DECISION SUPPORT SYSTEM FOR MEDICAL STAFFS AND SUPPLIES DISTRIBUTION PLANNING

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นางสาว ครองสิญจ์ สมประสงค์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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ครองสิญจ์ สมประสงค์ : ระบบสนับสนุนการตัดสินใจเพื่อการวางแผนการลำเลียงแพทย์และเวชภัณฑ์. (DECISION SUPPORT SYSTEM FOR MEDICAL STAFFS AND SUPPLIES DISTRIBUTION PLANNING) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ.ดร. เหรียญ บุญดีสกุลโชค, 280 หน้า.

วิทยานิพนธ์ฉบับนี้รายงานการพัฒนาระบบสนับสนุนการตัดสินใจสำหรับการวางแผนการลำเลียงบุคลากรและเวชภัณฑ์เพื่อปฏิบัติงาน ณ หน่วยแพทย์เคลื่อนที่ องค์กรที่ศึกษาได้ให้บริการหน่วยแพทย์เคลื่อนที่มาเป็นเวลานานแก่ผู้อาศัยอยู่ในท้องถิ่นทุรกันดารและขาดโอกาสในการรับบริการทางสาธารณสุขจากโรงพยาบาลภายในพื้นที่ วิทยานิพนธ์ฉบับนี้จึงมุ่งหวังที่จะพัฒนาระบบสนับสนุนการตัดสินใจที่สามารถช่วยให้พนักงานวางแผนการออกหน่วยแพทย์เคลื่อนที่สามารถวางแผนการลำเลียงบุคลากรและเวชภัณฑ์ไปยังพื้นที่ปฏิบัติงานได้อย่างมีประสิทธิภาพและประสิทธิผลทั้งนี้ยังสามารถช่วยลดความยุ่งยากในการตัดสินใจของเจ้าหน้าที่วางแผนรวมถึงสามารถสร้างแผนการออกหน่วยอยู่ภายใต้ต้นทุนการขนส่งที่เหมาะสม

ระบบสนับสนุนการตัดสินใจที่พัฒนาขึ้นแบ่งออกเป็น 2 ส่วนตามธรรมชาติของการให้บริการและการวางแผน โมเดลในการตัดสินใจของระบบที่พัฒนาขึ้นแบ่งออกเป็น 2 โมเดลทำงานแตกต่างกัน คือ โมเดลสำหรับการจัดเส้นทางการออกหน่วยสำหรับการออกหน่วยแบบต่อเนื่อง(Round-Trip) และโมเดลสำหรับเลือกโรงพยาบาลสนับสนุนบุคลากรสำหรับการออกหน่วยแบบไม่ต่อเนื่อง(One-day Trip) ในการจัดเส้นทางการออกหน่วยได้ประยุกต์ใช้แนวทางปัญหาการจัดเส้นทางการเดินรถ (Vehicle Routing Problem) เพื่อสร้างแผนการออกหน่วยแบบรายปีสำหรับการออกหน่วยแบบต่อเนื่อง และได้ประยุกต์ใช้ปัญหาการมอบหมายงาน(Assignment Problem)ของปัญหาการจัดตารางมาใช้ในการเลือกโรงพยาบาลที่เหมาะสมในการสนับสนุนบุคลากรทางการแพทย์โดยทั้งสองโมเดลใช้ระยะทางเป็นตัวบ่งชี้ถึงค่าต้นทุนการขนส่งระหว่างดำเนินการขนส่ง

จากผลการทดสอบระบบพบว่า วิธีการหาคำตอบของโมเดลที่ใช้ในการตัดสินใจที่พัฒนาขึ้นสามารถให้ค่าระยะทางรวมในการเดินทางลดลงจากเดิม 10.86% และผลการประเมินความพึงพอใจของผู้ใช้งานพบว่าระบบสนับสนุนการตัดสินใจที่พัฒนาขึ้นมีความน่าจะเป็นในระดับสูงที่จะนำไปใช้ในการวางแผนในสภาวะการทำงานจริงขององค์กร

ภาควิชา ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบผลิต ลายมือชื่อนิสิต..
สาขาวิชา การจัดการทางวิศวกรรม ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก..........
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KEYWORDS : DECISION SUPPORT SYSTEM/ DECISION MODEL / DISTRIBUTION PLANNING / VEHICLE ROUTING PROBLEM/ MOBILE MEDICAL SERVICE

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This Thesis reports the development of decision support system for medical staffs and supplies distribution planning for mobile medical service. The studied organization has provided medical services for many years for people who have limited access to governmental healthcare services at local hospitals. The aim of this research is to develop the decision models of the decision support system that enables planners to effectively and efficiently plan the distribution of medical staffs and supplies to operation sites within the appropriate transportation cost.

The developed decision support system can be classified into round-trip distribution planning and one-day trip distribution planning according to the nature of medical resource distribution. There are two main decision models developed for the decision support system. The decision model of round-trip distribution planning applies Vehicle Routing Problem (VRP) to find of operation routes within acceptable cost. Assignment Problem Model (AP) is applied to help in assigning auxiliary hospitals to support medical staffs to operation site in one-day trip planning. Both decision models apply distance as the decision making criteria to reflect cost of transportation occurred during delivering.

The system testing shows that the proposed methodology can reduce the total distance of operation route in round-trip distribution by 10.86%. From user satisfactory evaluation test, the result shows that the decision support system have high possibility to be implemented in planning process of the future .

Regional Center for Manufacturing

Department : System Engineering .... Student's Signature ....

Field of Study : Engineering Management Advisor's Signature ....

Academic Year : 2009 ....

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CHAPTER I

INTRODUCTION

There are many researches and case-studies in Logistics Management of many companies in business sector e.g. manufacturing, delivery service and agriculture industry. But, there are only a few researches focusing on how service organizations especially in non-profitable organization applying Logistics Management into their work practice. In this research, Logistics Management will be applied to help the organizations in Thailand which is currently and charitably providing healthcare services to local residents.

1.1 Background of the research

According to The Ministry of Public Health of The Kingdom of Thailand, there are many healthcare services provided to local citizens such as medical treatments in local hospitals and private clinics. However, there is other distinctive form of healthcare service; this service is called “Mobile Medical Service”. Mobile medical service usually aims to provide medical treatments to inhabitants who reside in the outskirts or in distant areas including those who have fewer opportunities accessing to healthcare services in local hospitals. These people including frontiersmen, rustics and the poor have limited access to local hospitals due to the handicap of transportation and communication. Mobile medical service is usually found in developing country such as Thailand, Vietnam and India. Even though the transportation and communication system of Thailand are gradually developing that every community can reach to the healthcare services in local hospitals both of the governmental hospitals and private hospitals, mobile medical service is continuously provided to help people in need. The organizations that provide mobile medical service are the provincial public health offices acting under the authority of The Ministry of Public Health, the Red Cross and private hospitals. The most outstanding organization in providing the mobile medical service as well as the studied organization in this research is The Princess Mother’s Medical Volunteer Foundation that started its operation since March 1969 with network of 53 voluntary provinces up to the present [1].

In mobile medical service, the planning of the distribution of medical staffs and supplies plays a very crucial role in helping the organization to reduce operation cost and allowing the organization to focus more on other important activities such as the investment on developing medical instruments. By planning the distribution of medical staffs and supplies will help facilitate medical staffs to travel into operation sites while also maintain acceptable transportation cost for organizations providing the service. Yet, the distribution planning of medical staffs and supplies for mobile medical service is not an easy task. It requires a lot of experiences of planners as well as efficient tools to help make a better decision by providing useful information to support decision making. In mobile medical service distribution planning, most key decisions are identical to those of other companies in logistics planning and management e.g. route planning, fleet size and numbers of vehicle required. However, in mobile medical service, the goal is different from those of other industries. It is not the transportation cost that needs to be prioritized but on-time delivery and customers' satisfaction are emphasized. In mobile medical service, the medical staffs and supplies must be ready at the operation site in time to provide the medical services within the appropriate operation route visiting all requested sites to maintain high customer service level and morality in service.

In the operation of mobile medical service of studied organization, there are four types of service activities provided; general mobile medical service, mobile dentistry, mobile ophthalmologist service and medical funds for the invalid. The distribution planning of medical staffs and supplies is highly required especially in mobile dentistry service to initiate the operation route to serve the customers within the provided budget. In general mobile medical service which primary illnesses are diagnosed and cured, planners have to plan on which hospitals should support medical staffs to be operating in scheduled operation sites including the method of distributing those medical staffs to operation sites. These decisions are not easily made. Planners require a lot of necessary information to help support the decision making as well as a tool to help analyze and compute the suggested solution of operation route and distribution method in order that planners can use those suggested information to create the distribution plan for mobile medical service. The distribution planning of medical staffs and supplies is a part of operation planning process of mobile medical service to support the operation at scheduled operation sites. There are four associates involving in mobile medical operation planning; local public health office, provincial public health office (53 volunteer province), central office of the foundation and local hospitals. The planning process starts from local public health offices by select the appropriate sites according to the organization's policy and sending a requisition to their provincial public health office to analyze and start the site screening process to select the number of proper operation sites within designated quotas. Then, the provincial office will issue the formal operation requisition to central office of the foundation and wait for the approval of operation plan. The central office will analyze and organize the optimal operation route under the organization's constraints and local conveniences to issue the approval of operation plan. After the operation plan is issued, the provincial public health office will decide the local hospitals responsible of supporting medical staffs to scheduled operation sites. Then, when reach the schedule those medical staffs are distributed directly from local hospitals to operation sites. Medical supplies will be distributed from single supply warehouse in the province to operation sites. The current planning process does not allow planners to decide on another medical staffs and supplies distribution method so the organization does not realize that there is another form of distribution method that can help reduce the cost of transportation in transporting medical staffs and supplies to operation sites. Figure 1.1 illustrates the current operation planning process of mobile medical service of the studied organization.

Therefore, the efficient planning of the distribution of medical staffs and supplies is very crucial for the organizations providing mobile medical services to complete its organizational goals and to provide medical treatments for the people in needs of the service. In this research, the decision support system for distribution planning of mobile medical staffs and supplies are designed in order that it can facilitate the planners to efficiently plan the distribution of medical staffs and supplies to operation sites responsively to the demands of mobile medical service from geographically spread requested sites within the appropriate cost of transportation.

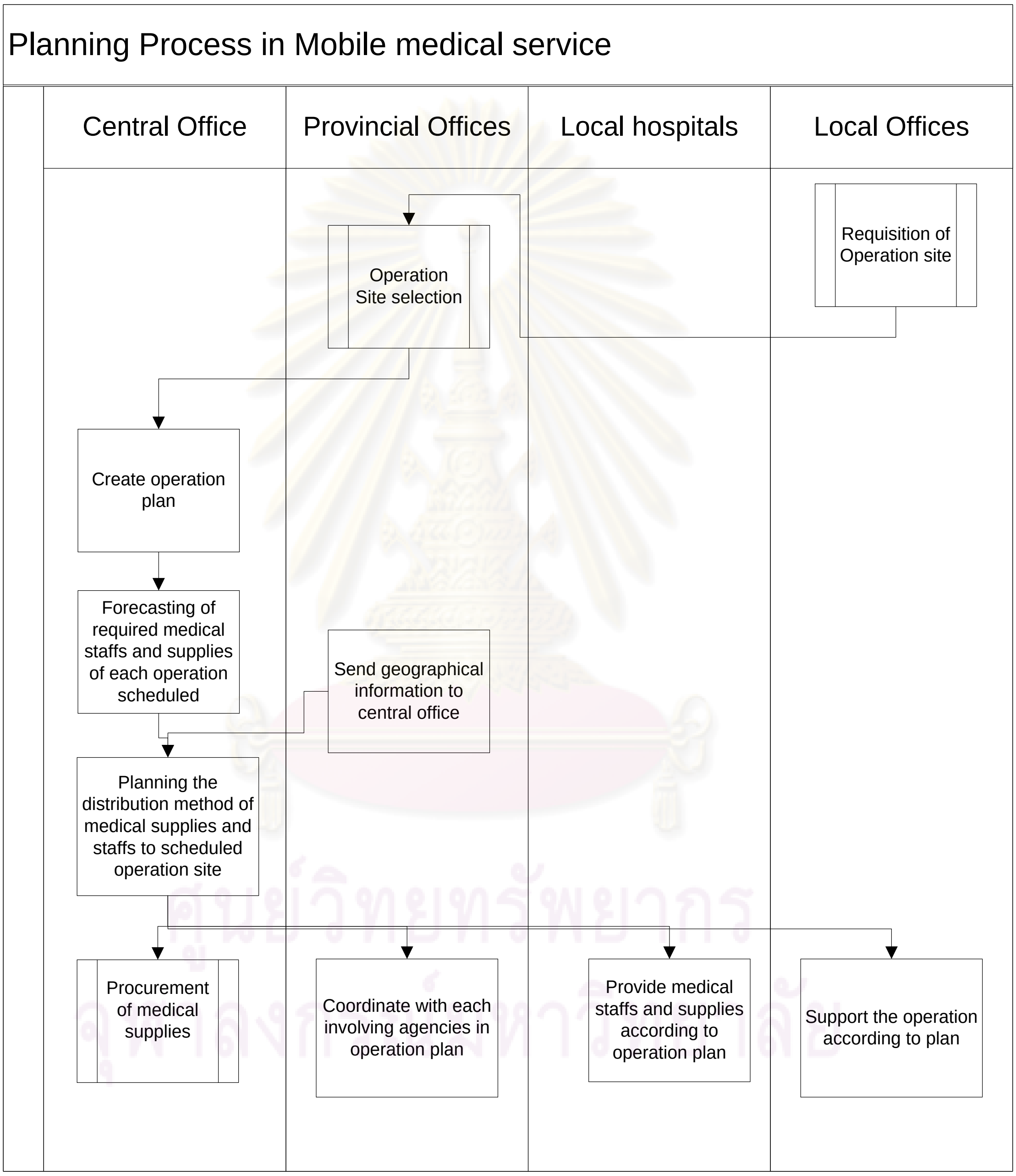

Figure 1. 1 Mobile medical service operation planning process

1.2 Objectives

The purpose of this research is to develop the decision support system to help in planning the operation route in order that the operation route can satisfy all requested sites under variant constraints in real working situation of planning the mobile medical service medical staffs and supplies distribution. The decision support system is designed and developed as the suggested tool for organizations providing mobile medical services to help the planning officers to easily decide on mobile medical operation route and distribution method of medical staffs and medical supplies to operation sites as in operation schedule with acceptable cost.

1.3 Research Scope

In this research, the decision support system, hereafter known as DSS, is designed and developed to help planners plan the distribution of medical staffs and supplies to support the operation of mobile medical service. The developed DSS is one of the functions of the operation support system for mobile medical service which consists of medical staffs and supplies forecasting, medical staffs and supplies distribution planning and operation information system and information system for mobile medical service. In distribution planning of the developed DSS is classified into two main parts according to the characteristics of service that are mobile medical route planning for the characteristic of consecutive operation (also called “round-trip distribution planning”) and medical staffs and supplies distribution method for the characteristics of intermittent operation (also called “one-day distribution planning”).

For round-trip planning, the DSS analyze and process input data received from the forecasting function and site requisition function of the operation support system to organize the appropriate operation route to meet the objective of the foundation as well as to be in accordance with the convenience or requirement of local agents. The operation route is a model scheme for mobile medical unit to operate at certain operation site at specific service-time period which is already approved by the chief executives or the boards of the organization and kept in the set-up data of operation support system. Vehicle Routing Problem (VRP) is applied to develop the decision model of the DSS by adding constraints, factors of the real situation in working environment, and objective function complying with the organization goal (to reduce the transportation cost) into the decision model of the DSS in order to be compatible with the real operation of mobile medical service as much as possible. Figure 1.2 presents example of the model scheme of the foundation's mobile dentistry operation route. The current operation route planning of the foundation can only specify, on certain service date, where the operation site is. However, with the developed DSS, each route will have the information of how many medical staffs and supplies are required including the total number of vehicles required. This information will later be the necessary input data of the volunteer registration process in the operation support system.

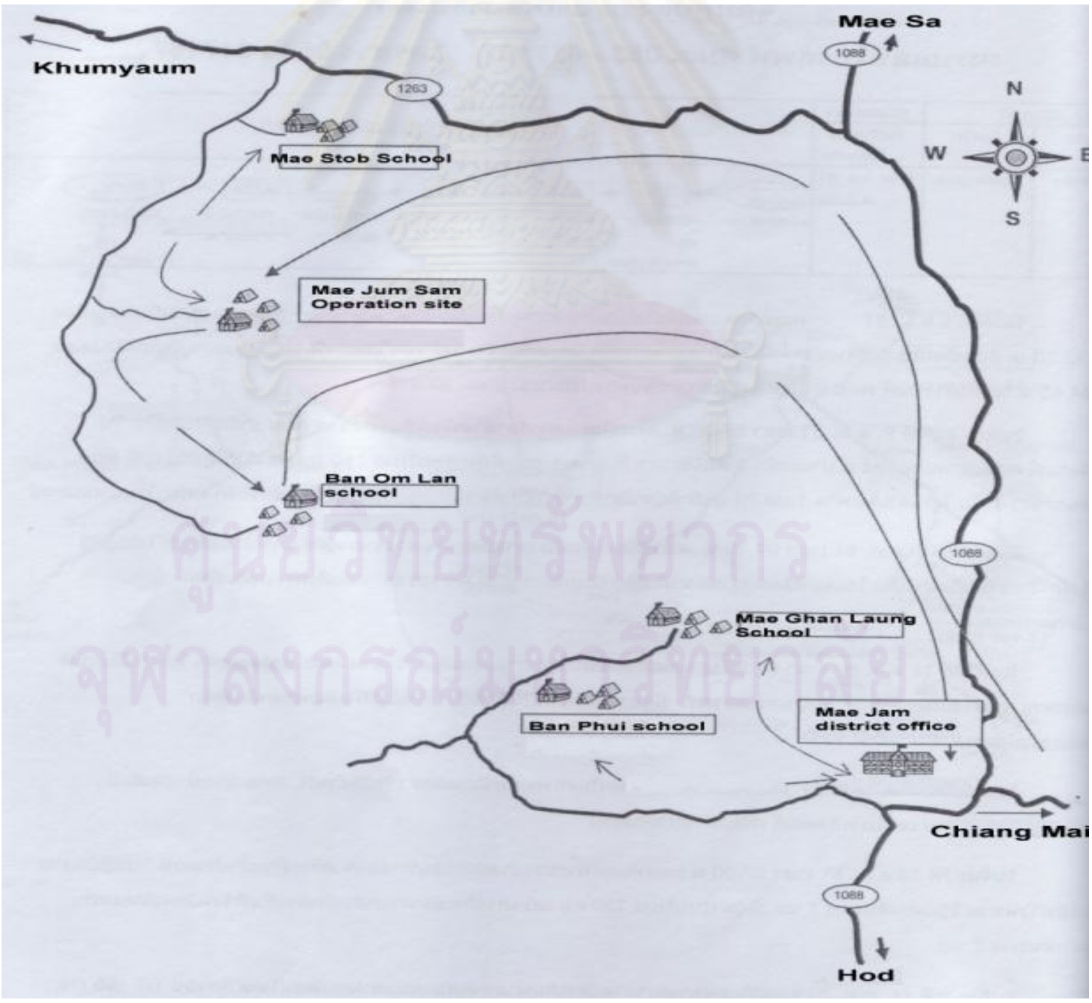

Figure 1. 2 Mobile dentistry service operation routes

Source: Mobile Dentistry Service Operation plan in fiscal year 2009

For one-day trip distribution planning function, the developed DSS assigns local hospitals to be responsible in supporting medical staffs to scheduled operation site at specific service date. The operation schedule is received as input data after approved and issued by the central office to the provincial health office. During this stage, the forecast of medical staffs and supplies at each operation site and the total number of existing voluntarily registered medical staffs at each hospital during the specific planning time frame are received. Medical staffs in this type of mobile medical service operation come from local hospitals in the province. Medical supplies are available to be transported to scheduled operation site at single supply warehouse of each province. Mostly, the supply warehouse of each province is provincial public health office; however, some province uses capital local hospital as the supply warehouse in order that medical supplies will be better preserved. After the DSS have computed the data assigning local hospitals to support medical staffs at each scheduled operation site, the distribution method is selected to transport those medical staffs and supplies to the operation site. Planner is required to evaluate the alternatives of distribution methods by assessing provided measurements of each method and choose one distribution method as the proper distribution method in transporting medical staffs from local hospitals to each scheduled operation site according to the prioritized measurement. There are three types of distribution method in the developed DSS; direct from hospital, meeting point and pickup route. Each distribution method has its advantages and disadvantages. Nevertheless, DSS will help planners to better evaluate those methods by showing the computed result of each necessary measurement so the planners can make a better decision on proper distribution method. In current practice of the studied organization, the alternative restricts only to the method of “direct from hospital to operation site”. The developed DSS increases the distribution method alternatives for planners furnishing to reduce the cost of transportation and increase in the utilization of vehicles. Figure 1.3 shows the network model of one-day trip mobile medical service in the province of Ratchaburi and Figure 1.4 illustrates the features of each distribution method developed in DSS.

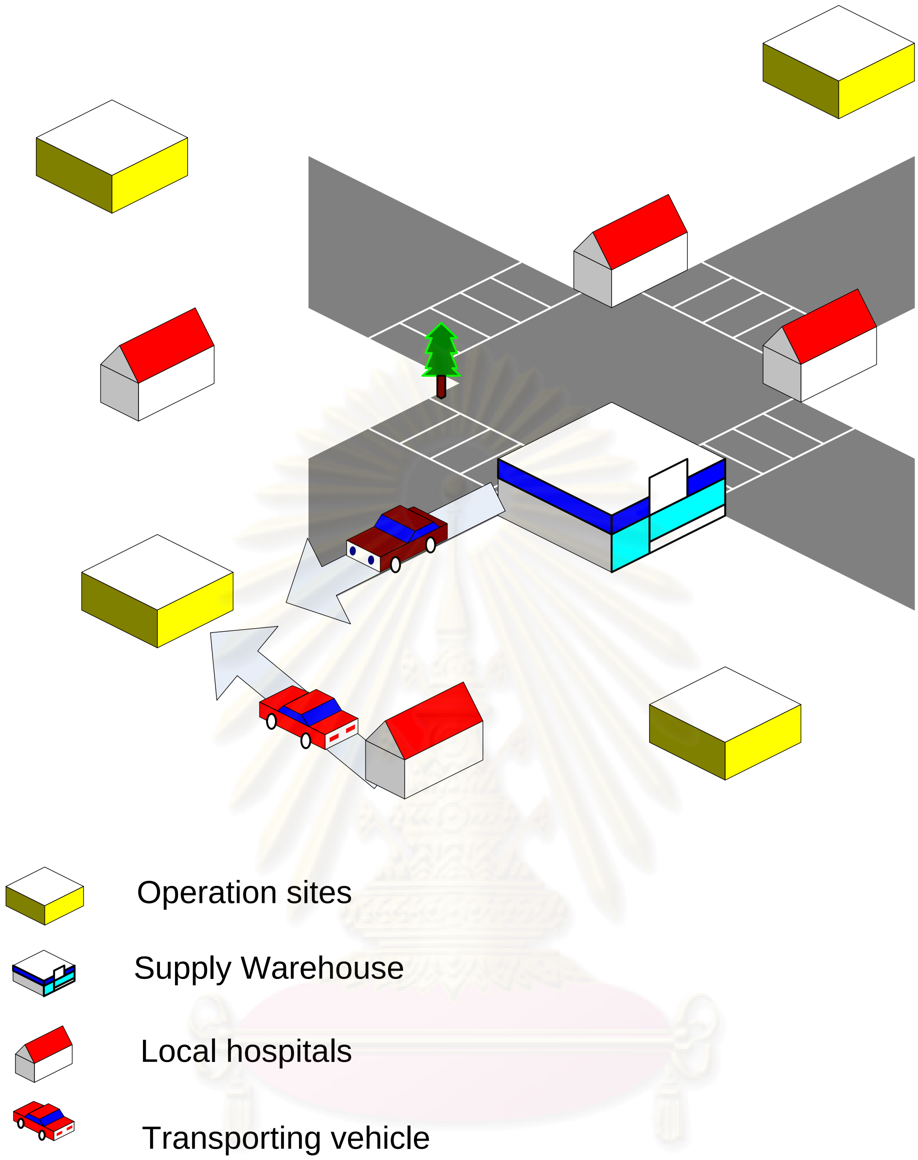

Figure 1. 3 Modeled network of one-day trip mobile medical service

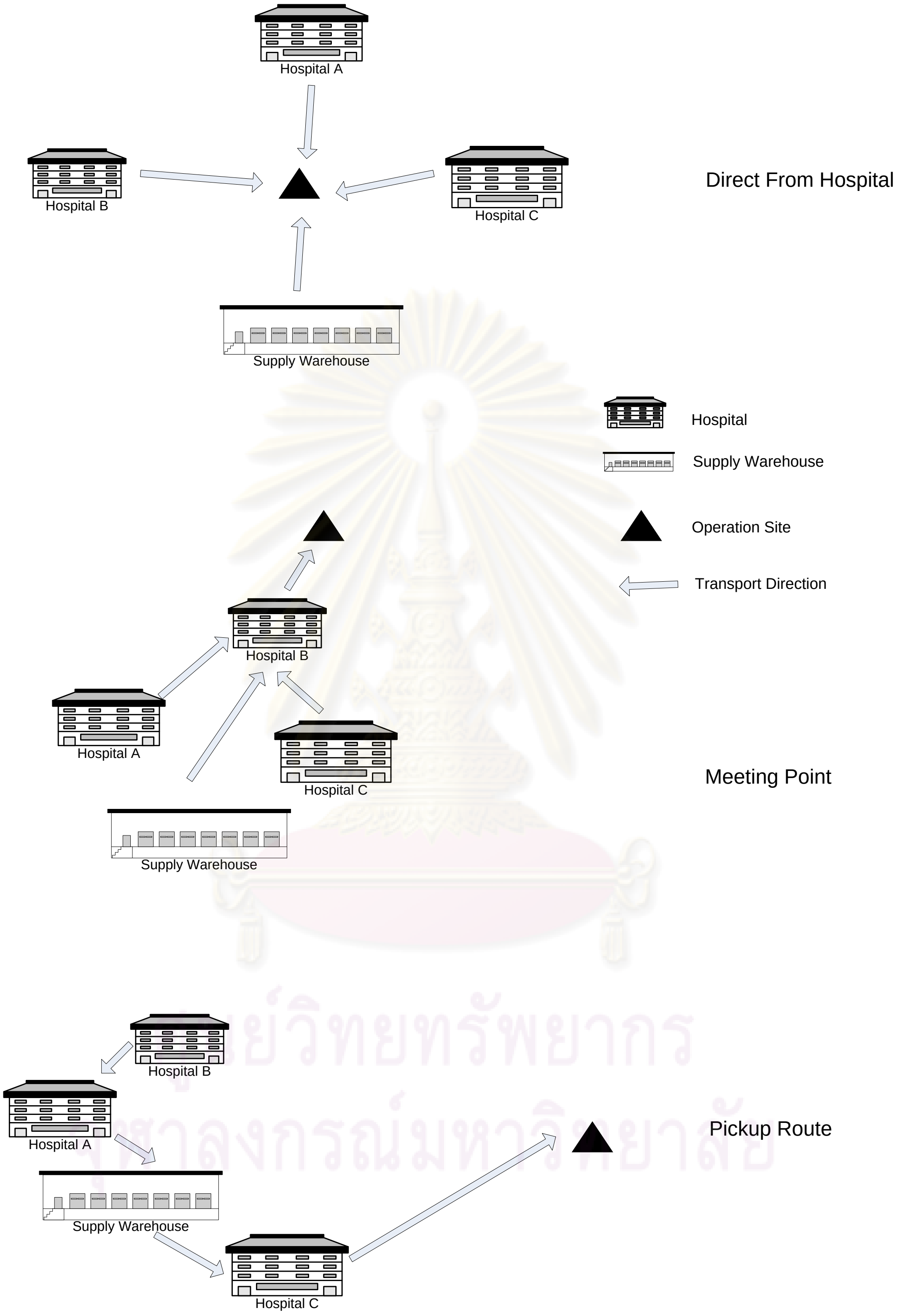

Figure 1. 4 Distribution method’s features

The scope of this research includes the design of decision support system for medical staffs and supplies distribution planning to support the operation of mobile medical service. The developed DSS consists of two main functions; operation route planning for consecutive operation and distribution method selection for intermittent operation by proposing the decision models of these functions of DSS including the design of Graphic User Interface (GUI) and information system structure of the developed decision support system to facilitate the planners to efficiently use DSS in decision making of distribution planning. System evaluation of the decision models is done in 3 distinctive basis that are comparison between the current foundation practice and results from computed result of DSS, the robustness of decision model in finding the solution by using generic test cases to evaluate the capability of the decision models, and user satisfaction evaluation using statistical approach in analyzing responses from involving agents. Implementation of the developed DSS is excluded in research scope including the program coding; only the results from the computation of the program are analyzed and discussed.

1.4 Limitation and Assumption

In this research, there are many limitations and assumptions applied to develop the DSS. To present all the limitations and assumptions, they can be classified into two categories according to the content of those limitations and assumptions; limitations and assumption in research methodology and limitations and assumptions in decision model computational process.

Limitations and assumptions in research methodology:

1. The main studied organization of mobile medical operation planning process is Thailand's Princess Mother Medical Volunteer Foundation that has provided mobile medical service in The Kingdom of Thailand for many years since 1969 under the authority of The Ministry of Public Health.

2. The operation of mobile medical service in this research studied in order to design the distribution planning process in decision support system are service operation in normal situation excluding natural disaster, epidemic disease dispersion and emergency situation.

3. Supply warehouse have the ability to replenish medical supplies to be available for distribution to operation sites according to operation plan. Warehouse management including the replenishment of medical supplies is excluded from research scope.

4. In medical staffs and supplies distribution planning, even though the foundation has 53 volunteer provinces, but the planning scheme is done in yearly basis of governmental fiscal budget separately for each type of operation; round-trip and one-day trip.

5. The design of decision support system of mobile medical operation support system is based on the assumption that data and information transmission is available in every involved associate and each associate can access to data and information stored in database within the provided authorities.

6. Medical staffs are restricted to only doctors, dentists, nurses and pharmacists. Other supporting staffs are excluded in the research scope.

7. Medical treatments in developed DSS are restricted to mobile dentistry service and general mobile medical service handling with the general and primary diseases. Mobile ophthalmologist service and medical funding for the disabled are excluded from research scope.

Limitations and assumptions in decision model can be divided into two sub groups that are decision model in round-trip or consecutive operation and decision model in one-day trip or intermittent operation.

Limitations and assumptions in decision model of round-trip operation route planning:

1. The demand of medical staffs at each requested site equals to the forecast of medical staffs and is known before distribution planning. It can be said that the demand of medical staffs at each requested site is deterministic.

2. In each service date, only one operation site is served. However, there can be more than one medical units in each site located so close to one another that the distance among any medical units makes no difference and can be considered as one operation site.

3. There is unlimited number of vehicles available for medical staffs and supplies distribution. Yet, the capacity of each vehicle is limited to be able to contain no more than 10 people equivalent units and every vehicle is identical.

4. The service-time periods or durations (usually, each service-time period takes one week to complete the mobile medical service task) are identified beforehand according to organization's goal.

5. Each of the service-time periods requires only a medical team of which the types of medical staffs in the team are restricted to be doctor, dentist, nurses and pharmacists.

6. Operation route received as the result from DSS is in yearly basis for each province. The solution from DSS may not be the optimal solution; however, it is the acceptable and feasible solution that satisfies all the required constraints within the proper computing time.

7. In operation route planning, the traffic condition and road characteristics do not affect the data processing of DSS or the solution of operation route even

though the distance between two nodes in the system is exact distance by road transportation.

8. There is only one depot in each province which the vehicle leaves this depot and follows operation route then arrives to the depot when the all service tasks are finished. The depot can be the capital local hospital or the provincial of public health office or any proper place according to DSS's data setting up of users.

Limitations and assumptions in decision model of one-trip distribution planning:

1. All the necessary information is received before the assignment of local hospitals to support the medical staffs to operation sites including the demand of medical staffs and supplies at each site, the medical staffs available at each local hospitals, and operation schedule.

2. There is unlimited number of vehicles available for medical staffs and supplies distribution. Yet, the capacity of each vehicle is limited to be able to contain no more than 10 people equivalent unit and every vehicle is identical.

3. Each volunteer medical staffs can operate at the operation site once per month which means that he/she can register to be a medical volunteer in every month but can register once a month.

4. The distribution method planning is done on monthly basis for each province and the volunteer medical staffs are mostly from local hospitals.

5. Each province is restricted to have only one supply warehouse. The warehouse is capable of having required medical supplies available to be distributed to operation site according to operation schedule.

6. In each operation date, only one distribution method can be selected to distribute medical staffs and supplies from different sources to operation site.

7. The solution of assigning local hospital to do the task of supporting medical staffs to scheduled operation may not be the optimal solution but it is the feasible solution that satisfies all restricted constraints within the acceptable computing time.

1.5 Definitions

The definitions in this research are given as follow in order to be mutually understandable along the entire research.

1. DSS stands for Decision Support System which is a kind of software in the functions of management information system. DSS helps decision makers to make decisions in circumstances or situations of business in unstructured problem or semi-structured problem.

2. Medical staffs refer to medical volunteers who apply to operate for mobile medical service; these staffs restrict to only doctors, dentists, nurses and pharmacists.

3. Medical supplies refer to supplies used in mobile medical service which includes medicine for primary care and disposable medical supplies.

1.6 Expected benefits

This research expects that the developed decision support system will help the planners of mobile medical service provider organization to easily plan the distribution of medical staffs and supplies to support the operation of mobile medical service. The developed DSS is beneficial to planners for it provides the solution to the problems and facilitates supporting information for decision making of planners. The developed DSS will increase the efficiency in planning the distribution of medical staffs and supplies;

moreover, it will reduce the difficulty and perplexity of distribution planning and help increase the quality of the solution to the problems as well as reduce the risk of relying only on the experience of planners. Last but not least, the developed DSS is expected to help the organization reduce the cost of transportation in order to focus or invest more on other important activities.

1.7 Research Presentation Methodology

There are seven chapters in this research; the overview research presentation methodology can be described as follow;

- Chapter II in this research is the Literature Review of Operation Research (OR) theories usually applied in Logistic planning especially the vehicle routing problem and mathematical model in transportation planning. Moreover, the concepts and theories in designing the efficient decision support system is studied and summarized. In addition, researches and application in adopting the vehicle routing problem in industry Logistics planning and management including real case studies of using vehicle routing problem to lessen the transportation cost is discussed in the chapter.
- Chapter III presents the analytic discussion of the current distribution planning process of the studied organization from the observation including the problem formation to develop the decision model for the decision support system of mobile medical staffs and supplies distribution planning for mobile medical service. In addition, input data are described in detail as well as the new proposed distribution planning process to be compatible with the operation in the developed decision support system.
- Chapter IV includes the detailed description of decision models developed in the DSS concerning the identification of objective function, constraints of each decision model, and the description of solution searching process of decision model.

- Chapter V relates the testing results from decision support system evaluation result including the capability of decision model in finding the acceptable solution, improvement in using the proposed decision model comparing with other approaches , and statistical analysis of user satisfactory evaluation
- Chapter VI shows the overall design of information system structure of the developed decision support system including the Graphic User Interface(GUI) and the operation procedure description of operations or activities to efficiently usage of the developed decision system to help the planning of medical staffs and supplies distribution
- Chapter VII is the summary of the research including recommendation in future improvement and system implementation.

CHAPTER II

LITERATURE REVIEW

This chapter includes the description of the theories and recent applications related to the problem in this research. There are 4 main topics to be discussed; those are applications concerning mobile medical service planning and operating, current logistics network model and best practices, decision support system, and vehicle routing problem.

In this research, the logistics network for mobile medical service is initiated with the objective to reduce transportation cost. Medical staffs and medical supplies distribution planning is highly focused in this research. Therefore, vehicle routing problem which is a computational problem is applied to solve the problem studied in this thesis.

2.1 Medical mobile service planning and service operation

The activities of Thailand's Princess Mother's Medical Volunteer Foundation has been commenced over 40 years with the aim to provide medical services to remote areas where there is limited access to transportation and communication. Mobile medical planning is conducted both decentralized and centralized approach to diversify 53 volunteering provinces. In real operation, the volunteers in each province will give medical services to certain places in the province with the cooperation with many governmental and private agencies (Hutachok, 1984 [1]).

The organization of the foundation is divided into 2 main parts which are central office and regional office.

The central office is responsible to cooperate with other agencies and 53 regional offices to provide convenience and supporting of medical operators. These are functions of central office.

2.1.1 Central office responsibilities

- Aggregate results and commence operation plan

At each volunteer province, the committees will gather to generate the planning meeting on site selection, responsible officers and vehicles to be used. Generally, the meeting is held every 3 month or 6 month or yearly basis before passing the plan to central office. After receiving the plan, central office will aggregate those plans and launch master plan in order to start preparing necessary items such as medical supplies, vehicles and medical staffs for the scheduled operation.

- Vehicles

Vehicles used in medical service operations consists of 4 wheeled cars, speed boats and helicopters available to be used according to the geographical appropriateness of operation sites. Cars are remained at regional office for supporting the operations.

- Medical supplies

Medical supplies are delivered to each regional office through third logistics service providers in order to be used in time of operation.

- Coordination among involved agencies both central and regional

Central office has responsibility to coordinate with central hospitals and regional hospitals for transferring critical patients or special diseases which required treatments at central hospital.

2.1.2 Regional office responsibilities

The organization chart of regional office can be presented in Figure 2.1.

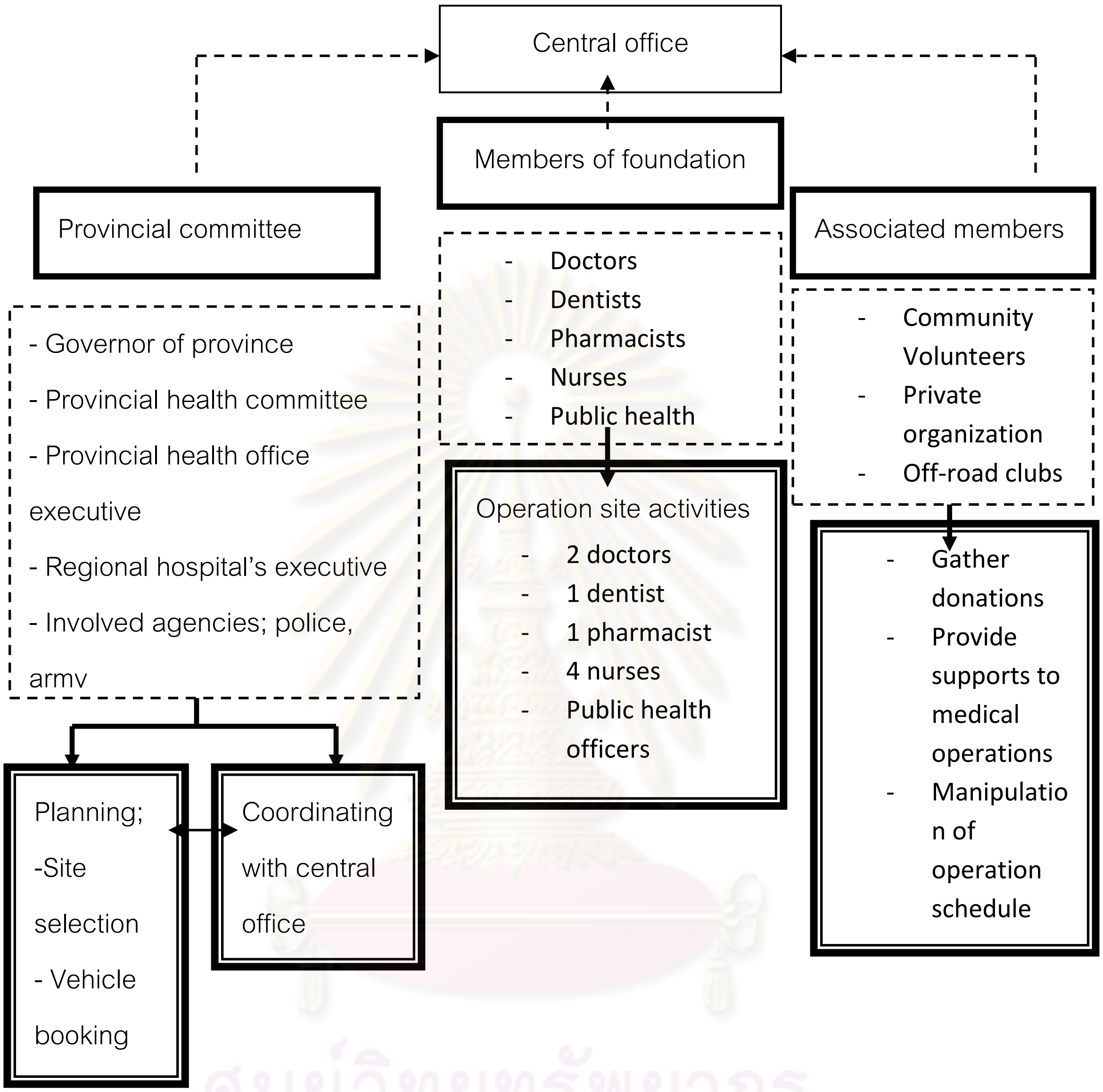

Figure 2. 1 Regional center's organization chart

Source: Adapted from Hutachok [1]

2.1.3 Objectives of medical mobile service

- To have medical staffs providing medical services to patients residing in remote areas and having limited access to local hospitals.
- To prevent epidemic such as malarial.

- To have opportunities to meet with residents in the remote communities or village and give some fundamental consumers goods as donations.
- To transfer special patients or special cases to potential hospital for treatments.

2.1.4 Principles in site selection

- Must be remote areas where medical services are scarcely provided or have limited access to nearest local hospitals.
- Must have high level of safety for volunteer during operations.
- Should have recursive operation to observe feedback from last services.

Apart from the princess mother medical volunteer foundation, there are a lot of medical mobile service providers currently operating with the same goals and objectives. However, the foundation network and management approach is formally addressed due to long operation and history.

There are very little applications addressing the distribution planning of mobile medical service or other services which share the same characteristics of mobile medical services. These following researches are the example of distribution planning for mobile medical service.

2.1.5 Applications concerning medical mobile planning

In determining operation route of service operation resembling the service of operation in mobile medical service, there are a few researches conducted to generate operation location of the service starts from Banerji [3] who presented the hierarchical approach in determining operation locations for community development block which scattered througout rural india by using area selection planning. Set covering and P-median algorithms is used to find the optimum solution in network designing of where the center of community should be. There are a lot of social factors used in this paper such as agriculture, market centers, local hospitals and schools. However, the author suggested that by using hierarchical apporach is not very justified since there are too many factors concering area planing not just distances that vehicle have travelled. Moreover, the weight of each factor affect the area selection is not truly known since there are no discrete information about each factors. Later , Geoffrey [2] presents a hybrid covering model which is used to locate stations and allocate ambulance route. The author designed a model to find the optimum solution to allocate emergency units to facility sites. In the system testing, the author generated 55-nodes network to observe whether 10 units with 10 facility sites can cover to services all 55 nodes by using LINDO program to generate mathematic model. The result shows that with this method 95% of nodes in the system is adequately arranged into ambulance route. The paper concludes that for better coverage of sites or nodes, the responsibility zones should be applied and allocates certain amount of responsible unit in the zone.

From this two researches , mostly in planing service operation resembles the operation of mobile medical service is the application in using facilities lcation selection theories in order to cover or provides services to scatterd nodes over certain areas and the allocation of responsible units to particular zone or areas. However, there are not yet the application in using combinatorial approaches in routing the operation sites of service operation.

Next topic, the decision support system principle is discussed. The decision support system is directly related to this research since the decision support system of medical staffs and medical supplies distribution planning will be developed to help planning officers to comfortably manage to reduce redundancy in planning and effectively select the distribution method with approapriate cost.

2.2 Decision support system

In this topic, the decision support system and structure of the decision support system is introduced.

Decision is very important in human being's lifestyles. The quality of decision depends upon experiences, individual capability and concerning factors. With the increasing capability of computers' technology, computerized information system is applied on decision making process to increase the productivity of decision making and contributes higher benefits in today business.

Decision support system evolves upon the basis of needs in organization management to be responsive, convenient, correct and precise. However, the decision support system is developed to help facilitate decision making of the users not to make the decision for users (Kitti, 2008 [4]).

2.2.1 Decision making definition

Decision making occurs almost every minutes of human being's routine life such as choosing the method to go to schools which requiring factors like fees, distances, time, convenience and traffic jams. Decision making is the important responsibility of managers to bring company toward success. The decision making process generally starts from the analysis of problem to find root causes as well as solution concepts in the form of choices or alternatives. Then, the best alternative is chosen to solve the problem. Then, there should be some controlling or monitoring system applied to measure whether the method can efficiently and effectively solve the problem. Therefore, the definition of decision making is summarized from the process of decision making.

