of the rules developed, with the specific aim of reducing the uncertainty within the developed KB system. The development of the KBCLMM through the integration of the KB methodology, GAP Analysis and AHP technique is a novel approach for planning and designing a CLMM, especially for the automotive manufacturing environment.

To achieve the *Objective 3* of the research, the KBCLMM System was then validated through the industrial and published case data to ensure its validity, reliability, and applicability, as presented in Chapters 7. There were four industrial cases and two published cases involved in the verification process. The verification analysis and detailed results of GAP and AHP for one of the industrial case organisation, i.e. PROTON were discussed and presented in detail, while the results for other organisations were summarily covered and are shown in detail in Appendix E. Based on the information retrieved from the organisations' data and knowledge gained from the interview with the experts, the verifications results were used to improve the KBCLMM System (*Objective 4*). The System found to be work as planned, valid, reliable, consistent, and has the capability in identifying and suggesting the areas that need improvement.

Finally, thorough the process of development, application and validation of KBCLMM System, the advantages and limitations of the System has been discovered (discussed in Section 8.3 and 8.4). Based on these advantages and limitations, the *Objective 5* of recommendation for future work has been suggested (discussed in Section 8.5).

8.2 Summary of Results Findings for KBCLMM

For this study, four industrial case verification and validation results were completed, which involved four automotive manufacturing organisations, PROTON, PERODUA, PHN, and PROFEN. The results from the KBCLMM System performance during the verification and validation process showed that the System successfully captured the reality of what was existing in these four organisations towards CLMM implementation.

The System revealed that PROTON has achieved 82% *Good Points*, indicating that 18% of the pre-requisites for achieving CLMM environment were absent. This implies that PROTON is moving towards the CLMM environment but is presently quite a distant from the best practice position, which was agreed by the participant in the verification and validation process. The participant however mentioned that PROTON management is in the direction of improving its lean manufacturing practice and supply chain management. For PERODUA, the main competitor of PROTON, the System found that the achievement is better with 87% of *Good Points*. This achievement was agreed by the PERODUA participant. Even the interviewee from PROTON admitted that PERODUA performance in terms of lean manufacturing is better than PROTON due to the reason that PERODUA is partly owned by TOYOTA.

For the suppliers of both PROTON and PERODUA, the KBCLMM System found that the performances of PHN (1st- tier Supplier) achieved 79% while PROFEN (1st-tier and 2nd- tier Supplier) achieved 66% of *Good Points* respectively. Although the participants from both of these suppliers did not want to comment on their results of the verification and validation process, but both PROTON and PERODUA participants have the same opinion on their suppliers' performance percentages. According to them, the more upstream the suppliers (in order of 1st, 2nd, 3rd ... up to raw material suppliers) from OEMs, the least the adoption of lean manufacturing practices. This is inline with the results found by the KBCLMM System. In addition to the reality captured in the verification and validation process, it was also found that the System also gave guidance to the involved organisations to achieve the best practice CLMM.

The System also captured the activities in the CLMM that have potential opportunity for collaborative development through the lean value chain gap measurement in CLMM as discussed in Section 7.3.5. The results showed what the organisations' potential opportunity of their abilities compared to their partners' potential opportunity in the lean chain. In this research, the lean value chain gaps between Original Equipment Manufacturers (OEM) and their suppliers were evaluated. From the results, there were some gaps between customer and suppliers which could obstruct the CLMM achievement. In this case, the KBCLMM System showed its capability as a Decision Support System to assist both customers and suppliers to work collaboratively to improve their activities.

8.3 Comparison of Results with Global Automotive Industry

In the context of the global automotive industry, the results of the longitudinal case studies in Chapter 7 revealed that all of the tested organisations were achieving below the WCM global standards. These include the market, financial, lean chain, delivery time, technology, and effectiveness of waste elimination.

From the strategic point of view, market analyses results for all organisations have shown that all companies involved are basically domestic market oriented which do not focus on the global market. Based on statistics by International Organization of Motor Vehicle Manufacturers [OICA (2007)], Figure 8.2 shows the global market share in the automotive industry. PROTON and PERODUA market share is only 0.2% each, which is considered as insignificant when comparing to other automotive manufacturers, e.g. GM with 13.0% market share.

