

CHAPTER 9

CONCLUSIONS AND FUTURE RESEARCH

9.1 SUMMARY AND CONCLUSIONS

In this thesis, the research dealing with the Public Healthcare Facility Planning Using Location Allocation Models was presented. Based on the real-world data, a walk through the various stages of planning the location of the facilities was done which integrated the information and policy of the public healthcare delivery system in Malaysia.

The location of the facility and the allocation of demand to the facility were the kernel of the system. In this problem, the location allocation models considered were as follows:

1. Un-capacitated type;
2. Capacitated type;
3. Multi objective type; and
4. Conditional dynamic type.

All these extensions were part of the facility location planning and were required in real-world operations. In Chapter 1, the importance of location analysis in the health service planning and why this particular research was necessary were explained. After a broad review of several relevant models in Chapter 2, the Malaysian Health Delivery System was explained, together with the scope of this study and the profiles of the study areas in Chapter 3.

Chapter 4 began with an introduction of the relevant basic models, p -median and Maximal Covering Location Models (MCLP) that were used in the study. Each was introduced together with its solution approaches. An application of both models to the study area of 179 nodes network was illustrated. The models were solved using the commercial optimisation software CPLEX 10.2 which provided an overview on the performance of the current location decisions in the study area in terms of service coverage percentage and the average travelled distance. A sensitivity analysis on the current location of the facility against the national policy on the two objectives was also done.

In Chapter 5, the basic models were extended to include the capacity of each facility as a constraint. Based on the national policy of emphasising on the service coverage, the capacitated MCLP (CMCLP) was presented as the first model for healthcare public facility planning in Malaysia. Several algorithms for solving the CMCLP were discussed in this chapter and a Genetic Algorithm based heuristic was proposed to solve the problem. A new chromosome representation was described, followed by the adapted genetic operators which were the crossover and the mutation operators. The performance of the algorithm was tested on the benchmark data from the literature (of size 30 nodes, 324 nodes and 818 nodes networks) and compared with the performance of CPLEX 10.2.

A locational analysis based on the CMCLP was also done for the study area of size 179 in this chapter. It was performed to gauge the national policy on capacity for a facility. Three sets of capacities based on government policy, staff perception as per the building design and the proposed policy were imposed for the analysis. Because of the

nature of the problem where the capacity of the facility as in the policy was very tight, the GA based heuristic outperformed the commercial optimisation software, CPLEX 10.2. The analysis was extended to a larger real data network of 809 nodes network.

It was also noted that the travelled distance was also an important measurement in the healthcare delivery. Hence, the capacity constraint was also imposed onto the p -median model and described in detail in Chapter 6. Before testing the GA-based algorithm on the capacitated p -median (CPMP), the chromosome representation was modified to suit the common assumption of every node which was as a potential location site and compared to the known test instances from the literature. An analysis using the CPMP model on the 179 nodes network and performance comparison of the CPMP to CMCLP using the 809 nodes network were also conducted. It was concluded that the GA-based heuristic was a comparable alternative that could obtain nearly optimal solution within reasonable computational times.

In Chapter 7, the capacitated models were extended to a more complex model. First, two objectives were combined in optimising the location of a facility and the allocation of demand to a facility as well as reformulate as a bi-objective model. Since the two objectives combined contradicted each other, the weighting method was employed. The method was used because the values of the assigned weight were easier and controlled to suit the data and ensure that the maximisation of the percentage of the service coverage became the priority. The bi-objective model was solved using GA and compared to the performance of Lagrangian heuristic and LINDO. GA produced better results in some cases and also provided alternative solutions to the problem.

Second, time was incorporated into the model in order to properly plan and accommodate for changes in the future. A dynamic conditional CMCLP that solved the

problem when several facilities were to be located was reformulated in addition to the set of existing facilities. The bi-objective model of maximising the percentage of service coverage whilst simultaneously minimising the average travelled distance by those who were out of the service distance coverage had been used to model this dynamic conditional CMCLP. As the population or the demand volume in the study area increased over time horizon, the problem was to locate an existing facility with the potential to be upgraded and/or to locate an additional new facility within a pre-specified time such that the coverage was maximised. The performance of the existing facilities was analysed with the increasing demand and a process in selecting the facility to be upgraded and the location for a new facility were proposed. This model was then applied in planning the location of the facility and the allocation of the demand in order to improve and maintain the performance of the healthcare delivery system in the study area.