Decision making is the process or systematic approach in selection appropriate methodology from provided alternatives or information to achieve objectives and goals. Decision making is a part of problem solving process (Kitti, 2008 [4]).

2.2.2 Characteristics of business decision making

Business decision making is different from general decision making since it must follow these following characteristics;

- Can be made individually or group decision making
- May requires multi objectives criteria which contradicts to one another
- Have numerous alternatives
- The result of present decision making can be estimation or forecasting of future business operation
- Every time of decision making contains risk which varies from the decision makers' experiences and capabilities
- What-if analysis is used to real future operation
- Decision making in experimental situation on real circumstances. Therefore, it is likely to fail; usually occurring when trial and error of single objectives for consideration
- The environment is consistently changing

2.2.3 Problem formation requiring decision making

Managers are required to make decisions in business operation such as production planning, breakeven decision, project feasibility and product or services prices. These activities need clarified to correct factors that affect the decision making. However, adequate information is not availably provided for every problem. Therefore, estimation and forecasting is required. The problem formation can be classified into 3 distinctive types.

- Structured Problem

Structured problem is the problem with exact solution method or problem that can generate mathematical model formation. In other word, structured problems are problem with all required information available for solving. For example, the inventory level, if decision makers knows exact demand, EOQ(economically order quantity), safety stock and reordering point, decision makers can calculate the result from inventory level formation.

- Unstructured Problem

Unstructured problem is the problems which have no exact solution or methodology. It cannot be generated using mathematical model. The information is not sufficient enough to solve the problem; therefore, decision makers' capability and experiences are highly required to solve the problem such as stock investment decision. This is because decision makers cannot be sure whether the invested stocks will contribute profits at the end of fiscal year.

- Semi structured Problem

Semi structure problem have specific characteristics. There is no standard process for solving problem. This type of problems required partial process for solving problem with the mixture of decision makers' experiences. Information only supports the decision making. For example, if the exact demand of product is not known, the inventory level formation cannot be solved. Therefore, artificial intelligence (AI) should be developed to forecast the product demand in the future before substitute into mathematical formation. AI may help improve the quality of decision making

2.2.4 Decision making and problem solving

In business, a good decision making is highly required not only strategic planning but also tactical and operational framework in order to achieve goals. Many organizations have agreed to the idea of using information technology for more efficient decision making (Kitti, 2008 [4]). Decision making is considered to be a phase in problem solving process of human being. When problems occur, the decision making for best alternatives in problem solving process is conducted.

Decision making process is to define steps in decision making to solve the problems occurring inside the organization with constraints with the appointed process for required solutions.

The decision making pattern is different depending on appropriateness to the problems or decision makers. Herbert and Simon[4] classified decision making into 3 phases which are intelligence phase, design phase, choice phase. Later Georgeand Huber [4] has integrated the decision making process into problem solving process to initiate 5 phase of problem solving which are intelligence phase, design phase, choice phase, implement phase and monitoring phase as shown in Figure 2.2

- Intelligence phase

At this phase, the problem source is investigated such as root cause of the problem, evaluation of consequences if the problem is left unsolved and environmental factors affecting the problems in order to create model which is used to describe characteristics and causes of the problems. This model aims to divide problems into parts and find solutions to each part. The result of this phase is decision statement. The key concept is to always solve the problems at root cause or original cause.

- Design phase

At this phase, generic alternatives for decision making are analyzed. The generic alternatives must possibly solve the problems and contribute highest benefits. Moreover, the objectives of decision making are also created at this phase. Models, decision tree or decision table are precious tools to develop alternatives for decision making.

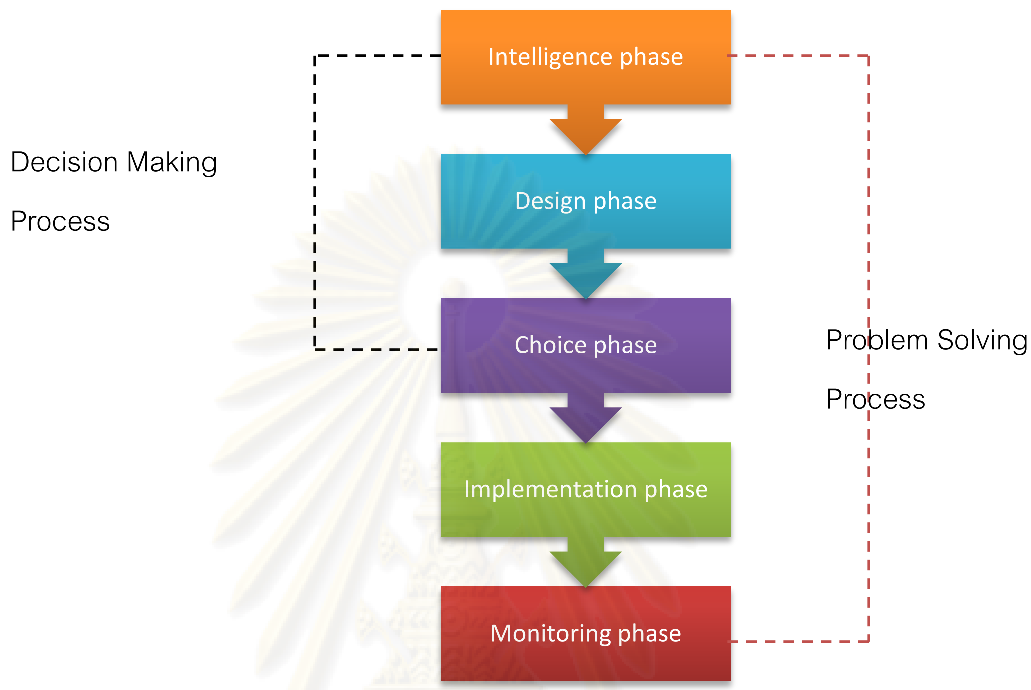

Figure 2. 2 Decision making and problem solving process

Source: Adapted from Kitti [4]

- Choice phase

At this phase, alternatives are evaluated and selected to the best single alternative. The best alternative will be used to solve problems in real situation.

- Implementation phase

At this phase, the chosen alternative is implemented to solve the problem. However, it can be successful or failed to implement the solution. If failed, decision makers can revisit any phase for reviewing the decision making process.

- Monitoring phase

This phase is the last phase of decision making process or problem solving process. The alternative is evaluated after being implemented to real situation. If the result of that alternative is unsatisfactory, the root cause of why the implementation fails is reviewed and investigated to improve the decision making process.

2.2.5 Type of decision making

To develop appropriate decision support system to certain problem, type of decision making should be classified. Type of decision making can be classified by 3 criteria which are classified by number of decision makers, classified by the structure of the problem and classified by organizational structure as shown in Figure 2.3.

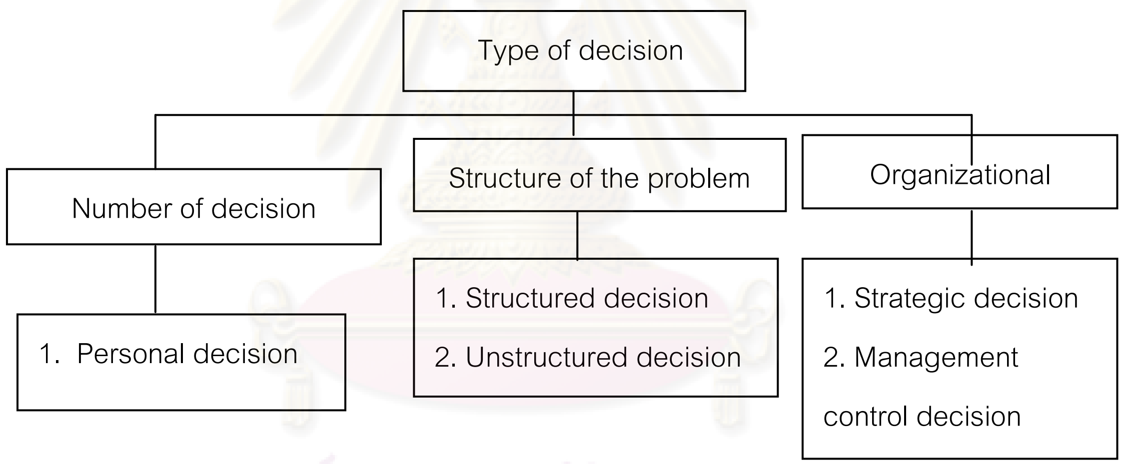

Figure 2. 3 Type of decision making
Source: Adapted from Kitti [4]

Medical staffs and medical suppplies distribution planning is considered to be semi structure problem which requiring standadized process of problem solving for structured parts and decision making based on experince for unstructured parts. Decision support system can be developed to organize, manage and evaluate best alternative for solving problems. Distribution planning decision is the responsibilty of managers or planners in operational level which affects the organization in narrow operational scale not the strategic level.

2.2.6 Definition and evolution of decision support system

The evalution of decision support system starts from Scott Morton[1] has given the definition of decision support system (DSS) as the system which operates with computer for decision makers to integrate data and models to benifitially solve the unstructured problem. Later in 1978, Keen and Scott Morton stated that DSS is the system that linked with human brains to work unitedly with computer capability to improve decision making. In other word, DSS is the computerized system which helps support decision makers to deliberately handle with the semi structured problems.

The development of DSS, fundamentally, initiates from the need to implement information technology for efficiently and effectively decision making. DSS has been evolved for approximately 50 years and is still improving to be more reliable for decision makers.

- Pre-evolution

  During the time of 1950, computer was used as tool for business sector in business data processing. However, when the business got too complex and the number of reports were drastically increasing, managers required more time to spend on reading and analysing the reports. Therefore, information technology for supporting operations of managers was invented. It was known as management information system (MIS).

- Second phase

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[1] as cited in [4]

During 1960 to 1970, the computerized network processing was gaining its popularity since through computer network, many computers can be integrated and share information among one another. In the late 1970, computer program was developed to help office works. This system can reduce paperwork and lead to responsiveness and convenince to users. This system was called office automation system (OAS).

- Third phase

During 1970- 1980, there was attempts to create DSS which was the computerized processing for alternatives to support decision making of managers.

- Fouth phase

Artificial Intelligent(AI) has been developed for expert system since 1990s. This system can help decision makers to solve problems with high complexity as if the experts recommend. AI is developed from the decision process of human being and allow computer to imitate the process to find solutions to the problem.

- Present

Intelligent agent(IA) is the newest technology of information system in 21st century. This is because IA can access to other database around the world through internet and facilitate e-commerce business.

2.2.7 Type of decision support system (DSS)

According to Holsapple and Whiston[2] , DSS can be classified into 6 categories.

- Text-oriented DSS

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[2] as cited in [4]

- Database-oriented DSS
- Spreadsheet-orinted DSS
- Slover- oriented DSS
- Rule-oriented DSS
- Compound DSS

Holsapple (as cited in [4]) classify the type of DSS by using processing method of data and data storage. For example, slover-oriented DSS is using the same processing method of C++ languaue in the development of DSS. The spreadsheet DSS is DSS which stores data or model in the form of Microsoft excel.

2.7.8 Architecture of DSS

The structure of DSS comprises of 3 important elements which are database, model base and user interface as shown in Figure 2.4.

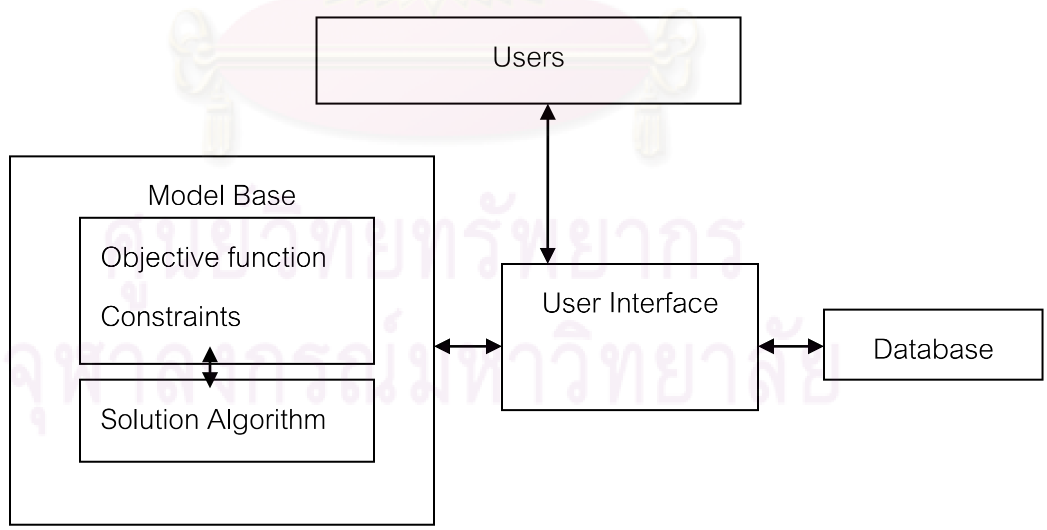

Figure 2. 4 Decision support system architecture

Source: Adapted from Kitti [4]

- Input data to system and database

  Data input for distribution planning consists both of external and internal sources of company. It can be classified into 2 types which are master files and business transaction files.

  - Master files
    - Vehicle characteristics such as vehicle capacity, weight, numbers of available vehicles
    - Charecteristics of Demand such as type of distribution items, weight and quantity
    - Charecteristics of customers
    - Geographical data such as location co-ordinates to give distributon network of distribution centers and customers.
  - Business transaction files represents the data used to communicate with customers such as order form or product requistion

- Objective function

  Objective function is organizational goal which is simulated to operational concerns. Objective function is different from one organization to other organization depending upon organizational policy. Generally, objective function concentrates on maximizing profits or reducing cost. According to Sawdy[10], cost ofphysical production distribution comprises of

  - Cost of shipment which depends upon the method of loading product into vehicle and type of vehicles.

- Cost of transportation is the most cost incurred activity in physical product distribution since it takes time and resource. This cost varies on vehicle speed, distance and traffic condition.

- Constraints

Constraints are factors affecting the difficulty in distribution planning analysis. Usually constraints in physical distribution are

- Capacity of vehicle such as capacitated capability, number of available vehicle
- Time constaints such as available time affecting the assigned numbers of vehicle and type of vehicle
- Demand constraints such as type and quantity of products
- Area constrints such as delivery point affecting type of vehicle

If too many constraints are applied, the solution cannot effectively solve the problems. The process for solving problems may starts from slightly increasing conditions and constraints then evaluating constraints to be consistent with the problem. For example, Bell [11] developed estimators to solve problems then applying time constraints for considering and improving answers. This reduce complexity in problem solving and analysis. The most efficient approach is to divide constraints into 2 types that are hard constaints-must follow the constraints and soft constaints- flexible to the constriants.

- User interface

Distribution planning requires user interface between users and computer. The example of interactions between computer and user in distribution planning are

- Users define problem characteristics and scope of problem
- Computer choose necessary data and information to analyze the problem
- Users compares solution from computers to their solutions and choose best alternatives
- Users allow computer to further study the problem for clarifying problem analysis
- Users edits solution by using experiences rather than solution from the computers

Therefore, DSS requires coordinate and cooperation between users and computers to gain high benefits. Krolok, Felts and Marble (as cited in [4]) suggested that with the interactions between users and computers, time for solving problems can be reduced drastically especially in complex problems.

At present, the concepts in problem solving for distribution planning from Krolok can be classified into 2 aspects which are

- Heuristics for analysing distribution planning decision making
- Interaction between users to improve decisions from DSS

These 2 aspects help improve efficiency in distribution planning such as reduce solving time and increase reliablity for users of DSS.

In conclusion, decision support system is the system which linked between human' s brains and computer capabilities in order to improve decision making. DSS requires computer to support individual or decision makers can manage to solve semistructured problem effectively and efficiently. DSS distincts from other information system in

- Able to cope with semistructured problems
- Able to support operation in every level of decision making; strategic, tactical and operational
- Associates group decision making and individual decision making
- Contributes benefits such as efficientcy in working, decision making and organization controlling of those which implementing DSS

2.3 Current logistics model

Logistics model principle applied in this research consists of 3 models which are direct shipping, hub and spoke paradigm and milk run model.

2.3.1 Direct shipping

Direct shipping is usually applied for long range logistics or physical distribution such as passenger cars and buses. Products are transported from place of origins to point of delivery. This transportation model is capable of accessing to any point of delivery and is very flexible and agile to demand changes. However, if the vehicle is not fully utilized, this transportation method is not very efficient leading to waste and unnecessary cost in deficiency in vehicle utilization. The transportation model is presented in figure 5. This transportation method is very popular and adopted by many organizations since there is no complex system to manage or plan the distribution. This method is currently practiced by the foundation and other mobile medical service providers [1]. Figure 2.5 shows the distribution network of direct shipping approach.

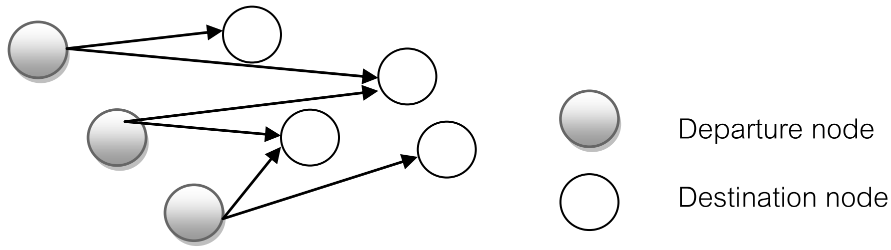

Figure 2. 5 Direct shipping distribution model

Source: Adapted from [43]

2.3.2 Hub and spoke paradigm

The hub-and-spoke distribution paradigm (or model or network) is a system of connecting all departure nodes to all destination nodes or spoke by hubs in which all traffics move along spokes connected to the hubs. The model is commonly used in industry, in particular in transport, telecommunications and freight transportation. This distribution model is very cost effective and has high utilization of vehicles. The model can be represented by Figure 2.6.

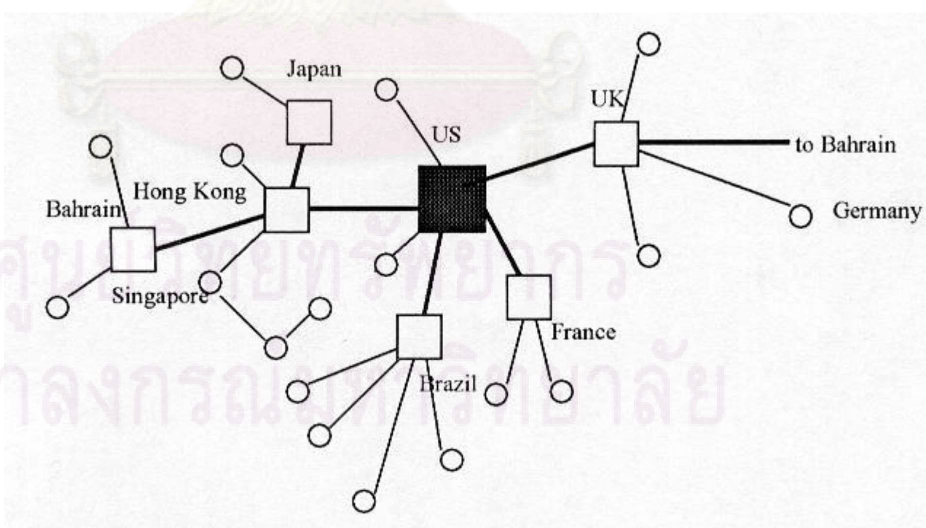

Figure 2. 6: Hub and spoke network

Source: Picture from http://www.lboro.ac.uk/gawc/rb/rb74.html

- Benefits
  - For a network of n nodes, only n - 1 route are necessary to connect all nodes; that is, the upper bound is n - 1, and the complexity is O (n). This compares favorably to the (n (n - 1))/2 routes, or O (n2) that would be required to connect each node to every other node in a point-to-point network.
  - The small number of routes generally leads to more efficient use of transportation resources. For example, aircraft are more likely to fly at full capacity, and can often fly routes more than once a day.
  - Complicated operations, such as package sorting and accounting, can be carried out at the hub, rather than at every node.
  - Spokes are simple, and new ones can be created easily.
  - Customers may find the network more intuitive. Scheduling is convenient for them since there are few routes, with frequent service.
- Drawbacks
  - Because the model is centralized, day-to-day operations may be relatively inflexible. Changes at the hub, or even in a single route, could have unexpected consequences throughout the network. It may be difficult or impossible to handle occasional periods of high demand between two spokes.
  - Route scheduling is complicated for the network operator. Scarce resources must be used carefully to avoid starving the hub. Careful traffic analysis and precise timing are required to keep the hub operating efficiently.

- The hub constitutes a bottleneck in the network. Total cargo capacity of the network is limited by the hub's capacity. Delays at the hub (caused, for example, by bad weather conditions) can result in delays throughout the network. Delays at a spoke (from mechanical problems with an airplane, for example) can also affect the network.
- Cargo must pass through the hub before reaching its destination, requiring longer journeys than direct point-to-point trips. This is often desirable for freight, which can benefit from sorting and consolidating operations at the hub, but not for time-critical cargo and passengers.
- In a spoke-hub network the hub is likely to be a single point of failure.

2.3.3 Milk run model

Milk run model concentrates on picking up production materials from different suppliers according to scheduled time for just in time delivery for production. At each time, vehicle will carry materials or product up to maximum capacity of vehicle. Each vehicle will travel around appointed suppliers. Milk run system is more complicated than hub and spoke system. Hub and spoke only needs coordination between customers and numerous suppliers while milk run requires all involved agencies in the supply chain [7]. The distribution model is shown in Figure 2.7.

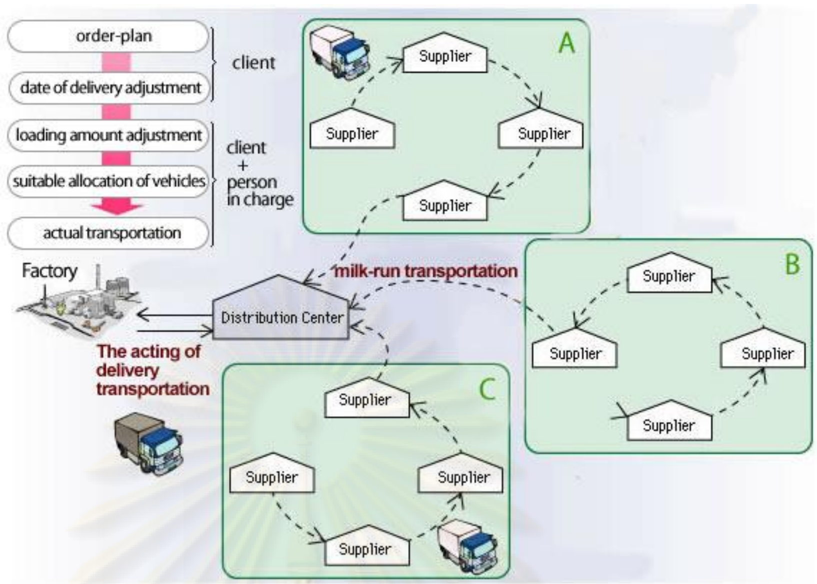

Figure 2. 7: Milk run distribution model

Source: Picture from http://www.ryobi-holdings.jp/transport/images/02/supplier_en.jpg

- Benefits
  - Vehicle leaves depot with empty pallet enables to carry other product back to the depot
  - Use fewer number of vehicle to complete task
  - Reduce transportation cost
- Drawbacks
  - Required high skilled planning officers
  - The distribution system is complicated and hard to understand
  - Require coordination from all involved agents
  - Require high performance information technology

2.4 Vehicle routing problems Theories

Vehicle routing problem (VRP) is one of the most important problems in logistics and supply chain management [8]. VRP can be applied to physical distribution from suppliers or vendor to customers or suppliers to warehouse or factory plant. Companies find ways to reduce cost by applying efficient distribution methodology. By improving the firms' logistics management, numbers of vehicle, lead-time in delivery and customer service level can increase drastically. Generally, the distribution planning can be divided into 3 levels.

- Strategic planning
- Tactical planning
- Operational planning

Strategic planning is a part of policy or company's direction in management such as the design and location of depot or warehouse. Tactical planning involves the decision of how many vehicles the company should buy for achieving corporate goals. VRP is the problem in operational level of distribution planning. In other word, how a company manages to distribute its products or services to each routes at the possible minimum cost. VRP is considered to be NP hard integer programming problem which the computational time required for solving problem increases exponentially to the problem's size [9].

2.4.1 Type of vehicle routing problem

In this research, medical staffs and medical supplies distribution by road transportation routes from one depot to meet the requirement of scheduled operation sites is focused. The problem has the characteristics of vehicle routing problem that vehicles will leave depot and follows route and return to depot.

Generally, the fundamental vehicle routing problem is to define route of each vehicle to deliver products to customers with minimum cost. However, VRP can be different depending upon the management, situation and objectives of each company. VRP can be classified by different attributes as shown in Table 2.1.

Table 2. 1 Type of vehicle routing problem

Characteristics	Options	Characteristics	Options
Size of the fleet	-One -Multiple	Housing of the fleet	-Single depot -Multiple depot
Type of demand	-At the nodes -On the arcs -On the nodes and the arcs	Network type	-Undirected -Directed
Vehicle capacity	-All the same -Different -Unlimited	Maximum route time	-Same for all vehicles -Different for all vehicles -Not present
Type of operations	-Pickups only -Deliveries only -Mixed	Objectives function	-Minimum total routing costs -Minimum fixed and variable costs -Minimum numbers of vehicle

Source: Adapted from Murdick [60]

2.4.2 The diversification of Vehicle Routing Problem

VRP is the generalization problem of Travelling Salesman Problem. In other word, VRP is considered to be multiple TSP which is the problem of generating m routes from depot to nodes in the system. At each route, total demand should not exceed capacity constraint of vehicle with the objectives to minimize total transportation cost [11].

VRP in real operation has many side constraints such as time windows and numbers of depot leading to complexity in solving problem and diversification of VRP. The diversification of VRP can be presented below.

The level of complication of vehicle routing problem varies from the simplest to the most difficult that no searching method can find the optimized answers. The type of vehicle routing problem can be classified into 3 types according to the level of problem complication.

- Travelling Salesman Problem
- Multiple Traveling Salesman Problem
- Vehicle Routing Problem

2.4.2.1 Traveling Salesman Problem (TSP)

Traveling salesman problem is the simplest problem in vehicle routing problem series. The vehicle leaves single depot to visit all customers within one route ignoring the limitation of time constraints and vehicle capacity and return to the depot. As presented in Figure 2.8.

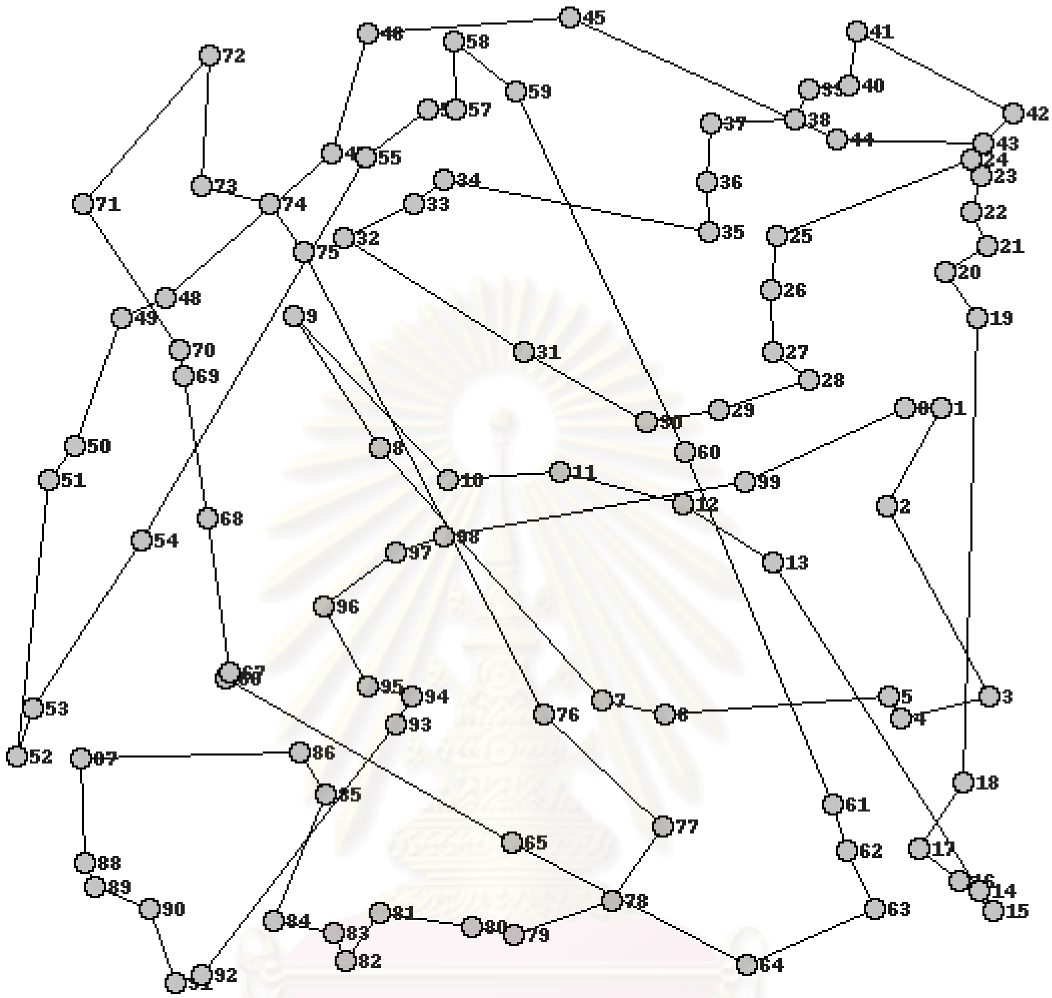

Figure 2. 8: Traveling Salesman Problem (TSP)

Source: Adapted from [12]

2.4.2.2 Multiple Travelling Salesman Problems (M-TSP)

The M-TSP is the more complicate solution of Traveling Salesman Problem since there can be many routes to visit all customers in the network without the constraint of time and vehicle capacity.

2.4.2.3 Vehicle routing Problem (VRP)

The vehicle routing problem aims to find the numbers of routes and the sequence of customers in each route from the distribution center that leads to the minimum cost of transportation of every vehicle under constraints of delivery such as the capacity of vehicle and delivery time. The complication of vehicle routing problem evolved through time as presented in Figure 2.9.

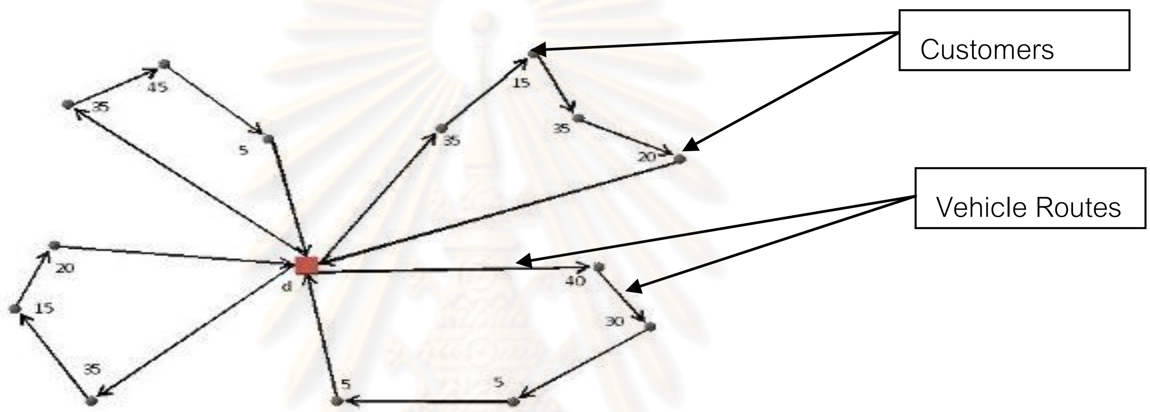

Figure 2. 9 Vehicle routing problem

Source: Adapted from [44]

Researchers are trying to add side constraints in order to be resembled to real practice and work environment as much as possible. These are the variation of vehicle routing problem in recent decades;

- Capacitated Vehicle Routing Problem(CVRP)

  It is a VRP with additional side constraints of capacity of vehicle which all available vehicle share the same maximum capacity.

- Multiple Depot Vehicle Routing Problem(MVRP)

  It is a VRP with many depots in the system. Therefore, the assignment of which customers should receive from which depots is considered with the objective to minimize total travelled distance or minimize total cost of transportation.

- Vehicle Routing Problem with time windows (VRPTW)

  It is a VRP with time constraints or time boundary such as start time, finished time and time service duration.

- Split Delivery Vehicle Routing Problem(SDVRP)

  It is VRP which each node can be visited more than one time.

- Vehicle Routing Problem with Pick-up and Delivery(VRPPD)

  It is VRP which vehicle travels to pick-up and at the same time delivers the products to customers.

- Vehicle Routing Problem with Backhauls (VRPB)

  It is VRPPD which requires finishing the delivery before picking up.

- Periodic Vehicle Routing Problem(PVRP)

  It is the mixture between VRP and assignment problem which generating routes for certain periodic requirement from customers.

If the problem have at least one element based on uncertainty, the problem will shift to stochastic vehicle routing problem (SVRP). However, the problem in this research is considered to be deterministic.

2.4.3 Solution techniques

In the past, to find the solution of VRP, the experience of planners and unsophisticated routing strategy is applied due to the fact that the problem size is not big or complicate. The quality level of solution is acceptable. However, when the business is growing leading to the complication of distribution system, the proper distribution route can drastically lessen the redundancy in operations and transportation cost. Therefore, the problem size becomes too big and complicated to use the planners' experience in generating feasible distribution route. Computerized approach is applied to help find the better feasible solution more systematically and more efficiently within less computational time. To find the solution of vehicle routing problem, the approaches can be classified into two types that are Exact Optimization and Heuristic Optimization. Each of the approaches has its advantages and disadvantages. Exact Optimization can find the optimized solution by generating mathematical model with longer computational time when the problem size is bigger. Heuristic Optimization can lead to the approximate optimal solution with less computational time comparing with the Exact Optimization. Therefore, in complicated and big-sized problems, Heuristic Optimization is generally applied to find the feasible solution.

Due to the fact that VRP is a computational problem which had been studied for over 40 years to find the optimized solution within reasonable computing time, many researchers focus on using heuristics and metaheuristics as searching method for optimum solution rather than using exact approaches.

2.4.3.1 Exact Optimization

By applying this approach, the best solution is gained. However, the computational time is too long and insensible to real practice. Exact optimization can be used with fewer customers in the system. The techniques used for exact optimization are

- Linear programming

  This technique is also adapted to solve VRP [14]. However, it can only solve small sized problem of VRP which can be formulated into linear equation. The maximum size that can be solved by this method is 42 customers which are proposed by Dantzig, Fulkerson and Johnson [20].

- Dynamic programming

Bellman [21] is the first pioneer researcher who adopts dynamic programming to solve VRP. This technique finds best solution by determining a solution for each node added to the routes. Later, Held and Krap (as cited in [15]) criticized that the method is only effective when apply to the problem with less than 13 customers due to the limitation of computer memory and required computing time.

- Branch and Bound

This technique comprises of 2 steps for solving problem which are branching and bounding. Branching is to divide a big sized problem into many of independent small-sized problems. Bounding is to define the lower bound of best solution. During branching, the big-sized problem will be substituted by small sized problems with lists of possible solution to each problem. These small sized problems are partially able to find the answers. Therefore, the small sized problem will be smaller than the initiated problem [18].

2.4.3.2 Heuristics search method

The heuristics search method developed from the idea to save computational time. Heuristics search method can be classified into 3 categories;

- Constructive method

Constructive method is applied to find the feasible solution with focus on computational time and cost. It does not concern with improvement of solution. These are examples of algorithms in this category

  - Nearest neighbor algorithm

Savelsbergh [19] described that this method is a greedy algorithm. Route generation begins at the depot and selects the nearest node to visit. Then, vehicle travels from the last visit node to the next nearest remaining nodes. This process is iterative until the tour or requirement is completed. The effectiveness of this algorithm is calculated by Equation 2.1.

Equation 2. 1

$$\frac{Length\ of\ nearest\ neighbor\ tour}{Length\ of\ optimum\ tour} \leq \frac{1}{2}[Log_2 n] + \frac{1}{2}$$

- Nearest insertion algorithm

Rosenkrantz (as cited in [17]) was the first to introduce this algorithm. The algorithm will chose a node closet to any node in sub-tour for insertion. This is the process of this algorithm

1. Start a sub-graph with one node
2. Find node j with minimum cost from i to j and from sub tour ,i-j-i
3. Choose node k which is the closet to any node j in the sub-tour
4. Find an edge (i,j) which minimizes $d_{jk} + d_{kj} + d_{ij}$ and insert k between i and j.
5. Repeat step 3 and 4 until all nodes are included in the tour

The ratio of solution from this method to the optimum solution is calculated by Equation 2.2.

Equation 2. 2

$$\frac{Length\ of\ nearest\ insertion\ tour}{Length\ of\ optimum\ tour} \leq\ 2$$

- Savings algorithm

This method is first introduced by Clark and Wright [26]; it is a simple algorithm which is easy to understand. It is the most adopted heuristics for finding solution of VRPs. The general idea of this algorithm is to merge 2 routes (0,…,i,0) and (0,j,…,0) into single route of (0,…,i,j,…,0) with the distance saving of the formula in Equation 2.3 and Figure 2.10 shows the saving algorithm route merging concepts.

Equation 2. 3

$$S_{ij} = C_{i0} + C_{0j} - C_{ij}$$

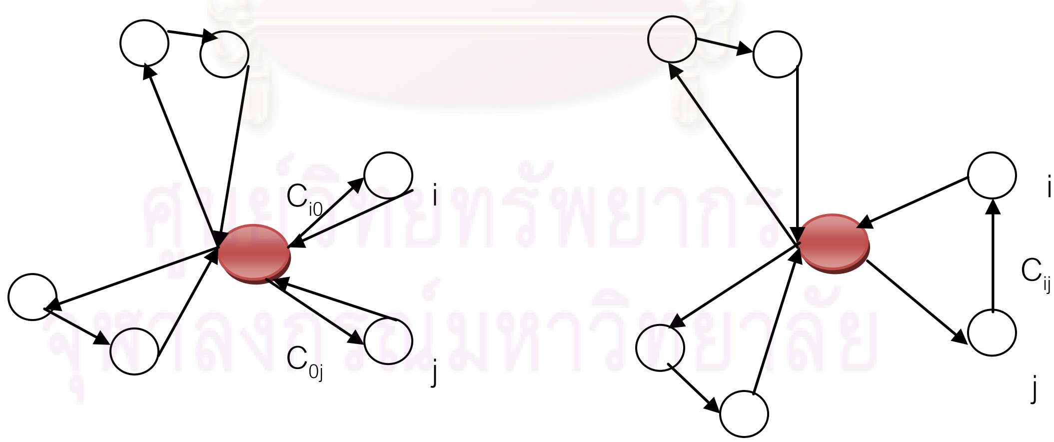

Figure 2. 10 Saving algorithm's merging routes concepts

Source: Clark and Wright [26]

The procedure of saving algorithm method can be presented as follow

1. Calculate $S_{ij} = C_{i0} + C_{0j} - C_{ij}$

   for ij = 1,…,n and $i \neq j$ and 0 refer to depot

2. Create n vehicle routes (0,i,0) for i = 1,…,n
3. Sort S_{ij} in descending order
4. Create sub-tour using point i and j with highest S_{ij}
5. Repeat step 4 until finish the tour

There are recent researches concerning the development of saving algorithm such as matching based saving algorithm introduced by Desrochers and Verhoog [22]. The algorithm focuses on the rearrange the whole set of routes rather than just point i and j merging route.

- Multi-route improvement heuristics

  This heuristics aim to improve feasible solution by exchanging edges or nodes within or between vehicle routes. These following examples are the heuristics developed to improve feasible solution of VRP

  - Thompson and Psaraftis [23]

    The concept of "b-cyclic, k- transfer" is applied to develop heuristics for VRP. Routes are selected and k customers from each route are shifted to the cyclic route permutation.

  - Van Breedam[24]

    This heuristics is developed using the concept of 2 cyclic exchanges by classifying improvement operations as string cross, string exchange.

  - Kinderwater and Savelsbergh [25]

Exchanging nodes is applied as the method of improvement. 3 main operations in solving are relocation, crossover and customer exchange. Since tours are not considered in isolation, both edges and nodes are exchanged between different tours.

- Phase algorithm

  Phase algorithm can be classified in 2 types which are

  - Cluster-first, route-second

    The delivery points are grouped then the solution is found for each group. The example of this approach includes Fisher and Jaikumar's method, Sweep algorithm, Petal algorithm and Taillard's algorithm

  - Route-first, cluster-second

    The giant tour is firstly generated by using TSP. Then the VSP is applied to generate second phase routes within the giant tour. The example of this approach is school bus routing.

2.3.4.3 Metaheuristics search method

Metaheuristic emphasized on the performing of a deep exploration of the most promising solution search space. The quality of the solution of metaheuristic approaches is far better than the obtained solution from classical heuristics. These are examples of metaheuristic developed to solve VRP.

- Ant Colony Optimization(ACO)

Marco Dorigo [27] pioneered this algorithm inspired by the behavior of ant colonies. The algorithm applies TSP and quadratic assignment problem as procedure to find solutions. The procedure of this algorithm has 2 phases which are the construction of vehicle routes and the update of generated routes. There are other algorithms recently developed for solving VRP such as Ant Colony System (ACS), MAX-MIN Ant system (MMAS) and hybrids of colony optimization with local search.

- Generic Algorithm (GA)

GA is one of the most adopted metaheuristic approaches. According to Braysy [28], the GA is basically initiated by Holland [29] and applied to real situation by De jong [30]. The concept is very simple that is to survive of the fittest including the selection and genetics used to evolve solutions to problem. The solution must be formed in a string similar to human chromosome.

According to the literature (cited in [20], [28], [29], [45], [46], [47]), the genetic algorithm consists of 3 operators; selection, reproduction and mutation. Firstly, individuals within population are selected on the fitness to reproduce the offspring for new population which sharing the same characteristics of previous generation. After that, the characteristics are combined to create a child with better fitness to ensure survival. Then, mutation phase is entered, chromosomes are manipulated randomly. Tan [31] urges that the main objective of mutation is to avoid becoming homogenous which leads to local optimum. Randomness creates higher chances of population variance.

The genetic algorithm consumes time in finding solutions. Therefore, there are many researchers trying to reduce computing time by adding variants to GA procedure such as Ann Tighe and K.C Tan [32] by focusing on all aspects of algorithm including representation of solution, selection process, reproduction process and mutation process.

- Simulated Annealing

SA is a stochastic relaxation using statistical mechanic to solve VRP. The method uses multi routes improvement heuristics to find another solution. If the new one is better than the latest one, the new one is applied immediately without condition. If the new one is worst, it is depending on the T value as the temperature of the annealing [33].

- Tabu Search

Tabu search uses the improvement method to find the solution. Tabu search helps local search or neighborhood search to being trapped in local optimum by allowing non-improvement moves. It helps prevent cycling back to previously visited solution by using tabu lists which record the recent history of the search [34].

Ultimately, heuristics search method is the most appropriate approach to finding solution of VRP due to reasonable computing time. However, there are lot of examples from developing heuristics but not practically be able to work in real situation. Heuristics search method is allowed to combine with different type of heuristics to improve computational time such as the work of Thangiah[35] who uses generic algorithm to partition customers in sectors, then create a route of each sector with the insertion method of Golden and Stewart[36] , then the route is improved using k-exchange of Osman [37].