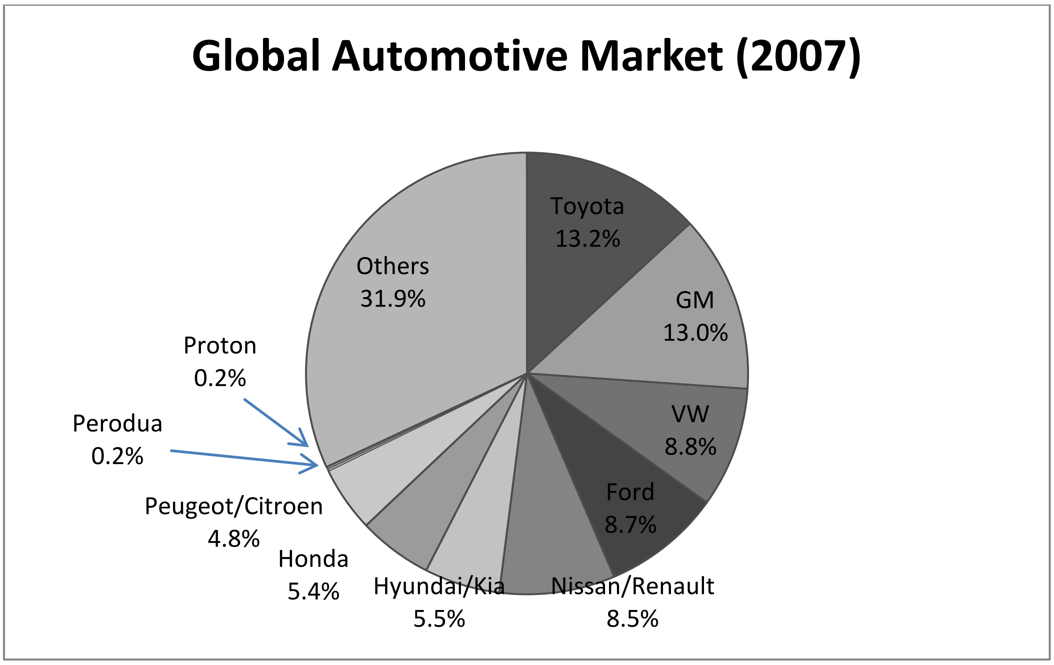
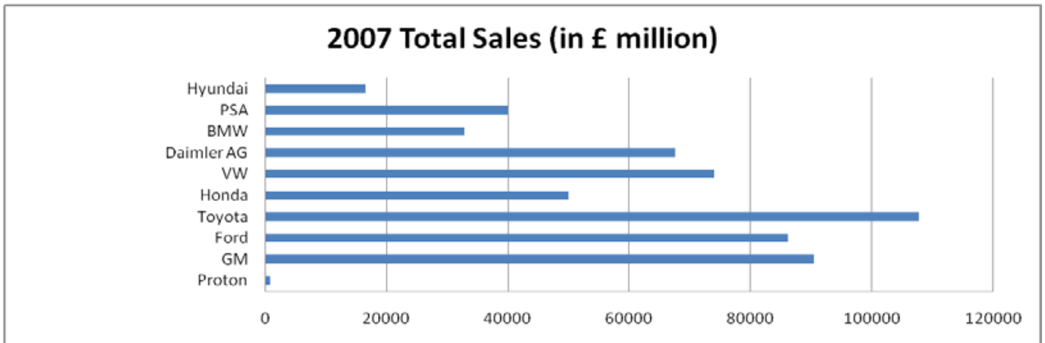


Figure 8.2: Global Automotive Market Share in 2007 (source: OICA (2007))

Results from financial analysis of the organisation (only financial report of PROTON available) also have concluded that the organisation is far behind the global automotive manufacturers. Total sales of PROTON are less than 1% of Ford or General Motors (GM) sales as shown in Figure 8.3.



	Proton	GM	Ford	Toyota	Honda	VW	Daimler AG	BMW	PSA	Hyundai
2007 Total Sales (in £ million)	722	90561	86250	107874	49942	74050	67591	32851	39900	16535

Figure 8.3: Total Sales of Selected Automotive Manufacturers in 2007 (source: Annual Reports of the Companies)

In terms of profit (Figure 8.4), while Toyota made £7.4 billion, PROTON lost £87 million. However, two of the biggest manufacturers were in worse condition, i.e. Ford with £1.35 billion loss and GM with £19.366 billion loss.