Chapter 8 discussed the strengths and advantages of each model used in representing the Malaysian public health delivery system. It is hoped to be able to provide alternatives and insights to the planners in ensuring the best network of healthcare delivery system in Malaysia.

In summary, the following key contributions were made in this study:

1. An improvement algorithm that performed well on real networks and when the capacity is limited was suggested. The algorithm could provide a quality solution within reasonable computational times.
2. Different policy value for the facility was proposed and analysed. Acceptable values and good improvements were obtained.

3. A conditional dynamic model which incorporated the fact of existing facilities and the growth of demand in time as of real operations in the system framework were developed.
4. Several case studies were completed by applying the algorithms and formulations. The analysis results indicated that significant improvements could be achieved by applying the proposed planning steps in the system.

9.2 FUTURE RESEARCH

Although many aspects of the public healthcare facility location planning for Malaysia has been successfully modelled and analysed in this research, there are still many problems that are unsolved and are left for future study.

9.2.1 Hierarchy in Public Healthcare Delivery System

This thesis explored many possible aspects of modelling the location of the public facility that provided first hand healthcare services to the population in Malaysia. However, some of the population may not be able to be treated at the first point of contact only, which could be due to the seriousness of the illness or the distance to the nearest facility. As mentioned in Section 2.3, there was also a need to simultaneously locate a different number of services like local clinics, community health centres and regional hospitals. An extension of the location model that also incorporates the service hierarchy is an important aspect to be pursued for the Malaysian healthcare facility planning. In this study, only the policy regarding the capacity of the community clinics was analysed and it was concluded that it should be revised in accordance to the increase of the total

demand volume and service productivity level. Hence, the national policy regarding the capacity of each type of facility as well as its service boundary should be analysed.

9.2.2 Heuristic Algorithm

In this study, the use of the genetic algorithm based heuristic to solve all the models in comparison to various other heuristics was proposed. In Chapter 5, the algorithm in solving the Maximum Covering Location Problem when the capacity is limited (CMCLP) was introduced and applied. The sensitivity analysis on the performance of the algorithm, based on the assumptions and based on the benchmark data, was done in comparison to the commercial optimisation software CPLEX 10.2. The algorithm found optimal solutions in all cases in shorter time in comparison to CPLEX 10.2 which produced solution sets that violated some of the capacity constraints in the allocation process.

In Chapter 6, the modified version of the genetic algorithm based heuristic from Chapter 5 was used to solve p -median problem with limited capacity (CPMP). The performance of the algorithm was compared to several heuristics using new test instances. This algorithm managed to find nearly optimal solutions similar to another GA based algorithm (CGA and Ghoseiri's) proposed to solve CPMP. This is because of the large solution space produced by the algorithm. The use of another algorithm to provide the initial solution instead of being randomly generated by the GA based algorithm could be a good alternative. Due to the huge solution space generated, it was conjectured that GA with seeded population would be able to produce better results. The

Insertion was used as the mutation operator which may not be diversified enough in creating a totally new chromosome; hence the different types of operators could be tested in creating more potential solutions in the state of being trapped in a local optima too early.

An aspect to look into is the application of exact algorithms to solving the problems. The incorporation of heuristic method may be able to speed the computational time especially in solving larger problems.

9.2.3 Others

In this study, the multiple objectives (maximising coverage and minimising travelled distance) were considered in the models and weights were used to transform the multiple objectives into a uniform objective function value. Including the operational cost into the objective could be a better element in planning for locating or upgrading the facility.

In addition, an economic analysis of the tradeoffs between the operational costs and the benefits gained from the facility relocations and reallocations is an interesting area for future research. Since the operation of a system is supported by the medical officers and nurses, it is important to consider the corresponding staff scheduling problem, especially for the flexible allocation and borderless service boundary scheme. Another related optimisation problem would be to find the proper capacity limit or the number of staff for a system when certain performance levels are designated.

In summary, future research should continue to find good initial solutions and improve the algorithms, as well as to look at other relevant optimisation problems in the public healthcare delivery system.