2.5 Literature Review

The Vehicle Routing Problem (VRP) has long been studied for almost five decades; the problem becomes one of the most widely studied problems in combinatorial problems. The constraints are added in order that the problem resembles the real practice and environment as much as possible. Most researches aim to find the better methodology to find the better feasible solution closed to optimized solution. The inspiration comes from the work of Dantzig and Ramser which the work had been published around 1950s. The reasons why VRP has received much attention from researchers are the problem can be found often in everyday life and the problem is theoretically complicated and challenging in developing methodology in finding optimized solution. The problem can be classified into two categories of deterministic and dynamic depending upon the characteristics of necessary information. Deterministic problems are problems that all necessary information is already known before generating route while dynamic problems are problems that all necessary information follows one after another during the generation of routes. In the literature review of this research, only deterministic problems are discussed due to the fact that the problems in this research are assumed to be deterministic. The classical problem of vehicle routing problem is Traveling Salesman Problem (TSP) which came to interest researchers in 1920 by the mathematician and economist named Karl Menger before being introduced around the world by Merill Flood. Then in 1954, George Dantzig, Ray Fulkerson and Selmer Johnson have proposed the searching algorithm which can find solution of the TSP with the 49 customer nodes. Then, the problem is evolving continually until 2004; Applegate Bixby Chva'tal Cook and Helsguan can find the feasible solution of vehicle route to visit 24,978 cities in Sweden. VRP is the generalization of TSP which has more than 1 vehicle which the problem are classified into many types according to the characteristics of the problem. Generally, VRP are assumed to be deterministic which all necessary information is known before the routing starts. The problem starts with the objective to minimize the total transportation cost to visit all nodes, then side constraints such as the capacity of the vehicle is added into the model; the problem is called Capacited Vehicle Routing Problem (CVRP). However, if there is more than one depot, the problem is called Multiple Depot Vehicle Routing Problem (MDVRP). The problem of which vehicle delivers products to customers as well as pick up products from the customer to deliver to another customers is called Vehicle Routing with Pick-up and Delivery(VRPPD)(Lu and Dessouk,2004). When there are constraints of time windows in delivery involves the problem is called Vehicle Routing Problem with Time Windows (VRPTW) which is studied widely in both mathematical model generation and searching algorithm development. There are other types of VRP which constraints are added to imitate the real working environment into the problem. The approach in finding solution of VRP is developed in both Exact Optimization and Heuristic Optimization. By using Exact Optimization, in 1980, Paraftis applied the Exact Algorithm by using Dynamic Programming approach; then, in 1985 Kalantari et al, developed the Branch and Bound algorithm to find the solution of Single Vehicle Pickup and Delivery Problem which is capable to find the optimized vehicle route of 15 customer nodes. Kolen et al, proposed the same approach of Kalantari et al to find the solution of VRPTW. Then in 1997, Ruland and Rodin proposed the branch and cut algorithm which can also find optimized solution to the 15 customer node problem. Dumas et al, developed column generation approach by using branch and cut algorithm to solve the pickup and delivery problem with hard time windows which can find the optimized solution of 55 customer nodes to be visited by one vehicle. Linear programming relaxed set covering and column generation are proposed by Lu and Dessouk to find the solution of multiple vehicle routing with pickup and delivery by applying branch and cut algorithm which can find the feasible solution of using 5 vehicles and 17 customer nodes. The Exact Optimization approach takes high computational time and the efficiency in finding optimized solution decrease when the problem size is bigger. As a result; many researches are aiming to develop the Heuristic Optimization which leads to the better quality of solution within reasonable computational time. Heuristic approach can be classified into classical heuristic and Metaheuristic approach which the efficiency in finding optimized solution is developed. As for the classical Heuristic, the most adopted method is saving algorithm which has been proposed by Clarke and Wright in 1964. The algorithm aims to find the vehicle routes by finding the saving distance in using vehicle to visit many customer nodes instead of using a vehicle to visit one customer node. The work process of the algorithm includes parallel approach and sequential appraoch of which Gillbert et al proposed that the parallel working process leads to better solution quality. Apart from saving algorithm, in 1987, Solomon had proposed the preliminary routing of Push Forward Insertion Heuristic(PFIH) which the possible solution are listed in the preliminary stage and enter the improvement stage of generating appropriate route. This approach is comprehensive and high efficiency in finding solution; moreover, the upper-bound of the numbers of vehicle is known before routing. The algorithm try inserting new customer nodes in between the already arranged customer nodes at the best position within the route complying with the constraints of vehicle capacity or delivery time windows.

There are many applications of VRP applied to solve problems in real situation for many organizations. These following are successful applications of using heuristics to solve generic problem of the company in real operation situation.

Generally, vehicle routing problem is widely applied in physical product distribution and material transportation for production planning. Even though, vehicle routing problem is applied in distribution management of many freight or physical distribution, there are less applications applying vehicle routing problem to help plan and manage logistics system of medical or other healthcare services.

Vehicle routing problem are applied to distribution decisions of milk and ice-cream company to deliver the product to customers with the constraint of limited shelf-life of milk and ice-cream during transportation. According to Klibbua [47], 2 opt algorithm is used to generate routes with the objective function of minimize distance. Dijkra's algorithm is used to find the shortest path between two nodes which can be applied to this thesis. Moreover, the limited shelf life of the product follows the characteristics of medical staffs' available time for operation in this research. The vehicle routing is applied to the distribution of milk and ice cream distribution with the side constraints of product limited shelf life with the responsibility zone in the distribution. Later, Orawan [48] have studied the routing system for trucks to collect solid wastes in Bang Kean area. The branch and bound method is applied to find the giant route then cluster into several routes. Dijkra's algorithm is used to find the shortest path between each pair of collecting point. The idea of truck travelling to correct solid wastes is identical to the problem in this research. However, the heuristics search method is applied to solve the problem rather than use the exact optimization methodology. Then, Suthee [49] has proposed the development of the vehicle routing system for consumer product in restroom with single depot to distribute the product to other retail stores with the objectives to minimize total travelled time. Clark-Wright is applied to cluster customers of diverse areas. The real travel time is collected with the assumption of normal traffic condition and the time for loading product depends on size of product. Saving algorithm is used to solve routing problem. The concepts of collecting real travelled time can be also applied to this thesis. Krisakrai [50] has developed routing system for gasoline delivery. Three types of vehicles are available with side constraints of some road are not permissible to travel. The saving algorithm is applied to solve the problem with the reason of simplicity and less computation time. This research gives the suggestion of Clark-Wright method to lessen the computational time to fins solution with the quality competitive to other method. There are attempts by Naruporn [51] to develop vehicle routing system for distributing home furniture with 3 different types of vehicle which are used to deliver goods according to different distance. The saving algorithm is applied to find feasible solution with the reason of its simple and easy to understand characteristics. Moreover, Floyd-Warshall was used to find the shortest path. The research can be the example of multiple item distribution which follow the same approach of this thesis that also focus on distributing variety of products to customers.

Then, Thanest [52] has developed vehicle routing system for physical distribution with a single depot, multiple types of vehicles to customers with the objective to minimize distance using saving algorithm of Clarke- Wright to generate initiate routes then the route improvement is conducted by exchanging nodes in existing routes. The problem of this thesis is partially identical to the problem in this research with the single depot of vehicles. Later, Yuthachart [53] complicated the problem of vehicle routing in real case application by developing vehicle routing program with the objective to minimize distance with single depot and one vehicle with the comparison among three techniques of finding solution: 1-Tree Lagrangean Relaxation , Artificial neutral networks and Generic algorithms to test which method can provide the shortest distances. The concepts used in this research about the generation of route then improve the feasible solution by setting lower bound for search space can be utilized and adapted to match the problems of this thesis. The research developed by Pongpaut [54] introduced the routing system for medical supplies distribution system for different building in hospital. The problem can considered to be stochastic since there was uncertainty in demand, time windows for delivery and variety of product. Savings algorithm, 2 opt Algorithm and Anti-intersection Algorithm are applied to find the solution to the problem. The research can contribute a good example to this thesis since some of the validation techniques such as sets of test data can be adapted with this research. Then, Kritnapat [55] developed the dynamic programming for solving VRP with guaranteed service time and capacitated vehicle. The develop heuristics works in three iterative manner; data preparation, route establishing and vehicle dispatching. Heuristics of route establishing and vehicle dispatching can be applied to this research such as conditions when another vehicle is needed when all requirements at nodes on route is not satisfied. Suttipong [56] develops the GIS based vehicle routing for good distribution under capacity of vehicle and deliver point constraints. Saving algorithm is applied again to solve problem with Dijkra's Algorithm for finding shortest path. The concept of finding the shortest path between two nodes can be applied to this research. The research of Vipada and Duangpan (as cited in [57]) proposed the prototype of transportation management system for a frozen food manufacturer. The distribution operation has certain time window allowed. Saving algorithm is applied to solve problem since the manual operations are not flexible enough for changing orders. The methodology of gaining data of distance can be adapted to this research by using data retrieved from digital map program and Mappoint Asia's website. Lastly, Thanat [57] develops the vehicle routing system for daily meal delivery by motorcycles. The problem is identical to Vipada and Duangpan since there has certain time windows allow for operation. Saving algorithm is applied to solve problem with A* search algorithm to find the shortest path. The research 's objective function follows the same concepts of this research that is to minimize the number of vehicles, and travelled distances with side constraints of vehicle capacity and time windows.

In conclusion, VRP is applied in many of real business practice with the objective to reduce transportation cost. Saving algorithm is the most adapted heuristics because of its easy to understand characteristics. VRP is considered to be NP hard problem with complexity varies upon the numbers of side constraints. The solution search method can be conducted in 2 different approaches which are exact optimization and heuristics optimization. The heuristics approach cannot guarantee that the best solution is found; however, when comparing with the exact solution approach, the computation time is less and reasonable in practice. Therefore, many heuristics are developed to find solution of VRP.

CHAPTER III

PROBLEM DESCRIPTION

In this Chapter, the mobile medical distribution planning process of the studied organization are introduced including the problem statement on decision criterion applied in this research which is different from other industries in Logistic planning. Distribution planning of medical staffs and supplies is classified into 2 different processes according to the characteristic of service operations provided: Round-trip and One-day Trip. Input data as well as other necessary information for the developed decision support system to efficiently find the solution in distribution planning is listed.

3.1 Data Collection

The study of mobile medical service distribution planning process is important to identify the characteristics or problems that the organization currently experiences; moreover, it can lead to greater opportunities in finding better alternatives to fix some problems that the organization does not realize before [4]. By knowing adequate details in mobile medical staffs and supplies distribution planning of mobile medical service can lead to better understanding of planning process including the objectives of each step in the process; thus, the design of decision support system can be more easily developed to comply with the current planning process or slightly different but still meet the organization's objectives. The benefits of studying the operation process are

- Better understanding of problems or operation process
- Realize objectives and constraints or limitations that affect the result of operation or planning
- Access to the fundamental data that can be beneficial in further research procedure

In this research, three types of mobile medical service are observed. Planning officers are interviewed[1]. Each observed operation site operates in different service activity. Those sites are

- Ratchaburi Province, Khon Kaen Province and Prachuapkhirikhan Province; providing normal mobile medical service
- Phetchabun Province; proving mobile oculist service
- Chiangmai Province; providing mobile dentistry service

Even though each observed site are operating in different type of service activity, medical staffs and supplies distribution planning process and medical staffs and supplies distribution to operation sites shares some identical characteristics as well as different aspects that can be summarized and described in three different categories of distribution planning; medical staffs and supplies distribution in normal mobile medical service, medical staffs and supplies distribution in mobile dentistry service and medical supplies and staffs distribution in mobile oculist service.

3.1.1 Medical staffs and supplies distribution in normal mobile medical service

Generally, in normal mobile medical service, primary diseases are diagnosed and cured. The distribution planning process of the studied organization starts when the provincial mobile medical service operation plans are approved from the central office. Planners at each provincial office will designate responsible local hospital to support medical staffs to each scheduled operation site. The closet hospitals usually assigned to do the task. Then, the provincial will issue the collaborative action plan to those supporting hospitals as well as other associates (local representatives, supply warehouse and private medical volunteers) to confirm the date of operation and responsibilities. The day before the scheduled date, involved associates will prepare medicine, proper vehicles and volunteer medical staffs ready for operation in the following day. Before this day, it can be a lot of changes in collaborative action plan according to how each provincial planner coordinates with other associates or each

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[1] Interview details can be founded in Appendix A

provincial management and administration style. At the operation date, volunteer medical staffs are transported from their auxiliary hospitals to operation site while medical supplies are transported from local supply warehouse to operation site. When the service is over (usually takes about 8 hour per operation day), medical staffs and remained supplies are distributed back from operation site and return to each auxiliary source. Figure 3.1 shows the distribution route of medical staffs from their auxiliary hospitals to operation sites and distributed back when the service is over.

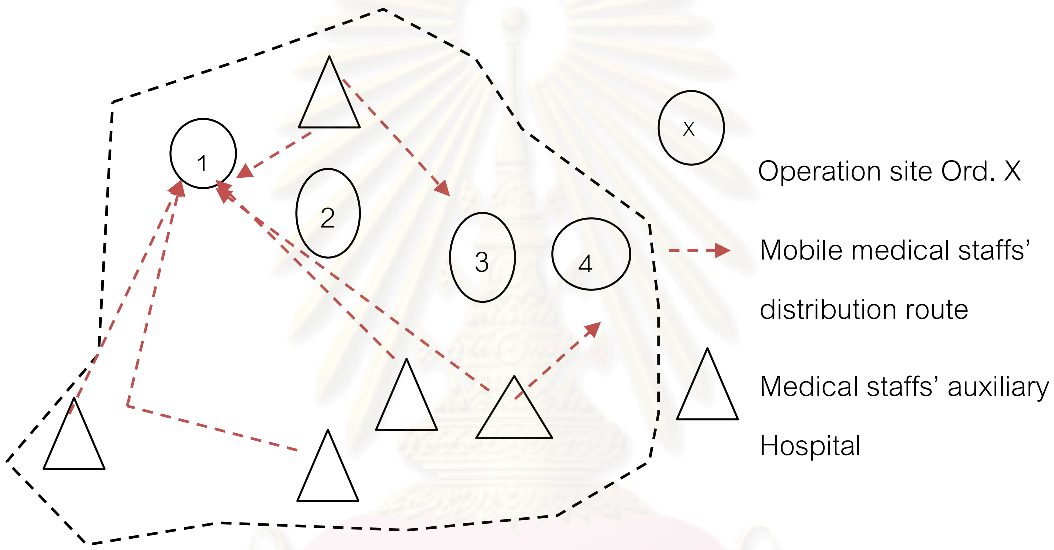


Figure 3. 1 Mobile medical staffs and supply distribution characteristics

Medical supplies are usually not stored at the next scheduled operation site waiting to be used at the next time. This due to the fact that the duration of the next operation schedule is approximately 2 week away from the previous or longer resulting in the increased risks that medical supplies will be expired and it will be irrational for the organization to invest in medical supplies holding cost which may lead to higher operation cost of the organization. This distribution characteristic is the general case practice. However, in different provinces, different approaches of medical supplies are used to comply with the administrative system or executive habits. These are the three different examples of medical resources distribution characteristic of each observed province in normal mobile medical service.

The medical staffs and supplies distribution characteristic of Ratchaburi province follows the described simple case due to the fact the province itself are rounded-shape in geographical structure. Moreover, almost every village in the province can easily access to nearest local hospital because of the development of provincial road transportation system. Therefore, it is more easily to transport medical staffs and supplies directly from their auxiliary hospitals to scheduled operation sites. However, this medical supplies distribution characteristics results in inadequate usage of vehicle utilization and over number of vehicles used to deliver medical staffs and supplies to operation sites. If there are a lot of responsible hospitals located quite close to one another or in the same passage way to operation site, this distribution characteristic can be considered as wasteful usage of vehicle in the industry's point of view. However, mobile medical service is not industrialized service organization; but it operates in charitable basis. Therefore, the organization does not realize that there are wastes occurring in this medical staffs and supplies distribution characteristic. This is partly due from the fact that this approach is in practice for a very long time that it becomes the habitual pattern of medical staffs and supplies distribution method to operation site. Figure 3.2 illustrates how medical supplies are distributed to scheduled operation sites.

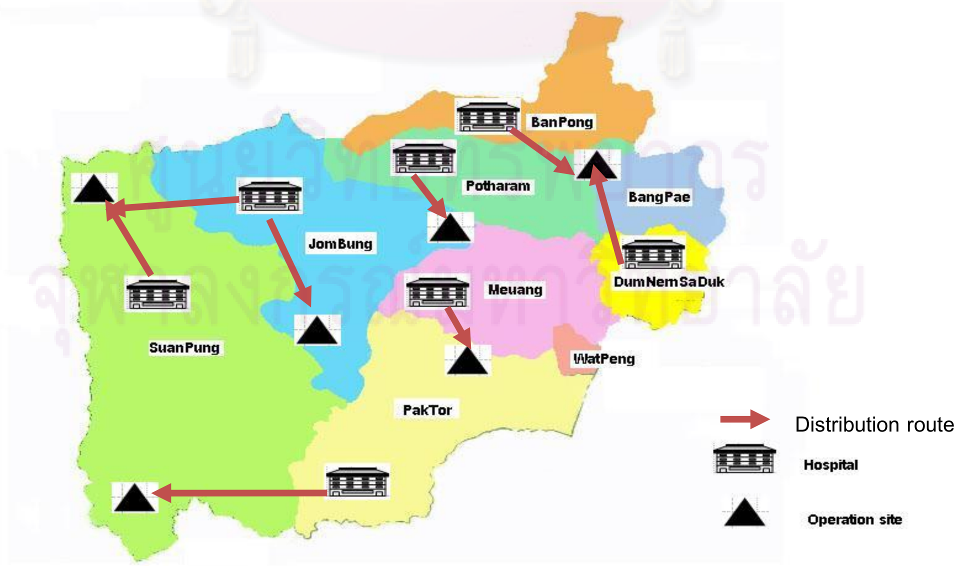


Figure 3. 2 Medical supplies distribution characteristic in Ratchaburi province

The medical supplies distribution characteristics of Prachuapkhirikhan province are slightly differs from those of normal case. This is because of the fastigiated shape of geographical structure of the province that it takes about 100 km of travelled distance from the north of the province to the south. Therefore, the mobile medical service cannot operates at the proper cost if there is only one warehouse in the province because of high transportation cost for distributing medical supplies to all scheduled operation sites in the province. As a result, there is medical supplies warehouse located in each service zone. There are 3 service zones in Prachuapkhirikhan. Each zone is responsible for providing service to equal number of villages. When the provincial plan for mobile medical service is approved, the plan will be issued to each service zone to settle the responsible hospitals in the zone to support medical staffs to scheduled operation sites within the service zone. At the operation date, medical staffs and supplies are distributed from their auxiliary hospitals to operation site; when the service time is over, medical staffs and remained supplies are transported back to where they are form. This distribution characteristic is different from the normal case in the number of medical supplies warehouses and restrictions in responsibility of each local hospital to provide the medical staffs to operation site. Local hospitals cannot support medical staffs to villages in the different zones. The method helps reduce the total transportation cost since the distance travelled of medical staffs and supplies distribution is less than the normal approach since it travels within each service zone. However, since the medical staffs is required to voluntarily register to operate at the operation site for mobile medical service, if the local hospitals in the service zone have so few medical staffs that medical staffs cannot provide their free time to operate for mobile medical service, the shortage of volunteer medical staffs in that zone can occur leading to the borrowing the medical staffs from other zones which will cost higher transportation cost or may lead to the cancellation of mobile medical service. Nevertheless, the method is appropriated for provinces that have the same fastigiated geographical structure and several capital hospitals located dispersedly though the entire province. Figure 3.3 presents how medical supplies are distributed to operation sites in Prachuapkhirikhan province.

Figure 3. 3 Medical supplies distribution characteristic of Prachuapkhirikhan province

The medical supplies distribution characteristics of Khon Kaen Province mostly follow the normal distribution pattern like those of Ratchaburi Province. However, in the case of medical supplies shortage, mobile medical unit will make a requisition to nearby hospitals to borrow those inadequate medical supplies. Since the medical supplies of the studied organization are mostly free of charge received from the donation of other profitable organizations, the exchange between hospitals in the organization's network within the same province is practical. However, sometimes, the organization must return the medical supplies borrowing from local hospitals which are used up at operation sites back to those local hospitals by equal equivalent value. For example, operation site A borrows 200 units of Paracetamol from local hospital C, the organization can either return 100 units of Tylenol or 200 units of Paracetamol back to hospital C.

However, this pattern of medical supplies distribution results in management complexity due to the fact that the returned medical supplies are not actually equal to the borrowed ones as well as the transportation cost per unit that the organization has to pay to return small-sized lot of medical supplies through transportation service of back to hospital.

3.1.2 Medical staffs and supplies distribution in mobile ophthalmologist service

The distribution pattern of mobile oculist service is complex because of its detailed and specific service operation that the studied organization is providing. Mobile oculist service requires medical staffs to go to operation site in order to screen the customers (patients) with eyes diseases who can be cured such as those who suffer from Cataract disease which require eyes operation to remove eyes' lens which will be replaced by aspheric lens which has to be specially and individually ordered in order to match with each individual customer. In order to make aspheric lens, prescription is required. Therefore, medical staffs are firstly transported to screen patients and to issue prescriptions to make aspheric lens for each individual patient. Then, in the next two weeks, the same medical staffs will return to operation site to operate the removal of patients' eyes lens replaced with aspheric lens. Medical staffs in this case are mostly volunteer oculists from Bangkok or private hospitals since there are so few oculists or none in regional or local hospitals in the country. Figure 3.4 shows the distribution pattern of medical staffs and supplies to operation sites in mobile oculist service.

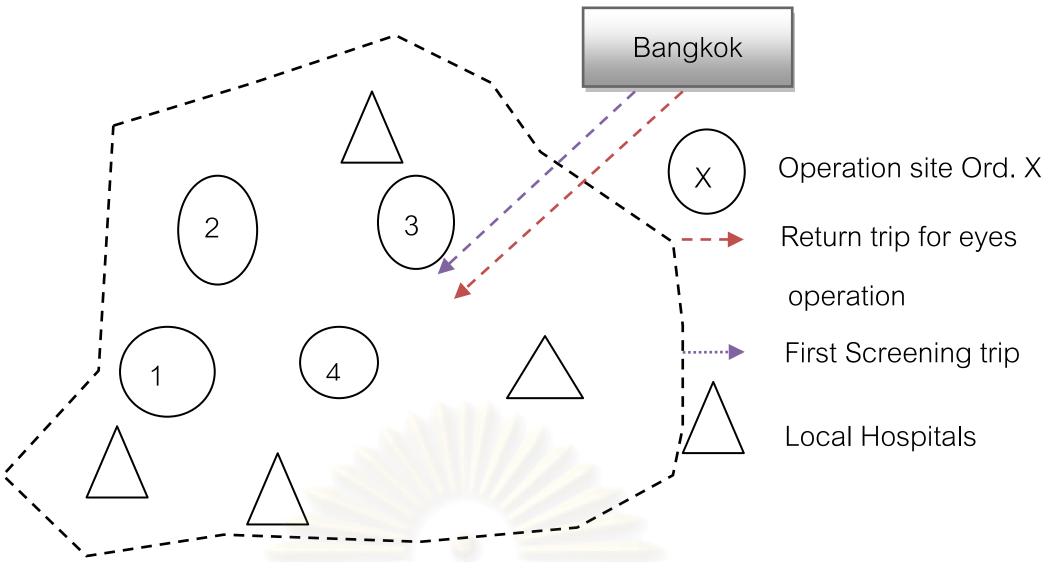


Figure 3. 4 Distribution patterns of medical staffs and supplies in mobile ophthalmologist service

Since mobile oculist service has a very complex and detailed service operation; the same medical staffs are transported twice to the same operation site; medical supplies are individually different and specific in each patient; the service preparation and operation planning require special process that cannot be integrated into the same distribution planning process like those of mobile dentistry's service operation and normal operation. Moreover, due to the distinctively small-sized service operation compared with the other two services and difference in medical supplies preparation including the types of medical supplies, the proposed decision process in the developed decision support system does not include the mobile oculist in the scope of distribution planning process of the developed system.

3.1.3 Medical staffs and supplies distribution in mobile dentistry service

The distribution pattern of mobile medical staffs and supplies distribution are the same since medical supplies and medical staffs are loaded in the same vehicle and transported to operation sites in each operation route due to the fact that the organization has limited numbers of vehicles to enter the area of operation sites. Medical staffs are usually from the hospitals in Bangkok or private hospitals. These medical staffs are voluntarily registered to provide medical services at operation sites; they usually spend their available holidays of the year by registering as mobile dentists of the organization. The process of mobile dentistry service of the studied organization starts at the operation requisition process; each regional public health offices in each province will brainstorm with provincial public health office as well as the experienced representatives from the studied organization to make the requisition and to consensually determine which operation sites should be added in each operation route that the organization is available for providing mobile dentistry service. Once the yearly operation route is announced these medical staffs will register to work at their preferable operation routes. After the operation plan, operation scheduled is approved as well as the total numbers of members in medical team are registered as required, these medical staffs will be transported to provincial public health office or other meeting places that the studied organization determines. Usually medical supply warehouse are used as the meeting center in order that the vehicle that used to transported medical staffs and supplies to operation sites in the previous operation route can prepare and load medical supplies and staffs as well as to return the previous medical team to go back to Bangkok or leave the province. Once medical staffs and supplies are ready and fully loaded, each operation sites is visited one by one as in operation scheduled of the operation route and vehicle will return to medical supply warehouse to prepare for another trip in the next operation route at the same time that the next medical team is entering or arriving at the province waiting to start the journey at medical supply warehouse. Figure 3.5 shows the medical staffs and supplies distribution pattern of mobile dentistry service.

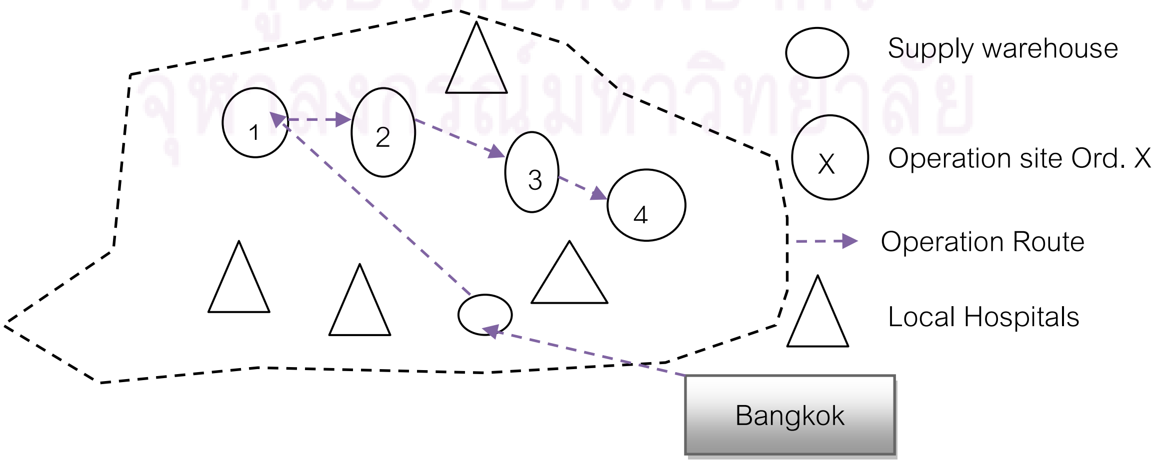


Figure 3. 5 Medical staffs and supplies distribution pattern of mobile dentistry service

Unlike normal mobile medical service that the volunteer medical staffs are from local hospitals within the same province as those of operation sites, mobile dentistry service usually uses medical staffs from Bangkok and other provinces. However, in normal mobile medical service, there are dentists providing medical service to the customers as well. Since the medical supplies used in normal medical service and mobile dentistry service are not very different and have high frequency in usage and quantity, these different types of services can be integrated into the same planning process of the developed decision support system in order to help the planning officers of the studied organization or another charitable organizations which provide the resembled mobile medical service operations as those of the studied organization to use the developed system to plan the operation route and distribution method of mobile medical service.

3.2 Selection of Objective's Function

From the Literature Review in Chapter 2, most companies use total transportation cost as the company's objectives and goal and aim to reduce the cost as much as possible. However, to determine total transportation cost as objective function in vehicle routing problem can lead to difficulty and complexity in finding optimal solution of decision model [5]. Therefore, most research usually applied distance and transportation time as objective function in vehicle routing problem rather than use total transportation cost as those of companies' objective. Objective function plays the most important role in decision making since it is the measurement to evaluate best alternative from others. There are many factors to realize before selecting appropriate objective function such as capability in data collection, convenience and promptness in data analysis and quality of data analysis. These are the analysis of using distance, time and cost as objective function.

- Distance

By using distance as objective function can lessen the complexity in finding solution of decision model since the distance represents transportation cost that directly vary with distance. The less distance travelled, the less expense will be lost in transportation including maintenance cost, fuel cost and etc. However, distance value is affected by many physical factors such as road network, traffic system and route characteristics. Therefore, to use distance as objective function must base on the concise assumption to ignore road network or route characteristics.

- Time

  By using time as objective function is more complex than distance since there are many other factors that affect the time in transportation such as traffic condition and limitation in entering delivering place leading to inconvenience in computing traveling time. To use time as objective function is usually appropriate to companies that value time of delivering as the important quantitative measurement in service quality such as post delivery service and third's party logistics providers.

- Cost

  By using cost as objective function is the most complex approach in finding solution since there are many activities and factors leading to the change in cost of transportation such as cost of loading and unloading from vehicle, administration cost, inspection cost and cost of delay. Many organizations try to seek ways to reduce transportation cost; therefore, most research about companies' case studies usually use cost as objective function. By using cost as objective function is the most preferable objective function of companies; however, there is cumbersome difficulty in generating mathematical model for decision model since some factors may not have rational scaling factors to convert those factor into cost. Therefore, if the cost of transportation during delivering period is focused, distance can be used instead as objective function since during the delivering period the cost of transportation is directly varied by distance [10]. Figure 3.6 shows the linear relationship between transportation cost and distance during delivering period.

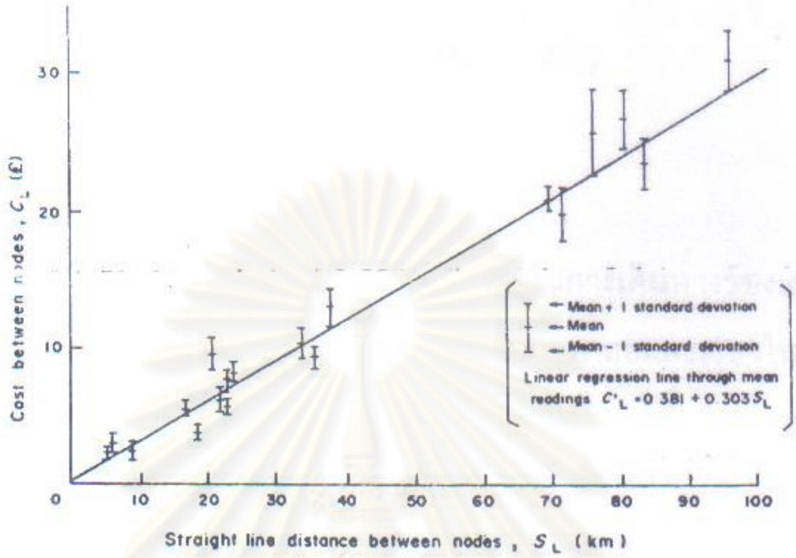


Figure 3. 6 Linear relationship between transportation cost and distance during transportation period [10]

From the objective function analysis, in this research, distance is used as objective function of both decision models of round-trip distribution planning and one-day trip distribution planning. The cost function is usually consists of two types of cost that is fixed cost and variable cost. In transportation, fixed cost is usually cost of borrowing vehicles, administration cost and setup cost while variable cost usually the cost that increase during delivering such as cost that varied by distance. In mobile medical service, every operation sites must be visited in order that the organization can retain highest customer service level which is the studied organization's objective and policy. Only cost that varied by distance during transportation is focused since other fixed costs e.g. medical staff remuneration, administration cost, and vehicle hiring cost are not responsible directly in organization's budget but are handled by other companies in the form of donation. This differentiates the decision making criterion is the mobile medical service distribution of medical resources from those of other industries.

3.3 Problem Formation

Even though there are a lot of types in mobile medical service of the studied organization, in the distribution pattern points of view, the service operation of mobile medical service can be classified into two distinctive patterns according to the distribution pattern that are consecutive operation and intermittent operation.

Consecutive operation is the service operation resembling the operation of mobile dentistry service. It can also be called “Round-trip Distribution Planning” in this research. Medical staffs and supplies are stored at exactly one certain place waiting to be transported to customer nodes in operation route. The key decision making point in round-trip distribution planning is to decide which operation sites should be in which operation route of each service-time period. For example, in the time period of 1 October 2009 to 7 October 2009, which operation sites should be added into the operation route of this service-time period and in what sequence. Therefore, the operation route of each service-time period is arranged so that the operation route’s measurements or objective’s function are satisfied within the constraints that the numbers of operation sites in each operation route do not exceed the total working days of the service-time period. After the operation route of each service-time period is gained, the quantity of medical staffs and supplies required in each trip of operation route is calculated to create the strategic year plan for the organization to open the registration of medical staffs (which is not included in this research scope) for making full detail in year plan for consecutive operation or round-trip distribution plan.

Intermittent operation is the service operation resembling the operation of normal mobile medical service. It can be called “One-day trip Distribution Planning” in this research. Medical staffs are stored in different types and quantities in the hospitals around the province but medical supplies are stored in exactly one certain place that is supply warehouse in the province. The key decision points are in each operation site, which hospitals should support their medical staffs in which type and quantity in order that at the operation site, medical staffs are available to operate as required numbers to meet the objective set in the decision support system. Another decision point is after the supporting hospitals to each operation site is identified, how or which method those medical staffs from their auxiliary hospitals will be transported to operation site. For example, at operation site A, on day 12 October 2009, 3 doctors, 3 dentists, 3 nurses, 3 dentist's assistants and 3 Pharmacists are required to successfully operate at the operation site. By using the developed decision support system, planners can easily determine the supporting hospitals and type and quantity of medical staffs that the supporting hospitals should support to operation site. From the previous example, Hospital a should support 3 doctors, 2 dentists, 1nurses, 1 dentist's assistants and 1 Pharmacists while Hospital b should support 0 doctors, 0 dentists, 1nurses, 1 dentist's assistants and 1 Pharmacists and Hospital c should support 0 doctors, 1 dentists, 1nurses, 1 dentist's assistants and 1 Pharmacists. Therefore, at this stage, the type and quantity of medical staffs of each supporting hospital are known. Then another important decision point follows; how those medical staffs will be transported from hospital a, b, and c to operation site A. In the current practice of normal mobile medical service of the studied organization, medical staffs are transported directly from their auxiliary hospitals to operation site. This distribution method is the most agile and flexible approach in distributing medical staffs to operation site. However, the vehicle is not utilized and usually required a lot of vehicle to transport all medical staffs to operation sites. Therefore, two patterns of distribution method are designed and added in the developed decision support system in order to create opportunities to reduce transportation cost; meeting point and medical staff pickup route are the two new pattern proposed in the decision support system.

Meeting point is inspired by the Hub and Spoke system of airfreight transportation. When there are many nodes in distribution network, by transporting from many departure nodes or spokes to certain point called "Hub" before being aggregated and transported to the same destination nodes or spoke will have lower cost of transportation than by directly being transported from all departure nodes to the same destination node [13]. Figure 3.7 shows the illustration of Hub and spoke distribution system. In mobile medical service, especially with a lot of supporting hospitals collaboratively support medical staffs to operation site, meeting point may help reduce the cost of transportation from all hospitals to operation site.

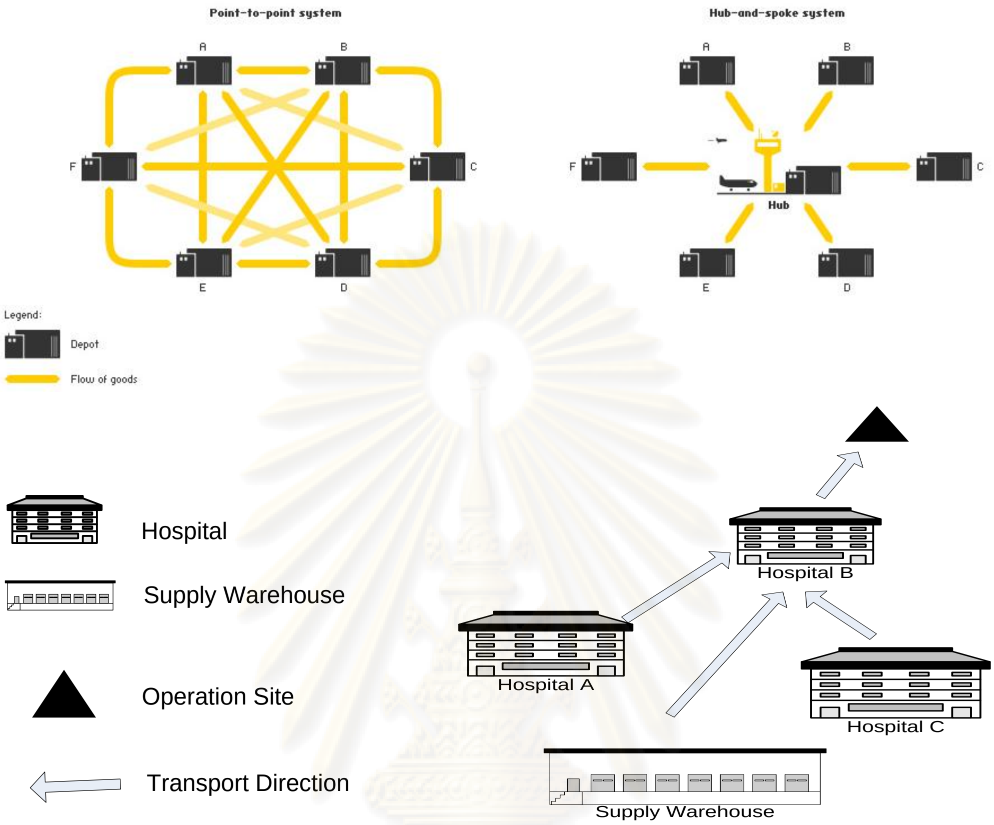
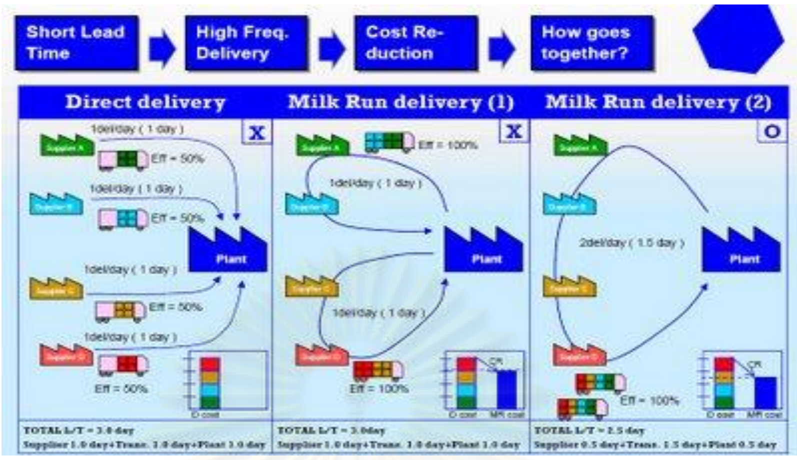


Figure 3. 7 Hub and spoke distribution system

Source: logistics management by Pfohl [13];

Another distribution method is medical staff pickup route which in this research "pickup" will be used to shorten the name. The method is inspired by Toyota's Logistics System called "Milk run". Toyota applies Milk Run system to pick up raw materials from different suppliers in order that all parts will be transported just in time for production at work station. Some applied practice of Milk Run is long-haul freight transportation. When there are a lot of distribution center dispersedly located in different place. Some products are available only in specific distribution centers. The customers ordered the product lot which consists of lots of different types of products that stored in different distribution centers. Milk Run will be applied to generate pickup route from those different distribution centers in order that the customer receives the product as order with less transportation cost. Figure 3.8 shows the illustration of Toyota's Milk Run



system in picking up raw materials for entering work station of production line.

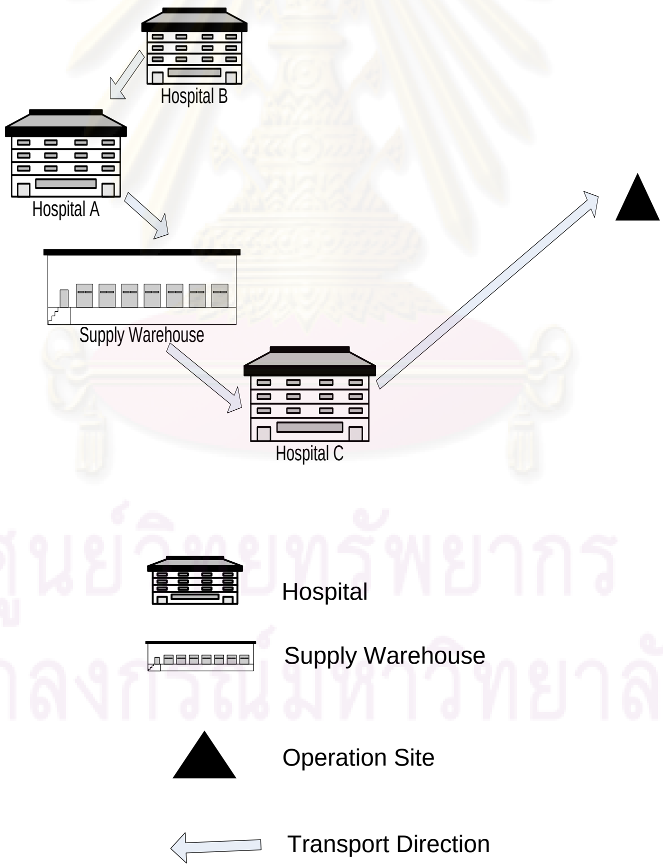


Figure 3. 8 Toyota's Milk Run distribution system

Source: Lean Logistics [13]

Each distribution method has its own unique advantages and disadvantages. Table 3.1 shows the analysis of benefits and drawbacks of each distribution pattern in different perceptions which are distance, vehicle utilization, time and flexibility.

Table 3. 1 Analysis of benefits and drawbacks of each distribution pattern

Attributes	Distance	Level of flexibility	Utility of vehicle	Travel Time	Complexity in management
Direct from hospital	High	High	Low	Fast	No
Meeting point	Moderate	Moderate	High	Moderate	Moderate
Pickup route	Low	Low	High	Opportunities lost time	High

The developed decision support system will calculate the measurement for planners to make decision on distribution method based on the fact that which measurement is prioritized the most by planners or organization's objectives. The information of supporting hospitals, type and quantity of medical staffs each supporting hospital support to operation site and distribution method can be used to create the monthly operational plan for mobile medical service of each province on yearly basis. Figure 3.9 illustrates the overview of stages and scope of developed decision support system in medical staffs and supplies distribution planning process of operation support system for mobile medical service.

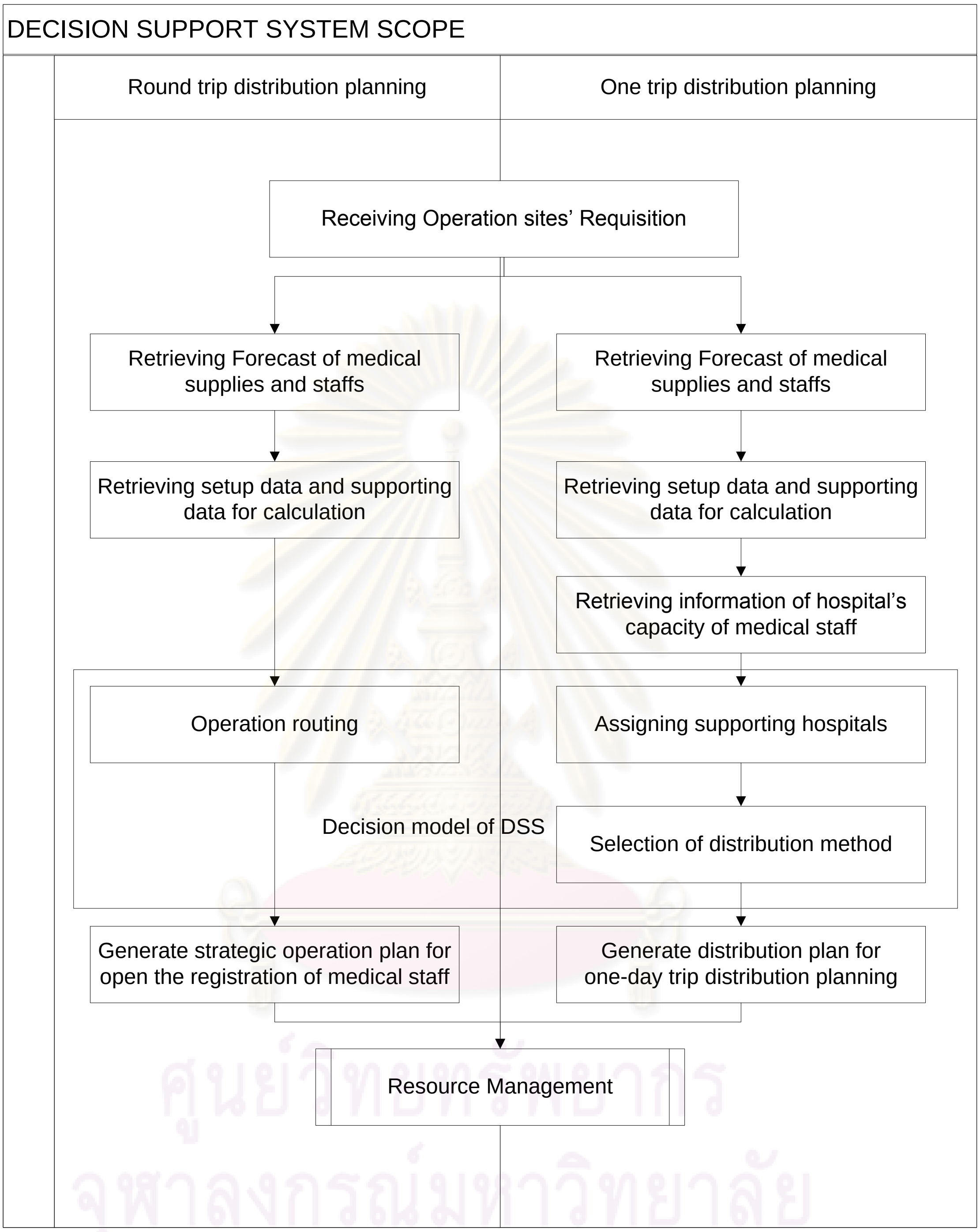


Figure 3. 9 Overview of decision support system for medical staffs and supplies distribution planning

The developed decision support system is able to plan the distribution of the two types of service operation concurrently; however, the logic of decision model in the developed decision support system is different and independent from each other.