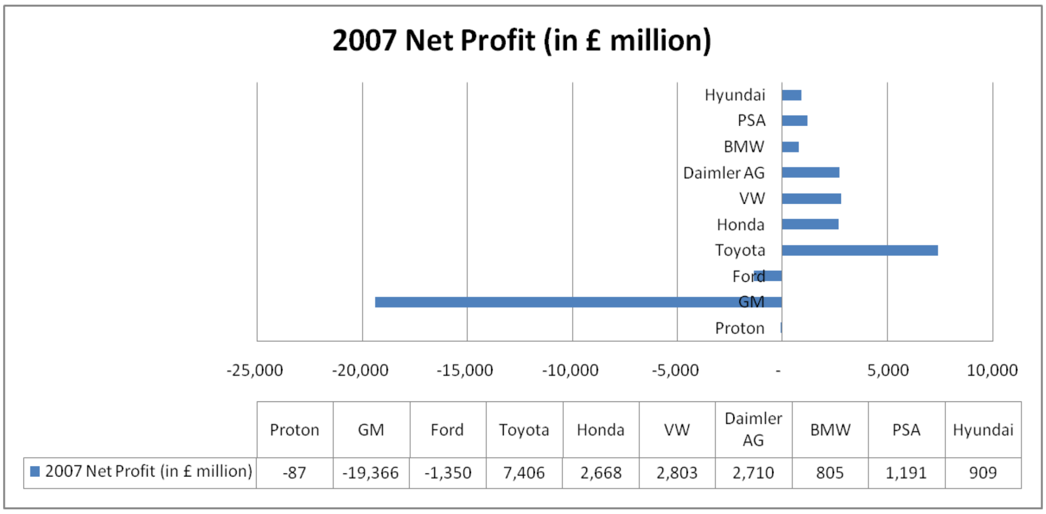


Figure 8.4: Net Profit of Selected Automotive Manufacturers in 2007 (source: Annual Reports of the Companies)

From the lean manufacturing chain aspects, the issue faced by most of the organisations under study was more on the external lean chain especially the integration with the suppliers. However, two giant automotive companies, Ford and GM also share the same problem [Donnelly *et. al.* (2002), Donnelly and Morris (2003)]. According to Donnelly *et. al.* (2002), the tradition in dealing with suppliers throughout in western countries is extremely adversarial and based on short-term contracts. On the other hand, Japanese automakers such as Toyota and Honda, view suppliers as partners instead of outsiders [Monden (1998), Womack and Jones (2003), Sako (2004)].

In term of competitive priorities, most of the organisations, have issues of time and delivery. According to Mohamed (2008), PROTON and PERODUA are currently take an average of 24 hours to build one car. For the time taken to develop a new product, the average time taken is currently between 27 and 36 months. Table 8.1 illustrates these two time dimensions in comparison to the global automotive manufacturers. The assembly time found to be on par with the global average, while product development time is still below average.

Table 8.1: Performance of Time and Delivery Priorities by Regional Automotive Industries

	Malaysia	**Japan**	**North America**	**Europe**	**Others**
Assembly time/ vehicle (hours)	24 [1]	16.8 [2]	25.1 [2]	36.2 [2]	20.6 [3] (Hyundai) 24 [1] (Global average)
Development time (months)	27-36 [1]	12-24 [4,5]	28-34 [5]	24-36 [4]	27 [1] (Global average)
Sources:	[1] Mohamed (2008) [2] Womack *et. al.* (1990) [3] Wyman (2008) [4] Liker (2004) [5] Magee (2008)				

Finally, as revealed by the KBCLMM System, all of the organisations under study have issue with technology resources and process effectiveness. However, similar issue is also found in the other developing countries' automotive industries. According to Laosirihongthong and Dangayach (2005), the automotive manufacturers in developing countries should invest more in technology related resources such as information technology, computer aided design (CAD), computer numerical control (CNC) and product innovation.

In contrast, global automotive manufacturers are well known of their technology capabilities. According to Womack and Jones (2003), German automotive manufacturers such as Porsche, BMW, and Mercedes-Benz are traditionally rated as having the strength of superior technology, or *technik* in German language. On the other hand, Japanese manufacturers have the capability of selecting the right technology to use, which support the human, process, and environment [Liker (2004)]. Table 8.2 shows some examples of technology and process capabilities of global automotive leaders.

Table 8.2: Examples of the Best Process and Technologies of Global Automotive Manufacturers

Manufacturer	Pioneer/ Best Practice for the following Process/Technology
Honda	• Variable Valve Timing and Electronic Lift Control (VTEC) • Hydrogen fuel cell vehicle (2008)
BMW	• Efficient dynamic fuel-saving
Porsche	• Tiptronic automatic transmission
Mercedes-Benz	• Anti-lock braking system (ABS) (1978) • Electronic Traction Control System in (1985)
Toyota	• Elimination of Production Waste (*Muda*) • Quick Changeover • Hybrid-electric car (Toyota Prius in 1997)
Volvo	• Safety features such as o 3-point Safety Belt (patented in 1958) o Side Impact Protection System (1991) o Collision Warning with Brake Support (2006)
Ford	• Mass production system (1914)
Sources	Monden (1983), Womack *et. al.* (1990), Wikipedia (2008), Wikipedia (2009)

In essence however, from the results presented in Chapter 7, the KBCLMM System has found that the organisations involved have fundamentally in the direction of achieving global standard of lean manufacturing management. These organisations have some similar issues which enable them to work collaboratively in lean manufacturing chain.

