CHAPTER 9

CONCLUSION AND RECOMMENDATIONS

9.1 Introduction

This chapter summarises the thesis findings on the importance of the conceptual design approach for LVAM through the implementing of KBLVAM System. The development of KBLVAM System has covered the important issues related to the LVAM environment at the strategic and operational level. There are six main perspectives of the KBLVAM System that identify the GAP between the existing condition and the industry benchmark of low volume automotive manufacturers. The developed perspectives include *Manufacturer Environment (Level 0), LVAM Manufacturer Business* (Level 1), *LVAM Manufacturer Resource (Level 2), LVAM Car Body Parts Manufacturing (Level 3), LVAM Competitive Priorities (Level 4),* and *LVAM Lean Process Optimisation (Level 5).*

9.2 Research Achievement

The main aim of this research was to develop a hybrid KB model which incorporates Gauging Absences of Pre-requisites (GAP) analysis and Analytic Hierarchy Process (AHP) methodology embedded in the system. The objectives of this research as outlined in Chapter 1, have successfully been achieved with the development, implementation, verification and validation of the KBLVAM. The GAP between the actual condition and the ideal case (benchmarking) is thoroughly assessed before the final decision is made. As a result, the developed

KBLVAM System is capable in assisting the automotive manufacturers in their decision making process in designing and implementing the LVAM. A summary of the research activities is shown in Figure 9.1.