The developed decision support system is one of the components of operation support system for mobile medical service research project. The developed decision support system is in the planning process of mobile medical service which can be illustrated in Figure 3.10.

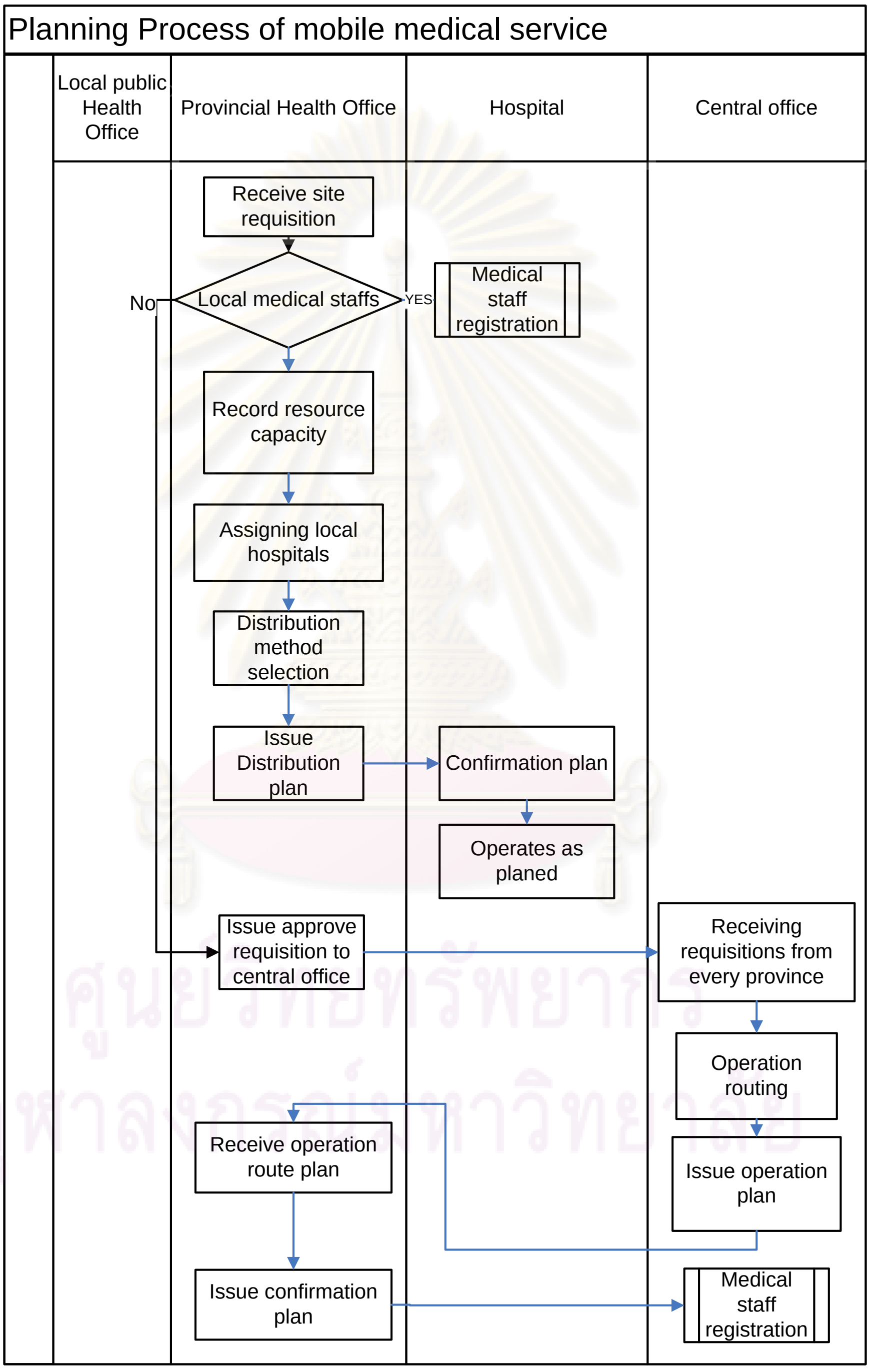


Figure 3. 10 Planning process of mobile medical service

After the requested operation sites is approved by the studied organization and the forecast of required numbers of medical staffs and supplies at each site are received, the distribution planning process of the developed decision support system for each type of service operation begins.

The round-trip distribution planning will generate information about the operation route for each service-time period. This information will later be used to create yearly operation plan for this type of service of mobile medical staffs and as the guideline information at the step of volunteer medical staff registration.

One-day trip distribution planning will generate information of the lists of supporting hospitals, type and quantity of medical staffs that each supporting hospital must support to operation site and selected distribution method of medical staffs to each operation site. This information will later be used to create yearly basis distribution plan of this type of mobile medical service within each month boundary of operation schedule and as the guideline information at the step of volunteer medical staffs working schedule arrangement.

3.4 Fundamental Input Data

In order to design and develop decision support system for medical staffs and supplies distribution planning, there are a lot of important data and information needed as input data of the decision model of the developed decision support system such as detail of operation site, distance, service-time period, convenience time period of operation site and forecast of type and quantity of required medical staffs at each operation site. In this section, the input data can be classified into three types according to the function of data in the developed decision support system; that are set-up data, input data and supporting data.

3.4.1 Set-up data

Set-up data are data concerning the requirement of decision support users. These data are static; do not change often and different to other organization according to the organization (user)'s policy. In this research the set-up data consists of service-time period (only in round-trip planning), detail of each province' associates in organization (user)'s network.

- Service-time period

Service-time period is the most important data for round-trip operation route planning. Generally service-time period hardly changes due to the fact that the service-time period is generated and approved by executive managers of the organization according to the budget available in the fiscal year or organization's policy. The service-time period is crucial for the decision model in round-trip planning to determine the working day of each service-time period which will be the most important or hard constraint in the decision model of operation routing and the important information to create year plan of round-trip mobile medical service. Service-time of each province is different from other province according to agreement between the regional head of public health office of each province and the central office of studied organization. Usually in mobile medical service, each service-time period is 1 week long due to the fact that the volunteer medical staffs can only devote their free time for mobile medical service no greater than 7 days consecutively. As a result, the service-time period of mobile medical is usually within 7 days. Moreover, the service-time periods of the same province are different in different season. For example, in province A, in winter there are 10 service-time periods while in summer there are 20 service-time periods (each service-time period is 1 week long). This can be due to the reason that in winter, there are likely to have fewer customers to visit the operation sites because of the weather condition and difficulty in transportation into operation site during the season. However, the service-time period depends greatly upon the agreement between management level from both regional and central office. Table 3.2 shows the service-time periods of Chiangmai province for mobile dentistry service that remain unchanged for the past 5 year from fiscal year 2004 to fiscal year 2008[2].

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[2] fiscal year 2004 starts from October 2003 to September 2004

Table 3. 2 Example of service-time period of Chiangmai of fiscal year 2004-2008

Winter	Summer
1 October – 7 October	1 March – 7 March
8 October – 14 October	8 March – 14 March
15 October – 21 October	15 March – 21 March
22 October – 28 October	22 March – 28 April
29 October – 4 November	29 April – 4 April
5 October – 11 November	5 April – 11 April

- Detail of each province in organization's network

Thailand has about 76 provinces geographically dispersed around the country. However, the studied organization has about 53 provinces as the organization's volunteer network. That means there are mobile medical service provided in these 53 provinces both normal mobile medical service and mobile dentistry. Therefore each detail of the province concerning every village in every district of each province must be stored in the decision support system database in order that the operation site detail can be linked with this set-up information leading to better management of database for the developed decision support system and less redundancy in data collection of database which can help improve data flow efficiency in operation support system for mobile medical service. Apart from the geographical detail of each province, the detail of supply warehouse location and hospitals in the province should also be stored as set - up data due to the fact that the supply warehouse is strategically decided and cannot be changed easily as well as each hospitals in the province. Therefore, the necessary information about detail of each province in the network is listed and presented in Table 3.3.

- Every villages in each district of the province
- Every district in the province
- Supply warehouse location
- Every Hospitals in the province

- Type and quantity of the organization's volunteer medical staffs in each hospital

Table 3. 3 Example of necessary information about detail of Chiangmai province[3]

Supply warehouse	District	Villages	hospital	Total Medical Staffs			
				doctors	dentists	nurses	Pharmacists
Public Health Office	Hang Dong	13	14	11	11	11	111
	Nong Kaeo	9					
	Han Kaeo	9					

3.4.2 Input data

Input data are data concerning the requisition of operation sites from decision support users. These data are dynamic and can be edited or changed during time through time before processing into the decision model of the developed system. In this research the input data consists of details of operation site, operation date (only in one day trip planning) and convenience time period of operation site (only in round-trip planning)

- Detail of operation site

Detailed of operation site requires the specific detail of location of mobile medical unit. For example, operation site is at Ban Lan Ka School in Ban Lan Ka village of Yang Hak district in Ratchaburi Province. This are the required information about details of operation site which is not actually used in decision model of the developed decision support system; however, it will help users to correctly designate exact distance from operation site to other operation, hospitals and supply warehouse in the province.

[3] Data are from Mobile Medical Service Operation schedule[5]

- Operation date

In one-day distribution planning, the operation date or operation schedule is important information in communicating with other mobile medical service supporting agents. Even though this information does not directly affect the decision process in decision model of the developed decision support system, it is the crucial information for medical staff's working day arrangement in order that medical staffs are available to operate at the operation site as scheduled date. Operation date is usually changed according to the convenience of local officers involving in mobile medical service at operation site; however, the operation date cannot be changed when the operation schedule is already approved by the studied organization.

- Convenience time period of operation site

In round-trip distribution planning, the developed decision support system allows local public officers to make a requisition with one specific service time-period which they thinks is appropriate to have mobile medical service operate during that time. This will help both organization and local officers to consensually agree with the operation route since the requirement of local officers is served and also satisfied organization's operation route objective and within limitations and constraints. However, it is optional for operation sites to request the specific service-time period. If they think that they can be visited in anytime within the available service-time period, they can ignore to specify the required service-time period.

3.4.3 Supporting data

Supporting data are data that help the calculation of designed decision model to be able to find the solution for users. These data can be both dynamic and static and can be edited or changed during time through time or do not change at all. In this research the input data consists of distance from operation site to another operation sites, hospitals, and supply warehouse. The forecast of type and quantity of required medical staffs and supplies at each operation site is also considered as the supporting data as well as type and quantity of volunteer medical staffs available in each hospitals (only in one day trip planning).

- Distance

The distance used in the developed decision support system is the exact distance by road transportation from one place to another. There are several applications to help determine the exact distance from one place to another such as exact road estimation using graph theory and Manhattan's scaling factor [5]. The application used in this research to collect the exact distance data from operation site to another operation site, supply warehouse, and hospitals in the province is Google Map which is the application using GIS (Geographic Information System) technology to find the distance between any two points in road network. Then the distance between any two points in each province's road network will be stored in distance matrix database to be used further in decision model. By using this data collection approach, the exact distance stored in database will lead to the most correct information within the assumption that traffic condition and system do not affect the distance value from one place to another [14].

- Medical staffs and supplies forecast

Medical staffs and supplies forecast reflects how many medical staffs and supplies are required at each operation site during specific time in operation schedule. Medical staff forecast value can represent the medical staffs needed in the operation site in order that the mobile medical staff can provide service adequately to expected customers in the operation site. However, it does not reflect how many customers (patients) are served. In one-day trip distribution planning, this information plays a very interesting role in determining which hospitals are able to adequately support the medical staffs to the operation site.

- Type and quantity of medical staffs in each hospital

It can be said that this information is the supply of medical staffs of local hospitals in the province. In one-day trip distribution planning, this information will help cut off undesirable alternatives leading decision model to higher chance of finding better solution in deciding which hospitals should support medical staffs to which operation site. The quantity of each type of medical staffs is medical staff in the province that is also the organization's volunteer medical staff. Usually, in one-day trip distribution planning, only local medical staffs are selected to provide medical services at operation site and return homes within affordable travelling time.

To summarize, there are three types of fundamental input data; set-up data, input data and supporting data for decision model of the developed decision support system to correctly find the feasible solution that can satisfy all limitations and constraints of decision model. The decision model can be classified into two distinctive models that are decision model for round-trip distribution planning to find operation route of each service-time period of each province and decision model for one-day trip distribution planning to assign hospitals to support medical staffs to operation site including the decision model in determining the distribution method of those medical staffs from supporting hospitals to operation site. Figure 3.11 shows the summary of required input data of the two decision models to find the solution in the developed decision support system.

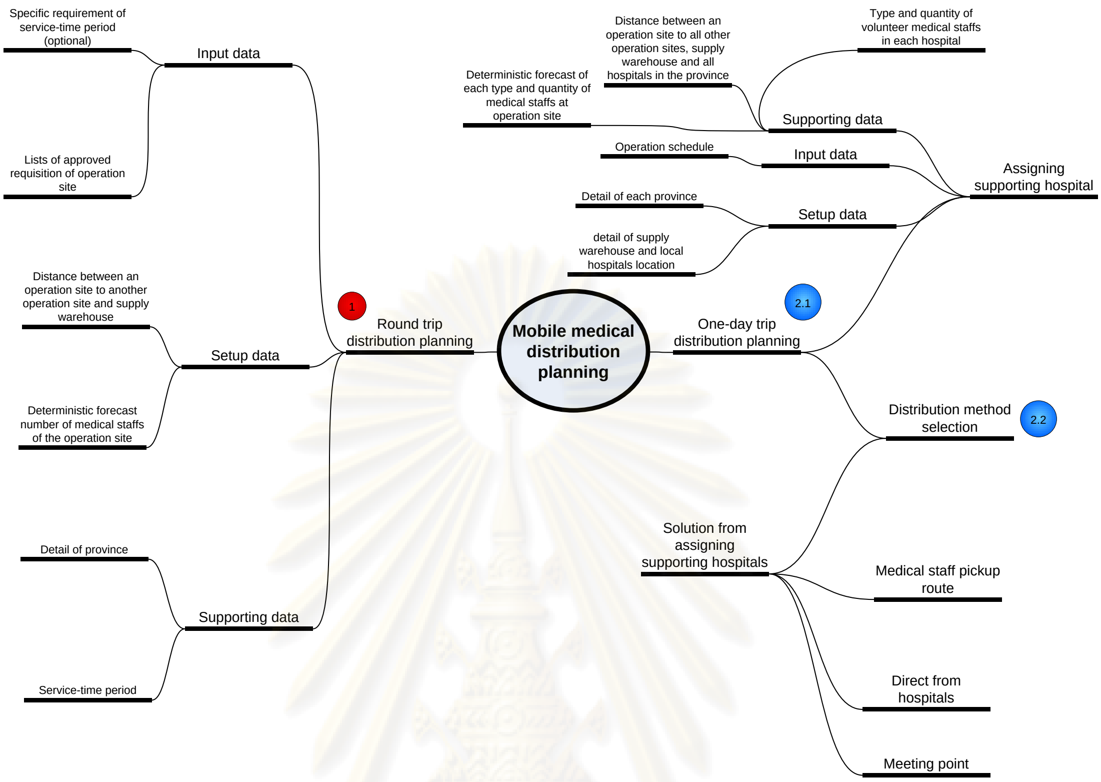

Figure 3. 11 Input data to decision models in developed decision support system

From Figure 3.11 the input data for decision models in the developed decision support system can be summarized that in round trip distribution planning, these are necessary input data for decision model to suggest operation route of each service-time period including the number of members required in medical team of each trip.

Set-up data for round-trip distribution planning

- Service-time period of each province in each season in the fiscal year of planning
- Detail of each province; lists of districts and villages in each district and supply warehouse location

Input data for round-trip distribution planning

- Lists of approved operation sites of each province including details of operation sites; location, village, district, type of medical service(dentistry or normal medical service)
- Specific requirement of service-time period (Optional)

Supporting data for round-trip distribution planning

- Deterministic forecasted demand of medical staffs and supplies at each site during specific time period
- Distance between an operation site to all other operation sites and supply warehouse.

In one-day trip distribution planning, these are necessary input data for decision model to suggest which hospitals should support what type and how many medical staffs of each supporting type to operation site including the distribution method to transport these medical staffs to operation site.

Set-up data for one-day trip distribution planning

- Detail of each province; lists of districts and villages in each district
- Detail of supply warehouse location, hospitals in the province, type and quantity of medical staffs at each hospital

Input data for round-trip distribution planning

- Lists of approved operation sites in the form of operation schedule (operation site with operation date) of each province including details of operation sites; location, village and district.

Supporting data for round-trip distribution planning

- Deterministic forecasted demand of medical staffs and supplies at each site during specific time period
- Distance between an operation site to all other operation sites, supply warehouse and all hospitals in the province.
- Type and quantity of volunteer medical staffs in each hospital in each month of each province

CHAPTER IV

DESIGN OF THE DECISION MODEL

The developed decision support system in this research can be classified into two different decision models in order to provide users: planning officers, with the proper information to generate distribution plan of medical staffs and supplies for mobile medical service. The first decision model is operation routing decision model to generate operation route of each service-time period of round trip distribution planning and the second model is agent assignment model to determine potential hospitals to support medical staffs to operation route including the selection of distribution method for transporting those medical staffs as well as medical supplies to scheduled operation site.

4.1 Operation Route Planning

Operation route planning is the key decision point in round trip planning for mobile medical service. According to the Literature review in Chapter 2, Vehicle Routing Problem (VRP) can be applied to help arrange operation route of each service-time period of round-trip operation route planning. However, the problem in this research can also be considered as the Multiple Traveling Salesman Problem (M-TSP) to lessen the complexity of the problem. In M-TSP, all demand nodes should be visited by m salesmen. In this type of combinatorial problem, the number or routes are known in advance; only which nodes to be added into which route are decided. Moreover, all salesman or vehicles starts from single depot and return to the same depot. In mobile medical service of round-trip service operation follows all the general characteristics of M-TSP in combinatorial problem class that are

- All operation sites must be added in to an operation route of service-time period
- The number of operation route are known in advance that are equal to the number of service-time periods in each province
- All operation route will start at supply warehouse and return to supply warehouse after visit all operation site in operation route

Therefore, M-TSP is applied in this research to suggest operation route of each service-time in round trip distribution planning. According to Chapter 2, there are many approaches to find the solution to M-TSP which is one of the problems in the NP hard problem class. In this research, constructive heuristic approach will be used to form the decision model for the developed decision support system to suggest operation route of each service-time period within the assumption that

- In each working day, only one operation site can be visited
- There is only one operation route in one service-time period
- The number of medical staffs operating at operation site can exceed the forecasted medical staffs but cannot be less than the required quantity
- Each operation route can only provide single medical service such as normal mobile medical or mobile dentistry. It cannot provide two types of medical services at the same time in the same site in round trip operation due to the difference in medical instrument preparation.
- All medical staffs and supplies are ready to be transported at supply warehouse which acts as the depot

The decision model to create operation route for round trip distribution planning can be classified into two main stages that is the preliminary routing and within operation route improvement. In preliminary routing stage, Saving Algorithm or Clark and Wright's method which is one of the most famous heuristics applied in logistics planning of many business [10] is applied to primarily create the initial feasible operation route for round trip distribution planning. After the initial solution is found, the solution is improved by applying 2-Opt Algorithm concept by developing another improvement heuristic to find the better solution from the initial feasible solution. Therefore, the decision model of the developed decision support system for round trip distribution planning can be classified into

- Preliminary routing using Saving Algorithm
- Improvement heuristics using 2-Opt Algorithm; within route improvement

By using heuristic approach to find the feasible solution cannot be guaranteed that the optimal solution is gained; however, the feasible solution with adequate quality level is gained from heuristic of decision model. In this research, saving algorithm is applied to primarily arrange the operation route before entering into solution improvement phase of the decision model. Saving algorithm is advantageous for its direct approach and takes less time in finding solution; however, the solution depends greatly on the first nodes selected into the route to find other nodes to be added later into route. Therefore, in small size problem (within 60 demand nodes), the efficiency and capability to find solution of saving algorithm is adequate to gain high quality solution closed to optimal solution; nevertheless, saving algorithm is found to lose efficiency and capability greatly when the problem size grows bigger to 100 demand nodes[38]. In this research, the problem is middle sized problem with demand nodes or operation site about 50-60 operation sites of each province. Therefore, the problem size is within the range that saving algorithm can still perform its best potential in finding solution with adequate solution quality level. Even though the solution gained from decision model is not the optimal solution but it can be guaranteed that the solution is the solution with adequate quality level.

4.1.1 Preliminary operation routing

In this stage, heuristic tries to find the initial feasible solution with the objective to minimize total travelled distance that is;

Equation 4. 1 Operation routing's objective function

$$\min_{\forall r_i \in T} \sum_{\forall i,j \in r_i} d_{ij} \quad when\, r_i = [0, i, j, \ldots r]$$

When;

r_i = Set of operation sites in route r_i

d_{ij} = Distance from operation site i to operation site j when i, j are in the same route r_i

T = Set of service-time period T= 1, 2, 3,…, m

Under these following constraints;

- All operation site must be added into at least one of operation route

- The number of operation site in operation route of each service-time period cannot exceed the total working day available in each service-time period
- Operation sites with specific requirement in any service-time period must be added into the operation route of that service-time period; if not, the penalties are added.

The last constraint is added in order that all operation sites with specific requirement to have mobile medical service operate at specific service-time period must be visited during the required service-time period. If this constraint cannot be satisfied, the penalties in distance unit are added into the objective function. However, in practice, there can be so many operation sites requested for the same service-time period exceeding the available working days of that service-time period leading that the hard constraints cannot be satisfied. Operation route with number of operation sites exceed service-time working days is not allowed to occur. Therefore, in this case, the penalties will always be added into the objective function because the operation sites' requirement of specific service-time period constraint is not satisfied. After that, these unsatisfied sites will be considered as operation site with no specific requirement of service-time period and it can be served in any service-time period. As a result, penalties do not affect much on operation routing solution. However, it will affect greatly in the case that there are fewer operation sites requesting to have mobile medical unit during the same specific service-time period than the service-time period numbers of working days when these requested sites are not added into the operation route in required service-time period. In this research, the penalty cost of ignoring operation site's requirement to have mobile medical service operates during specific service-time period is destined to be 50 km. in distance unit.

In order to find the initial feasible solution, the heuristics of decision model in round trip distribution planning applied the saving algorithm of Clark and Wright which have the fundamental concepts of using Savings Matrix Method as follow;

- Savings Matrix Method Calculation; saving value between node (operation site) i and node (operation site) j in this research means the distance that is saved by adding node i and node j from the different route into the same operation route.

- Generate numbers of initial routes which is equal to the number of requested operation sites
- Sort out the Saving Value from highest to lowest; the higher saving value, the better chance to be added first into operation route.
- Rearrange the sequence of operation route by adding an operation site which has the highest saving value with the existing node in operation route until all constraints are satisfied and all operation routes can visit all operation sites.

In saving value calculation, according to Breedam [39], there are three approaches to use saving value as the measurement to add other nodes into routes that are;

- Sequential Saving Heuristic

  Sequential saving heuristic is the heuristic which applied saving algorithm to generate one-by-one vehicle routing by adding a demand node in to the end-point of vehicle route by sorting saving value from maximum to minimum. By adding nodes into operation route needs to emphasize on limitations and constraints of the decision model. This method is famous for its advantage in vehicle utilization since the new vehicle will be added when the previous vehicle is loaded over its capacity. However, the solution from the approach may not be optimal solution. Clark and Wright (1964), Gaskell (1967), Yellow (1970) and Paessens (1988) (as cited in [12] and [13]) have adopted the approach in finding solution.

- Parallel Saving Heuristic

  Parallel saving heuristic is the approach in adding two nodes which is not yet arranged into any vehicle route into the route. Then another pair of nodes which has the highest saving value is considered to be added into route. If one of the nodes is belonged one of the vehicles routes, add the pair of nodes into that route within the limitations and constraints. If both nodes are not yet added into any of routes, create new route with the two nodes as the first pair of nodes in the route. This approach is advantageous for the fairness in adding nodes in route and the added nodes in route are well distributed and not brunched together. Knowles (1967), Tillman and Cochran (1968), Holmes and Parker (1976), McDonald (1972) and Buxey (1979) (as cited in [14] and [15]) have adopted the approach in their research.

- Generalized Saving Heuristic

  Generalized saving heuristic is the adaptation of parallel saving heuristic to consider adding two nodes which is not yet arranged into route to be added into the same route. Moreover, the approach also sees that the parallel arranged routes can be combined with each other to create new route if it leads to the reduction in the total distance. Therefore, the approach needs to calculate gain from the merging between two routes leading to longer computing time. Altinkemer and Gavish (1991) and Desrochers and Verhoog (1989) (as cited in [12] and [13]) have adopted the approach in finding solution.

In this research, the Sequential Saving Heuristics (SS) is applied to add operation site into operation route because by using SS, it can lead to easier approach in developing the decision support system and to use the end of route to find the operation node to be added into the route can lead to the better chance in merging the proper nodes from the various initial route together by considering saving value. Moreover, planners can easily manage the numbers of vehicle to be use in transporting medical staffs and supplies to operation site. This leads to a well-structured dispersion of operation nodes within operation route. Another reason to use SS approach is that in this research, the number of operation route is known beforehand and initial routes are create to be equals to the operation sites in the first step, then to combine those initial routes which each route has one operation route together in order that when the decision model finish searching solution all nodes are merged into the operation routes which equal to the numbers of service-time periods.

In this research, the decision model aims to satisfy the requirement of specific service-time period of operation site as first priority, and then saving value will be the measurement to merge the initial routes of operation nodes to be single operation route within the required constraints. Firstly the initial routes of operation site with the same requirement of service-time period are merged together. This is because the decision model needs to compromise between local requirement and convenience and the objective function of minimizing the transportation cost reflected through distance of the studied organization. These are the procedure in heuristic of the decision model in the developed decision support system for round trip distribution planning

- Saving Matrix Generation

  Saving Matrix is the most important in operation routing and affects greatly on correctness and quality of initial feasible solution. From Literature Review, there are 2 type of saving matrix; half matrix and full matrix. Half matrix is usually based on the assumption that the distance from node i to node j equals to distance from node j to node i. by using half matrix can lessen time in the saving calculation and vehicle routing process by half. Therefore, in this research, half matrix is applied as saving matrix in order that the calculation time is reduced by half since the distance from operation site i to operation site j is equal to the distance from operation site j to operation site i. However, full matrix is better simulate the reality of road transportation that distance from node i to node j usually does not equal to distance from node j to node i.
- Initial route creation using greedy algorithm; the total numbers of routes creates equals to the numbers of operation site. Each initial route has an operation site in the route.
- Merging routes with the same requirement of service-time period into a single combined route of each service-time period. In case that there are no route with the specific requirement in service-time period, to merge the initial route of operation route together, the routes of the pair of nodes with the highest saving

value is combined together. Then the end node of the combined route will be used to find other initial routes of operation site to be added into the combined route as long as all constraints and limitation are satisfied.

- Arrange sequence of operation sites in combined operation route of each service-time period including the approach to merge other routes into the combined operation route of service-time period

  To arrange the sequence of operation sites with saving value technique starts from the first existing set of nodes in operation route. For example, A and B is the first pair of node in operation route. To determine whether node C should be added into the same operation route as the next node in the route sequence or not, Ballou [13] have proposed that to do so, there are three approaches of comparing using saving value as the measurement :

  - Merging route of operation site C to the combined operation route of operation site A and B when A is the farthest node from the depot (A is the end-node of operation route). The saving value in merging operation site C into the route can be calculated as in Equation 4.1 and Figure 4.1 shows the illustration of combining initial route of operation C into the combined operation route of A and B.

Equation 4. 2

$$S = [d_{0C} + d_{C0} + d_{0A} + d_{AB} + d_{B0}] - [d_{0C} + d_{CA} + d_{AB} + d_{B0}]$$

$$S = d_{C0} - d_{CA} + d_{0A}$$

When;

S = Saving value occurring in merging initial route of operation site A into the combined operation route of operation site A and B

d_{ij} = distance between node i to node j when 0 is the depot

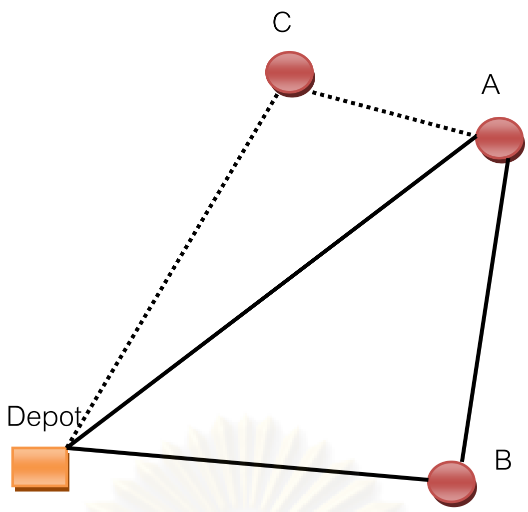

Figure 4. 1 Merging operation site C into combined operation route of operation site A and B

- Merging route of operation site C to the combined operation route of operation site A and B when B is the farthest node from the depot (B is the end-node of operation route). The saving value in merging operation site C into the route can be calculated as in Equation 4.2 and Figure 4.2 shows the illustration of combining initial route of operation C into the combined operation route of A and B.

Equation 4. 3

$$S = [d_{0C} + d_{C0} + d_{0A} + d_{AB} + d_{B0}] - [d_{0A} + d_{AB} + d_{BC} + d_{C0}]$$

$$S = d_{0C} - d_{BC} + d_{B0}$$

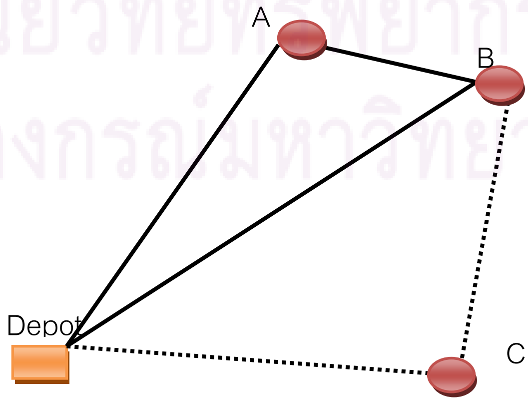

Figure 4. 2 Merging operation site C into combined operation route of operation site A and B with B is the end node of the operation route

- Merging route of operation site C to the combined operation route of operation site A and B when A is the farthest node from the depot by adding operation site C in between operation site A and B. The saving value in merging operation site C into the route can be calculated as in Equation 4.3 and Figure 4.3 shows the illustration of combining initial route of operation C into the combined operation route of A and B.

Equation 4. 4

$$S = [d_{0C} + d_{C0} + d_{0A} + d_{AB} + d_{B0}] - [d_{0A} + d_{AC} + d_{CB} + d_{B0}]$$

$$S = d_{0C} + d_{C1} + d_{AB} - d_{AC} - d_{CB}$$

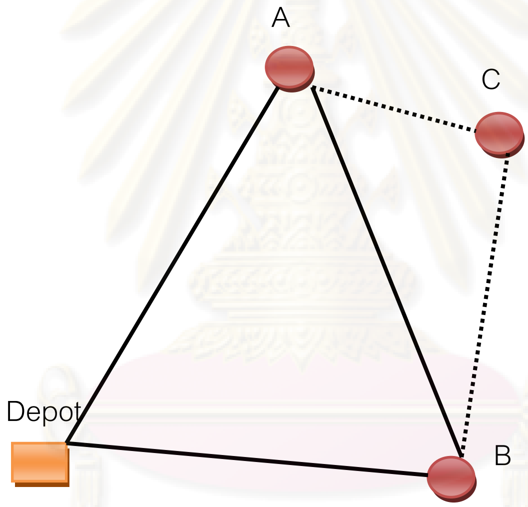

Figure 4. 3 Merging operation site C into combined operation route of operation site A and B in between operation site A and B

In this research, one end-sided node will be used to find another appropriate node to be added in the next sequence of operation route. Usually, the closet node to the depot will be the first node to visit while the other node will be the end-sided node which will be used to find another node in order to merging the route together. Moreover, another reason to use one-sided node is because it lessens the complexity and calculation time by adding nodes into route sequence until reaching the limitation or constraint of decision model.

- The calculation of number of medical staffs in medical team for each trip including medical supplies quantity in each trip and number of vehicles should be required to do the transportation task.

After each service-time period has its own operation route, the next step is to calculate the number of members that should be in the team in order to provide the medical service to operation sites in the operation route at the highest customer service level which means that the number of medical staffs operating at operation site can exceed the forecasted number of medical staffs required in each operation site in operation route; however, the number of medical staffs is not allowed to be less than the forecasted number of medical staffs required to operate at each operation in operation route. Therefore, the maximum forecasted number of medical staffs required to operate in all operation sites of operation route is the representative value of the number of medical team members that should be operating during the service-time period. Equation 4.4 shows formula to calculate the required number of medical team member should be operating during each service-time period.

Equation 4. 5

$$R_{r_i k} = \max_{\forall i,j \in r_i} R_{ik}$$

$R_{r_i k}$ = The number of required member in medical team type k of operation route r_i

R_{ik} = The forecast number of medical staff type k of operation site i

k = Set of medical staffs type in the medical service providing during operation site k = 1, 2, 3, 4,…, k

It costs less to load all required medical supplies of all operation sites in the operation route into the vehicle before the journey starts. This is because when the medical supplies are out of stock during operation trip will cause the supply warehouse to deliver to operation site to replenish the stock; this causes increase in transportation cost due to high cost of stock ordering and delivering cost per unit especially if the order quantities of medical supplies are less than the economical order quantity. Therefore, all required medical supplies for every operation site during the trip of each service-time period should be loaded before the vehicles leave depot and follow the operation route of mobile medical service. Equation 4.5 shows the formula to calculate the required medical supplies should be loaded and transported during each service-time period.

Equation 4. 6

$$D_{r_i f} = \sum_{f=1}^{f} \sum_{\forall i,j \in r_i}^{r} D_{if}$$

When;

$D_{r_i k}$ = The number of required medical supplies type k during the operation route r_i

D_{ik} = The forecast number of medical supplies type k of operation site i

f = Set of medical supplies type in the medical service providing during operation site f = 1, 2, 3, 4,…, f

To calculate the number of vehicles required in transporting both medical staffs and supplies to operation sites in operation route of each service-time period, in this research, the medical staffs and supplies will be considered as person unit equivalents. The capacity of vehicle can transport 10 person equivalent units. To transport medical supplies together with medical staffs using the same vehicle, medical supplies must first be converted into person unit equivalent. Each type of medical supplies have different unit; however, in this research, any different unit measurement of each type of medical supplies is recognized as “a supply unit measurement”. 100 supply unit measurements equals to 1 person equivalent. Therefore, to calculate the number of vehicle required during each service-time period can use the following formula shown in Equation 4.6.

Equation 4. 7

$$\boldsymbol{V_{r_i}} = \left\lceil \frac{R_{r_i k} + \frac{D_{r_i f}}{\widetilde{\boldsymbol{C}}}}{\boldsymbol{C}} \right\rceil$$

$\boldsymbol{V_{r_i}}$ = The number of vehicles required in transporting medical staffs and supplies to operation sites during operation route $\boldsymbol{r_i}$

$\boldsymbol{\widetilde{C}}$ = The person equivalent scaling factor; in this research equal 100 medical supplies units measurement.

$\boldsymbol{C}$ = The capacity of vehicle restricted to 10 person equivalent unit.

The work procedure of decision model involves the work procedure of using computer to help processing the data and finding the initial feasible solution.

Step 0: Calculation of number of working days of each service time period

In each service-time period which is the set up data in the developed decision support system, it is very crucial to calculate the available working days of each service-time period since the available working days are important as the constraint of finding feasible solution that the total operation sites in operation route of each service-time period cannot exceed the total number of available working days of the service-time period. Equation 4.7 shows the formula which is used to calculate the available working time service-time period.

Equation 4. 8

$$\mathrm{N_T} = (\mathrm{ST_T} - \mathrm{ET_T}) - 1$$

When;

$\mathrm{N_T}$ = The numbers of available working days in service-time period T

$\mathrm{ST_T}$ = The Start Date of service-time period T

$\mathrm{ET_T}$ = The end Date of service-time period T

This formula is capable in calculation when the start date and end date of service-time period is in the same month

Step 1: Calculation the saving value of every pair of operation sites

Computer starts to calculate the saving values of every pair of operation site and stored the saving value in saving matrix in the database for helping the processing of decision model by using the following formula as shown in Equation 4.8.

Equation 4. 9

$$S_{ij} = d_{oi} + d_{oj} - d_{ij}$$

S_{ij} = saving value in merging operation site i to be in the same route as operation j and o is the depot

Saving value examination and adjustment

- Set equals to 0 if node i and node j are the same node
- Set equals to 0 if calculation gives minus saving value

Step 3: Create total initial routes equals to total numbers of requested operation site.

Step 4: Merging routes of the same requirement in service-time period to be the single combined operation route of the time period.

At this stage, check whether the number of operation sites or node of each set of operation route of each service-time period exceed the number of available working days of each time period;

Equation 4. 10

$$N < N_T$$

If return true value;

Check whether how many initial routes of operation node are of each service-time period.

If N = 1 let that node be the first node to visit including the end-node of the combined operation route of the service-time period. Then, start step 5

If N $\geq$ 2 start Step 4.1 and Step 4.2 until all operation sites are arranged in the sequence of the combined operation route. Then, start step 5

If return False value; starts the operation route sequence arrangement

Step 4.1 To do the operation route sequence arrangement

Among those operation sites, select one pair of operation sites which has the highest saving value (If there are many pairs of nodes with the same highest saving values; select the pair of node with the lowest difference between the pair's forecast number of every type of medical staff required at the operation site). Let the closet node to the depot be the first node to visit and the other is the end-node of operation route.

Step 4.2 From the end-node, find the remaining operation sites that has the highest saving values from the end-node to be added as the next node in the operation route sequence of the service-time period (If there are many remaining operation sites give the same highest saving values with the end-node; select the operation node which give the lowest difference between the node and mode of the number of medical staffs of combined operation route if the mode of operation route equals to 0 replace mode value with the average forecast of medical staff of operation site.

Then, check whether the number of operation in the operation route equals to available working day of the service-time period or not.

Equation 4. 11

$$N = N_T$$

If returns true value; the operation route of the service-time period is already gained and other remaining unarranged operation sites are address with no without specific requirement of service-time period. Then start step 5.

If returns false value; Repeat Step 4.2 until the number of operation in the operation route equals to available working day of the service-time period or the value of Equation 4.10 returns true value.

Step 5: After every operation route of service-time period has the end-node operation site, sort the highest saving value of every pair of nodes.

Step 5.1: Select one of the remaining unarranged initial route of operation site with no specific requirement in service-time period with highest saving value between the node to each end-node of operation route in each service-time period and record value c = the number of times the node is selected as the highest saving value to the end-node of particular service-time period operation route. Go to Step 5.2

Step 5.2: Check whether c = 1

If return true value, Merge the initial route of the node in to the next sequence of the end-node in operation route. Go to Step 6.

If return false value,

Select to merge the initial route of the node in to combined operation route of service-time period that give the highest saving value between the node and end-node in the service-time period operation route. Repeat Step 5.1 until all operation routes of service-time period can select one of initial route operation site to be merged in the combined operation route of service-time period.

Step 6: check whether the number of operation sites in every combined operation route equals to the available working days of each service-time period or not as in Equation 4.10.

If return false value; let the newly added operation site in the combined operation route of each service-time period be the end-node of the operation route. Repeat step 5.

If return true value; start step 7.

Step 7: Calculate the number of members in medical team required in operation route of each service-time period including the type and total number of medical supplies required in each service-time period as in the formula from Equation 4.4, 4.5 and 4.6 and display the result and end program.

Figure 4.4 and 4.5 illustrates the summary of decision model work procedure in the form of program flowchart.

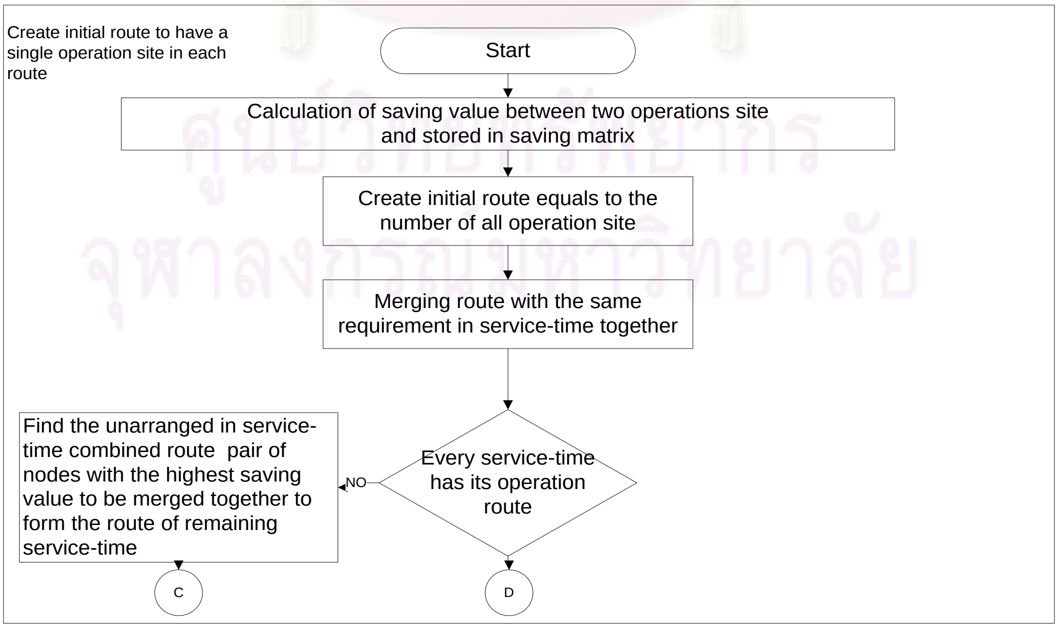

Figure 4. 4 The summary of decision model work procedure

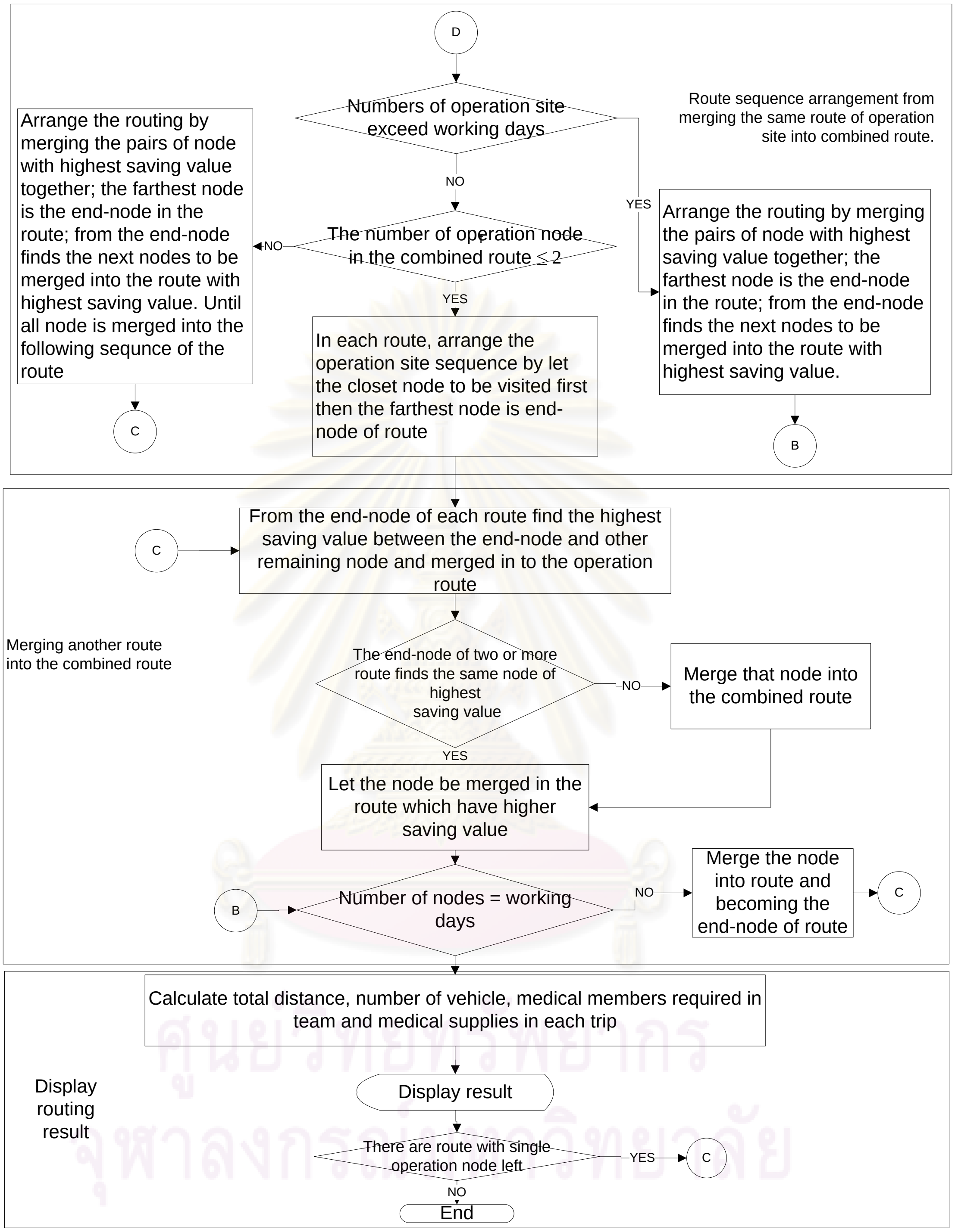

Figure 4. 5 The summary of decision model work procedure (continued)

4.1.2 Route improvement heuristics

After the preliminary route is gained from applying saving algorithm, the improvement heuristic is aiming to improve the preliminary route through search mechanism. In general practice, there are two approaches in route improvement;

- Within route improvement
- Between route improvement

In this research, only within route improvement is focused due to the fact that in preliminary routing the sequential saving heuristic is applied; therefore, it can be guaranteed that each operation site has been arranged in the proper operation route in service-time period. This already leads to the acceptable quality of initial feasible solution; therefore, only within route improvement is practical to find the solution that is improved from the preliminary routing,

Within route improvement

The within route improvement is one of the approaches in composite procedure of vehicle routing. In this research, the 2-Opt algorithm is applied to cut off connecting arc between two pair of operation nodes in the operation route and revert the operation route so that two new connecting arcs is generated leading to the different operation route sequence from the previous solution. According to Braysy and Gendreau [39], by using 2 opt algorithm can lead to the optimal solution with acceptable computing time.