8.4 Advantages of KBCLMM System

The KBCLMM System has a number of benefits, noted during its development and application, which can be outlined as follows:

- The KBCLMM System acts as a decision support system which can advise the management on a particular activity that need to prioritise on the development of CLMM based on the current situation assessment. The system also offers an integrated approach that can be used as guidance to the management in planning and designing the CLMM. The System successfully showed these advantages in the verification and validation process as discussed in Chapter 7.

- The development of the System is in a modular approach, but integrated as a whole. Information and production rules in the system can be modified and amended easily by the developer.

- The KBCLMM System was found to be user-friendly by the participants, combining the enhanced GUI with supplementary information during the interactive sessions.

8.5 Limitations of KBCLMM System

This research has successfully achieved its objectives and has generated important and interesting findings. However, some limitations of the KBCLMM System still need to be addressed. The identified limitations are described below.

- The KBCLMM System is developed using *AM for Windows* software, an expert system shell. *AM for Windows* has its own limitations, in terms of memory, allocating the control of program during execution, illegal functions being performed and lack of flexibility to amend information that had been input in the earlier procedure.
- The uncertainty factor (fuzzy logic) has not been used with the rule-base, and is an area for future work. However, in the current research, this problem was tackled by providing detailed explanations for every rule.
- The rule-based approach in the system also has limitations. Since *AM for Windows* does not have its own inference engine that could support

deducing the rules, the KBCLMM System consisted of a huge number of lines (syntax) which affected the effectiveness of the system during execution.

- Since there is no available system designed for CLMM development, it is hard to benchmark the effectiveness of KBCLMM in terms of its functionality and acceptability.

8.6 Recommendations for Future Work

Despite the novelty of approaches in planning and design of the CLMM as presented in this thesis and based on the findings and the limitations of this research, there are still areas of further improvements. The following recommendations are listed for the future work.

- In this research, there are around 700 KB rules contained in the KBCLMM System. In addition, there were another hundreds of rules contained in the detailed explanations for each of the questions which need further elaboration. It is recommended that to make the KBCLMM System applicable to other industry and more reliable, an estimate of 1500 to 2000 rules need to be developed. The System should also utilise the web-based technology, which could be reached by multiple organisations in multiple tiers in the KBCLMM web.
- In order to maximise the capability of the KBCLMM System, the confidence level of the user should be added while answering the question, due to the subjectivity of the question, which requires only a Yes/No/Do not know answer. By including the user confidence level, for example, through fuzzy logic application, it could improve the user

judgement and could influence the calculation of the improvement priorities.

- The process of entering the data in the KBCLMM System is based on an interactive mode, which can take a considerable time to accomplish, due to the user having to answer all the questions in a serial way. It is possible to design a database, which can store all the information and connect it to the KBCLMM System.
- The statistical tests necessary to gauge the reliability and consistency of the KBCLMM System has not been done. It is recommended that statistical tests should be done to the assessment results in order to justify the particular hypothesis in the KBCLMM System. This would require repeated verification and validations.
- A simulation model should be developed to complement the KBCLMM System. This stochastic modelling will assist the managers and developer to understand the manufacturing system at a deeper level. Once a simulation model is established, the bottlenecks or the stages where process is most time consuming, can be found. The simulation model then should be developed, verified, validated, simulated, and analysed to complement the System.
- In this research, the focus is on the basic CLMM, involving the OEMs and their first and second tier suppliers. It would be possible to expand the organisational involvement by considering upstream and downstream organisations, as well as government agencies. The upstream organisations might include third tier suppliers up to raw material

suppliers, and downstream organisations include distributors down to end users.

- The verification and validation process is done in the Malaysian setting, which is totally different in terms of policy, culture and practice. It is recommended that the KBCLMM System should be validated in other environments, which can provide further opportunities for its improvement.
- The verification and validation process is done in the automotive manufacturer environment, which is slightly different to other manufacturing environments. It is recommended that the KBCLMM System should be validated in the other manufacturing environments or settings, which can also provide further opportunities for its improvement.

8.7 Conclusion

The thesis objectives were to develop a hybrid KB system by embedding GAP Analysis and AHP Approach for the planning and design of the CLMM. This chapter has consolidated the discussions made regarding the planning and design of the CLMM, has reviewed the achievement of the objectives of the research, and has summarised the overall conclusions about the KBCLMM System. Finally, the advantages, limitations of the system and recommendations for future research work have been outlined. It can be concluded that the KBCLMM System provides a sound and reliable prototype for organisations to use in planning and designing of the CLMM for capturing, maintaining and sustaining the organisation competitive advantage through the power of Lean Manufacturing Management collaboration.