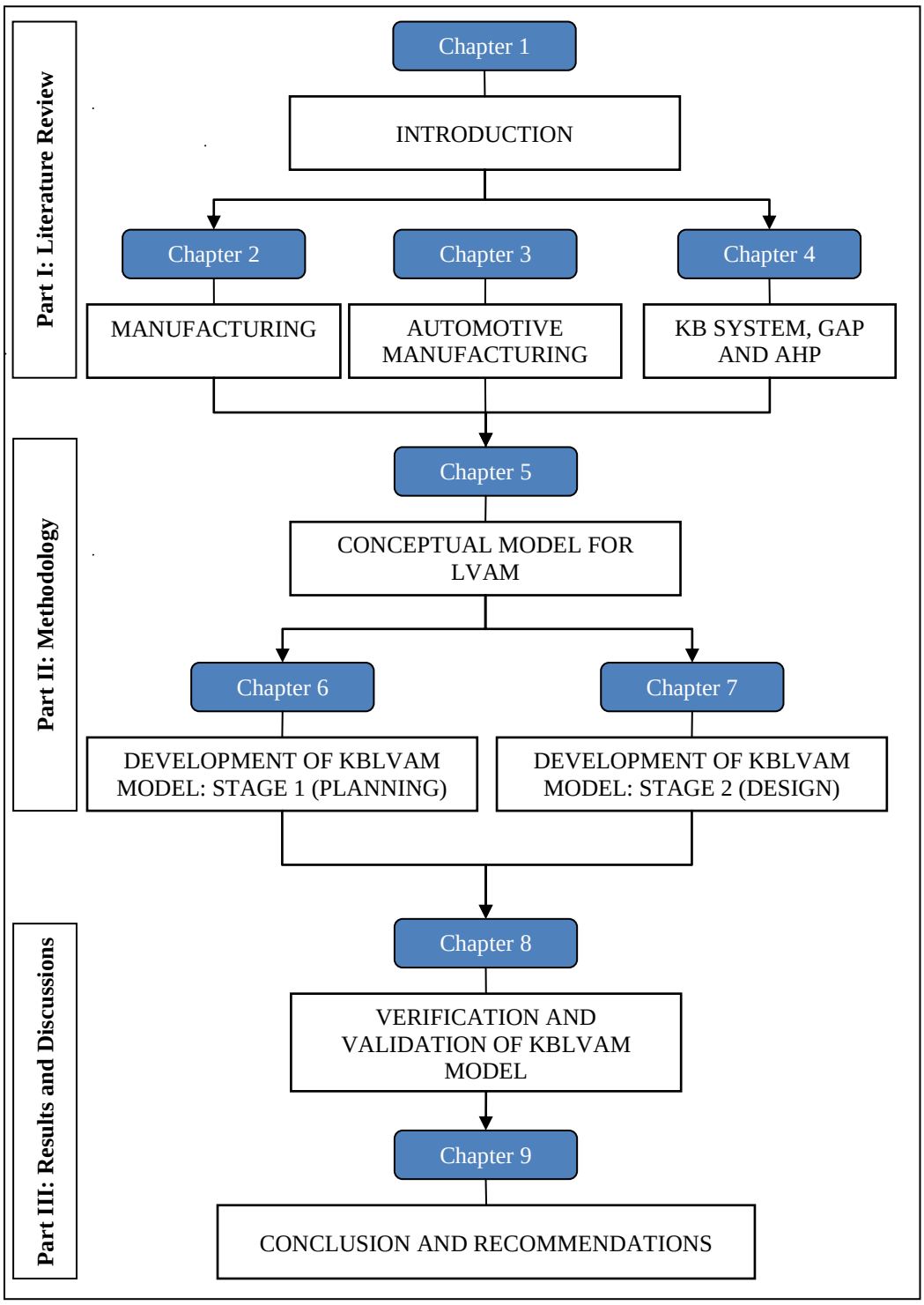

Figure 9.1: Summary of research activities

Chapters 1, 2, 3 and 4 of the research have proceeded from a background of automotive industry globally followed by extensive literature review in the areas of manufacturing, automotive manufacturing, and Artificial Intelligence (AI) in order to fulfil the *Objective (a)*, which is to design a conceptual model of LVAM. In Chapter 1, the research has proceeded from a background of automotive industry globally especially in the HVAM and LVAM environment, in order to formulate the research project aim and objectives. Based on the study, the research methodology to be adopted was then presented. The research was focused on the LVAM by using a hybrid KB System, which was a blend of KB System, GAP and AHP. In Chapter 2, a review of three types of manufacturing processes that involved high, medium and low production volumes was done. It was revealed that manufacturing segments have different methods of processes depending on the types of business, products, facilities and lay-out. Chapter 2 also reviewed the concept of lean manufacturing, which focused on waste reduction at all levels throughout the company. Furthermore, in Chapter 3, the review revealed that automobile manufacturers have been introducing many new approaches, especially in the area of design, product/tooling design, manufacturing and suppliers which were very important for automotive manufacturing. In Chapter 4, key AI techniques were studied in order to design a hybrid KBS for LVAM. There were seven AI techniques reviewed in this chapter, which involved GA, ANN, SA, FL, FBS, CBR, and KBS. Chapter 4 also reviewed AHP technique, which is a tool to support multi-attribute problems by prioritising the areas that are needed for improvement, and based on a series of questions that have been analysed by the GAP analysis technique.

Chapter 5 of the research has proposed the KBLVAM model, which consists of two stages of the Planning (Stage 1) and the Design (Stage 2). The developed system integrates the use of GAP analysis and AHP technique in the formation of the model. This conceptual model was then converted into a structured KBLVAM System based on *AM Enterprise* software capability by describing each component in the model and its relationship. This framework consists of six interrelated levels with five main perspectives; *Manufacturer Environment, LVAM Manufacturer Business, LVAM Manufacturer Resource, LVAM Car Body Parts Manufacturing, LVAM Competitive Priority* and *LVAM Lean Process Optimisation.* The formation of the conceptual model and later translated into a hybrid KB/GAP/AHP System has fulfilled the *Objectives (b),* and *(c).*

Chapters 6 and 7 have elaborated the detailed KBLVAM model development for Planning (Stage 1) and Design (Stage 2). The Planning stage focused on the strategic area, which related to the *LVAM Manufacturer Environment, LVAM Business, and LVAM Manufacturer Resources.* The *LVAM Manufacturer Environment*, is in Level 0, which is used to compile in the general information and background of the LVAM manufacturer. The *LVAM Business* Perspective, is in Level 1, to gather the data from two modules, namely *Financial Analysis* and *Market Analysis* in order to assess the current financial status and market position of the manufacturer. The *LVAM Manufacturer Resources* Perspective, is in Level 2, has three modules; *Human*, *Technology* and *Financial* with the main focus to determine the current manufacturer condition towards LVAM resources.

In Stage 2, the Design stage concentrated on the operational area, which involved with three levels of the KBLVAM System structure. The system started with Level 3 – *LVAM Manufacturer Capability – Car Body Parts Manufacturing* Perspective, Level 4 - *LVAM Manufacturer Capability – Competitive* Perspective, and Level 5 - *LVAM Manufacturer Capability – Lean Process Optimisation* Perspective. The developed KBLVAM System is also the novel approach for the planning and designing a LVAM.

Chapter 8 of the research discussed the verification and validation process of the KBLVAM System through the industrial and published case data to ensure its validity, reliability, and consistency applicability in order to fulfil the *Objectives (d)*, and *(e)*. There were two industrial cases and two published cases involved in the verification process. Two Malaysian manufacturers involved in the industrial case study were Proton and Miyazu Malaysia. The verification analysis and detailed results of GAP and AHP for Proton were discussed and presented in detail in this chapter, while the results for Miyazu were summarised and are shown in detail in Appendix C. The validation analysis for published case studies used Proton and Toyota data. The results of the GAP and AHP analysis were discussed in detail in this chapter, indicating how each could be used to prioritise the sub-modules and modules for performance enhancement. The System found to be working as planned, valid, reliable, consistent, and has the capability of recognising and signifying the areas that need improvement.