These are the procedure in improvement heuristic of the decision model in the developed decision support system applying the 2-Opt algorithm concepts to improve the initial feasible solution for round trip distribution planning. The concepts of 2 Opt algorithm is the improvement heuristic which consider the distance reduced in changing the sequence of operation sites in operation route by recreate two new connecting arcs for two pairs of operation sites. If the route is improves, the distanced from new connecting arcs will reduce the preliminary route's total distance so the gain value must be in positive value. For example, let operation route sequence is operation a, b, c, d, e, f, g as shown in Figure 4.6.

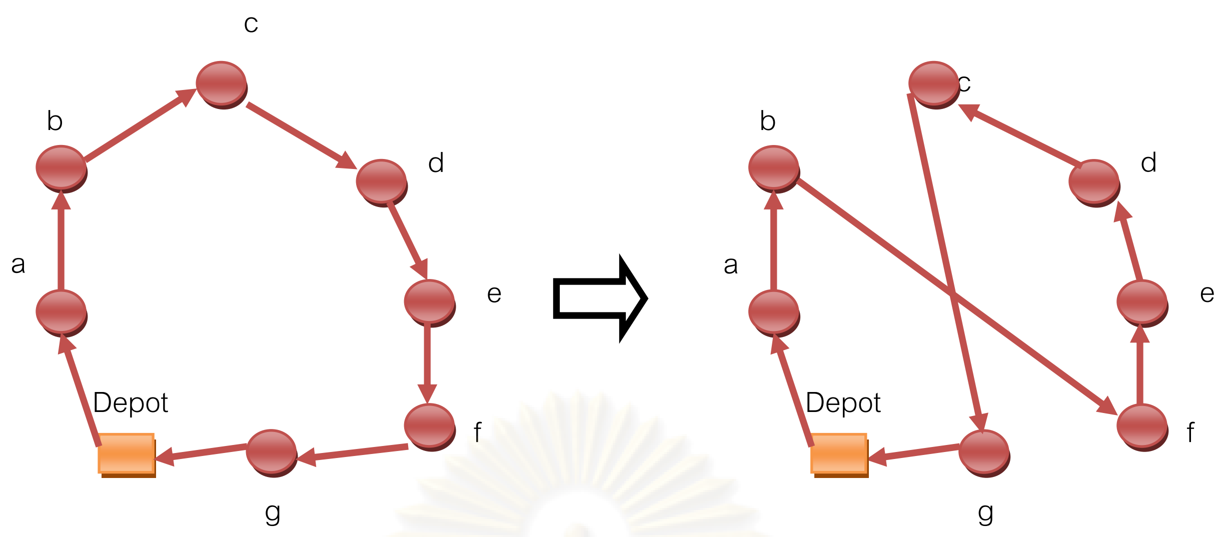

Figure 4. 6 2-opt algorithm changing two node connecting arc

- Cutting off two arcs connecting two pair of nodes

  In this research, due to the fact that in real practice, the total number of operation sites in operation route will not exceed 10 operation sites since the same medical team members cannot operate for a long period because of limitation in available holidays. As a result, the problem in this research when considering using 2-Opt algorithm as within route improvement heuristic is small sized problem. Therefore, in this research, to cut off every possible connecting arc of two pairs of operation sites of the initial operation route does not affect the computing time but leads to higher quality in improvement solution. Therefore, in the example, with seven operation sites in operation route, there are (7+1) (7-2) = 40 pattern of cutting two connecting arcs between two different pairs of operation sites.

- Reverting the operation route and creating two new arcs for new operation site sequence of operation route

  After cutting all possible connecting arcs, calculating the gain value received from reverting operation route sequence as shown in Figure 4.7 by using the formula as in Equation 4.12.

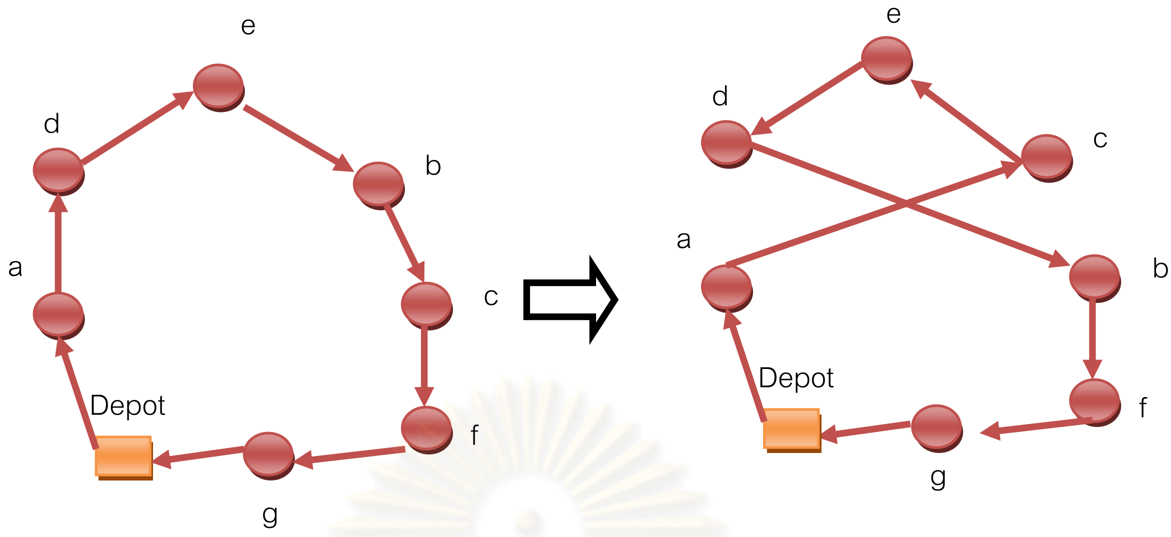

Figure 4. 7 Reverting route sequence

Equation 4. 12

$$Gain = (d_{ad} + d_{bc}) - (d_{ac} + d_{db})$$

In this stage, choose the solution that give the highest positive gain value and recognize the solution as the recorded solution instead of initial feasible solution.

- Recursive Step

  Repeat the two steps above until the result of reverting the operation route and creating two new arcs for new operation site sequence of operation route cannot lead to positive gain value or the calculation flow reach the stopping criteria(usually determined number of recursive loop); the latest recorded solution is the solution from the improvement heuristic.

The work procedure of decision model involves the work procedure of using computer to help processing the data to improve the initial feasible solution to better improved solution.

Step 0: Receiving information of initial operation route from preliminary routing. Then calculate and store the total distance of the initial operation route in variable r.

Step 1: Setting exchange value = 0 for staring the recursive loop. Exchange value = 0 means that there is significant improvement in the current calculation loop.

Step 2: Cutting off two arcs connecting two pair of nodes

Computer starts cutting the two arcs connecting the first operation site in operation route until all possible patterns is received. If there are 5 nodes in operation route, (5+1)(5-2) =18 means that there are 18 possible patterns of cutting two connecting arcs.

Step3: Reverting the operation route and creating two new arcs for new operation site sequence of operation route of all possible patterns. For example, computer starts cutting of arcs connecting arcs between s_i and s_{i+1} and s'_{i-1} and s'. Revert the operation sequence and creating two new connecting arcs of (s_i , s') and (s'_{i-1} , s_{i+1}). Then calculate the gain value all cut off patterns. Check whether there is any positive gain from cutting two connecting arcs or not

If return true value; set exchange value = 0 and start step 4.

If return false value; Stop improvement and shows the latest record of route and total distance in variable r.

Step4: Select the highest positive gain value as the improved solution. Record the new total distance in variable r.

Step5: Check the number of time entering the recursive loop

Equation 4. 13

$$n > n_c$$

If returns true value; Stop improvement and shows the latest record of route and total distance in variable r.

If returns false value; Repeat Step 2.

Figure 4.8 illustrates the summary of decision model work procedure of improvement heuristic in the form of program flowchart.

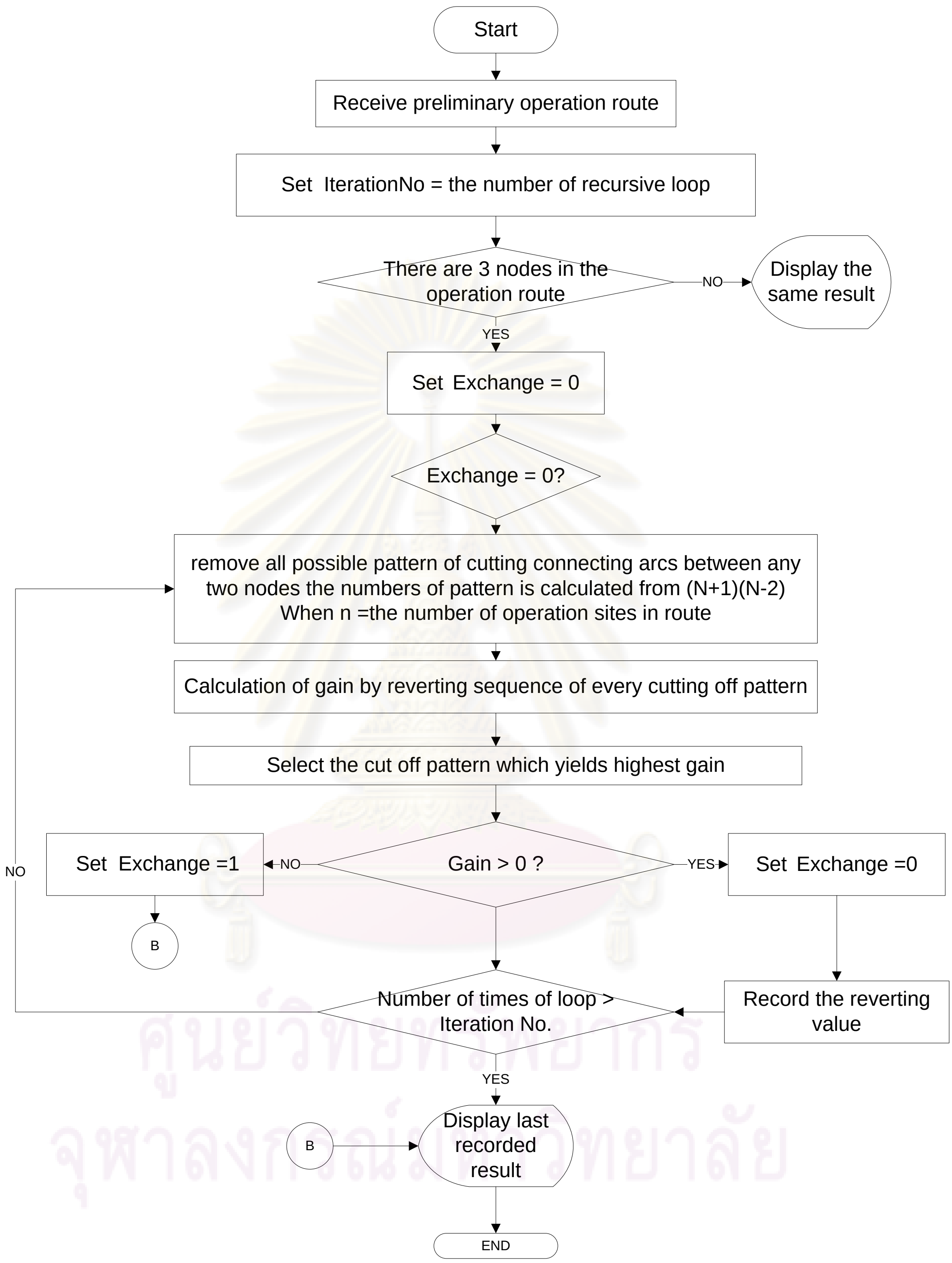

Figure 4. 8 the summary of decision model work procedure of improvement heuristic

4.1.3 Extension of decision making in operation routing

The decision making of preliminary routing of the developed decision model is to assign operation sites into the route of each service-time period. There is constraint on the specific requirement of service-time period at some operation sites. To satisfy this constraint leads to higher total distances of every service-period, but can satisfy the convenience of local officers. The decision model developed in this research can also be applied in the situation that all operation sites have no specific requirement in service-time period. With no specific requirement, operation sites can be assigned to any service-time period's route.

At searching step of merging a pair of routes into a combined route of each service-time period, without the constraint in specific requirement, any pair of routes with highest saving value is combined leading to the better end-point of each service time period's route with lower distance variation in distance between the two operation sites. This differs when the specific requirement in service-time period is implemented: high distance variation between two operation sites As a result, it can greatly lessen the total distance of every time period; however, the convenience of local officers is ignored. Therefore, it depends on the planners' consideration to tradeoff between convenience of local officer leading to higher service impression and total transportation cost: which condition should be prioritized.

In real practice, the convenient operation date of local officers can be changed according to the master plan from the central office of organization. Without the pre-specified in service-time period requirement, planning officers should have a lot of communications with local officers to compromise and change the convenience requirement according to the master plan from central office as the suggestion from computational result of the developed decision support system.

4.2 Agent Assignment

Agent Assignment is the key decision point in planning one day trip service operation for mobile medical service. According to the Literature review in Chapter 2, Assignment Problem (AP) can usually be applied to help assigning machines to jobs in scheduling problem class. However, the problem in this research can also be considered as the one of the application of using Assignment Problem (AP) to help assign hospital to support medical staffs to operation sites. In this research, to assign hospitals to support medical staffs to operation sites can be viewed as Generalized Assignment Problem (GAP) which is the problem that the number of agents is equal m agents while the number of jobs equals n jobs which resembles the problem in this research that there are m hospitals (agent) and n operation sites (job). Generally, the constraints of GAP are

- Agents cannot do the job over its capacity
- In each job, only one agent is assigned to do the job

The constraints of GAP is different from real practice of one-day trip distribution planning for a hospital can support to any operation sites while in each operation site, medical staffs can be supported by many hospitals. The relationship between agents and jobs in GAP follows the 1-1 relationship while in this research relationship between hospitals and jobs are many-many. Because of many-many relationship basis, the problem in this research is complicated; moreover, the capacity of hospitals consists of different independent types of medical staffs. Therefore, heuristic search method will be applied in decision model in order to help GAP to achieve feasible solution of assigning hospitals to support medical staffs to operation site within the assumption that;

- In each operation date, only one operation site exists for mobile medical service
- The total capacity of every type of medical staffs of every hospital exceeds the total forecasted number of every type of medical staffs of every operation.

- There are only four type of medical staffs in one-day trip distribution planning; doctors, dentist, nurses and pharmacists.
- All medical supplies are ready to be transported at supply warehouse which acts as the depot
- Each medical staff can operate in mobile medical service at operation site once per month.
- When a hospital is assigned to support the medical staffs to operation site, hospitals have to support at the requested quantity of each requested site or support at the available quantity of the hospital.

The decision model to assign hospitals to support medical staffs to operation site for one-day trip distribution planning can be classified into two main stages that is the assignment of supporting hospitals and distribution method selection. In the assignment of supporting hospitals, heuristics and linear programming (LP) will be together applied to find the solution of which hospitals should support medical staffs to which operation sites. Then after the initial feasible solution of number of medical staffs from hospitals to each operation sites is known. It will enter into distribution method selection phase. During the distribution method selection stage, all required measurement of each distribution method is calculated according to each decision model in each distribution method. Then the decision support system will show the result of calculation as the necessary information for users to decide and choose the distribution method according to their prioritized measurement; the measurement of each distribution method are total distance, number of vehicles and average travel time of a person. Therefore, the decision model of the developed decision support system for one-day trip distribution planning can be classified into

- Assigning supporting hospitals; using heuristics and Linear Programming
- Distribution methods ‘measurement calculation

In assigning supporting hospital, the objective of this research aims to find the acceptable feasible solution not the optimal solution or best solution methodology.

Therefore, the answer of using heuristics and Linear Programming together to assign the supporting to hospitals aims to minimize the distance from all supporting hospitals to operation site as first priority and may not lead to the optimal solution of assigning supporting hospital; however, the solution is practical in serving requirements of operation site.

4.2.1 Assigning supporting hospitals

To assign supporting hospitals to operation site, the objective function of assigning supporting hospital to operation is to minimize the distance from supporting hospitals to operation site that is;

Equation 4. 14 Assigning supporting hospital's objective function

$$\text{Minimize} \quad z = \sum_{j=1}^{m} \sum_{i=1}^{n} d_{ij} x_{ij}$$

when;

$j \in J$ and J = Set of operation sites; j = 1, 2, 3, 4, 5, 6,…, m

$\mathbf{i} \in \mathbf{I}$ and $\mathbf{I}$ = Set of hospitals; $\mathbf{I}$ = 1, 2, 3, 4, 5,…, n

$\boldsymbol{d_{ij}}$ = Distance from hospital i to hospital j

$\boldsymbol{x_{ij}}$ = 1 if hospital i is assigned to support medical staffs to hospital j

= 0 if hospital i is not assigned to support medical staffs to hospital j

Under these following constraints;

Constraint 1 as shown in Equation 4.15

All hospitals cannot support medical staffs at the quantity of each type of medical staffs exceeding their capacity.

Constraint 2 as shown in Equation 4.16

All operation sites' medical staffs 'requirement in every type of medical staffs must be served.

Constraint 3 as shown in Equation 4.17

The total number of hospitals assigned to support medical staffs to each operation site cannot exceed the total number of hospital in the province.

Constraint 4 as shown in Equation 4.18

Total capacity of every type of medical staffs of every hospital must exceed total requirement of every type of medical staffs of every operation sites.

Equation 4. 15

$$\sum_{j=1}^{m}\sum_{k=1}^{4} a_{ijk}\, x_{ij} \le \sum_{k=1}^{4} B_{ik}$$

Equation 4. 16

$$\sum_{j=1}^{m}\sum_{k=1}^{4} R_{jk} = 0$$

Equation 4. 17

$$\sum_{i=1}^{n} x_{ij} \le n \qquad \text{for } \forall\, j \in J$$

Equation 4. 18

$$\sum_{i=1}^{n}\sum_{k=1}^{4} B_{ik} \ge \sum_{j=1}^{m}\sum_{k=1}^{4} D_{jk}$$

When

$$R_{jk} = D_{jk} - \sum_{i=1}^{n} a_{ijk}\, x_{ij}$$

$k \in K$ and

K = Set of type of medical staff; k = [doctor (1), dentist (2), nurse (3), Pharmacist (4)

a_{ijk} = number of supported medical staff of k type from hospital i to hospital j

B_{ik} = Total capacity of hospital i of medical staff type k

R_{jk} = Remaining requirement of operation site j of medical staff type k

D_{jk} = Forecasted demand or requirement of operation site j of medical staff type k

To solve the problem, some problem statements should be first introduced to clarify how the problem is complicate and different from other job scheduling problems. The problem presented in this research in assigning hospitals is complicate due to multiple resource requirements at demand side. Medical resources required in mobile medical service operation are doctors, dentists, nurses and pharmacists. These four types of medical resource are working in different functions and responsibilities at the same operation site. Doctor and dentist are the important resources since the medical service are provided directly by these two types of medical resources. Nurse and pharmacist are required to support the work of doctor and dentist. In addition, doctor and dentist are considered to be more important resources at the operation site than nurse and pharmacist due to the lack of doctors and dentists at the location selected to be operation site. In assigning auxiliary hospitals, planning officer aims to firstly fulfill the demand of doctors and dentists at operation sites since these types of medical resources have lower proportion in quantity than those of nurses and pharmacists. The multiple types of medical resources are classified into two categories: dominant personnel and supporter personnel. The proposed methodology in this paper also aims to assign auxiliary hospital in order that all multiple-resource requirements of demand side are totally fulfilled with higher concentration on dominant personnel type which is the strategy in finding solution of the proposed methodology.

In the dominant category, priority rank is applied to classify the resource priority. In mobile medical service, doctor is the type of medical resource with higher priority since it is the main type of medical resources demanded at the operation site. Medical services at operation sites are usually primary healthcare and general disease diagnose. In the real practice of mobile medical service planning, dentistry services are also provided at operation sites as the second priority rank medical services since there is mobile dentistry unit specifically providing dentistry services to operation sites: mobile dentistry are not included in the scope of this paper. Doctors are more intensely required at the operation sites of mobile medical service than dentists. By defining the priority rank of each medical resource type in the dominant category allows the proposed methodology to efficiently find the acceptable solution complying with the aims of planning officers in the selection of auxiliary hospitals to firstly satisfy all requirements in the significant types of medical resources of demand side.

In supporter category, both nurse and pharmacist are supporters of dominant medical resources and are not involved directly in providing medical services. As a result, no priority rank is applied in this category. Nevertheless, these two types of medical resource should still be fulfilled.

In order to find the feasible solution of assigning supporting hospital, IV-phase sequential heuristic is developed as the solution searching methodology to find the feasible and practical solution of assigning auxiliary hospitals to support multiple-resource to operation sites. The developed Heuristic are divided into four consecutive phase by continually relaxing constraint of multiple-resource requirement at the demand side until all are fulfilled. Assignment Model (AP) is applied during each phase to find the optimal solution within each computational recursion. Since the demand side requires four different types of medical resources, the searching Heuristic is divided into four related phase in order to find the solution that all multiple-resource requirements are served while maintaining to minimize total distances in accordance with objective function. The solution gained from previous phase will act as input data of the next phase with the developed Heuristic. The Heuristic is developed to prioritize more greatly on the fulfillment of medical resources in dominant category than supporter category.

In Phase I, instead of fulfilling all multiple-resource at demand side, only dominant category of medical resource are focused. Demands of both doctors and dentists of each demand node should be fully served since both types are dominant types of medical resource requirements. By this approach, the multiple-resource requirement fulfillment constraint is relaxed from four medical resource types to two significant types. This allows Heuristic to find the preliminary solution that will be used as input data successively through all of the four phases until all multiple-resource requirements are fulfilled. The preliminary solution, from phase I, reflects greatly on the final solution of the developed Heuristic. Nevertheless, it can be guaranteed that the appropriate selection of auxiliary hospitals to operation sites is achieved since in each computational recursion, Linear Programming (LP) of assignment model (AP) is applied to find the optimal solution. During each heuristic phase, linear programming is applied to solve the GAP problem in that phase when there are combinations occurring in order that the optimal solution of the part is gained. Therefore, at each phase the solution gained can be guaranteed as optimal solution from using linear programming. The solution will then be entered into another heuristic phase to continually assign supporting hospital to support medical staffs to operation sites.

Phase II and Phase III aims to relax multiple-resource requirement constraint with focusing on all medical resource types in dominant category should be fully served. The highest priority rank requirement: doctor, in dominant categories should be firstly fulfilled in phase II and the next highest priority rank requirement: dentist is fulfilled in phase III successively. At this stage, if all multiple-resource requirements are not yet fulfilled, the phase IV in the developed Heuristic is activated. In phase IV, the medical resource categories make no affect on decision making of selecting auxiliary hospitals. All types of medical resources share the same priority rank. This means all hospitals with the availability in capacity of the remaining multiple-resource requirements at demand side can be selected as the auxiliary hospitals.

During each individual phase, the developed Heuristic is working recursively until the stopping criteria are met. When they are met, the solution gained from each step is acting as input data to the next successive steps until all constraints are satisfied. However, it can sometimes be the situation that many optimized solutions with same the value of objective's function but difference in supporting decision variable (x_{ij}). This can cause many combinations of feasible solutions resulting in longer computing time. Therefore, at the end of using LP, screening function is developed to screen these answers to select the most appropriate answer in order to lessen the numbers of hospital supporting to operation site. The decision model of one-day trip distribution planning in assigning supporting hospital consists of the following phase:

Phase I: Potential hospitals which can support all doctors and dentists at operation site at the same time

During this phase, hospitals that pass the criterion of having number of doctors and dentists over requirement of operation sites are added to the list of “potential supporting hospital”. However, at each operation site it is not necessary that the total number of potential supporting hospital is equal to those of other. Some hospital can support to an operation site but cannot support to another operation site. The potential hospitals added in the list but cannot support medical staffs to some operation sites; X_{ij} value of that hospital to those operation sites equals 0 and it will be the constraint for sub problem of GAP that the decision model will solve through linear programming. The relationship in supporting medical staffs from hospitals to operation sites is 1-1 relationship. However, it depends on how many potential hospitals are there on the list. If there are more hospitals than operation sites (with at least one hospital can support the medical staffs to), every operation sites must be served by one hospital. If there are less hospitals than operation sites (with at least one hospital can support the medical staffs to), every hospital must serve to one operation site. The heuristic will stop finding solution in this phase when there is no potential hospital on the list or the total requirement of every operation sites in doctor and dentist equal 0.

Phase II: Potential hospitals which can support all doctors at operation site

During this phase, hospitals that pass the criterion of having number of doctors over requirement of operation sites are added to the list of “potential supporting hospital”. The heuristic will stop finding solution in this phase when there is no potential hospital on the list or the total requirement of every operation sites in doctor equal 0.

Phase III: Potential hospitals which can support all dentists at operation site

During this phase, hospitals that pass the criterion of having number of dentists over requirement of operation sites are added to the list of “potential supporting hospital”. The heuristic will stop finding solution in this phase when there is no potential hospital on the list or the total requirement of every operation sites in dentist equal 0.

Phase IV: Potential hospitals which can support at least one type of medical staff at operation site

During this phase, hospitals that pass the criterion of having at least one type of medical staff that match the requirement of operation sites are added to the list of “potential supporting hospital”. The heuristic will stop finding solution in this phase when there is no potential hospital on the list or the total requirement of every operation sites in every type of medical staff equal 0.

When combine all solution from every phase of heuristic, the acceptable solution is gained. Then the decision model of distribution method measurement calculation will start the process.

The work procedure of decision model involves the work procedure of using computer to help processing the data and finding the feasible solution of assigning supporting hospital in one-day trip distribution planning.

- Phase I

Step 0; Computer begin calculate the total forecasted number of medical staffs in every type of every operation site as well as the total capacity of medical staffs in every type of every hospitals. Then check whether the total capacity of all hospital is greater that the total requirement of medical staff of all operation sites or not

Equation 4. 19

$$\sum_{\mathrm{i}=1}^{\mathrm{n}}\sum_{k=1}^{4} B_{\mathrm{ik}} \geq \sum_{\mathrm{j}=1}^{\mathrm{m}}\sum_{\mathrm{k}=1}^{4} \mathrm{D}_{\mathrm{jk}}$$

If returns true value; go to step 1

If return false value; add the dummy medical staff to supply warehouse in the quantity equals to the shortage of each type of medical staffs

$$C_{dummy\ k} = \sum_{\mathrm{j}=1}^{\mathrm{m}}\sum_{\mathrm{k}=1}^{4} \mathrm{D}_{\mathrm{jk}} - \sum_{\mathrm{i}=1}^{\mathrm{n}}\sum_{k=1}^{4} B_{\mathrm{ik}}$$

When;

$C_{dummy\ k}$ = the dummy quantity of medical staffs waiting at supply warehouse of medical staff type k

Step1: Create potential hospital lists that have the capacity of doctors and dentists over the requirement of in every operation sites. Check whether there are hospitals can be added into potential list or not

If returns true value; go to step 2.

If returns false value; stop the calculation in this phase. Then, skip to another calculation phase.

Step 2: Take operation sites to form the row of assignment table sorting from the earliest operation date and take the list of potential hospital to form the column sorting the number of operation sites that the hospital has potential to serve medical staff. Then set the x_{ij} value of the hospital i that cannot support to operation site j equals to 0. Then go to step 3.

Step 3: Check whether there are combination case of more than one operation site can be served by the same set of potential hospitals

If return true values; divide problems into set of assignment problem in each combination. The total numbers of divided problems equals the total number of combination case. Then go to Step 4.

If return true values; go to Step 4.

Step 4; in each divided assignment problem check whether number of rows is less than number of column or not

Equation 4. 20

$$n_{row} < n_{column}$$

If return true value; set the LP constraint of the summation of assignment value by each row equal to 1 and the summation of assignment value by each column to be 0 or 1(as in Equation 4.21 and 4.22). This means that each operation site has to be served by one hospital. Find the shortest distance optimal solution that leads to the least remaining requirement of medical staffs in the operation. Then go to step 5.

Equation 4. 21

$$\sum_{j=1}^{n} x_{ij} = 1 \ \forall\, i \in I$$

Equation 4. 22

$$0 \le \sum_{i=1}^{m} x_{ij} \le 1 \ \forall\, j \in J$$

If return false value ; check whether number of rows is equal to the number of column or not

Equation 4. 23

$$n_{row} = n_{column}$$

If return true value; set the LP constraint of the summation of assignment value by each row equal to 1 as well as the summation of assignment value by each column equal 1(as in Equation 4.24 and 4.25). This means that each operation site has to be served by one hospital and one hospital can serve to one operation site. Find the shortest distance optimal solution that leads to the least remaining requirement of medical staffs in the operation. Then go to step 5.

Equation 4. 24

$$\sum_{j=1}^{n} x_{ij} = 1 \ \forall\, i \in I$$

Equation 4. 25

$$\sum_{i=1}^{m} x_{ij} = 1 \ \forall\, j \in J$$

If return false value; set the LP constraint of the summation of assignment value by each row equal to 1 or 0 but the summation of assignment value by each column equal 1(as in Equation 4.26 and 4.27). This means that each operation site has to be served by one hospital and one hospital can serve to one operation site. Find the shortest distance optimal solution that leads to the least remaining requirement of medical staffs in the operation. Then go to step 5.

Equation 4. 26

$$0 \leq \sum_{j=1}^{n} x_{ij} \leq 1 \;\; \forall\, i \in I$$

Equation 4. 27

$$\sum_{i=1}^{m} x_{ij} = 1 \;\; \forall\, j \in J$$

Step 5: After getting the optimal solution from the divided assignment problem of each calculation time. Summarize the solution. Then, check whether each solution from the divided assignment problems have repeat case of same hospitals supporting to more than one operation sites or not

If return true value; let the hospital support medical staffs to the operation site which has shortest distance from the hospitals.

If return false value; record the supporting value. The supporting value of hospital i to operation j in medical staffs type k (a_{ijk}) is shown in Equation 4.28. Then update the requirement of operation sites and capacity of hospitals as shown in Equation 4.29 and 4.30.

Equation 4. 28

$$a_{ijk} = min\begin{cases} Requirement\ of\ medical\ staff\ type\ k\ of\ operation\ site\ j \\ capacity\ of\ medical\ staff\ type\ k\ of\ hospital\ i \end{cases}$$

Equation 4. 29

$$B_{ik} = B_{ik} - \sum_{j=1}^{n} a_{ijk}\, x_{ij}$$

Equation 4. 30

$$D_{jk} = D_{jk} - \sum_{i=1}^{n} a_{ijk}\, x_{ij}$$

Then, return to Step 1 until the requirement of all operation sites in doctors and dentists equal to 0. Stop the calculation in this phase. Then, skip to another calculation phase.

- Phase II

The decision work procedure in Phase II is identical to phase I except that in step 1 the screening criterion of potential hospital is relaxed to be the hospital with the capacity of doctors over the requirement of in every operation sites. Moreover, in step 5, the process will stop if the requirement of medical staffs of every operation sites in doctor equal 0

- Phase III

The decision work procedure in Phase III is identical to phase I and phase II except that in step 1 the screening criterion of potential hospital is relaxed to be the hospital with the capacity of dentists over the requirement of in every operation sites. Moreover, in step 5, the process will stop if the requirement of medical staffs of every operation sites in dentist equal 0

- Phase IV

The decision work procedure in Phase IV is identical to phase I, II and III except that in step 1 the screening criterion of potential hospital is relaxed to be the hospital with at least one type of the capacity of medical staff in required type of operation site is not equal 0. Moreover, in step 5, the process will stop if the requirement of medical staffs of every operation sites in every type of medical staff equal 0

Figure 4.9 illustrates the summary of decision model work procedure of assigning supporting hospitals in the form of program flowchart.

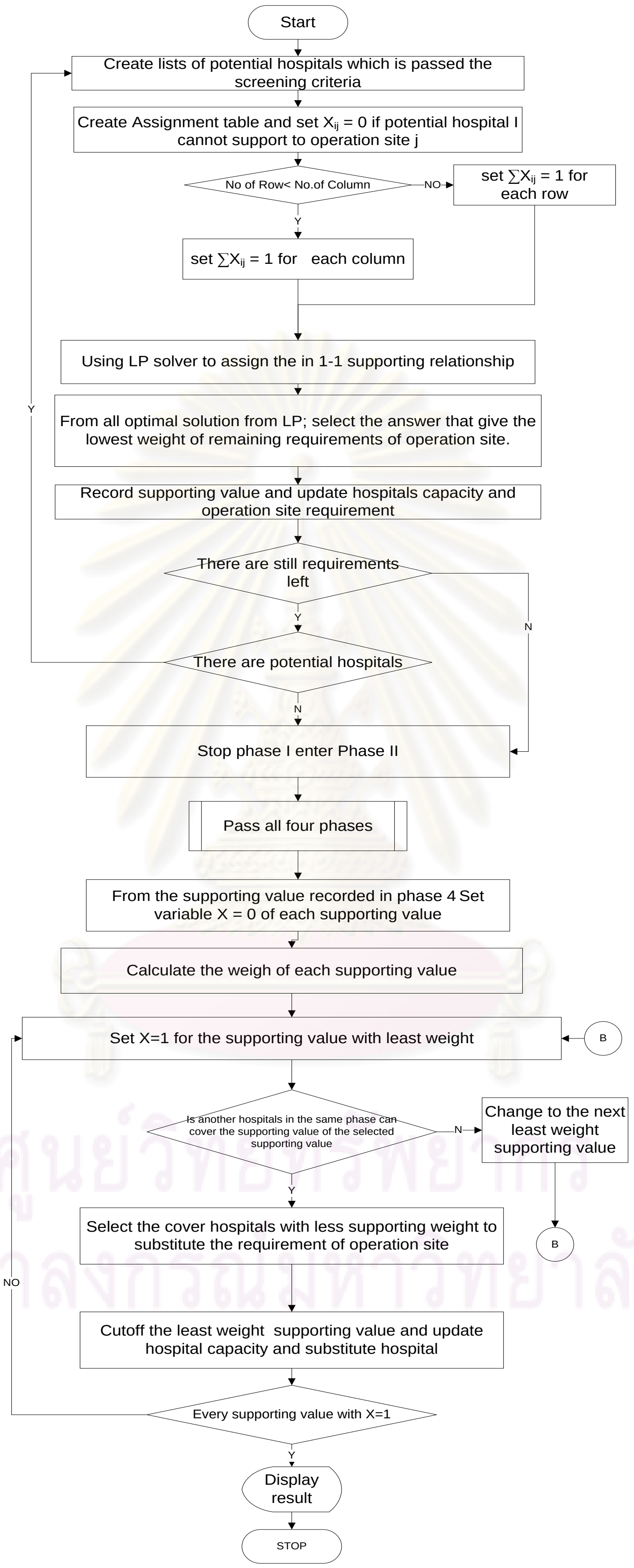

Figure 4. 9 summary of decision model work procedure of assigning supporting hospitals

4.2.2 Distribution methods' measurement calculation

After the solution of assigning supporting hospital is gained, the information of what type of medical staff and how many medical staffs of that type are supported to which operation site by which hospital is known. The next step of one-day trip distribution planning is to calculate the measurement of each distribution method in order to provide the necessary information for users to decide which distribution method to be used in transporting those medical staffs from their auxiliary hospitals to operation site under the assumption that during an operation date only one method of distribution method is allowed.

These are the calculation process in the decision model of one-day trip distribution method selection which is classified by distribution method that each method is applied different approaches to calculate the measurement.

- Normal distribution method; direct from hospital

This is the most straightforward distribution method and is the long practiced method of the studied organization. To calculate the measurement of distance, numbers of vehicle and travel time of a person using this distribution method are as formula in Equation 4.32, Equation 4.33 and Equation 4.34.

Equation 4. 31

$$s_{1j} = \sum_{i}^{m} V_{1ij}\, d_{ij} x_{ij}$$

Equation 4. 32

$$V_{1ij} = \left\lceil \sum_{i}^{m} \frac{\sum_{\forall k} a_{ijk} x_{ij}}{C} \right\rceil$$

Equation 4. 33

$$T_{avg\,1j} = \frac{\sum_{i}^{m} t_{ij} \sum_{k=1}^{4} a_{ijk}\, x_{ij}}{\sum_{i}^{m} \sum_{k=1}^{4} a_{ijk}\, x_{ij}}$$

Equation 4.32 shows the formula of calculating exact distance from supporting hospitals and supply warehouse to operation site. The distance from a hospital to

operation site depends on how many medical staffs that hospital is supported as well as the capacity of vehicle in transporting person equivalent unit to operation site.
Equation 4.33 shows the formula of calculating the total number of vehicles used in transportation and Equation 4.34 shows the formula of the average weighted time of 1 person will take to travel to operate at the operation site.

- Meeting point.

Meeting point distribution method can be applied in medical staff transportation when there are three hospitals or more collaboratively support the medical staffs to operation site. The qualification of meeting point is the hospital or place that leads to the total shortest distance from other hospitals to meeting point and to operation site. To find the meeting point using computer to process data is picking the hospitals with the most total number of supported medical staffs as the first trial; calculate the travel distance if that hospital is destined as meeting point. Record the total distance using the hospital as meeting point, then changing other hospitals to be meeting point and repeat the calculation and record data. Repeat the process until all hospitals and supply warehouse has the total distance as meeting point. Select the shortest travel distance and use that meeting point.

Meeting point is advantageous for its utilization of vehicle and flexibility in traveling to meeting point as well as less number of vehicle require in transportation. However, the number of vehicles increase when there are many supporting hospitals to operation site and total number of medical staffs supported to operation site. Equation 4.31 shows the formula of calculating exact distance from supporting hospitals and supply warehouse to operation site. The distance from a hospital to meeting point depends on which hospital is the meeting point and how many medical staffs from that hospital is supported to operation site as well as the capacity of vehicle in transporting person equivalent unit to operation site. Equation 4.32 shows the formula of calculating the total number of vehicles used in transportation and Equation 4.33 shows the formula of the average weighted time of 1 person will take to travel to operate at the operation site.

Equation 4. 34

$$s_{2j} = \sum_{i}^{m} V_{2ij} d_{io} x_{ij} + V_{2oj} d_{oj} \ \text{ when } o \in I \text{ and } \forall i \in I$$

Equation 4. 35

$$V_{20j} = \max \left\{ \begin{array}{c} \left\lceil \dfrac{\sum_{i}^{m} \sum_{k=1}^{4} a_{ijk} x_{ij}}{C} \right\rceil \\ \sum_{i}^{m} V_{2ij} \end{array} \right.$$

Equation 4. 36

$$T_{avg\,2j} = \frac{\sum_{i}^{m} t_{io} \sum_{k=1}^{4} a_{ijk} x_{ij}}{\sum_{i}^{m} \sum_{k=1}^{4} a_{ijk} x_{ij}} + t_{oj}$$

- Medical staff's pickup route.

Medical staff's pickup route can be applied in medical staff transportation when there are two hospitals or more collaboratively support the medical staffs to operation site. To generate pick up route, Dijkra's algorithm to find the shortest path is applied to find the shortest distance of medical pickup route. The Dijkra's algorithm is used to find the shortest path from one node to other nodes assuming all arc lengths are positive. In this research, Dijkra's algorithm can be used to find the shortest path from operation node to other supporting hospitals or supply warehouse. To find the medical staffs' pickup route can be described:

Step 0: Receive the supporting hospitals and supply warehouse location from assigning supporting hospital solution. Set all nodes with the permanent label of 0.

Step 1: each adjacent node to permanent node by a single distance arc is labeled as temporary label equal to the distance of arc joining the node to operation site. Each other node will have a temporary label as ∞.

Step 2: Choose the node with the lowest temporary label and make it to be labeled with permanent label of 0. Now that hospital i is the (k+1)th node to be given a permanent label; therefore, hospital i is the kth closet node to operation site. At this stage, the temporary label of any hospital (suppose hospital d) is the length of the shortest path from operation site to hospital d that passes only through nodes contained in k-1 closet nodes to operation site. For each hospital j that now has a temporary label and is connected to hospital i by an arc, hospital j's temporary lebel will be replaced by Equation 4.38

Equation 4. 37

$$\min\begin{cases} hospital\ j'\ current\ temporary\ label \\ hospital\ i's\ permanent\ label + length\ of\ arc\ (i,j) \end{cases}$$

The new temporary label for hospital j is the length of the shortest path from operation site to hospital j that passes only through nodes contained in the kth closet node to operation site. The smallest temporary label will become permanent label. The node with the new permanent label is the (k+1) closet node to operation site. Repeat step 2 until all node has the permanent label. Go to Step 3.

<u>*Step 3:*</u> After that, change the pickup route sequence backwardly to get the pickup route from supporting hospitals to operation site. Figure 4.10 shows the summary of Dijkra's algorithm in the form of programming pseudo code.

```
Begin

  Initialise P = {r}, T = V - {r}
  Initialise d(s) = 0, pred(s) = 0
  Let d(j) = c(n,i)
  Let pred(j) = r

  For all (s,j) ∈ A
      d(j) = ∞ for other nodes

      While P≠V do
            Choose minimun i ∈T
            d(i) = min {d(j): j ∈T}

            Update P and T:
              P = P {i}
              T = T - {i}

            Update temporaryLabels:
              For all j ∈A(i)
                  Compute d(j) = min {d(j), d(i) + c(i,j)}
                  Set pred (j) = I
                End for

      End do
  End for

End // end function
```

Figure 4. 10 Dijkra's algorithm

Source: Introduction to Mathematical Programming [40]

From Figure 4.10,

P = Set of permanent label node

r = Operation site r

V = Set of temporary label node

$d(S)$ = Shortest path distance from operation node r to node s

$pred(s)$ = Shortest path sequence route from operation node r to node s

$c_{(i,j)}$ = Distance from node i to node j

$A(i)$ = Set of nodes that are adjacent to node i

Medical staff pickup route is advantageous for its utilization of vehicle as well as less number of vehicles require in transportation but is disadvantages in flexibility of traveling along the route as well as the time lost in traveling to other places before going to the operation site. However, the method is appropriate for the case that supporting hospitals are dispersed along the same passageway to operation site. Equation 4.35 shows the formula of calculating exact distance from supporting hospitals and supply warehouse to operation site. The distance from a hospital to meeting point depends on the total number of supported medical staffs as well as vehicle capacity since in this distribution method the vehicles required in transportation will together leave the first hospitals and visit all hospital in the pickup route until reach the operation site. Equation 4.39 shows the total distance calculation formula; Equation 4.40 shows the formula of calculating the total number of vehicles used in transportation and Equation 4.40 shows the formula of the average weighted time of 1 person will take to travel to operate at the operation site.

