CHAPTER 9

9. CONCLUSIONS AND FURTHER RESEARCH

9.1 CONCLUSIONS

One of the critical goals of the project management is to reduce the project duration and towards this, planning and scheduling methodologies exist and concurrent engineering is being practiced in project scheduling. In concurrent engineering environment, coordination among dependent activities in terms of precedence relations and resources need to be carefully planned. A detailed study and analysis on multi-agent coordination for project scheduling have been carried out and an approach for multi-agent coordination environment consisting of a standard operating procedure and a coordination mechanism has been framed and presented. The coordination process includes overlapping of activities, task scheduling and the effective resource allocation. In order to achieve the effective project scheduling, priority rules for the resource allocation are proposed. In this research, the concepts for activity overlapping and rescheduling of activities have been designed and a prototype has been developed to prove the concepts.

A prototype for resource allocation based on priority rules in order to minimise the project duration by overlapping the activities of the project has been designed and developed. The developed software prototype has been tested for the project scheduling problems with time points and time periods, and tests for equal time periods have also been conducted. The results clearly show that the developed system is capable of producing consistently good results for the resource-constrained project scheduling.
9.2 ACHIEVEMENTS

The main contribution of this work is the development of coordination technique that can easily be integrated with a standard operating procedure to improve the performance in multi-agent environment. This approach is applied to project scheduling, one of the difficult NP-complete optimisation problems. Shortening project makespan is critical to project success in the project management and the experimental results show that the approach effectively enhances the performance of project scheduling for optimisation objective of reducing project makespan. As a primary driver of progress and an effective management tool, resource allocation among the project activities can strongly influence project makespan. One of the advantages of MAS comes from the coordination among agents which enables better solutions to problems that cannot easily be solved by centralised method.

This research has discussed the project activities, overlapping and resource allocation. By exhibiting the interdependencies between overlapping and resource allocation, the gap between two separate streams is bridged and demonstrated that the decisions to overlap should be made jointly to exploit the full potential. When all information about the tasks are estimated and obtained, the introduced system computes efficient overlapping. The system allows for analysing results regarding the influence of percentage of overlapping in the total project duration and it can be employed to evaluate the benefits of reducing the project makespan.

The method presented here can overcome the limitations of previous computation methods of the lead time of a project such as PERT and GERT. This system is more tractable than GERT and it can play an important role in planning and
managing of the project by helping to analyse and evaluate the project structure. Although PERT and GERT can provide good computation on simple cases, they are limited in terms of handling complex network patterns. On the contrary, the test results show that this method can provide good estimates in a complex project and it is important to compute the lead time of complex project because it is a crucial indicator in project management.

9.2.1 Concepts to identify task overlapping

An attempt has been made to answer the following question: how can activities that are nominally sequential be beneficially overlapped? The relevance of the question stems from the fact that many processes are nominally sequential and overlapping them helps to improve the effectiveness in terms of lead time. Overlapping is concerned with shortening the project duration not by shortening the individual activities, but by increasing the overlap period among them. The classification of the exchanged resource on two dimensions, its early release of resource from upstream and late requirement of resource for downstream activities helped to determine how to overlap the activities. It is seen that various ways of overlapping result in different performance trade-offs. Modelling the trade-offs helps to identify the different types of overlapping and show that the different types of overlapping differ only as a matter of degrees of overlapping and not as a matter of kind. The developed system helps to decide how the activities are overlapped and also helps to understand the relationships between the type of overlapping and the performance trade-offs.
9.2.2 Resource Allocation

A multi-agent coordination approach has been presented in tightly coupled environments and this approach consists of procedures and coordination strategies. This coordination is applied to project scheduling, one of the difficult NP-complete combinatorial optimisation problems. The framework and the associated models are found to be useful to overlap activities and reduce project makespan.

9.3 LIMITATIONS

In conclusion, possible limitations to the approaches are presented here. First, it is implicitly assumed that the overlapping of tasks is in the critical path. Projects that exhibit network structures such as cycle and iterative patterns are not considered in this approach. In addition, the following activity patterns are not considered: ⊙ an interdependent overlap which deals with the case where any of two activities affect each other and ⊙ multiple overlap which represents the overlapping relation involving three or more activities.

In this research, projects with simple network structures (sequential and branch-merge patterns of activities) are only considered. Further, the methodology proposed considers the zero time-lags between activities and non-zero time-lags between activities are not considered.
9.4 RECOMMENDATIONS FOR FURTHER RESEARCH

In this work, priority rules based resource allocation algorithm for the project scheduling has been presented to compute the lead time of the project by overlapping the activities involved. To evaluate the proposed algorithm, a case study and computational results have been done. From these results, one can see that the algorithm can be successfully employed in estimating the lead time of a complex project with constraints on resources. This system and several assumptions may not describe all situations occurring in the project management because of the intractability and the general characteristics of the system. Despite the restrictions, this system allows one to analyse a complex project with time aspect on resources, unlike PERT. This research work can be further extended in the following directions: Resource allocation in Multi-project environment, projects with non-zero time lags between activities, integration onto a decision support system, resource allocation for uncertain task durations, cost of applying Concurrent Engineering and projects with iterative and cycle patterns.

**Resource allocation in Multi-project environment** - It is noted that the effect of resource allocation among multiple projects is not considered in this thesis. Although this may not be restrictive for firms using dedicated platform teams, there are many firms which do not dedicate resources to specific projects. It needs to be examined how resource allocation may be modelled and included with the formalism developed in this thesis. This view of project scheduling creates several opportunities for future research.

**Projects with non-zero time lags between activities** - The research work can be further extended to develop algorithms for managing non-zero time lags between activities and for scheduling the activities.
Integration onto a decision support system - The relationships between resource allocation and branching of tasks in scheduling (policies introduced for deterministic scheduling) are established and the resource allocation decisions are made by using priority rules. The sequential and overlapped scheduling decision suggested in this research is a formalised decision making environment and it would be easy to implement this type of decision rule into a decision support system.

Resource allocation for uncertain task durations - When task durations are not determined and estimated, it will lead to inaccurate results regardless of the methodology used for project scheduling. Uncertainty in task durations is a limitation for task overlapping. Hence, this research work can be extended by identifying a mechanism to overlap the activities and to schedule the activities with uncertain task durations. New measures of uncertain task duration will have to be developed and next research step must provide better insights into the process of this uncertainty in task duration.

Cost of applying concurrent engineering – While applying concurrent engineering in project management, it generates benefits. The resource allocation in particular human resources allocation, while scheduling the project under concurrent engineering is considered. The cost side of applying concurrent engineering in project management opens up avenues for further research.

Projects with iterative and cycle patterns - This research can be extended to include additional activity patterns such as iterative and cycle which may appear in a more complex project. One can also extend the overlapped model by considering several situations such as interdependent overlap and multiple overlap.