Finally, through the process of development, verification and validation of KBLVAM System, the advantages and limitations of the research has been discussed in Section 9.3 and 9.4. Based on these advantages and limitations, the

Objective (f) of recommendation for future work has been suggested in this chapter.

9.3 Advantages of KBLVAM System

The advantages of the developed KBLVAM System, which have been noted during its development and application:

- LVAM environment involves the stages of car body development from market research, design concept, engineering, manufacturing, and distribution, which require specific knowledge and experience. Thus, the developed KBLVAM System, which considers all these requirements as an integrated system, is able to manage the whole process of car body development for LVAM.
- The KBLVAM System helps the manufacturers on how to set-up the niche car models in LVAM environment, based on the knowledge stored in the System. As the knowledge in the KBLVAM System is based on the benchmark practices, the manufacturers are able to set the business target for their LVAM models.
- The KBLVAM System provides decision support to the management of the LVAM manufacturers in identifying the specific problems in the development and manufacturing processes of LVAM models, and how to tackle the problems by prioritising the efforts in the focus area.
- The KBLVAM System provides the methodology for prioritising efforts of LVAM manufacturer to improve performance of the entire

organisation and to improve the competitive position of the organisation through the benchmark exercise. The GAP between the existing condition of the LVAM manufacturer and the industry benchmarked is assessed and then prioritised by using the AHP methodology. Then after the appropriate actions to the problems, the GAP between the industries benchmarked is reduced.

- The System is user-friendly and can be used by the majority of the management staff, especially the *Explanation Facility* support during the interview sessions, helps the user to select the appropriate options.
- The development of the System is in a modular construction, but integrated as a whole. Meaning that, any information at any stage can be easily amended, especially when new knowledge is acquired.

9.4 Limitations of Research

Although the developed KBLVAM Model has shown potentials in providing suggestions for manufacture improvement, but the System is still at the prototype stage. Therefore, it still has some limitations as described below.

- The KBLVAM model is designed for LVAM environment, which could be different to the other manufacturing environment such as chemical plant. Therefore, the adjustment should be made to the certain performance variable including their related knowledge bases in order to be implemented in the other manufacturing environments.

- Since there is no available system designed for LVAM development, it is difficult to benchmark the effectiveness of KBLVAM in terms of its performance.
- The knowledge acquisition process only focuses on the important LVAM areas to be improved. There are potentially unlimited rules that can be implemented in LVAM environment, which is impossible to include every rule in the model.
- The developed KBLVAM is supported by the *AM for Windows* software. The software itself has its own limitation in term of insufficient memory because the rules consisted of a huge number of lines, which affected the performance of the KB System during execution.
- The uncertainty factor (fuzzy logic or Bayesian) has not been used with the rule-base in this research, and it was replaced by providing detailed explanations as the *Explanation Facility*.
- The developed KBLVAM system which is similar to other KBS initiatives has been considered as "black boxes" by some top level managers (Mosqueira-Rey et al., 2008). This is because the mechanics of the decision making process are developed by the knowledge engineer and the human experts in the field of LVAM environment. Purposely, only the input and outputs are visualised by the users. Therefore it is difficult for the top level managers to visualise the reasoning inside the system and may not appreciate the hard work in developing KBS.

9.5 Recommendations for Future Work

In order to improve the developed KBLVAM, the following items are recommended for the future work.

- In this research, the knowledge acquisition is only concentrated in the area of the car body parts. It is recommended to expand to the other areas including the painting, trim and final, and engine parts. So that the knowledge contained in the KBLVAM is a complete system for LVAM environment.
- In this research, there are over 2,400 KB rules contained in the KBLVAM System. In consideration of other areas in the car manufacturing such as above, it is recommended that another 3,000 to 4,000 rules to be added to the KBLVAM System.
- The verification and validation process is done in the Malaysian automotive environment, which is a totally different situation in terms of policy, culture and practice. Therefore, it is recommended that the KBLVAM System should be verified in other countries (including the developed countries), which can create the opportunities for its improvement.
- The verification and validation process is done in the automotive manufacturing environment, which is different to the other manufacturing set-ups. It is recommended that the KBLVAM System should be verified and validated in the other environments or settings,

by adjusting the rules, which can create the opportunities for other applications.

- In this research the early involvement of suppliers during the development stage is important to reduce the project timing. However, the Intellectual Property right of the LVAM manufacturer was not considered during the KBLVAM development. The Intellectual Property right of the LVAM manufacturer should be protected especially when dealing with suppliers by introducing the mechanism of Non-Disclosure Agreement (NDA) in the future KBLVAM System.
- The developed KBLVAM system considered the quality aspect as a separate module in the Design stage of LVAM environment. As for future work, these strategic and operational aspects of the LVAM environment should consider the explicit integration of quality element (TQM approach) along the different levels and modules and acts as a quality control mechanism within the conceptual model as proposed in Figure 9.2.