Equation 4. 38

$$\mathbf{s_{3j} = V_{3j} \sum_{i}^{m} d_{ir} x_{ij} + d_{dj} \text{ when } i, d, r \in I \text{ and } I = \{1, 2, 3, 4, \dots, r, d\}}$$

Equation 4. 39

$$V_{3j} = \left\lceil \frac{\sum_{i}^{m} \sum_{k=1}^{4} a_{ijk} x_{ij}}{C} \right\rceil$$

Equation 4. 40

$$\mathbf{T_{avg_{3j}} = \frac{\sum_{i}^{m} t_{ir} \sum_{k=1}^{4} a_{ijk} x_{ij}}{\sum_{i}^{m} \sum_{k=1}^{4} a_{ijk} x_{ij}} + t_{dj}}$$

To summarize, in round-trip distribution planning of medical staffs and supplies for mobile medical service, VRP is applied to solve the problem of scheduling operation sites into service-time period predefined by the organization. There is constraint added to variant the problem from other normal cases of VRP: specific requirement of operation sites in service-time period. The constraint exists for the convenience in operation of local officers. With the developed decision model of DSS, operation route that feasibly satisfied all constraints are gained. In one-day trip planning, auxiliary hospitals is assigned to support medical staffs to operation sites. The problem in this research is distinguished from other normal assignment problem cases: the demand and supply side have multiple types of medical resources. As a result, the developed decision model aims to feasibly assign auxiliary hospitals to cover all multiple-resource requirements within the minimized transportation cost. Moreover, each distribution method measurement calculation is introduced for benefiting the planners to select the most appropriate distribution method to transport medical staffs and supplies to operation site as the most prioritized criterion among: total distance, average travel time per person and numbers of vehicle used in transportation.

CHAPTER V

DECISION MODEL EVALUATION

This Chapter introduces the evaluation testing of decision model in the developed decision support system. The evaluation methodology process is designed in order to test the robustness of decision model, the efficiency of decision model, and the satisfaction evaluation of future users.

5.1 Evaluation methodology

The evaluation methodology of any developed system including the decision support system is required before further implementing the system into real operation in the real situation. Usually the system evaluation process can be classified into 2 approaches [41];

- White-box Testing is the evaluation process that focuses on the correctness of system processing inside the developed program such as the program module and the structure of information system of the program. White box Testing aims to test primarily on the overall structure of the developed program.

- Black-box Testing is the evaluation of input data' correctness and the solution retrieved from the calculation of the data processing and analysis of the developed program without the consideration of the structure or work flow of the program.

In this research, the system evaluation process applying the black-box testing can be classified into 3 main approaches that are; the decision model's robustness, the efficiency of decision model, and users' satisfactory evaluation.

5.2 The robustness of decision model

The robustness of decision model relates the testing of the decision model in capability to find feasible solution of every possible input data or situation when implemented as model in the decision support system.

In this research, there are two decision models developed: round trip distribution planning and one-day trip distribution planning. In round trip distribution planning, the preliminary operation routing using greedy saving algorithm plays the most important role to attain the initial solution that will be improved through within-route improvement Heuristic of the decision model. The better quality initial operation route is achieved, the better the improved solution will be. In one-day trip distribution planning, the assigning supporting hospitals is required before selecting the distribution method. Therefore, to prevent users to skip the assigning supporting hospital step, the distribution method measurements 'calculation modules should not be activated until the assigning supporting hospital module is over and the feasible solution is gained.

5.2.1 Preliminary operation routing in round trip distribution planning

This testing is designed to analyze the robustness in capability to find solution of decision models including decision constraints and limitation that may lead to unfeasible solution or conflicts in operation routing of the decision model. The known correct answer is used to test and compare the solution from the decision model. However, it still needs more complicated procedure in testing for decision model's faults that can occur. In the testing procedure, 5 test cases[1] are created to test the capability and correctness of finding solution to those test cases of the decision model that are;

Test case 1: Every node has no specific requirement in service-time period

Test case 2: There are some service-time period that the number of requested operation sites to have mobile medical service operate during the service-time period exceeds the number of available working days

Test case 3: There are some service-time period that have no operation sites with the

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[1] Test Case Details are in Appendix B

specific requirement to have mobile medical service operate during that service-time period

Test case 4: Every service-time period that have some operation sites with the specific requirement to have mobile medical service operate during that service-time period

Test case 5: The mixture of some service-time period having no operation sites with the specific requirement to have mobile medical service operate during that service-time period and some service-time period having number of operation sites with the specific requirement does not exceed the available working day of those service-time period and some service-time period having number of operation sites with the specific requirement exceed the available working day of those service-time period.

The testing data are the real data in operation sites and distances between a pair of operation site available in operation plan of mobile dentistry service in Chiangmai province of the fiscal year 2008. The specific requirement of having mobile medical service operate during service-time period is randomly addressed. The testing result shows that the decision model can find the feasible preliminary routing solution of all five test cases within acceptable computing time and showed in Table 5.1 by using Intel® Core™ 2 Duo CPU P9600@ 2.66 GHz 1.99 GB of RAM as the testing computer.

Table 5. 1 The testing result of operation routing in round trip distribution planning

The Testing result of operation routing in Round trip distribution planning	Decision model	
	Distance(km)	Time(s)
Test Case 1:	4,935.61	0.89
Test Case 2:	7,262.66	0.81
Test Case 3:	5,128.06	0.83
Test Case 4:	5,304.09	0.89
Test Case 5:	5,068.76	0.94

By using the developed sequential saving heuristic to arrange preliminary operation route, from the testing result in Table 5.1, it has been shown that the favorable result can be gain in reasonable computing time of averagely 0.87 second. The developed approach depends greatly on the first set of operation sites into the route and the end-node of each route due to the fact that the end-node will be used to select other nodes to be merged into operation route. In test case 1, which all the operation sites have no specific requirement of having mobile medical service in any service-time period, the solution from the decision model gives the lowest total operation routes distance among every test case. This due to the fact that in other test cases, some operation sites are merged into the operation beforehand according to the specific requirement in service-time period; therefore, by doing so, it lessen the opportunities in merging those operation sites into appropriate route which may yield lower total distance. But when, there is no specific requirement of operation site involved, the pair of nodes with the highest saving value is merged together to form the combined route of each specific service-time period. However, the requirement of operation site is fully served; the operation site can have the mobile medical service operate during the selected service-time period. This satisfied the studied organization's strategic objectives in proving mobile medical service under reasonable transportation cost which in this case reflected through total distance as well as the local officer's convenience.

5.2.3 Within-operation route improvement of round trip distribution planning

The testing of within route improvement of round trip distribution planning follows the same approach of preliminary operation routing in round trip distribution planning with less complexity in testing procedure since the improvement of routing can be expected in advance since the improvement of preliminary routing must return better route sequence that lead to the reduction in total distance and the increase in solution quality. The operation sites of the preliminary route remain the same in operation route including the number of medical member and medical supplies required in medical team and the total number of required vehicles during the service-time period. Therefore, this testing is designed to be tested jointly with the preliminary operation routing testing. Table 5.2 shows the result of within route improvement from the preliminary route in the five generic test cases.

Table 5. 2 The testing result of improvement of preliminary routing

The Testing result of improvement in Round trip distribution planning	Before		After	
	Distance(km)	Time(s)	Distance(km)	Time(s)
Test Case 1:	4,935.61	0.89	3,180.29	1.08
Test Case 2:	7,262.66	0.81	4,259.19	1.07
Test Case 3:	5,128.06	0.83	4,580.89	1.64
Test Case 4:	5,304.09	0.89	4,301.44	1.07
Test Case 5:	5,068.76	0.94	4,259.19	1.09

By applying 2-Opt algorithm to improve the initial solution from the preliminary operation routing stage of decision model, the improvement result from Table 6.2 in the 5 generic test case shows that 2-Opt algorithm can reduce the total distance of preliminary routing averagely by 24.88% which leads to the better solution of operation route of round trip distribution planning. However, due to the fact that the developed algorithm applying 2 Opt approach in this research has cut off all possible patterns of cutting two connecting arcs between 2 pairs of operation sites; as a result, the computing time is averagely 37% longer than the preliminary routing.

5.2.4 Assigning supporting hospital in one-day trip distribution planning

This testing is designed to analyze the robustness of decision model in the capability of finding solution including decision constraints and limitation that may lead to unfeasible solution or conflicts in assigning supporting hospital of the decision model. The known correct answer is used to test and compare the solution from the decision model. However, it still needs more complicated procedure in testing for decision model's fault that can occur. In the testing procedure, 6 test cases[2] are created to test the capability and correction of finding solution of those test cases of the decision model that are:

Test case 1: Two operation sites per month with total medical staff requirement of every operation site less than total capacity of all hospitals and calculation process in phase I, II and III are skipped.

Test case 2: Five operation sites per month with total medical staff requirement of every operation site less than total capacity of all hospitals and calculation process in phase I is skipped.

Test case 3: Nine operation sites per month with total medical staff requirement of every operation site less than total capacity of all hospitals and calculation process in phase I and II are skipped.

Test case 4: Two operation sites per month with total medical staff requirement of every operation site more than total capacity of all hospitals.

Test case 5: Five operation sites per month with total medical staff requirement of every operation site more than total capacity of all hospitals

Test case 6: Nine operation sites per month with total medical staff requirement of every operation site more than total capacity of all hospitals

The testing data are the real data in operation sites and distance in the operation plan of the normal mobile medical service of Ratchaburi province of the fiscal year 2008. However, in real practice only two operation sites per month is scheduled in the operation plan. Therefore, the generic test data will combine all operation sites from fiscal year of 2008 to be in one month operation schedule in order to test whether the decision model has the capability to find the acceptable solution when the problem size is bigger. The testing result shows that the decision model can find the feasible solution of all 6 test cases within acceptable computing time and showed in Table 5.3 by using Intel® Core™ 2 Duo CPU P9600@ 2.66 GHz 1.99 GB of RAM as the testing computer.

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[2] Input data for all 6 generic test case is shown in Appendix B

Table 5. 3 The testing result of the decision model in finding feasible solution

No. Test Case	Distance (km)	Time(s)
Test case 1	645.6	0.90
Test case 2	1,416.3	0.99
Test case 3	1,356.3	0.92
Test case 4	124.6	0.64
Test case 5	317.7	0.65
Test case 6	817.1	0.73

Table 5.3 shows that all feasible solution of assigning supporting of all test cases can be found within the computing time average of X seconds. However, the in case that supply of total capacity of medical staffs of hospitals is dramatically less than the demand or forecast number of the requirement in medical staff of operation sites, it requires many hospitals to support medical staffs to operation site; therefore, the total distance in travelling from all supporting hospitals to all operation sites in test case 1, 2 and 3 are very high even with the low frequency in mobile medical service of 2 times per month. However, if the supply of total capacity of medical staffs of hospitals is approximately equals to the demand or forecast number of the requirement in medical staff of operation sites, the decision model can find the better solution due to the fact that the high potential hospitals are assigned to do the task in the supporting relationship of 1-1 which leads to the less numbers of hospitals assigned to support the medical staffs to operation sites. For example in the calculation result of test case 5 which can be presented in Table 5.4, mostly a single local hospitals is assigned to support the medical staffs to an operation site; therefore, leading in the reasonably less distance since the supporting hospital has the capability to cover all demands of medical staffs of the operation site. Almost supporting value is received from phase I of the decision model which can be guaranteed that the solution is optimal in the perspective of assignment model approach since the solution is gained from linear programming.

Table 5. 4 The supporting value of generic test case No.5

Supporting hospitals	Operation site	No. of medical staffs supported to each operation site				Distance (km)	Gained in Phase /iteration
		Doctor	Dentist	Nurse	Pharmacists		
H3	A	3	3	3	3	32.8	Phase 1/1
H2	C	3	3	3	3	69.0	Phase 1/1
H1	D	2	3	2	2	60.6	Phase 1/1
H4	E	3	3	3	3	38.7	Phase 1/1
H1	B	2	3	2	0	68.7	Phase 1/2
H5	B	0	0	0	3	47.9	Phase 4/1

5.2.5 Distribution method selection in one-day trip distribution planning

The testing of distribution method selection in one-day trip distribution planning follows the same approach of assigning supporting hospitals in one-day trip distribution planning with less complexity in testing procedure since the decision model only calculate the distribution methods' measurements of distance, time and number of vehicles used in transporting medical staffs to operation site. However, by testing using the same approach as assigning supporting hospitals test cases, each distribution method can be compared among one another in different circumstances and can lead to the conclusion that help strengthen the analysis of each distribution method's advantages and disadvantages. Therefore, this testing is designed to be tested jointly with the assigning supporting hospital testing. Table 5.5 shows the result of distribution method selection testing from the solution of assigning supporting hospital testing with the last three generic test cases.

Table 5. 5 Result of measurement calculation for distribution method selection

	Direct			Pickup			Meeting		
No. Case	Distance (km)	Vehicle (No.)	Time (s)	Distance (km)	Vehicle (No.)	Time (s)	Distance (km)	Vehicle (No.)	Time (s)
Test case 4	132.6	3	32.8	193.2	2	193.2			
	215.5	4	65.19231	140.2	2	66.48462	186.4	2	72.31538
Test case 5	88	3	33	106	2	53			
	201	3	69	208	2	104			
	177	3	61	114	2	57			
	101	3	39	92	2	46			
	183.6	3	63.9	147.8	2	67.9	144.8	2	67.13077
Test case 6	88	3	33	106	2	53			
	197	3	74.69231	386	2	140.0769	165	2	68.53846
	132	3	69	208	2	104			
	255	4	62.41667	146	2	58.5	130	3	58.16667
	100	4	24.33333	78	2	25.93333	64	2	24.93333
	68	3	19	84	2	19			
	211	4	61.41667	176	2	83.41667	150	3	60.5
	124	3	35	118	2	35			
	258.8	4	96.92667	202	2	98.2	204	3	98.2

From Table 5.5, the medical staffs' pickup route results in the least usage of number of vehicles in transportation leading to high utilization of vehicle to transport medical staffs to operation site. However, the method leads to highest weighted average time that a medical staff spends in traveling by the distribution method to operation site. Meeting point gives satisfaction on the utilization of vehicles from the meeting point to operation sites and satisfactory level of weighted average time a person used to go to operation sites. The direct distribution method which is the current practice in the studied organization usually has lowest weighted average time reflecting the flexibility of the distribution method; however, it generates lower utilization of vehicle due to the fact that it uses more vehicles to distributing the same amount of medical staffs to operation sites comparing with the other two methods. The distribution method that gives shortest distance in transportation depends on the dispersion of supporting local hospitals in the network. Direct shipping can be the distribution method that gives the shortest travel distance when all supporting hospitals are far from operation site or they are not in the same passenger way to the operation site. For example in operation site No.2 of test case 5, the supporting hospitals are not in the same passenger way of one another leading that the pickup route to have longer travelled distance than the direct distribution method.

From the result, it can be summarized that each method has its own uniqueness and drawbacks in transporting medical staffs to operation site. Direct method can leads to high flexibility and lower travel time while generate high distance and insufficient utilization of vehicle. Meeting point can be the safest way in transportation since the method leads to medium utilization of vehicle, distance and time in transporting medical staffs to operation sites. Pickup route can give the shortest travelled distance and high utilization of vehicle when hospitals are on the same passage way to operation site. However, the method can lead to the lost time of medical staffs spent in traveling in the route rather than in the operation site. User can select the most appropriate method according to the planners' prioritized measurements provided by the decision support system.

5.3 Decision model's efficiency

After all steps in decision model of round trip and one-day trip distribution planning of the developed decision support system had been tested to evaluate the capability and correctness of decision models to find the feasible solution from the generic test cases, the efficiency testing of the decision model is designed to test the efficiency of proposed decision model comparing with other approaches and current practice of the organization.

Generally, in testing to compare with other approach to the problem, optimal solution is used to compare with the solution from any the proposed solution. However, in this research, the optimal solution comparing technique cannot be adopted due to the fact that the optimal solution to the problem in this research is not easily gained because of the complexity of the problem. Therefore, comparing with other method is adopted to verify that the proposed decision model can efficiently find the feasible solution comparing with other approach in finding solution to the same problem.

To test the efficiency of the problem, the proposed decision model in round trip distribution planning using sequential saving heuristics is compared with the solution quality between current practice of the organization in finding solution and the proposed decision model.

To test the efficiency of the problem, the proposed decision model in assigning supporting hospitals in one-day trip distribution planning using integration of heuristics and linear programming approach is compared with the transportation model approach to test the quality of solution through the setup measurements. Moreover, the comparison of solution quality between current practice of the organization in finding solution and the proposed decision model can also be tested due to the fact that in current practice of the studied organization; there are the information on hospitals supporting medical staff to operation sites in the approved operation plan of Ratchaburi province.

To define the proper measurements used in decision model efficiency evaluation process, there are many measurement of each level to be used. According to Eibl [40], the level of measurement is classified into micro and macro level. The macro level concerns the measurement that affect to the overall organization such as the reduction of transportation cost while the micro level concerns the operational effect to the person currently in the operation such as planners can lessen the complexity in decision making process. In this research, distance will be the primary measurement to evaluate the solution quality of approaches in finding the solution to the problem; proposed decision model, other approaches and current practice of organization. Distance reflects the transportation cost during transporting period; therefore, it is usually applied as the evaluation measurement. The approach in finding solution that leads to higher total distance is likely to have less efficiency in finding the solution of the problem. The percentage of distance difference is used to evaluate the efficiency of the problem.

Generally the percentage of distance difference can be calculated using the formula in Equation 5.1; however, in this research the distance of optimal solution is not easily gained. Therefore, the current practice of organization is used to evaluation of the decision model efficiency

Equation 5. 1

$$distance\ diff = \frac{d - d_{compare}}{d_{compare}}$$

When;

d = total distance by using the calculation of proposed method

$d_{compare}$ = total distance by using the calculation of other method that need to be compared with

In this research, the efficiency evaluation of proposed decision model is designed to use the generic test case and use the solution from the proposed decision model and current practice of the studied organization to evaluate the proposed decision model's efficiency through percentage of distance difference as the quantitative measurement.

The current method of the studied organization using planners' experiences on operation routing can be gained through the operation plan of the fiscal year 2008 of mobile dentistry service. The total distance travelled of 9 service-time period during the winter of Chiangmai province is accumulated for 3,559 km[3] . Table 5.6 shows the result of the decision model efficiency in finding solution compared with the current practice and other approach in finding the solution

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[3] Detail of operation route are in the Appendix B

Table 5. 6 Efficiency of operation routing decision model testing result

Efficiency evaluation result	SS		SS(After)		ORG
	Distance(km)	time(s)	Distance(km)	time(s)	Distance(km)
Test Case 1:	4,935.61	0.89	3,180.29	1.08	3,559
	+38.15%		- 10.85 %		

SS = Sequential saving heuristics approach; the proposed method in decision model

SS (After) = The improvement of the proposed method in decision model

ORG = The studied organization approach in operation routing for mobile dentistry service

From Table 5.6, it can be summarized that the proposed decision model can give the solution better than the current approach of the studied organization using planner's experiences in determining operation route for round-trip distribution planning with the result of decrease in total distance of 10.85%[4] of the studied organization approach which is considered to be acceptable. However, to receive better solution than the organization approach, the preliminary routing should be improved through the improvement heuristic in the decision model. This due to the fact that by using saving method to merge the operation site into the combined operation route to be in the next sequence of the end-node of the combined operation route leads to deficiency in determining the appropriate sequence of operation site in the route. With the improvement heuristic developed in the decision model can help greatly in reducing the initial solution's total distance. As a result, the decision model can efficiently generate the good quality answer to planners in round trip distribution planning to help making the decision in generating operation plan.

[4] Details of the results can be found in the Appendix B

In one-day trip planning, the efficiency of decision model can be compared with the current approach of the studied organization from the operation schedule of Ratchaburi province mobile medical service of the fiscal year 2008[5]

Table 5. 7 Efficiency of assigning supporting hospital decision model testing result

No. of Test Case	Assignment Model Distance(km)	Transportation model Distance(km)	ORG Distance(km)
Case 4	124.6	178	-
Case 6	817.1	-	1,516

From Table 5.7, the approach used in the development of decision support system can dramatically reduce the number and total distance of hospitals supporting medical staffs to scheduled operation site. Moreover, when compare with the transportation approach, the developed method can lead to the better solution in less computing time due to the fact that the approach cut off some alternatives of hospitals supporting to the operation by using screening criterion to list the potential hospitals before assigning the medical staffs to operation sites; as a result, the developed method leads to the less numbers of hospital supporting medical staffs to operation site. Thus, the distance is shorter. Transportation approach is beneficial in the case that each hospital does not have to support all medical staffs into one operation site. However, the approach takes higher computational time to find the answer due to many variables involving in the computation process.

5.4 Users' satisfaction evaluation

Users' satisfactory evaluation is very crucial for the evaluation of the proposed decision support system because the proposed decision support system aims to propose the planning tool for mobile medical service distribution planners to easily plan the distribution of medical staffs and supplies to the operation site. Therefore, the seminar to interrogate the planners or other involving personnel in mobile medical

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[5] The detail of operation schedule can be found in Appendix B

service distribution planning is held at Thantong Room 1st floor Montien Riverside Bangkok on 16 October 2009 at 9:00 a.m. [6]in order to propose the decision models of the developed decision support system to the studied organization including other involving agents' representatives such as the planning officer of Ratchaburi provincial public health office, local public health office, hospitals, experienced volunteer medical staffs and other organization that is providing the mobile medical service resembling the operation of the studied organization such as Red Cross. The content of the seminar can be summarized in 3 main topics that are; the contextual of the proposed decision support system, the possibility in implementing the system into the operation and the suggestion from experience personnel.

- The contextual of the proposed decision support system

During the seminar, the scope of research and decision support system is described to seminar attendees that the proposed decision support system can be used to help the distribution planning of medical staffs and supplies in both intermittent operation (one-day trip)and consecutive operation(round-trip) of mobile medical service. At this point there are some arguments of the proposed system that the current operation of the studied organization is independently planned since the normal mobile medical service is usually the provincial mobile medical service which the medical staffs are from local hospitals in the province; the studied organization is only the coordinator in medical staffs and supplies distribution planning process. The mobile dentistry operation route is planned in the central office of the studied organization and is separated from the normal mobile medical service. However, all attendees agree that the scope of the research is clear and versatile in adopting to help the mobile dentistry operation route planners to easily generate the operation plan. Moreover, the idea of letting bottom-up requisition of operation sites from local offices into the decision support system interests many attendees' satisfaction due to the fact that the idea is the fundamental objective of the studied organization.

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[6] The detail of seminar can be found in Appendix C

After the decision model in round trip distribution planning is described, the decision model of one-day trip distribution planning is introduced. The idea is really stimulate interests in assigning hospitals to support the medical staffs to operation site since in the current practice; this decision stage is not included in the planning process. The current practice of the studied organization of assigning supporting hospitals usually assign the closet hospitals to the operation site as single supporting hospital completely ignoring the medical staffs and supplies requirement of operation site. Therefore, with the developed decision model, planners can focus more on the requirement of operation sites; thus the studied organization can fully served the customer as the organization's objective. The distribution method selection stage of the decision model in one-day trip distribution planning leads to controversial issues in medical staff pickup route distribution method due to the fact that the method requires medical staff to be waiting at the place for vehicles to pick up and transport to operation site while the medical staffs can go straight to the operation by themselves; therefore, the method can cause time wasted in waiting rather than time used in operation. However, they agrees that if the case that supporting hospitals are on the same passenger way to the operation site; the method can economically save both distance, and time including the utilization of vehicles used in transportation.

After all the decision models of the developed decision support system are introduced, the simulation of operation support of mobile medical service concerning the business workflow of the decision support system is described and demonstrated to seminar attendees. The attendees are impressed with the business workflow of the developed decision support system with the suggestion that the developed decision support system should be applied to help distribution planning in the pilot province in order to make an experiment whether the developed decision support system can really be used in real situation.

- The possibility in implementing the system

There are concerns over the subject of implementing the system into real situation due to the fact that there are many involving agents collaboratively operate at the operation sites of mobile medical service. Therefore, in order that the developed decision support system can be efficiently used to help officers in one day trip distribution planning, many information and data should be in the same format of all involving agents and must be correctly entered to the database. At present, all data and information from an agent are not linked to one another and are mostly in the form of paper documentation. Therefore, the developed decision support system may not be able to efficiently help the planner in decision making of medical staffs and supplies distribution planning when implemented into the real situation.

- The suggestion from experience personnel

There are some beneficial suggestions from the experience volunteer medical staffs concerning the selection of objective's function of the proposed decision model. In the special case of mobile medical service for emergency case, distance may not be the prioritized measurement to the decision model in finding feasible solution of operation route. However, in the scope of this research, the mobile medical service is operating in the normal situation excluding epidemic and emergency case. Therefore, only distance can be adequately used as objective's function to reflect the transportation cost of the medical staffs and supplies distribution to operation site.

After the seminar, questionnaires are sent to the seminar attendees to complete the satisfactory evaluation form concerning the proposed decision model of round trip and one-day trip distribution planning to evaluate the user satisfaction on the proposed decision model. The analysis result of users' satisfactory evaluation can be classified into the satisfactory evaluation of proposed decision model and the possibility evaluation of implementing the proposed decision model in real situation.

- The satisfactory evaluation of proposed decision model

To evaluate the users' satisfaction of the developed decision support system, questionnaires are distributed to seminar attendees coming from each involving agents of mobile medical service operation. The user satisfaction evaluation can be classified into three parts which are the satisfaction of round trip distribution planning's decision model concept, the satisfaction of one day trip distribution planning's decision model concept and the overall concepts of developed decision support system. Users' satisfactory evaluation is used to evaluate that the contentment of the future users on the developed decision support system is at what level including opinions and suggestions concerning the improvement of the developed decision support system.

5.4.1 Experimental Sample

The samples used in user satisfaction evaluation are the representative samples from all involving agents of mobile medical service planning and operation including the representative from the studied organization, local public health officers, provincial public health officers, hospitals, experienced volunteer medical staffs and other mobile medical service provider organization representatives. The sample size is 18 responses from seminar attendees; 4 responses from the studied organization, 1 response from local public health office, 6 responses from provincial public health officer, 2 responses from local hospital and 5 responses from other mobile medical service provider organization (Red Cross).

5.4.2 Data collection

The data collected for users' satisfaction evaluation is the opinion of seminar attendees on the concept of the developed decision support system through questionnaires[7].

5.4.3 Data Analysis

The seminar attendees are 30 people; 18 of them response to the distributed questionnaires which is accounted of 60% of seminar attendees. The data analysis is to interpret and analyze the questionnaires' responses on the satisfaction level of the developed decision system.

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[7] The detail of questionnaire can be found in the Appendix C

Table 5.8 shows the percentage of individual characteristics of response (n = 18). Experienced medical staff is the most response with 38.89% while local planner is the least response with the percentage of 5.56% of all response.

Table 5. 8 The percentage of individual characteristics of response

Individual characteristics	Number of People	Percentage
Medical staff	7	38.89%
Local Planner	1	5.56%
Central office Planner	6	33.33%
Provincial office Planner	4	22.22%

The evaluation assessment can be classified into three parts; round trip distribution planning's decision model concept, the satisfaction of one day trip distribution planning's decision model concept and the overall concepts of developed decision support system. Table 5.9 shows the overall satisfaction on each part of the developed decision support system.

Table 5. 9 Overall satisfaction on each part of the developed decision support system

Decision support system evaluation part	Mean	S.D.	Level of Satisfaction
Round trip distribution planning's decision model concept	3.844	0.923	Satisfied
One day trip distribution planning's decision model concept	3.833	1.058	Satisfied
The overall concepts of developed decision support system	4.069	0.810	Satisfied

From Table 5.9, users are most satisfied with the overall concepts of the developed decision support system with the highest mean of 4.069. However, all parts of the developed decision support system can lead to the high satisfaction of future user on the developed decision support system.

- Round trip distribution planning's decision model concept

To evaluate the user satisfaction of round trip distribution planning's decision model concepts, five subtopics are addressed to measure the level of user satisfaction. Table 5.10 shows the user satisfaction analysis of each subtopic to evaluate the user satisfaction of round trip distribution planning's decision model concepts.

Table 5. 10 User satisfaction analysis of each subtopic in round trip distribution planning

Round trip distribution planning's decision model concept	Mean	S.D.	Level of Satisfaction
The capability of decision model to find the solution of operation route	3.722	1.127	Satisfied
The decision model's concept is correct , appropriate and versatile	3.944	0.873	Satisfied
The input data is adequate , appropriate and versatile	3.944	0.873	Satisfied
The solution from decision model is appropriate to generate operation plan	3.944	0.873	Satisfied
The constraints of decision model is correct , appropriate and versatile	3.667	0.907	Satisfied

In round trip distribution planning's decision model concept, all subtopics can satisfy future user of the developed decision support system; however, the most satisfied topic in the developed decision support system is the decision model's concepts, the appropriate input data and the solution from the decision model which can be used to generate the operation plan.

- One day trip distribution planning’s decision model concept

To evaluate the user satisfaction of one day trip distribution planning’s decision model concepts, six subtopics are addressed to measure the level of user satisfaction. Table 5.11 show the user satisfaction analysis of each subtopic to evaluate the user satisfaction of one trip distribution planning’s decision model concepts.

Table 5. 11 User satisfaction analysis of each subtopic in one trip distribution planning

One day trip distribution planning’s decision model concept	Mean	S.D.	Level of Satisfaction
The decision model can help solve the problem in assigning supporting hospitals	4.000	0.970	Satisfied
The input data is adequate , appropriate and versatile	3.944	0.873	Satisfied
The solution from decision model is appropriate to generate operation plan	4.111	0.832	Satisfied
The possibility in using decision model to assign supporting local hospitals in real situation	3.944	0.938	Satisfied
The constraints of decision model is correct , appropriate and versatile	3.778	1.003	Satisfied
The possibility in using distribution method in the real situation			
Direct shipping	3.222	1.353	Satisfied
Meeting Point	4.000	0.970	Satisfied
medical staff pickup route	2.860	0.686	Medium

In one day trip distribution planning’s decision model concept, all subtopics can satisfy future user of the developed decision support system; however, the most satisfied topic in the developed decision support system is the solution from the decision model which can be used to generate the operation plan. This may help planners greatly in determining the supporting hospitals to operation site as scheduled.

All distribution method have the probability to be used in real operation in transporting medical staffs to operation; however, the medical staff pickup route can neutrally satisfy future user of the developed decision support system due to the fact that the method requires medical staffs to wait until the vehicles comes to pickup instead of go straight to the operation site leading to medical staff lost time or opportunity in providing service to customers.

- The overall concepts of developed decision support system

To evaluate the overall concepts of developed decision support system, three subtopics are addressed to measure the level of user satisfaction. Table 5.12 shows the user satisfaction analysis of each subtopic to evaluate the user satisfaction of the overall concepts of developed decision support system.

Table 5. 1 User satisfaction analysis of each subtopic in overall concepts

The overall concepts of developed decision support system	Mean	S.D.	Level of Satisfaction
The decision support system links up necessary distribution planning process	3.944	0.802	Satisfied
The decision support system can be the solution to difficulties in decision making	4.111	0.900	Satisfied
The possibility in implementing the decision support system into real situation	4.222	0.878	Very Satisfied

The satisfaction evaluation of the overall concepts of developed decision support system, all subtopics can satisfy future user of the developed decision support system; however, the most satisfied topic in the developed decision support system is the high possibility in implementing the decision support system into real situation. Even though there are some concerns over the linkage between information and data of many involving agents of mobile medical service, the overall concepts of the decision support system can help greatly in reducing the decision making difficulties in distribution planning process especially in operation route planning in round trip distribution plan.

To summarize, three approaches of the developed system evaluation is conducted; the evaluation of decision model's correctness, the evaluation of decision model's efficiency and user satisfaction evaluation, All testing approaches give favorable result. The testing of decision model's correctness reflects the capability of both decision models in finding solution in all generic test cases and return satisfactory quality of the solution. Moreover, decision model can give the answer which has closed quality level of experienced planners in round trip distribution planning. In addition, future users of the developed decision support system demonstrate high level of satisfaction of the overall concept of the developed decision model and suggest that there is possibility of implementing the developed decision support system into real operation in mobile medical planning process. Therefore, the developed decision support system can satisfactorily answer to the problem in distribution planning's decision making of mobile medical service planner with the capability to find the acceptable quality solution which can be used to generate the mobile medical service distribution plan.

CHAPTER VI

INFORMATION SYSTEM OF DECISION SUPPORT SYSTEM

This Chapter introduces the design of information system of the developed decision support system including the evaluation of correctness input data to be used in the computational process of the DSS. UML (Unified Modeling Language): which is the standardized model used in Object Oriented Programming (OOP) is applied in the design of information system which is beneficial for communication with programmers in the program coding.

6.1 Use case

The operations in the decision support system can be described by using “Use Case Diagram” which all activities or operations in the decision support system are listed and described to demonstrate the relationship between actor and activities in the system.

There are 3 activities classified into 2 main activities in the developed decision support system of mobile medical staff and supplies distribution planning for mobile medical service. 2 actors involve in managing these activities in the system. Use Case Table, Use Case Diagram and Use Case Template can be used to list all activities in the system, to demonstrate the relationship between actors and activities in the system and to show the detail of activities in the system consecutively.

6.1.1 Use Case Table

There are 2 actors involving in the developed decision support system. Use Case table will be used to describe each activity’s detail and the relationship between actor and each activity in the system. Table 6.1, 6.2, and 6.3 shows the Use Case Table of the decision support system of mobile medical staff and supplies distribution planning for mobile medical service.

Table 6. 1 Use Case Table of the decision support system

No. of activity	Actor	Case	Description
1 Operation Route Planning	Central office planner	Setup Data	Setting up data and information requires for the calculation of the decision model of round trip distribution planning that is to set up the service-time period of each province during specific season in the focused fiscal year
		Operation Site Requisition Management	Retrieve the operation site requisition of the focused province during specific season from the requisition database
		Supporting Data management	Retrieve the necessary supporting data for supporting the calculation of decision model from the main database such as distance matrix and forecast of medical staffs and supplies at the requested operation site.
		Operation Routing Calculation	Decision model find the feasible solution of round trip operation routing including the calculation of required medical staff in medical team
		Create Operation Plan	Create operation plan for round trip distribution by using solution from decision model and other necessary information

Table 6. 2 Use Case Table of the decision support system (continued 1)

No. of activity	Actor	Case	Description
2 Assigning Supporting Hospital	Provincial Office Planner	Operation Schedule Management	Retrieve the operation schedule of one-day trip operation the focused province during specific month from the operation schedule database
		Supporting Data management	Retrieve the necessary supporting data for supporting the calculation of decision model from the main database such as distance matrix and forecast of medical staffs and supplies at the requested operation site.
		Assigning hospital to operation site	Decision model find the feasible solution of assigning supporting hospitals to support the medical staffs to operation site
		Recording Supporting Value from hospitals to operations	Record the supporting value from each assigned hospitals to operation site in the calculation database
		Create Operation Plan	Create distribution plan for one day distribution by using solution from decision model and other necessary information
3 Distribution Method Selection	Provincial Office Planner	Supporting value Management	Retrieve the supporting value of the assigning hospital activity from storing database of the focused province during specific operation date

Table 6. 3 Use Case Table of the decision support system (continued 2)

No. of activity	Actor	Case	Description
3 Distribution Method Selection	Provincial Office Planners	Measurement Calculation	Decision model calculates the measurements of each distribution method and display the result
		Selection of distribution method	Actor select the distribution method for each operation date and stores information in the database
		Create Operation Plan	Create distribution plan for one day distribution by using solution from decision models and other necessary information

6.1.2 Use Case Diagram

Use Case Diagram is the illustration which demonstrates the relationship between activities in the system and actor. Figure 6.1 shows the Use Case Diagram of the developed decision support system and Figure 6.2 shows the Use Case Diagram of the developed decision support system in the setup data.

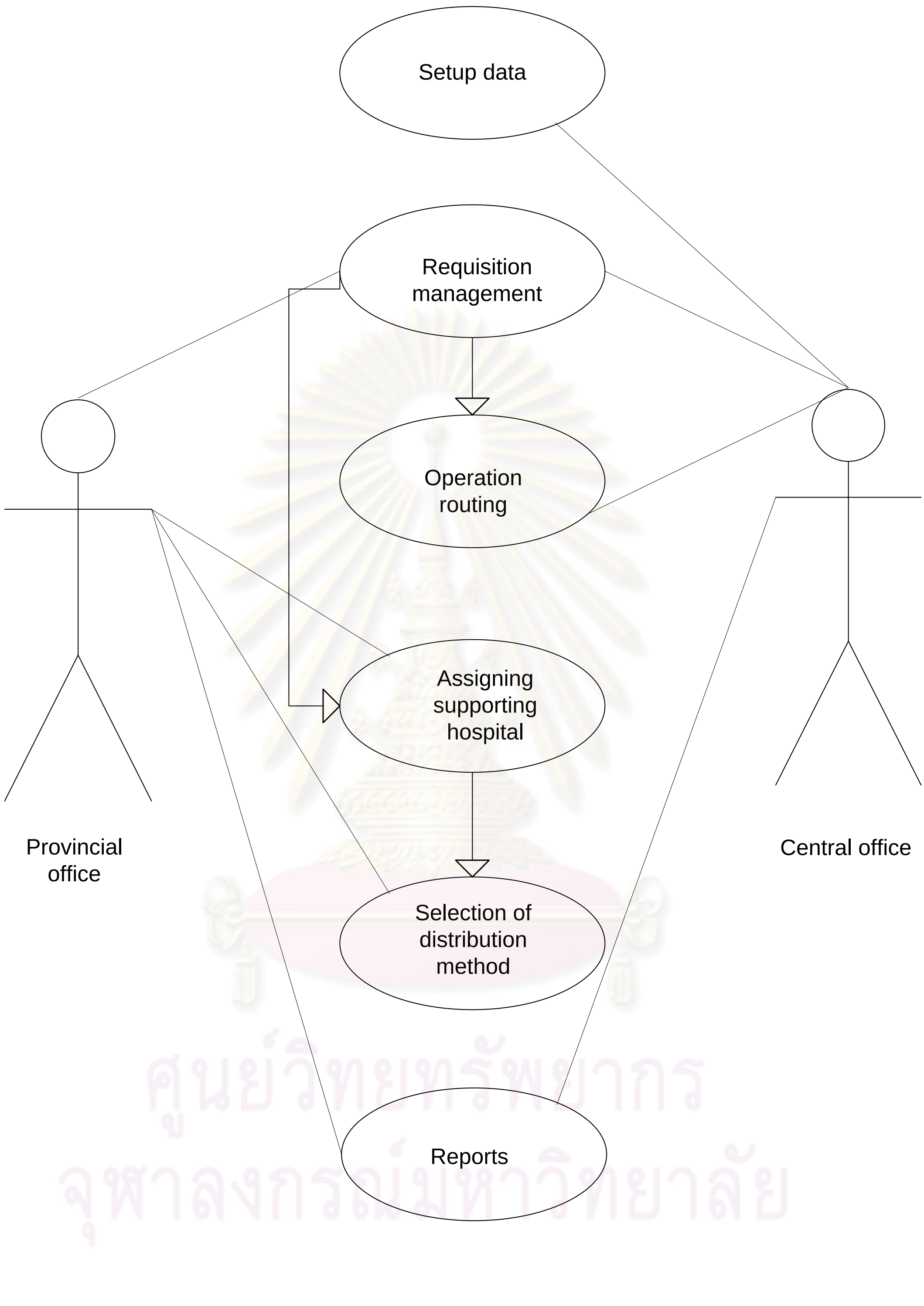


Figure 6. 1 Use Case Diagram of the developed decision support system

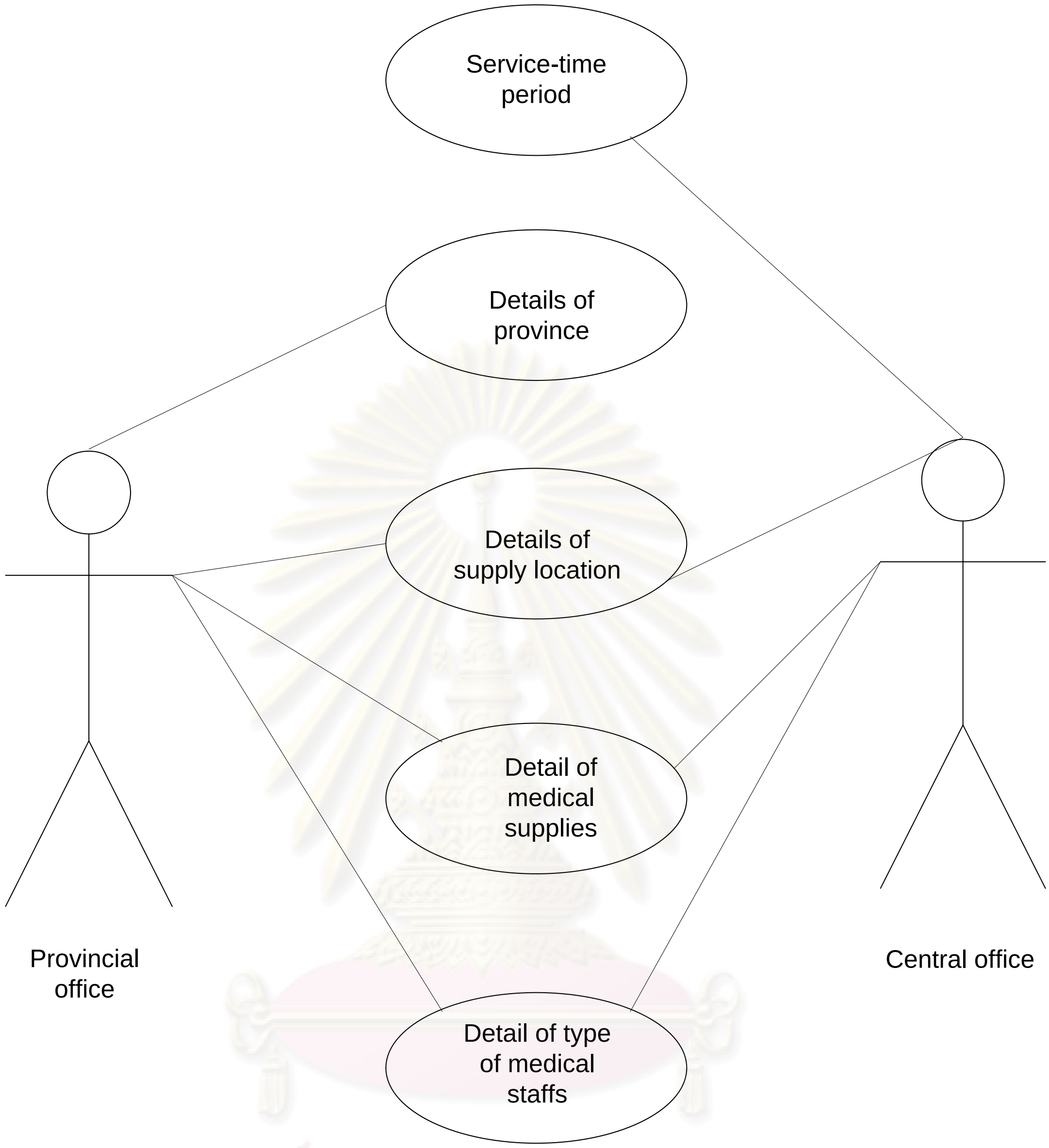


Figure 6. 2 Use Case Diagram of the developed decision support system in the setup data

6.1.3 Use Case Template

Use Case Template is the tool to describe the detail of activities in the system reflecting the process of work flow or work procedure of the activity which includes;

- Basic is main activity covering the focused activity in Use Case Template
- UseCase is the focused activity’s name

- Precondition is the conditions or rule before continue the operation in the activity
- Successful Post-condition is the result from finishing the activity
- Failed Precondition is the result from failing the activity
- Primary, Secondary Actors is the involving person of the activity
- Flow of Events is the procedure of activity's operation

In the developed decision support system; there are 10 Use Case Template concerning all activities in the system. Service-time data setting up is showed in Table 6.4 while all other Use Case Templates are listed in the Appendix D.

Table 6. 4 Use Case Template of service-time data setting up

Basic	Setup	
UseCase 1	Service-time Setting Up	
Precondition	Must be the time duration the destined as service-time for a province during specific season	
Successful Postcondition	Have service-time detail in database	
Failed Precondition		
Primary, Secondary Actors	Central office Planner	
Flow of Events	Step	Transactions
	1	Examine the existing service-time period detail
	2	Select to edit or add new service-time period
	3	Insert necessary detail of service-time period
	4	Insert duration of service-time period
	5	Save service-time period into database

6.2 Business Process

From the description of relationship between activities in the developed decision support system of medical staffs and medical supplies distribution planning and actors using Use Case Diagram, in the next step, business process is used to relate all activities to demonstrate the linkage and operation sequence in every activity in the developed system. The medical staffs and medical supplies distribution planning of the developed decision support system can be shown in Figure 6.3.