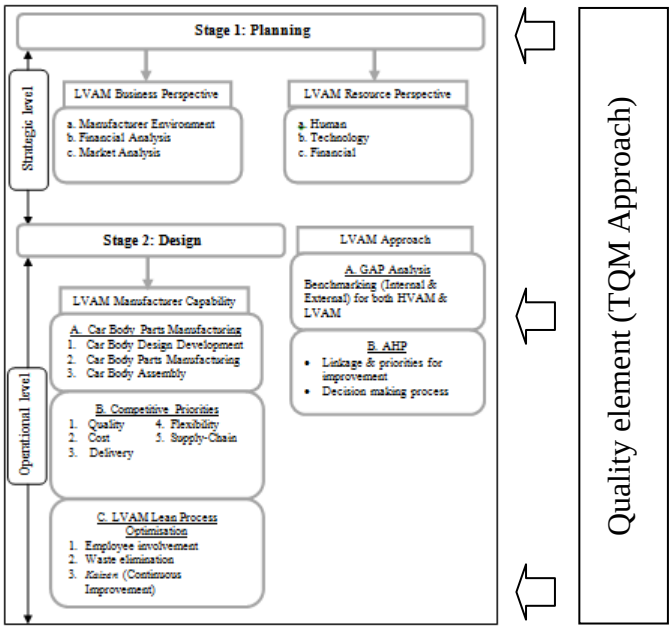

Figure 9.2: Future conceptual design of KBLVAM model

- The developed KBLVAM model considered the financial analysis which included the profit margins only at the Level 1 of the Strategic level. For future approach, the consideration of profit margins at different levels and modules (or departments) is important in order to monitor the areas that require more attention and to strategise appropriate actions. The incorporation of profit margin analysis also will help the LVAM manufacturer to address the issue of assessing the value of the KBS in the entire LVAM environment.
- The rigidity of the developed KBLVAM system is constrained by the software used for this research. It is necessary to have a more flexible KBS to respond to changes in the current dynamic business environment of the automotive industry. This can be done by using flexible expert system software which caters for dynamic and flexible changes of LVAM environment.

9.6 Final Remarks

This chapter has highlighted the discussions regarding the planning and design of the LVAM. The development of LVAM has focused on the six main perspectives of the KBLVAM System, which incorporated Gauging Absences of Pre-requisites (GAP) analysis and Analytic Hierarchy Process (AHP) methodology embedded in the system. This chapter has also reviewed the achievement of the objectives of the research in order to fulfil the *Objectives (a)* to *Objectives (f)* as outlined in the Chapter 1. Furthermore, the advantages of the KBLVAM System, limitations of the research, and the recommendation for future work have been discussed. As shown, the KBLVAM provides the decision makers in the LVAM environment, with a reliable prototype system for guiding and promoting the implementation of LVAM.

The development of the KBLVAM System was inspired from the reviews of manufacturing processes, automotive manufacturing environment, and AI techniques. Based on the extensive reviews, it was found that the automotive manufacturing industry requires various strategies to become competitive. One of the approaches was by implementing LVAM environment for niche models. In this LVAM environment, expert knowledge was very essential for the entire development and manufacturing processes to ensure the quality, cost, and delivery were achieved. Therefore, it was important to capture the expert knowledge in a system. Throughout the AI techniques, the KBS was the best system to be used for the LVAM environment because it used over 2,400 KB rules in deducing the solutions.

The developed KBLVAM model considered the entire LVAM environment from the strategic and operational aspects of an organisation. It covered from the background of the company, resource, manufacturing, competitive priorities, and until lean process optimisation. The developed KBLVAM system was structured into six levels and sixteen modules in order to form a hybrid system for LVAM body parts. The hybrid system was the combination of GAP and AHP methodology embedded in the KBLVAM.

The developed hybrid system is new in the LVAM area which helps the user to identify the existing LVAM level implementing in the company or to give the idea on how to set-up the LVAM business. The system assesses each level and modules of the user's organisation by using GAP analysis to identify the gap with the benchmark standards. Upon identifying the gap, the AHP technique embedded in the KBLVAM system will analyse and prioritise the areas that need to be rectified. It will suggest which areas need to be tackled in a systematic step by step process.

The developed KBLVAM system contributes a very useful tool for LVAM manufacturers to improve their competitive position by suggesting the improvement areas in a stepwise process in order to reduce the gap with the leaders in the LVAM environment. The KBLVAM system offers the users to identify the problems for the entire LVAM process, as well as within the modules and sub-modules. Therefore, specific improvement to the areas will also reflect the short term and long term achievement to the organisation.