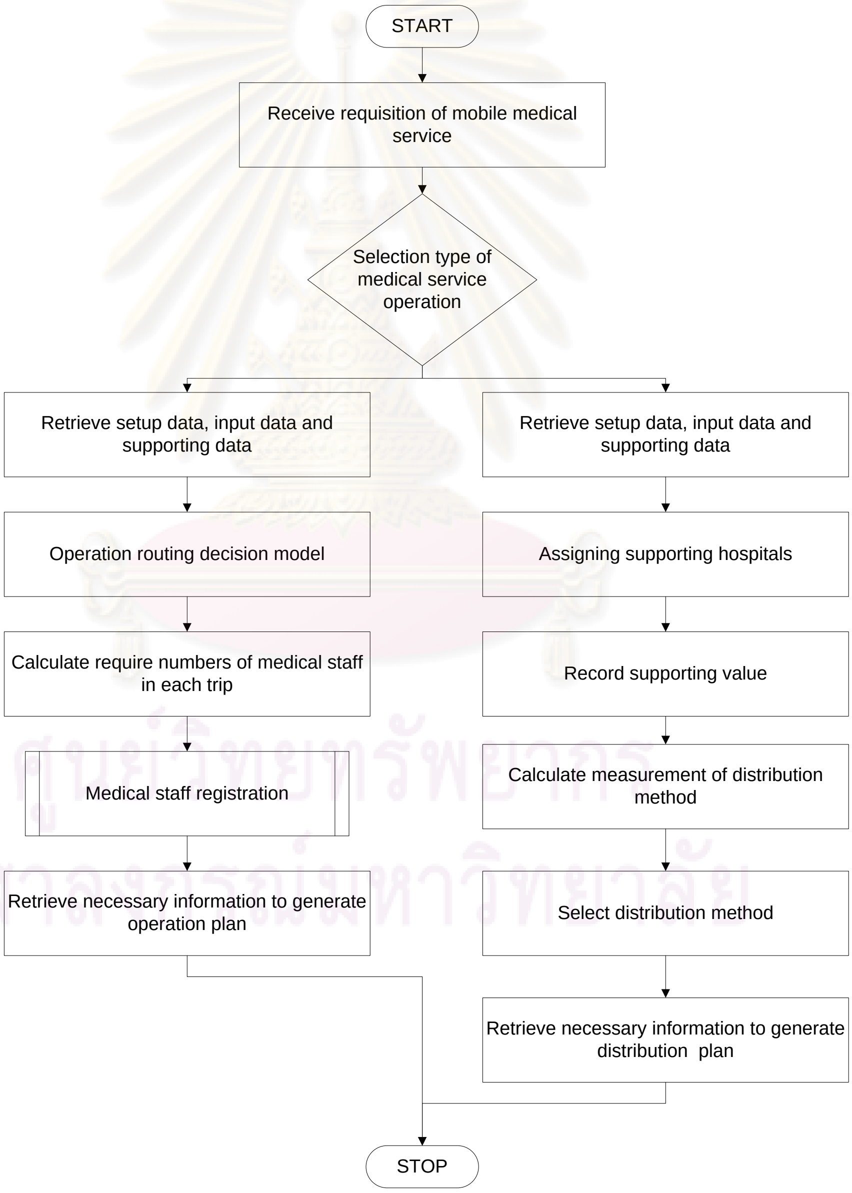


Figure 6. 3 The medical staffs and medical supplies distribution planning process of DSS

6.3 Graphic User Interface

Graphic User Interface (GUI) is the interaction between the decision support system and users so that users can interact with the system as required. The main function of GUI is to demonstrate data or calculated solution, receive data from user input and control the program by passing orders to operate the program. In this research, the conceptual design of GUI for the medical staffs and medical supplies distribution planning of the developed decision support system are as follow;

- Tree Diagram

To reach the GUI of every activity in the developed decision support system, Tree Diagram can be used to retrieve all GUI to be shown in the left hand side of computer screen. Tree Diagram also classifies the GUI category from the function of GUI in the system. The Tree Diagram of the developed decision support system in the operation support system of mobile medical service can be shown circled in Figure 6.4.

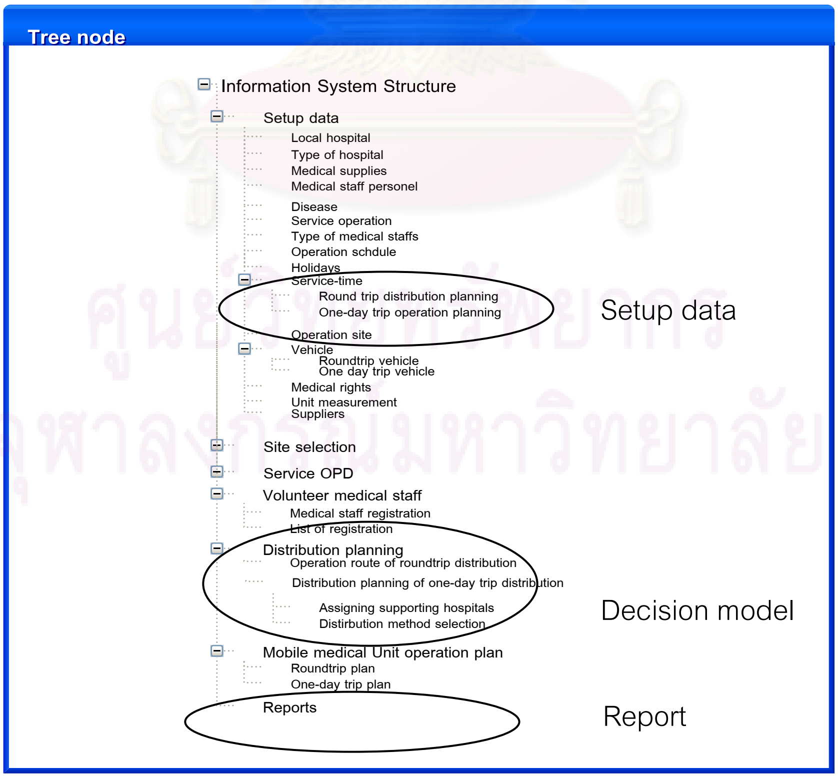


Figure 6. 4 Tree node diagram

To design GUI, operation sequence in each activity should be realized in order that GUI can help user to work more efficiently. In case that there is too much information to be shown in one page of GUI, tabs will be used according to the operation sequence of the activity or information category depends on the appropriateness. Pop-ups will be used to shown additional information of operation. GUI in the developed decision support system can be classified into 3 main categories that are;

- Setup data for entering input data necessary in calculation of the decision model
- Operation for recording information and other operations during users' actions
- Reports for displaying necessary information to users.

Table 6.5 shows the lists of GUI in the decision support system for planners to plan the distribution of medical staffs and supplies to operation site.

Table 6. 5 lists of GUI in the decision support system

Setup data	1. Service-time setup
Operation	2. Operation site Data management
	3. Retrieve requisition data
	4. Distribution method selection
Reports	5. Operation route display
	6. Assigned hospital display
	7. Operation and distribution plan

- User Interface Map

User interface map can be used to demonstrate the information flow, functions of all GUIs including how to access to the required GUI of the developed decision support system. Figure 6.5 shows the user interface map of all GUI in the developed decision support system including the specification of necessary information shown in each GUI.

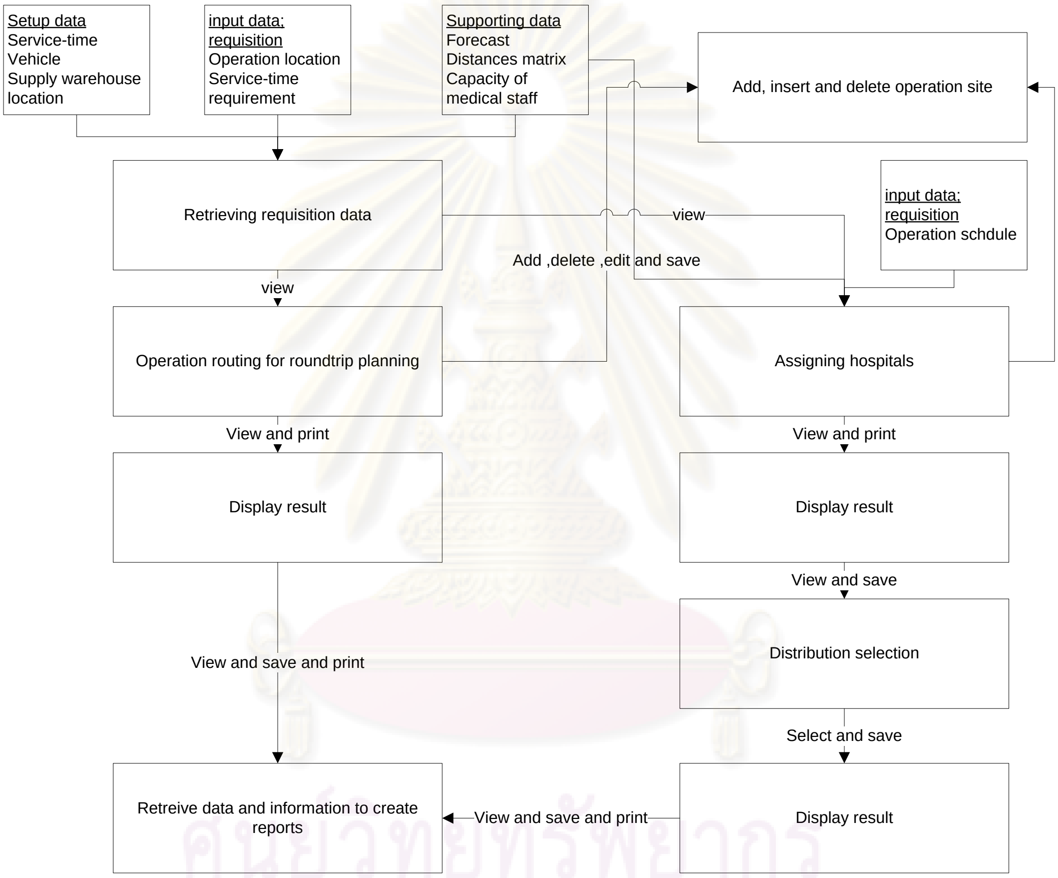


Figure 6. 5 user interface map of all GUI

- Planning Process

The planning process is to describe the workflow of using the developed decision support system in planning medical staffs and supplies to operation site. The planning process can be classified into 2 types according to the operation in distribution planning; round trip planning or one-day trip planning. Figure 6.6 shows the planning process of round trip distribution planning while Figure 6.6 shows the planning process of one day trip distribution planning.

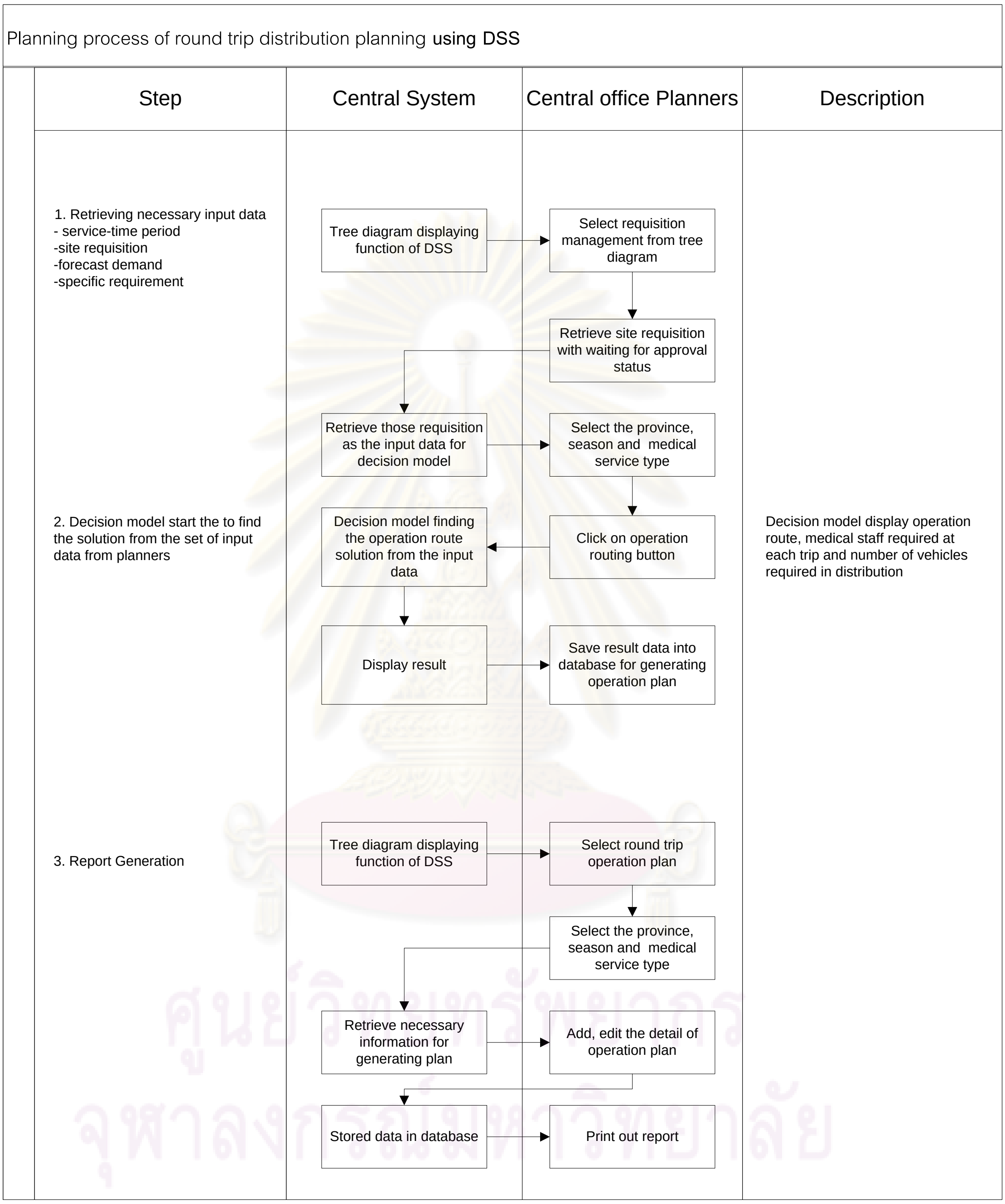


Figure 6. 6 Planning process of round trip distribution planning using DSS

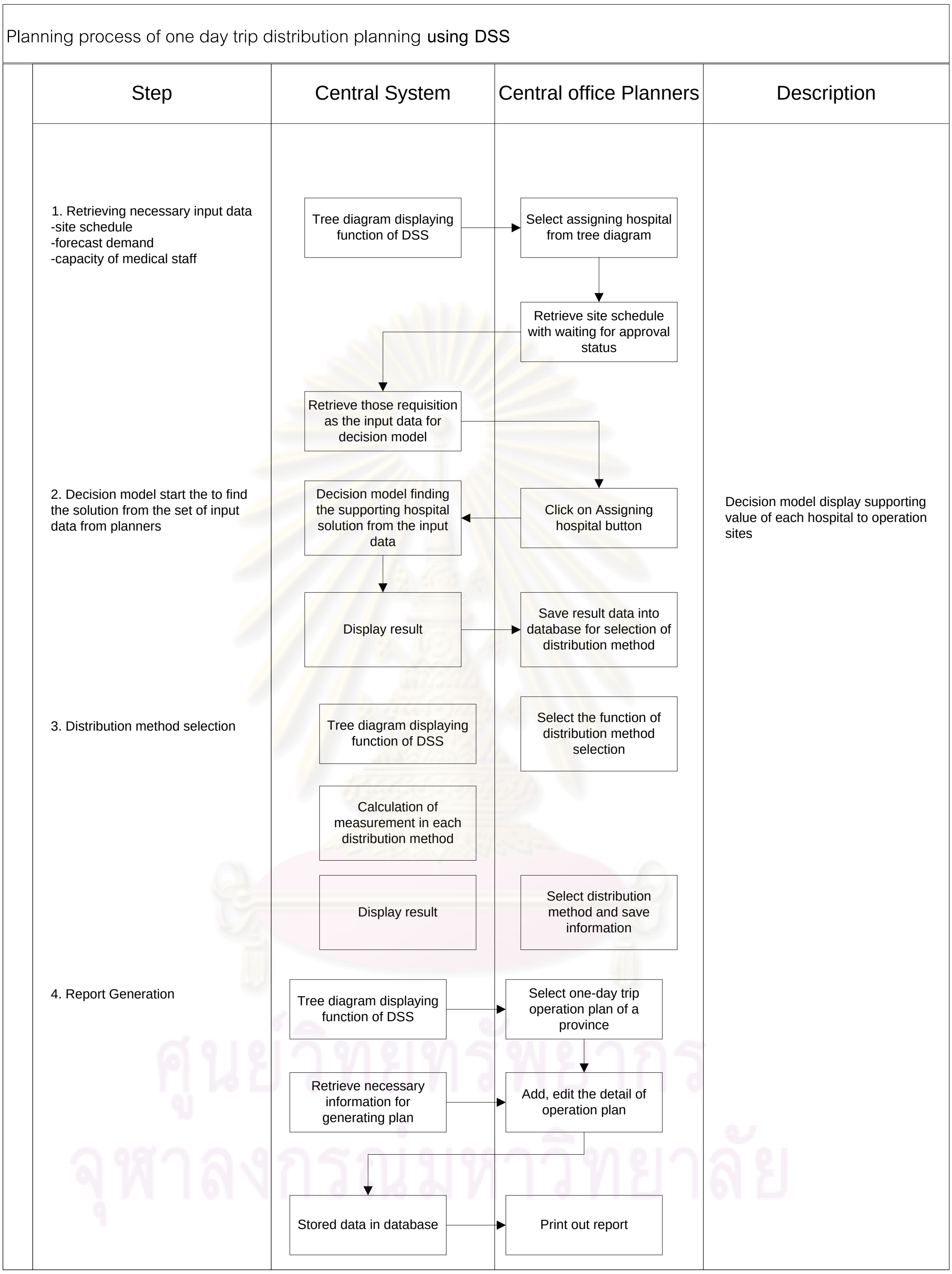


Figure 6. 7 Planning process of one day trip distribution planning using DSS

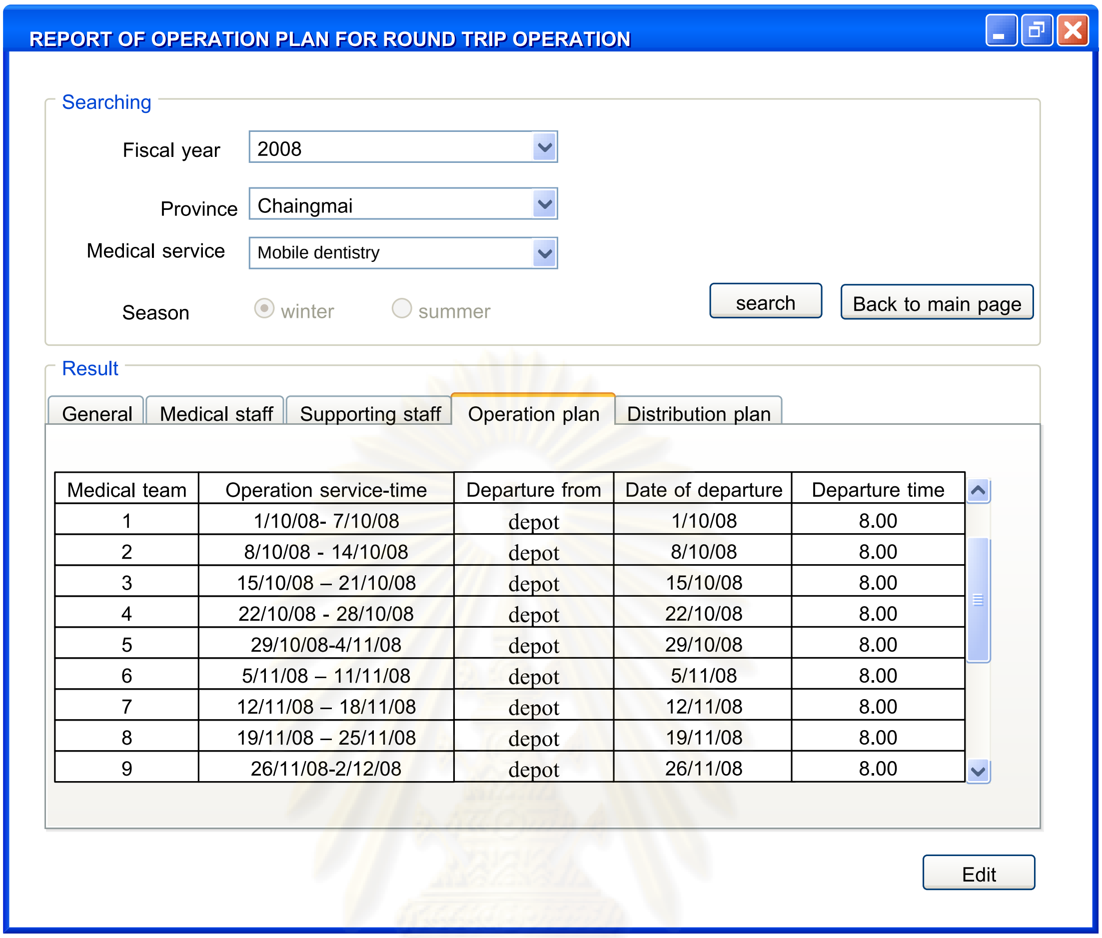
- Reports

In the developed decision support system of medical staffs and supplies distribution planning for mobile medical service, there are four reports that can be printed from the system. Table 6.6 shows the lists of reports and description of each report

Table 6. 6 lists of reports and description of each report

No. of report	Name	Description
1	Operation Route Display	The display of round trip solution from the decision model in operation routing which user can print to see the detail of each operation route.
2	Assigning hospital Display	The display of one day trip solution from the decision model in assigning supporting hospital to operation sites which user can print to see the detail of each supporting value.
3	Distribution Plan for one day trip	The distribution plan concerning the supporting hospitals to each of schedule operation sites; detail of supported medical staffs, distribution method, detail of loaded medical supplies,etc.
4.	Operation Plan for round trip	Operation schedule in each trip, required number of medical staff in medical team, number of vehicle used, detail of loaded medical supplies, etc.

The example of GUI in creating reports of operation plan for round trip distribution planning from the decision support system is shown below in Figure 6.8; however, the detail of all reports including detail of each GUI is in Appendix D



Medical team	Operation service-time	Departure from	Date of departure	Departure time
1	1/10/08- 7/10/08	depot	1/10/08	8.00
2	8/10/08 - 14/10/08	depot	8/10/08	8.00
3	15/10/08 – 21/10/08	depot	15/10/08	8.00
4	22/10/08 - 28/10/08	depot	22/10/08	8.00
5	29/10/08-4/11/08	depot	29/10/08	8.00
6	5/11/08 – 11/11/08	depot	5/11/08	8.00
7	12/11/08 – 18/11/08	depot	12/11/08	8.00
8	19/11/08 – 25/11/08	depot	19/11/08	8.00
9	26/11/08-2/12/08	depot	26/11/08	8.00

Figure 6. 8 GUI for creating report of operation plan for round trip distribution planning

Objective: To present the detail of operation plan and departure place, time and date in order that medical staffs can be waiting on the departure date at the right place and right time

Operation details: User can edit the detail of departure place and time for the practical appropriateness; however, departure date is not allowed to be changed including the operation service-time and medical team in the each trip. This report can be printed.

6.4 Decision support system evaluation

The DSS evaluation is done by picking up each decision module to test for any error that may occur during the usage of the decision support system. This approach of testing can be considered as white box testing which in this research consists of the testing of input data correctness in each step of decision support system module.

6.4.1 Testing of input data correctness

This testing is designed to test the correctness of input data including setup data, input data and supporting data before entering into the data processing of decision model. This information affects the capability in finding solution of decision model. Errors which can occur in input data are:

- Error of data entering
  - Detail of operation site; users may make mistake in data entering or incomplete data keying which may lead to the mistakenly pinpoint the operation site leading to miscalculation of operation route in round trip distribution planning and miscalculation of assigning the supporting hospital in one-day trip distribution planning due to the variance in distance between the operation site to hospitals, supply warehouse and other operation sites.
  - Detail of service-time period; user may make mistake in data keying of the available date, season or month of any service-time period which may lead to fatal error in solution of operation route in round trip distribution planning

To prevent the error in data keying, data examination before being stored in database including redundancy data detection and notification is designed into the system.

- Error of retrieving necessary data
  - Detail of capacity of each type of medical staffs of hospital; the capacity of each type of medical staffs of hospital is retrieved from the database that stores the data of volunteer local medical staffs available to work on the month of operation schedule at each hospital. If the data retrieving of the program mistakenly retrieves

this information from the database which can be occurred when the information is retrieved and updated elsewhere not through the program module, it will lead to the fatal error in assigning supporting hospitals without the correct information of medical staffs' capacity of that hospitals; therefore, the one-day distribution plan will be inaccurate and unpractical.

- Detail of forecasted number of medical staffs required at each operation site; this information is the most important information for assigning supporting hospitals to operation sites. Therefore, if there are mistakes in retrieving data from the forecasting system of the main database and there is missing information of some operation site, it may lead to fatal miscalculation of supporting hospitals.

To prevent the mistake in data retrieving is to defy the status of retrieved data that are retrieved and act as the supporting data in decision model of the developed decision support system; however, by defying data status may not help improve the correction of data in the case of data changing without passing any of the program module; therefore, the changing data are not stored at the main database.

The developed decision support system is the application designed to help support decision making in medical staffs and supplies distribution planning for mobile medical service. The decision support system can be used to plan the distribution of round trip distribution and one-day trip distribution according to users' requirement. The limitations of the developed decision support system:

- In each operation date, there is only one operation site.
- The operation route will not exceed the number of service-time period
- User can add, edit and delete operation sites before start the calculation of decision model
- In each operation date of one-day trip, user can only select one distribtuion method

- To input distance data, the Google Map application is available to find the exact solution between any two places

CHAPTER VII

CONCLUSION AND RECOMMENDATIONS

This research aims to develop the decision support system to help planning officers to efficiently plan the distribution plan of medical staffs and supplies to operation sites. The scope of the research is to develop the decision models for round trip distribution and one-day trip distribution under normal operation of mobile medical service and necessary information are known in advance before planning. The planning process is static planning for yearly plan of mobile medical service.

7.1 Conclusion of the research

To conclude the research, four topics are classified to described the entire work of the research that are;

- Operation routing and assignment model applied
- Data collection
- Design of decision model
- Structure of decision support system
- System evaluation

7.1.1 Operation routing and assignment model

From the Literature Review, vehicle routing problem is applied to be in the decision model of round trip distribution planning to decide the operation route and required medical staffs in each medical team of each service-time period. The objective function of the decision model is to minimize total distances in operation reflecting the reduction in transportation cost during the delivery. Since each medical staffs are voluntarily registered to operate at the operation site, the cost of medical remuneration and other fixed cost are excluded in the scope of the decision model. Distance is the most distinctive measurement to plan the appropriate operation route.

Assignment model is used to formulate the problem in assigning supporting hospitals to support medical staffs and supplies to schedule operation sites. The objective is to minimize the total distance travel from all supporting hospitals to all operation sites. By the approach, it can lessen the difficulties in selecting auxiliary hospitals of medical staffs to operate at the operation site.

To find the solution of decision model, there are many approaches such as exact algorithms and heuristic, this research also applies the most adopted Heuristic applied in real-practice cases of many companies: the saving algorithm, since it gives solution with acceptable quality in reasonable computing time. Moreover, by using the approach, the decision support system can be more comprehensive and easier in developing the program coding. However, the decision model proposed in this research is not the methodology leading to the optimized solution of the problem.

7.1.2 Data collection

The data collection in this research is the observation of real practice in mobile medical service planning process and service operations in order to understand more in the operations of mobile medical service. From the observation, it leads to the realization of problems and difficulty that planning officers have met during the planning process; moreover, due to the fact that the studied organization has many involved associates in providing mobile medical service, it leads to cumbersome problems in planning, coordinating and collaboration among all involved agents in mobile medical service. For example, in round trip planning, the process usually takes one or two month in generating operation routes until the consensual agreement of both local officer and central office perspectives are fulfilled. This leads to many redundant processes in planning and time wasted. From the observation, there are other forms of new distribution methods for the organization furnishing to reduce distances from supporting hospitals to operation sites. Those new methods are introduced in the research for planners can choose proper distribution method appropriate to geographical characteristic and prioritized measurement.

7.1.3 Decision model

The developed decision model in round-trip planning includes the preliminary routing and improvement of preliminary routing for round trip distribution planning. In one-day trip, the decision model to help assign supporting hospital is proposed. The preliminary routing follows the searching procedure:

- Create initial route of all requested operation sites
- Merging routes the same specific requirement in service-time period together into an operation route of that time period
- Merging other operation sites into operation route of service-time period until the number of operation sites equals to the numbers of available working day of the service-time period

The improvement heuristic applies the 2-opt algorithm to improve within route operation sequence. By cutting off two connecting arcs and revert the sequence of operation sites within the route until there is no cutting off pattern that leads to the positive gain value. The within route improvement help greatly in lessen the total distance from the preliminary routing using saving algorithm.

In one day trip distribution planning, assignment model is applied to formulate the problem. The searching solution procedure can be divided into four phase of which screening criterion for potential hospitals is different. The searching procedure of the decision model is:

- Screening and creating the list of potential hospital
- In each time of screening and the case of combination in the same set of hospitals can support to more than one operation site; assignment problem is applied to find the solution by using linear programming approach which leads to the optimal solution in every sub problems of the combination.
- After the supporting value is recorded, the distribution methods' measurement is calculated in order that users can select the most appropriate distribution method from their prioritized measurement.

7.1.4 The structure of decision support system

The structure of the decision support system can be divided into 3 parts;

- Retrieving necessary information for calculation
- Data processing and calculation of decision model
- Reports

The necessary information for calculation:

- Service-time period
- Detail of each province
- Lists of approved operation sites
- Specific requirement of service-time period (Optional)
- Deterministic forecasted demand of medical staffs and supplies at each site during specific time period
- Distance
- Type and quantity of volunteer medical staffs in each hospital in each month of each province

The data processing starts when all required information are retrieved from the main database through the interactions between user and the system via Graphic User Interface (GUI). The designed GUI is simply designed to match with the current planning process of organization as much as possible with less additional modules in planning operations. Decision model calculation procedures are hidden from users and only display the result of operation routing in roundtrip distribution planning and the result of supporting hospitals in one day trip distribution planning.

7.1.5 System evaluation and testing

The system evaluation and testing is classified into 3 testing method; the correctness of the model, the efficiency of decision model and user satisfaction evaluation.

The correctness testing aims to test the validation of input data as well as work flow of the developed decision support system including the capability of finding solution of decision model. The testing result shows that there may be some error occurring during the data and information retrieving from the database of the decision support system. Therefore, the developed system includes the status of input data especially the status of each requisition operation site in order that the same data would not be retrieved twice as the input of decision model. Moreover, in the setup data process, the decision support system develops notification when users are going to make mistakes in data entering such as redundant data entering.

The robustness of decision model is tested by generic test cases which is the real data from mobile dentistry operation route in different conditions and patterns which may occur during the requisition of operation site in both round trip planning and one-day trip planning. The result shows that the decision model has the capability of finding feasible solution for all generic test cases within the acceptable computing time.

The efficiency of the decision models is to compare the solution of the decision model with the current approach of the studied organization due to the fact that the problem occurs in this research is different from pervious researches; the optimized solution cannot be found easily. The decision model of round trip planning to generate operation route of each service-time period can find the solution better than the current approach of the studied organization by 10.86% of total distance only when the preliminary routes are improved through the within route improvement heuristics, This indicates that the improvement phase of preliminary routing is very crucial for operation routing in generate round trip distribution plan.

The efficiency testing in one-day trip planning applies the same approach as that of the round trip distribution planning. The real data and information are received from Ratchaburi province's mobile medical service plan since it is the only province with the decision result of assigning supporting hospitals to operation site. Moreover, in the same test data, transportation model approach is also used to compare the quality level with the proposed decision model. The result shows that the proposed decision model leads to least total travel distance from supporting hospitals to operation sites. The current approach leads to higher total distance because the medical staffs are form many hospitals to operate at the operation sites as well as the solution from the transportation problem approach. The proposed decision model leads to less total distance due to the fact that medical staffs are mostly from the same hospitals with the capacity to support all requirement of operation site in 1-1 relationship. Moreover, transportation approach leads to higher computing time due to the fact that at each operation site, there are four types of medical staffs required to do the task so the variables to generate linear programming model increases drastically when the numbers of hospitals increase as well as the numbers of operation site.

The user satisfaction evaluation is conducted to evaluate that the decision support system. From the statistical analysis of the questionnaires distributed to the experiment sample, future users of the developed decision support system are satisfied with the concept of the system and note that the developed system has high possibility in implementing into the planning process of mobile medical service.

7.2 Limitation of the developed decision support system

The developed decision support system can effectively and efficiently find the acceptable quality of solution of round trip distribution planning and one-day trip distribution planning under the constraints and assumption that

- In each operation data, there are only one operation site.

The decision model can find the solution when this assumption is true; however, in real practice, there can be many mobile medical units at the same operation date in the same province. Those units are operating closely to one another; as a result, the distance from one unit to another is not significant to change the solution of operation route. Therefore, it can be assumed that one operation site is operating on one operation date.

- During each month of one-day trip service operation, each medical staff can operate once on one operation site.

To assign supporting hospital to operation site, this assumption must be true. If one medical staff can operate in many times during the planning focused month, the decision model cannot return the efficient solution since in the developed model, if hospital is assigned to support the operation site, the capacity of medical staff of that hospital reduces until all medical staffs are used up which means that the hospital have no capacity to support medical staffs to any operation site. However, is the assumption is not true, once hospital is assigned to support the operation sites, in the developed decision model approach, the capacity of medical staff does not reduce leading to the repeatedly assignment of the hospital to support medical staffs to other operation sites if the hospital is closed to those operation sites and have enough capacity to support medical staffs. As a result, only the medical staffs in the hospital have to operate in many operation sites leading to high work load of medical staffs. Therefore, the decision model can find the effective and efficient solution of assigning supporting hospital once the assumption is true.

- Medical supplies are ready to be distributed when reach the operation schedule

In the developed, decision support system it is assumed that the medical supplies are readily waiting to be transport to the operation sites at supply warehouse. Therefore, the quantity of medical supplies in the warehouse is not included in the decision model. However, if there are factors concerning the capacity of supply warehouse is included, the decision model cannot find the feasible solution in this situation since there are another emerging factors leading to significant changes in assigning supporting hospital strategy such as the requisition period and order quantities of medical supplies in order that the supplies can be distributed in time of operation schedule.

- There are unlimited number of vehicles in transportation

In this decision support system, the number of vehicles for transportation is unlimited since in real practice, the studied organization can find adequate numbers of vehicles to transported medical staffs to operation sites. Therefore, the studied organization is not burdened with the fixed cost of hiring vehicles to use in operation; only the numbers of vehicles is required for the planning stage. Therefore, the decision model is assumed that there are unlimited numbers of vehicles in transportation. However, if the number of vehicles is limited in round trip distribution planning, it may affect the decisions in operation route concerning the numbers of medical staffs in medical team during each trip since there are limited vehicles to transport medical staffs to operation sites; therefore, the total member of each medical team cannot exceed the total capacity of available vehicles.

- The mobile medical service are operating at normal distribution to cure primary care disease

In this research, only the mobile medical service in normal operation is studied excluding the mobile medical in emergency situation, epidemic and natural disasters. This due to the fact that mobile medical service in normal operation is different in planning process and focused objectives as those of mobile medical service in natural disaster or emergency case. The decision model cannot be adapted to use in those situation since there are many other factors affecting the solution strategy of the decision model.

7.3 Recommendations

The developed decision support system can be further researched to improve the medical staffs and supplies distribution planning especially in the concepts of decision model due to the fact that, at this stage, decision model can only find the acceptable quality of solution in both round trip distribution and one-day trip planning. Further researches can use in-depth analysis approach to develop the decision model to be able to find the optimized solution in operation route planning or assigning supporting hospitals. These are recommendation for further research of decision support system for medical staffs and supplies distribution planning.

- In operation route planning, only distance is used as the measurement in the strategy of decision model of applying saving algorithm to find the solution of operation route of each service-time period. Due to the fact that the efficiency of saving algorithm decreases when the problem size is bigger. Other searching algorithm can be applied instead of saving algorithm such as Meta-Heuristics searching methods such as Tabu search, Genetic Algorithm or Ant Colony Optimization or even using dynamic programming to find the optimized solution of operation route of each time period.

- The planning process of the developed decision support system is static and forward for generating the yearly operation plan. Demands of medical staffs of each operation site are deterministic and known in advance. To complicate the problem furnishing to better quality of operation route solution and further development of decision support system, the demand of medical staffs can be in a form of stochastic demand with possibility value of the medical staff demand at specific period. Moreover, the planning process should be in dynamic environment: necessary information is revised continually as the planning process is going on.

- The objective function in this research is applied total distance as the only factor reflecting total transportation cost. To complicate the problem furnishing to optimized solution of operation route, total transport cost function can be applied in order that the solution from decision model can truly reflect the reduction the transportation cost of mobile medical distribution.

- In assigning supporting hospital to support medical staffs to operation site, transportation model can lead to the proper number of medical staffs from a supporting hospital to operation site instead of using the supporting strategy of the assignment model approach in this research; however, the numbers of variable may be boundless according to the numbers of hospitals in the province, numbers of scheduled operation sites and type of medical staffs. Therefore, there is an opportunities for further research to use the transportation approach in finding solution of assigning supporting hospitals to operation sites by using heuristics to cut off some combinations of variables using transportation approach

- The improvement heuristic of preliminary routing in this research restricted only in within route improvement or preliminary solution since the within route improvement can give a satisfactory quality of operation route. For future research, other approaches can be applied to improve the solution of preliminary route to find the better solution or even optimized solution of operation route.

- In assigning supporting hospitals to support medical staffs and supplies to operation sites is under the assumption that in a month medical staffs can operate at exactly one operation site. Therefore, to further research of the problem, there should be other constraints such as some medical staffs can operate at many operation sites in a month. This complicates the strategy of decision model in finding the solution.

In the information system structure of the developed decision support system, these are recommendation for further research or improvement of the system.

- The distribution method is restricted to a single pattern in distributing medical staffs and supplies from its auxiliary hospitals to operation site. For further research, distribution method can be mixed to distributing medical staffs from hospitals in one operation date.

These are recommendations for future development of decision support system for medical staffs and supplies distribution planning which may lead to higher efficiency of the DSS to help planners to efficiently plan the distribution of medical staffs and supplies. By having the DSS which can efficiently and smartly plan the distribution planning can reduce risks of depending solely on the experience of planners that is individually varied depending on planner's knowledge of province geographical characteristics and working history.

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Appendix

Appendix A

Appendix A: Involving agents interview

Table A- 1: List of Interview Details with Local Public Health Officers

Local Public Health Officers had been interviewed in order to understand the mobile medical service planning process in the stage of operation sites requisition. Criteria that planners need to consider before making a requisition of operation sites are distance from operation site to local hospitals, numbers of expected patients and disease characteristics. Table A-1 presents the summary of interview detail by each response from local public health office.

Auxiliary Source	Interviewee	Interview Date	Detail
Local Public Health (Lom Sak) Phetchabun Province	Kason Katmanee	14 March 2009	1. Types of medical services provided at Lom Sak including responsibilities of local public health office in mobile medical service 2. Characteristics on transportation of medical staffs and supplies to support service operation at operation site

Table A- 2: List of Interview Details with Provincial Public Health Officers

Provincial Public Health Officers had been interviewed in order to understand the mobile medical service planning process in the stage of supporting hospital selection, medical supplies preparation, operation plan creation and medical staffs and supplies distribution. Criteria that planners need to consider before making decisions on choosing the supporting hospitals to support medical staffs to operation sites are distance from supporting hospitals to operation site, numbers of volunteer medical staffs in each hospitals and medical staff available time for operation. Table A-2 presents the summary of interview detail by each response from provincial public health office.

Auxiliary Source	Interviewee	Interview Date	Detail
Provincial Public Health Khon Kean Province	Doctor Kimhan Yongratanakit	22 March 2552	- Characteristics on transportation of medical staffs and supplies to support service operation at operation site - Supply warehouse management: replenishment system, ownership of medical supplies
Provincial Public Health Ratchaburi Province	Chernchit Peukhom	22 March 2552	Characteristics on transportation of medical staffs and supplies to support service operation at operation site
Provincial Public Health Prachuapkhirikhan Province	Doctor Nathapong Chaisiri	22 March 2552	Characteristics on transportation of medical staffs and supplies to support service operation at operation site

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Table A- 3: List of Interview Details with Central Planning Officer of The Princess Mother's Medical Volunteer Foundation

Central planning officers of the foundation had been interviewed in order to understand the mobile medical service planning process in the stage of operation routing, selecting operation sites from requisition, local officers' coordination and supplies preparation and distribution. In the interviews, two service operations' distribution planning process including mobile dentistry and mobile oculist are examined in order that the criteria that planners need to consider before making decisions on operation routing are comprehended. As a result, it leads to the design of DSS which complies with the previous planning process of the foundation as much as possible. Table A-3 presents the summary of interview detail by each response from planning officers of central office.

Auxiliary Source	Interviewee	Interview Date	Detail
Planning Officer	Uma Chantasiri	March 2009 – September 2010	Planning process of mobile medical service in normal mobile medical service and mobile ophthalmologist.
Planning Officer	Viseth Intan	March 2009 – September 2010	Planning process of mobile medical service in mobile dentistry service including - Realistic constraints in operations - Transportation nature of the mobile dentistry service - Preparation of medical staffs and supplies for distribution - Time table of planning process

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Table A- 4: List of Interview Details with Central Planning Officer of The Princess Mother's Medical Volunteer Foundation

Auxiliary Source	Interviewee	Interview Date	Detail
Planning Officer	Narong Popriroth	March 2009	Planning process of mobile medical service in mobile dentistry service - Transportation of medical staffs - Volunteer medical staffs registration
Planning Officer	Perdtipong Ratanayomngamdee	March 2009	Planning process of mobile medical service in mobile dentistry service including - Realistic constraints in operations - Transportation nature of the mobile dentistry service - Preparation of medical staffs and supplies for distribution - Vehicle used in transportation

Appendix B

Appendix B: Testing data

B-1 Service time period of Chiangmai Province

Table B-1 shows the service-time period of mobile dentistry service of Chiangmai Province in fiscal year 2008; there are 9 service-time periods.

Table B- 1: Service-time period

Service-time_id	Duration	No. of Working days
1	1 Oct - 7 Oct	5
2	8 Oct - 14 Oct	5
3	15 Oct - 21 Oct	5
4	22 Oct - 28 Oct	5
5	29 Oct - 4 Nov	5
6	5 Nov - 11 Nov	5
7	12 Nov - 18 Nov	5
8	19 Nov - 25 Nov	5

B-2 Generic test case for round trip distribution planning

There are 5 generic test cases created as the computational experiment to test the efficiency of decision model in operation routing as well as the robustness of decision model in possible input data' characteristics or input data' situation. Each test case has different patterns of specific requirement in service-time period. These are 5 generic test cases for testing decision model of round trip planning. The distance data are real distance of real operation sites in fiscal year 2008 plan of mobile dentistry service.

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Table B- 2: Test case 1

Test case 1 represents the situation that in the input data, every node has no specific requirement in service-time period. This test case is the real situation of mobile dentistry service plan of Chiangmai province in the fiscal year 2008. This test case is designed to test the efficiency of decision model compared to the current organization approach.

Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O1	Ban Tung Yuo	บ้านทุ่งยั๊วะ	5	5	-
O2	Meung Kut	รร.เมืองกื๊ด	5	5	-
O3	Huai fuk Dap	ศศช.ห้วยฝักดาบ	5	5	-
O4	Kae Noi Suksa	รร. แกน้อยศึกษา	5	5	-
O5	Chalermprakriet	รร.ตชดเฉลิมพระเกียรติ	5	5	-
O6	Sam Meun	ตชดสามหมื่น	5	5	-
O7	Num Ru	บ้านน้ำรู	5	5	-
O8	Hua Mae Moeng	บ้านหัวแม่เมือง	5	5	-
O9	Doi Sam Meurn	รร.ดอยสามหมื่น	5	5	-
O10	Huai Pra Jao	ห้วยพระเจ้า	5	5	-
O11	Mae Sa Top	รรแม่สะต็อบ	5	5	-
O12	Mae Jum Sam	แม่จุ่มสาม	5	5	-
O13	Ohm Lan	รร.อมลาน	5	5	-
O14	Ngan Luang	รร.แม่หงานหลวง	5	5	-
O15	Ban Pui	บ้านพุย	5	5	-
O16	Ban Mae Long Tai	บ้านแม่ล่องใต้	5	5	-
O17	Ou Lo Kee Lang	โอโลคีล่าง	5	5	-

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O18	Pa deng	ตชด ผาแดง	5	5	-
O19	Tee Lee Per Kee	ทีเลอเปอคี	5	5	-
O20	Long Pae	ล่องแพ	5	5	-
O21	Tung Ting	ตุงติง	5	5	-
O22	Mae Ang Kang	แม่อ่างข่าง	5	5	-
O23	Mae Lai Duaung Jan	แม่ลายดวงจันทร์	5	5	-
O24	Mae Pok Bon	แม่ป๊อกบน	5	5	-
O25	Doi Luang	ดอยหลวง	5	5	-
O26	Lang Pa Ka	หลังป่าข่า	5	5	-
O27	Sob Lan	สบลาน	5	5	-
O28	Huai Kai Pa	ห้วยไก่ป่า	5	5	-
O29	Lu Ku Do	ลูกูดู	5	5	-
O30	Huai Ka Noon	ห้วยขนุน	5	5	-
O31	Pa Ka She	พะกะเซ	5	5	-
O32	Ma Ou Jo	หม่าโอโจ	5	5	-
O33	Tung Ton Kyou	ทุ่งต้นงิ้ว	5	5	-
O34	Le Tor	เลอะตอ	5	5	-
O35	Huai Nam Kun	ห้วยน้ำขุ่น	5	5	-
O36	Khon Muang	ขอนม่วง	5	5	-
O37	Huai Nam Rin	ห้วยน้ำริน	5	5	-
O38	Huai Pong	ห้วยปง	5	5	-
O39	Huai E go	ห้วยอีโก้	5	5	-
O40	Huai Pa Kak	บ้านห้วยป่าแขก	5	5	-
O41	Huia Muang Nai	บ้านห้วยม่วงใน(แม่นาวาง)	5	5	-

Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O44	Viang Na Pa	เวียงนาผา	5	5	-
O42	Pang Poi	ปางปอย	5	5	-
O43	Pong Juk Mai	โป่งจ็อกใหม่	5	5	-

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Table B- 3: Test case 2

Test case 2 represents the situation that there are some service-time period that the number of requested operation sites to have mobile medical service operate during the service-time period exceeds the number of available working days. This test case is designed to test whether the decision model can find the feasible solution and suggested date of operation to the sites that cannot be arranged as required service-time period.

Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O1	Ban Tung Yuo	บ้านทุ่งยั๊วะ	5	5	1
O2	Meung Kut	รร.เมืองกื้ด	5	5	2
O3	Huai fuk Dap	ศศช.ห้วยฝักดาบ	5	5	3
O4	Kae Noi Suksa	รร. แกน้อยศึกษา	5	5	-
O5	Chalermprakriet	รร.ตชดเฉลิมพระเกียรติ	5	5	-
O6	Sam Meun	ตชดสามหมื่น	5	5	-
O7	Num Ru	บ้านน้ำรู	5	5	-
O8	Hua Mae Moeng	บ้านหัวแม่เมือง	5	5	1
O9	Doi Sam Meurn	รร.ดอยสามหมื่น	5	5	-
O10	Huai Pra Jao	ห้วยพระเจ้า	5	5	-
O11	Mae Sa Top	รรแม่สะต๊อบ	5	5	-
O12	Mae Jum Sam	แม่จุ๋มสาม	5	5	6
O13	Ohm Lan	รร.อมลาน	5	5	-
O14	Ngan Luang	รร.แม่หงานหลวง	5	5	3
O15	Ban Pui	บ้านพุย	5	5	3
O16	Ban Mae Long Tai	บ้านแม่ล่องใต้	5	5	-
O17	Ou Lo Kee Lang	โอโลคีล่าง	5	5	-

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O18	Pa deng	ตชด ผาแดง	5	5	-
O19	Tee Lee Per Kee	ทีเลอเปอคี	5	5	1
O20	Long Pae	ล่องแพ	5	5	-
O21	Tung Ting	ตุงติง	5	5	-
O22	Mae Ang Kang	แม่อ่างข่าง	5	5	7
O23	Mae Lai Duaung Jan	แม่ลายดวงจันทร์	5	5	3
O24	Mae Pok Bon	แม่ป๊อกบน	5	5	-
O25	Doi Luang	ดอยหลวง	5	5	-
O26	Lang Pa Ka	หลังป่าข่า	5	5	-
O27	Sob Lan	สบลาน	5	5	-
O28	Huai Kai Pa	ห้วยไก่ป่า	5	5	3
O29	Lu Ku Do	ลูกูดู	5	5	-
O30	Huai Ka Noon	ห้วยขนุน	5	5	-
O31	Pa Ka She	พะกะเซ	5	5	-
O32	Ma Ou Jo	หม่าโอโจ	5	5	-
O33	Tung Ton Kyou	ทุ่งต้นงิ้ว	5	5	8
O34	Le Tor	เลอะตอ	5	5	-
O35	Huai Nam Kun	ห้วยน้ำขุ่น	5	5	-
O36	Khon Muang	ขอนม่วง	5	5	-
O37	Huai Nam Rin	ห้วยน้ำริน	5	5	4
O38	Huai Pong	ห้วยปง	5	5	-
O39	Huai E go	ห้วยอีโก้	5	5	-
O40	Huai Pa Kak	บ้านห้วยป่าแขก	5	5	9
O41	Huia Muang Nai	บ้านห้วยม่วงใน(แม่นาวาง)	5	5	-

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Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O42	Pang Poi	ปางปอย	5	5	9
O43	Pong Juk Mai	โป่งจ็อกใหม่	5	5	3
O44	Viang Na Pa	เวียงนาผา	5	5	1

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Table B- 4: Test case 3

Test case 3 represents the situation that there are some service-time period that have no operation sites with the specific requirement to have mobile medical service operate during that service-time period.

Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O1	Ban Tung Yuo	บ้านทุ่งยั๊วะ	5	5	1
O2	Meung Kut	รร.เมืองกึ๊ด	5	5	2
O3	Huai fuk Dap	ศศช.ห้วยฝักดาบ	5	5	-
O4	Kae Noi Suksa	รร. แกน้อยศึกษา	5	5	-
O5	Chalermprakriet	รร.ตชดเฉลิมพระเกียรติ	5	5	-
O6	Sam Meun	ตชดสามหมื่น	5	5	-
O7	Num Ru	บ้านน้ำรู	5	5	-
O8	Hua Mae Moeng	บ้านหัวแม่เมือง	5	5	-
O9	Doi Sam Meurn	รร.ดอยสามหมื่น	5	5	-
O10	Huai Pra Jao	ห้วยพระเจ้า	5	5	1
O11	Mae Sa Top	รรแม่สะต็อบ	5	5	-
O12	Mae Jum Sam	แม่จุ๋มสาม	5	5	-
O13	Ohm Lan	รร.อมลาน	5	5	-
O14	Ngan Luang	รร.แม่หงานหลวง	5	5	-
O15	Ban Pui	บ้านพุย	5	5	-
O16	Ban Mae Long Tai	บ้านแม่ล่องใต้	5	5	-
O17	Ou Lo Kee Lang	โอโลคีล่าง	5	5	-
O18	Pa deng	ตชด ผาแดง	5	5	1

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O19	Tee Lee Per Kee	ทีเลอเปอคี	5	5	-
O20	Long Pae	ล่องแพ	5	5	-
O21	Tung Ting	ตุงติง	5	5	-
O22	Mae Ang Kang	แม่อ่างข่าง	5	5	-
O23	Mae Lai Duaung Jan	แม่ลายดวงจันทร์	5	5	-
O24	Mae Pok Bon	แม่ป๊อกบน	5	5	-
O25	Doi Luang	ดอยหลวง	5	5	-
O26	Lang Pa Ka	หลังป่าข่า	5	5	-
O27	Sob Lan	สบลาน	5	5	2
O28	Huai Kai Pa	ห้วยไก่ป่า	5	5	-
O29	Lu Ku Do	ลูกูดู	5	5	-
O30	Huai Ka Noon	ห้วยขนุน	5	5	-
O31	Pa Ka She	พะกะเช	5	5	-
O32	Ma Ou Jo	หม่าโอโจ	5	5	-
O33	Tung Ton Kyou	ทุ่งต้นงิ้ว	5	5	-
O34	Le Tor	เลอะตอ	5	5	-
O35	Huai Nam Kun	ห้วยน้ำขุ่น	5	5	-
O36	Khon Muang	ขอนม่วง	5	5	7
O37	Huai Nam Rin	ห้วยน้ำริน	5	5	2
O38	Huai Pong	ห้วยปง	5	5	-
O39	Huai E go	ห้วยอีโก้	5	5	6
O40	Huai Pa Kak	บ้านห้วยป่าแขก	5	5	-
O41	Huia Muang Nai	บ้านห้วยม่วงใน(แม่นาวาง)	5	5	-
O42	Pang Poi	ปางปอย	5	5	9

O43	Pong Juk Mai	โป่งจ็อกใหม่	5	5	4
O44	Viang Na Pa	เวียงนาผา	5	5	1

Table B- 5: Test case 4

Test case 4 represents the situation that every service-time period that have some operation sites with the specific requirement to have mobile medical service operate during that service-time period.

Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O1	Ban Tung Yuo	บ้านทุ่งยั๊วะ	5	5	1
O2	Meung Kut	รร.เมืองกึ๊ด	5	5	-
O3	Huai fuk Dap	ศศช.ห้วยฝักดาบ	5	5	-
O4	Kae Noi Suksa	รร. แกน้อยศึกษา	5	5	-
O5	Chalermprakriet	รร.ตชดเฉลิมพระเกียรติ	5	5	-
O6	Sam Meun	ตชดสามหมื่น	5	5	2
O7	Num Ru	บ้านน้ำรู	5	5	-
O8	Hua Mae Moeng	บ้านหัวแม่เมือง	5	5	-
O9	Doi Sam Meurn	รร.ดอยสามหมื่น	5	5	-
O10	Huai Pra Jao	ห้วยพระเจ้า	5	5	-
O11	Mae Sa Top	รรแม่สะต็อบ	5	5	3
O12	Mae Jum Sam	แม่จุ๋มสาม	5	5	-
O13	Ohm Lan	รร.อมลาน	5	5	-
O14	Ngan Luang	รร.แม่หงานหลวง	5	5	-
O15	Ban Pui	บ้านพุย	5	5	-
O16	Ban Mae Long Tai	บ้านแม่ล่องใต้	5	5	4

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O17	Ou Lo Kee Lang	โอโลคีล่าง	5	5	-
O18	Pa deng	ตชด ผาแดง	5	5	-
O19	Tee Lee Per Kee	ทีเลอเปอคี	5	5	-
O20	Long Pae	ล่องแพ	5	5	-
O21	Tung Ting	ตุงติง	5	5	5
O22	Mae Ang Kang	แม่อ่างข่าง	5	5	-
O23	Mae Lai Duaung Jan	แม่ลายดวงจันทร์	5	5	-
O24	Mae Pok Bon	แม่ป๊อกบน	5	5	-
O25	Doi Luang	ดอยหลวง	5	5	6
O26	Lang Pa Ka	หลังป่าข่า	5	5	-
O27	Sob Lan	สบลาน	5	5	-
O28	Huai Kai Pa	ห้วยไก่ป่า	5	5	-
O29	Lu Ku Do	ลูกูดู	5	5	-
O30	Huai Ka Noon	ห้วยขนุน	5	5	7
O31	Pa Ka She	พะกะเช	5	5	-
O32	Ma Ou Jo	หม่าโอโจ	5	5	-
O33	Tung Ton Kyou	ทุ่งต้นงิ้ว	5	5	-
O34	Le Tor	เลอะตอ	5	5	-
O35	Huai Nam Kun	ห้วยน้ำขุ่น	5	5	8
O36	Khon Muang	ขอนม่วง	5	5	-
O37	Huai Nam Rin	ห้วยน้ำริน	5	5	-
O38	Huai Pong	ห้วยปง	5	5	-
O39	Huai E go	ห้วยอีโก้	5	5	-
O40	Huai Pa Kak	บ้านห้วยป่าแขก	5	5	9

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O41	Huia Muang Nai	บ้านห้วยม่วงใน(แม่นาวาง)	5	5	-
O42	Pang Poi	ปางปอย	5	5	-
O43	Pong Juk Mai	โป่งจ็อกใหม่	5	5	-
O44	Viang Na Pa	เวียงนาผา	5	5	1

Table B- 6: Test case 5

Test case 5 represents the situation that there are mixture of some service-time period having no operation sites with the specific requirement to have mobile medical service operate during that service-time period and some service-time period having number of operation sites with the specific requirement does not exceed the available working day of those service-time period and some service-time period having number of operation sites with the specific requirement exceed the available working day of those service-time period.

Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O1	Ban Tung Yuo	บ้านทุ่งยั๊วะ	5	5	1
O2	Meung Kut	รร.เมืองกึ๊ด	5	5	1
O3	Huai fuk Dap	ศศช.ห้วยฝักดาบ	5	5	1
O4	Kae Noi Suksa	รร. แกน้อยศึกษา	5	5	1
O5	Chalermprakriet	รร.ตชดเฉลิมพระเกียรติ	5	5	1
O6	Sam Meun	ตชดสามหมื่น	5	5	1
O7	Num Ru	บ้านน้ำรู	5	5	-
O8	Hua Mae Moeng	บ้านหัวแม่เมือง	5	5	-
O9	Doi Sam Meurn	รร.ดอยสามหมื่น	5	5	-
O10	Huai Pra Jao	ห้วยพระเจ้า	5	5	3
O11	Mae Sa Top	รรแม่สะต็อบ	5	5	3
O12	Mae Jum Sam	แม่จุ่มสาม	5	5	3

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O13	Ohm Lan	รร.อมลาน	5	5	3
O14	Ngan Luang	รร.แม่หงานหลวง	5	5	3
O15	Ban Pui	บ้านพุย	5	5	3
O16	Ban Mae Long Tai	บ้านแม่ล่องใต้	5	5	4
O17	Ou Lo Kee Lang	โอโลคีล่าง	5	5	4
O18	Pa deng	ตชด ผาแดง	5	5	4
O19	Tee Lee Per Kee	ทีเลอเปอคี	5	5	4
O20	Long Pae	ล่องแพ	5	5	4
O21	Tung Ting	ตุงติง	5	5	-
O22	Mae Ang Kang	แม่อ่างข่าง	5	5	5
O23	Mae Lai Duaung Jan	แม่ลายดวงจันทร์	5	5	-
O24	Mae Pok Bon	แม่ป๊อกบน	5	5	-
O25	Doi Luang	ดอยหลวง	5	5	6
O26	Lang Pa Ka	หลังป่าข่า	5	5	-
O27	Sob Lan	สบลาน	5	5	-
O28	Huai Kai Pa	ห้วยไก่ป่า	5	5	-
O29	Lu Ku Do	ลูกูดู	5	5	-
O30	Huai Ka Noon	ห้วยขนุน	5	5	7
O31	Pa Ka She	พะกะเช	5	5	-
O32	Ma Ou Jo	หม่าโอโจ	5	5	-
O33	Tung Ton Kyou	ทุ่งต้นงิ้ว	5	5	-
O34	Le Tor	เลอะตอ	5	5	-
O35	Huai Nam Kun	ห้วยน้ำขุ่น	5	5	8
O36	Khon Muang	ขอนม่วง	5	5	-

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Operation site_id	Name(Eng)	Name(Thai)	Doctors	Nurse	service-time_id
O37	Huai Nam Rin	ห้วยน้ำริน	5	5	-
O38	Huai Pong	ห้วยปง	5	5	-
O39	Huai E go	ห้วยอีโก้	5	5	-
O40	Huai Pa Kak	บ้านห้วยป่าแขก	5	5	9
O41	Huia Muang Nai	บ้านห้วยม่วงใน(แม่นาวาง)	5	5	-
O42	Pang Poi	ปางปอย	5	5	-
O43	Pong Juk Mai	โป่งจ็อกใหม่	5	5	-
O44	Viang Na Pa	เวียงนาผา	5	5	1

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B-3 Solution of generic test case for round trip distribution planning

The solutions from all test cases are received from testing on Intel® Core™ 2 Duo CPU P9600@ 2.66 GHz 1.99 GB of RAM computer. The developed program to test the searching result of decision model is in C++ Language using Visual Studio Professional 2008. Computational time also observed to test the capability of decision model in time used in searching feasible solution. Table B-7 presents the current solution from the fiscal year 2008 plan of mobile dentistry service of Chiangmai Province of the studied organization and Table B-8 shows the solution from decision model in preliminary routing before presenting the improved operation route through Table B-9. Test case 1 is the set of testing data that used to evaluate the efficiency of decision model in finding better solution quality than the current approach of the studied organization since all operation sites have no specific requirement in any service-time period of having mobile medical service operate during the service-time duration.

Table B- 7: Solution from fiscal year 2008 of mobile dentistry service plan (Test Case 1)

Route1	O1	O2	O3	O4	O5	
	บ้านทุ่งยั๊วะ	รร.เมืองกึ๊ด	ศศช.ห้วยฝักดาบ	รร. แกน้อยศึกษา	รร.ตชดเฉลิมพระเกียรติ	Distance
67	16	10	60	16	106	274.84
Route2	O6	O7	O8	O9	O10	
	ตชดสามหมื่น	บ้านน้ำรู	บ้านหัวแม่เมือง	รร.ดอยสามหมื่น	ห้วยพระเจ้า	Distance
109	17	8	17	53	70	274.36
Route3	O11	O12	O13	O14	O15	
	รรแม่สะต็อบ	แม่จุ่มสาม	รร.อมลาน	รร.แม่หงานหลวง	บ้านพุย	Distance
113	3	4	61	5	113	298.49
Route4	O16	O17	O18	O19	O20	
	บ้านแม่ล่องใต้	โอโลคีล่าง	ตชด ผาแดง	ทีเลอเปอคี	ล่องแพ	Distance
175	51	82	58	19	170	554.34
Route5	O21	O22	O23	O24	O25	
	ตุงติง	แม่อ่างข่าง	แม่ลายดวงจันทร์	แม่ป๊อกบน	ดอยหลวง	Distance
142	26	50	22	24	98	361.46
Route6	O26	O27	O28	O29	O30	
	หลังป่าข่า	สบลาน	ห้วยไก่ป่า	ลูกูดู	ห้วยขนุน	Distance
172	12	40	41	39	201	504.32
Route7	O31	O32	O33	O34		
	พะกะเช	หม่าโอโจ	ทุ่งต้นงิ้ว	เลอะตอ		Distance
184	18	28	46	181		456.54
Route8	O35	O36	O37	O38	O39	Distance

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	ห้วยน้ำขุ่น	ขอนม่วง	ห้วยน้ำริน	ห้วยปง	ห้วยอีโก้	
116	18	48	41	59	157	439.36
Route9	O40	O41	O42	O43	O44	
	บ้านห้วยป่าแขก	บ้านห้วยม่วงใน	ปางปอย	โป่งจ็อกใหม่	เวียงนาผา	Distance
171	19	33	40	31	102	396.17
					Total Distance	3559.88

Table B- 8: Solution from preliminary routing of decision model (Test Case 1)

Route1	O5	O1	O2	O3	O4	
	รร.ตชดเฉลิมพระเกียรติ	บ้านทุ่งยั้วะ	รร.เมืองกึ๊ด	ศศช.ห้วยฝักดาบ	รร. แกน้อยศึกษา	Distance
106	92	16	10	60	111	395
Route2	O8	O10	O9	O7	O6	
	บ้านหัวแม่เมือง	ห้วยพระเจ้า	รร.ดอยสามหมื่น	บ้านน้ำรู	ตชดสามหมื่น	Distance
120	33	53	65	17	109	397
Route3	O12	O15	O11	O14	O13	
	แม่จุ๋มสาม	บ้านพุย	รรแม่สะต็อบ	รร.แม่หงานหลวง	รร.อมลาน	Distance
116	82	75	79	61	120	533
Route4	O16	O17	O18	O19	O20	
	บ้านแม่ล่องใต้	โอโลคีล่าง	ตชด ผาแดง	ทีเลอเปอคี	ล่องแพ	Distance
175	51	82	58	19	170	554.34
Route5	O23	O22	O25	O21	O24	
	แม่ลายดวงจันทร์	แม่อ่างข่าง	ดอยหลวง	ตุงติง	แม่ป๊อกบน	Distance
160	50	96	99	93	140	638

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Route6	O29	O26	O28	O27	O30	
	ลูกดู	หลังป่าข่า	ห้วยไก่ป่า	สบลาน	ห้วยขนุน	Distance
234	103	94	40	13	201	685.1
Route7	O32	O31	O34	O33		
	หม่าโอโจ	พะกะเช	เลอะตอ	ทุ่งต้นงิ้ว		Distance
204	18	92	46	223		583
Route8	O36	O38	O35	O37	O39	
	ขอนม่วง	ห้วยปง	ห้วยน้ำขุ่น	ห้วยน้ำริน	ห้วยอีโก้	Distance
157	89	65	48	73	157	589
Route9	O40	O43	O42	O44	O41	Distance
	บ้านห้วยป่าแขก	โป่งจ็อกใหม่	ปางปอย	เวียงนาผา	บ้านห้วยม่วงใน	
171	96	31	44	62	157	561.17
					Total Distance	4935.61

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Table B- 9: Solution from improvement Heuristic of decision model (Test Case 1)

Route1	O2	O1	O3	O4	O5	
	รร.เมืองกึ๊ด	บ้านทุ่งยั๊วะ	ศศช.ห้วยฝักดาบ	รร. แกน้อยศึกษา	รร.ตชดเฉลิมพระเกียรติ	Distance
52	16	14	60	16	106	264
Route2	O9	O6	O7	O8	O10	
	รร.ดอยสามหมื่น	ตชดสามหมื่น	บ้านน้ำรู	บ้านหัวแม่เมือง	ห้วยพระเจ้า	Distance
76	14	17	8	33	70	218
Route3	O11	O12	O13	O14	O15	
	รรแม่สะต็อบ	แม่จุ๋มสาม	รร.อมลาน	รร.แม่หงานหลวง	บ้านพุย	Distance
113	3	4	61	5	113	299
Route4	O18	O20	O19	O16	O17	
	ตชด ผาแดง	ล่องแพ	ทีเลอเปอคี	บ้านแม่ล่องใต้	โอโลคีล่าง	Distance
162	19	19	15	51	209	475
Route5	O22	O21	O23	O24	O25	
	แม่อ่างข่าง	ตุงติง	แม่ลายดวงจันทร์	แม่ป๊อกบน	ดอยหลวง	Distance
127	26	28	22	24	98	325
Route6	O28	O29	O30	O27	O26	
	ห้วยไก่ป่า	ลูกูดู	ห้วยขนุน	สบลาน	หลังป่าข่า	Distance
107	41	39	13	12	172	384
Route7	O31	O32	O33	O34		
	พะกะเช	หม่าโอโจ	ทุ่งต้นงิ้ว	เลอะตอ	โอโลคีล่าง	Distance
184	18	28	46	181		457.12

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Route8	O38	O37	O39	O35	O36	
	ห้วยปง	ห้วยน้ำริน	ห้วยอีโก้	ห้วยน้ำขุ่น	ขอนม่วง	Distance
70	41	73	13	18	157	372
Route9	O40	O41	O42	O43	O44	
	บ้านห้วยป่าแขก	บ้านห้วยม่วงใน(แม่นาวาง)	ปางปอย	โป่งจ็อกใหม่	เวียงนาผา	Distance
171	18	33	31	31	102	386.17
					Total Distance	3180.29

Table B- 10: Solution from improvement Heuristic of decision model (Test Case 2)

Route1	ทีเลอเปอคี	ห้วยไก่ป่า	รร.ตชดเฉลิมพระเกียรติ	บ้านหัวแม่เมือง	บ้านทุ่งยั๊วะ	Distance
	O19	O28	O5	O8	O1	558.46
Route2	โอโลคีล่าง	แม่ป๊อกบน	รร.เมืองกิ๊ด	ตชดสามหมื่น	บ้านน้ำรู	Distance
	O17	O24	O2	O6	O7	336.84
Route3	ห้วยขนุน	ลูกูดู	เวียงนาผา	ศศช.ห้วยฝักดาบ	รร.ดอยสามหมื่น	Distance
	O30	O29	O44	O3	O9	434.08
Route4	ห้วยพระเจ้า	ห้วยปง	ปางปอย	พะกะเซ	บ้านแม่ล่องใต้	Distance
	O10	O38	O42	O31	O16	488.39
Route5	ขอนม่วง	ห้วยป่าแขก	แม่สะต็อบ	หลังป่าข่า		Distance
	O36	O40	O11	O26		588.49
Route6	ห้วยน้ำขุ่น	ตุงติง	รร.แม่หงานหลวง	รร.แม่จุ่มสาม	รร.อมลาน	Distance
	O35	O21	O14	O12	O13	399.5
Route7	ห้วยอีโก้	แม่อ่างข่าง	แม่ลายดวงจันทร์	หม่าโอโจ	บ้านพุย	Distance
	O39	O22	O23	O32	O15	492.24
Route8	ดอยหลวง	เลอะตอ	สบลาน	ตชด ผาแดง	ห้วยน้ำริน	Distance
	O25	O34	O27	O18	O37	441.28
Route9	รร.แกน้อยศึกษา	บ้านห้วยม่วงใน	โป่งจ็อกใหม่	ทุ่งต้นงิ้ว	ล่องแพ	Distance
	O4	O41	O43	O33	O20	519.91
					Total distance	4259.19

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Table B- 11: Solution from improvement Heuristic of decision model (Test Case 3)

Route1	ห้วยพระเจ้า	บ้านทุ่งยั๊วะ	รร.ตชดเฉลิมพระเกียรติ	ทุ่งต้นงิ้ว	ตชด ผาแดง	Distance
	O10	O1	O5	O33	O18	591.25
Route2	รร.เมืองกิ๊ด	ห้วยปง	ล่องแพ	โอโลคีล่าง	ห้วยไก่ป่า	Distance
	O2	O38	O20	O17	O28	380.11
Route3	แม่ลายดวงจันทร์	ห้วยขนุน	ศศช.ห้วยฝักดาบ	ตชดสามหมื่น	รร.แม่จุ๋มสาม	Distance
	O23	O30	O3	O6	O12	382.5
Route4	สบลาน	แม่ป๊อกบน	ปางปอย	เวียงนาผา	บ้านหัวแม่เมือง	Distance
	O27	O24	O42	O44	O8	518.51
Route5	เลอะตอ	แม่อ่างข่าง	บ้านน้ำรู	บ้านห้วยม่วงใน		Distance
	O34	O22	O7	O41		461.02
Route6	รร.แม่หงานหลวง	ทีเลอเปอคี	ห้วยป่าแขก	ขอนม่วง	รร.ดอยสามหมื่น	Distance
	O14	O19	O40	O36	O9	635.07
Route7	ห้วยน้ำริน	ห้วยอีโก้	บ้านแม่ล่องใต้	หม่าโอโจ	บ้านพุย	Distance
	O37	O39	O16	O32	O15	475.99
Route8	ห้วยน้ำขุ่น	ตุงติง	พะกะเช	ดอยหลวง	แม่สะต็อบ	Distance
	O35	O21	O31	O25	O11	384.98
Route9	รร.แกน้อยศึกษา	โป่งจ็อกใหม่	ลูกูดู	หลังป่าข่า	รร.อมลาน	Distance
	O4	O43	O29	O26	O13	751.46
					Total distance	4580.89

Table B- 12: Solution from improvement Heuristic of decision model (Test Case 4)

Route1	รร.เมืองกึ๊ด	บ้านทุ่งยั๊วะ	รร.ดอยสามหมื่น	โป่งจ็อกใหม่	ห้วยไก่ป่า	Distance
	O2	O1	O9	O43	O28	465.95
Route2	ตชดสามหมื่น	บ้านหัวแม่เมือง	บ้านน้ำรู	ห้วยน้ำขุ่น	ลูกูดู	Distance
	O6	O8	O7	O35	O29	481.8
Route3	โอโลคีล่าง	แม่สะต็อบ	รร.อมลาน	ห้วยพระเจ้า	ห้วยอีโก้	Distance
	O17	O11	O13	O10	O39	570.37
Route4	รร.แม่จุ๋มสาม	ห้วยขนุน	สบลาน	บ้านแม่ล่องใต้	ห้วยน้ำริน	Distance
	O12	O30	O27	O16	O37	574.43
Route5	รร.แม่หงานหลวง	แม่ลายดวงจันทร์	หม่าโอโจ	ตุงติง	เวียงนาผา	Distance
	O14	O23	O32	O21	O44	432.3
Route6	รร.แกน้อยศึกษา	บ้านพุย	แม่ป๊อกบน	เลอะตอ	หลังป่าข่า	Distance
	O4	O15	O24	O34	O26	394.25
Route7	แม่อ่างข่าง	พะกะเช	ทุ่งต้นงิ้ว	ตชด ผาแดง	รร.ตชดเฉลิมพระเกียรติ	Distance
	O22	O31	O33	O18	O5	478.31
Route8	ล่องแพ	ดอยหลวง	ปางปอย	ขอนม่วง	ห้วยปง	Distance
	O20	O25	O42	O36	O38	433.75
Route9	ทีเลอเปอคี	ห้วยป่าแขก	บ้านห้วยม่วงใน	ศศช.ห้วยฝักดาบ		Distance
	O19	O40	O41	O3		470.28
					Total distance	4301.44

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Table B- 13: Solution from improvement Heuristic of decision model (Test Case 5)

Route1	รร.ดอยสามหมื่น	บ้านทุ่งยั๊วะ	รร.เมืองกิ๊ด	โป่งจ็อกใหม่	รร.ตชดเฉลิมพระเกียรติ	Distance
	O9	O1	O2	O43	O5	375.46
Route2	ตชดสามหมื่น	แม่สะต็อบ	แม่ป๊อกบน	บ้านน้ำรู		Distance
	O6	O11	O24	O7		615.11
Route3	บ้านหัวแม่เมือง	ศศช.ห้วยฝักดาบ	รร.แม่จุ่มสาม	รร.อมลาน	รร.แม่หงานหลวง	Distance
	O8	O3	O12	O13	O14	474.16
Route4	รร.แกน้อยศึกษา	ห้วยพระเจ้า	บ้านพุย	ตชด ผาแดง	โอโลคีล่าง	Distance
	O4	O10	O15	O18	O17	474.84
Route5	เวียงนาผา	ล่องแพ	บ้านแม่ล่องใต้	หม่าโอโจ	แม่ลายดวงจันทร์	Distance
	O44	O20	O16	O32	O23	453.26
Route6	ห้วยน้ำขุ่น	ทีเลอเปอคี	ห้วยขนุน	สบลาน	หลังป่าข่า	Distance
	O35	O19	O30	O27	O26	479.89
Route7	ห้วยอีโก้	ตุงติง	พะกะเช	ทุ่งต้นงิ้ว	เลอะตอ	Distance
	O39	O21	O31	O33	O34	489.67
Route8	ห้วยไก่ป่า	แม่อ่างข่าง	ปางปอย	ขอนม่วง	ห้วยน้ำริน	Distance
	O28	O22	O42	O36	O37	447.68
Route9	ลูกูดู	ดอยหลวง	ห้วยป่าแขก	บ้านห้วยม่วงใน	ห้วยปง	Distance
	O29	O25	O40	O41	O38	449.13
					Total Distance	4259.2

B-4 Generic test case for one trip distribution planning

There are 6 generic test cases created as the computational experiment to test the efficiency of decision model in assigning supporting hospital as well as the robustness of decision model in possible input data' characteristics or input data' situation. Each test case has different patterns of total numbers of medical staffs' demand at each site (exceed or less than total capacity of every hospitals) and numbers of operation sites in planning boundary of one month. These are 6 generic test cases for testing decision model of one day trip planning. The distance data are real distance of real operation sites in fiscal year 2008 plan of mobile medical service in Ratchaburi province.

Table B- 14: Test case 1 (One-day Trip Planning)

In this test case, there are 2 operation sites operating at the same planning month which is the general case of normal mobile medical service that has operation frequency of twice per month in the different operation sites. The medical staffs' capacity of each hospital is the real data from The Ministry of Public Health Survey 2007[22]. However, the medical staffs' demand at each site is randomly addressed. The total demand of medical staffs exceeds the total medical staffs' capacity of every hospital in the province.

วันที่(Date)	Name	Operaton site	สถานที่	ความต้องการบุคลากร(Demand)				
				หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
12/12/2009	Ban Lan Ka	A	โรงเรียนบ้านลานคา	20	18	18	52	15
16/12/2009	Huai Pak	B	ห้วยผาก	12	21	21	43	12
			Total	32	39	39	95	27

Hospital_ID	Hospital	สถานที่	ศักยภาพของโรงพยาบาล(Capacity)				
			หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
H1	Ratchaburi	โรงพยาบาลราชบุรี	5	8	8	20	2
H2	Ban Pong	โรงพยาบาลบ้านโป่ง	3	9	9	10	5
H3	Dum Nern Sa Duk	โรงพยาบาลดำเนินสะดวก	5	8	8	5	4
H4	Potharam	โรงพยาบาลโพธาราม	3	9	9	8	7
H5	Jom Bung	โรงพยาบาลจอมบึง	3	1	1	10	3
H6	Bangpae	โรงพยาบาลบางแพ	2	0	0	11	2

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H7	Pak Tor	โรงพยาบาลปากท่อ	2	0	0	12	1
H8	Jed Sameurn	โรงพยาบาลเจ็ดเสมียน	2	1	1	6	1
H9	Wat Peng	โรงพยาบาลวัดเพลง	2	1	1	3	1
H10	Suan Pung	โรงพยาบาลสวนผึ้ง	2	0	0	5	1
H11	Pa Nu Rang Si	โรงพยาบาลค่ายภาณุรังษี	2	0	0	4	1
		Total	31	37	37	94	28

Table B- 15: Test case 2(One-day Trip Planning)

In this test case, there are 5 operation sites operating at the same planning month to test the assumption that decision model can still find the solution when the problem size is bigger. The medical staffs' capacity of each hospital is the real data from The Ministry of Public Health Survey 2007[22]. However, the medical staffs' demand at each site is randomly addressed. The total demand of medical staffs exceeds the total medical staffs' capacity of every hospital in the province.

วันที่(Date)		Operaton site	Name	ความต้องการบุคลากร(Demand) หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
12/12/2009	A	Ban Lan Ka	โรงเรียนบ้านลานคา	6	9	8	20	7
16/12/2009	B	Huai Pak	ห้วยผาก	8	8	4	20	7
18/12/2009	C	Pu Ta Kien	โรงเรียนบ้านพุตะเคียน	7	5	12	20	7
20/12/2009	D	Pong Heng	บ้านโป่งแห้ง	5	9	4	20	7
22/12/2009	E	Ratchaburi Prison	เรือนจำกลางราชบุรี	10	8	9	20	7
			Total	36	39	37	100	35

Hospital_ID	Hospital	สถานที่	ศักยภาพของโรงพยาบาล(Capacity) หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
H1	Ratchaburi	โรงพยาบาลราชบุรี	5	8	8	20	2
H2	Ban Pong	โรงพยาบาลบ้านโป่ง	3	9	9	10	5
H3	Dum Nern Sa Duk	โรงพยาบาลดำเนินสะดวก	5	8	8	5	4
H4	Potharam	โรงพยาบาลโพธาราม	3	9	9	8	7
H5	Jom Bung	โรงพยาบาลจอมบึง	3	1	1	10	3
H6	Bangpae	โรงพยาบาลบางแพ	2	0	0	11	2
H7	Pak Tor	โรงพยาบาลปากท่อ	2	0	0	12	1
H8	Jed Sameurn	โรงพยาบาลเจ็ดเสมือน	2	1	1	6	1
H9	Wat Peng	โรงพยาบาลวัดเพลง	2	1	1	3	1
H10	Suan Pung	โรงพยาบาลสวนผึ้ง	2	0	0	5	1
H11	Pa Nu Rang Si	โรงพยาบาลค่ายภาณุรังษี	2	0	0	4	1
		Total	31	37	37	94	28

Table B- 16: Test Case 3(One-day trip Planning)

In this test case, there are 9 operation sites operating at the same planning month to test the assumption that decision model can still find the solution when the problem size is bigger. The medical staffs' capacity of each hospital is the real data from The Ministry of Public Health Survey 2007[22]. However, the medical staffs' demand at each site is randomly addressed. The total demand of medical staffs exceeds the total medical staffs' capacity of every hospital in the province. All nine operation sites are the real operation sites in fiscal year 2008 plan of mobile medical service of Ratchaburi Province accumulated to operate in one month.

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วันที่		Operaton site	สถานที่	ความต้องการบุคลากร(Demand)				
				หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
12/12/2009	A	Ban Lan Ka	โรงเรียนบ้านลานคา	3	4	4	15	4
16/12/2009	B	Huai Pak	ห้วยผาก	3	2	2	15	3
18/12/2009	C	Pu Ta Kien	โรงเรียนบ้านพุตะเคียน	5	5	5	10	4
20/12/2009	D	Pong Heng	บ้านโป่งแห้ง	3	3	3	7	2
22/12/2009	E	Ratchaburi Prison	เรือนจำกลางราชบุรี	2	4	4	7	2
24/12/2009	G	Wat Ra Kung Tong	วัดระฆังทอง	5	6	6	12	4
26/12/2008	H	Ban Tri Ngam	โรงเรียนบ้านไทรงาม	3	6	6	10	2
28/12/2009	I	Rotari Pu Num Ron	โรงเรียนโรตารีพุน้ำร้อน	7	5	5	12	4
30/12/2009	J	Ban Ta Kor Lang	บ้านตะโกล่าง	3	6	6	9	4
			Total demand	34	41	41	97	29

Hospital_ID	Hospital	สถานที่	ศักยภาพของโรงพยาบาล(Capacity)				
			หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
H1	Ratchaburi	โรงพยาบาลราชบุรี	5	8	8	20	2
H2	Ban Pong	โรงพยาบาลบ้านโป่ง	3	9	9	10	5
H3	Dum Nern Sa Duk	โรงพยาบาลดำเนินสะดวก	5	8	8	5	4
H4	Potharam	โรงพยาบาลโพธาราม	3	9	9	8	7
H5	Jom Bung	โรงพยาบาลจอมบึง	3	1	1	10	3
H6	Bangpae	โรงพยาบาลบางแพ	2	0	0	11	2
H7	Pak Tor	โรงพยาบาลปากท่อ	2	0	0	12	1

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H8	Jed Sameurn	โรงพยาบาลเจ็ดเสมือน	2	1	1	6	1
H9	Wat Peng	โรงพยาบาลวัดเพลง	2	1	1	3	1
H10	Suan Pung	โรงพยาบาลสวนผึ้ง	2	0	0	5	1
H11	Pa Nu Rang Si	โรงพยาบาลค่ายภาณุรังษี	2	0	0	4	1
		Total	31	37	37	94	28

Table B- 17: Test case 4(One-day trip planning)

In this test case, there are 2 operation sites operating at the same planning month which is the general case of normal mobile medical service that has operation frequency of twice per month in the different operation sites. The medical staffs' capacity of each hospital is the real data from The Ministry of Public Health Survey 2007[22]. However, the medical staffs' demand at each site is randomly addressed. The total demand of medical staffs is less than the total medical staffs' capacity of every hospital in the province.

วันที่		Operaton site	สถานที่	ความต้องการบุคลากร(Demand) หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
12/12/2009	A	โรงเรียนบ้านลานคา	Ban Lan Ka	3	3	3	3	3
16/12/2009	B	ห้วยผาก	Huai Pak	2	3	3	2	3
			Total	5	6	6	5	6

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Hospital_ID	Hospital	สถานที่	ศักยภาพของโรงพยาบาล(Capacity)				
			หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
H1	Ratchaburi	โรงพยาบาลราชบุรี	1	8	8	20	2
H2	Ban Pong	โรงพยาบาลบ้านโป่ง	1	9	9	10	5
H3	Dum Nern Sa Duk	โรงพยาบาลดำเนินสะดวก	1	8	8	5	4
H4	Potharam	โรงพยาบาลโพธาราม	1	9	9	8	7
H5	Jom Bung	โรงพยาบาลจอมบึง	1	1	1	10	3
H6	Bangpae	โรงพยาบาลบางแพ	1	0	0	11	2
H7	Pak Tor	โรงพยาบาลปากท่อ	1	0	0	12	1
H8	Jed Sameurn	โรงพยาบาลเจ็ดเสมือน	1	1	1	6	1
H9	Wat Peng	โรงพยาบาลวัดเพลง	1	1	1	3	1
H10	Suan Pung	โรงพยาบาลสวนผึ้ง	1	0	0	5	1
H11	Pa Nu Rang Si	โรงพยาบาลค่ายภาณุรังษี	1	0	0	4	1
		Total	11	37	37	94	28

Table B- 18: Test case 5(One-day trip planning)

In this test case, there are 5 operation sites operating at the same planning month to test the assumption that decision model can still find the solution when the problem size is bigger. The medical staffs' capacity of each hospital is the real data from The Ministry of Public Health Survey 2007[22]. However, the medical staffs' demand at each site is randomly addressed. The total demand of medical staffs is less than the total medical staffs' capacity of every hospital in the province.

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วันที่		Operaton site	สถานที่	ความต้องการบุคลากร(Demand)				
				หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
12/12/2009	A	โรงเรียนบ้านลานคา	Ban Lan Ka	3	3	3	3	3
16/12/2009	B	ห้วยผาก	Huai Pak	2	3	3	2	3
18/12/2009	C	โรงเรียนบ้านพุตะเคียน	Pu Ta Kien	3	3	3	3	3
20/12/2009	D	บ้านโป่งแห้ง	Pong Heng	2	3	3	2	2
22/12/2009	E	เรือนจำกลางราชบุรี	Ratchaburi Prison	3	3	3	3	3
			Total	13	15	15	13	14

Hospital_ID	Hospital	สถานที่	ศักยภาพของโรงพยาบาล(Capacity)				
			หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
H1	Ratchaburi	โรงพยาบาลราชบุรี	5	8	8	20	2
H2	Ban Pong	โรงพยาบาลบ้านโป่ง	3	9	9	10	5
H3	Dum Nern Sa Duk	โรงพยาบาลดำเนินสะดวก	5	8	8	5	4
H4	Potharam	โรงพยาบาลโพธาราม	3	9	9	8	7
H5	Jom Bung	โรงพยาบาลจอมบึง	3	1	1	10	3
H6	Bangpae	โรงพยาบาลบางแพ	2	0	0	11	2
H7	Pak Tor	โรงพยาบาลปากท่อ	2	0	0	12	1
H8	Jed Sameurn	โรงพยาบาลเจ็ดเสมือน	2	1	1	6	1
H9	Wat Peng	โรงพยาบาลวัดเพลง	2	1	1	3	1

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H10	Suan Pung	โรงพยาบาลสวนผึ้ง	2	0	0	5	1
H11	Pa Nu Rang Si	โรงพยาบาลค่ายภาณุรังษี	2	0	0	4	1
		Total	31	37	37	94	28

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Table B- 19: Test case 6 (One-Day Trip Planning)

In this test case, there are 9 operation sites operating at the same planning month to test the assumption that decision model can still find the solution when the problem size is bigger. The medical staffs' capacity of each hospital is the real data from The Ministry of Public Health Survey 2007[22]. However, the medical staffs' demand at each site is randomly addressed. The total demand of medical staffs is less than the total medical staffs' capacity of every hospital in the province. All nine operation sites are the real operation sites in fiscal year 2008 plan of mobile medical service of Ratchaburi Province accumulated to operate in one month.

				ความต้องการบุคลากร(Demand)				
วันที่		Operaton site	สถานที่	หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
12/12/2009	A	โรงเรียนบ้านลานคา	Ban Lan Ka	3	3	3	3	3
16/12/2009	B	ห้วยผาก	Huai Pak	2	3	3	2	3
18/12/2009	C	โรงเรียนบ้านพุตะเคียน	Pu Ta Kien	3	3	3	3	3
20/12/2009	D	บ้านโป่งแห้ง	Pong Heng	2	3	3	2	2
22/12/2009	E	เรือนจำกลางราชบุรี	Ratchaburi Prison	3	3	3	3	3
24/12/2009	G	วัดระฆังทอง	Wat Ra Kung Tong	2	3	3	2	2
26/12/2008	H	โรงเรียนบ้านไทรงาม	Ban Tri Ngam	2	3	3	2	2
28/12/2009	I	โรงเรียนโรตารีพุน้ำร้อน	Rotari Pu Num Ron	3	3	3	3	3
30/12/2009	J	บ้านตะโกล่าง	Ban Ta Kor Lang	3	3	3	3	3
			Total	23	27	27	23	24

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Hospital_ID	Hospital	สถานที่	ศักยภาพของโรงพยาบาล(Capacity) หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)
H1	Ratchaburi	โรงพยาบาลราชบุรี	5	8	8	20	2
H2	Ban Pong	โรงพยาบาลบ้านโป่ง	3	9	9	10	5
H3	Dum Nern Sa Duk	โรงพยาบาลดำเนินสะดวก	5	8	8	5	4
H4	Potharam	โรงพยาบาลโพธาราม	3	9	9	8	7
H5	Jom Bung	โรงพยาบาลจอมบึง	3	1	1	10	3
H6	Bangpae	โรงพยาบาลบางแพ	2	0	0	11	2
H7	Pak Tor	โรงพยาบาลปากท่อ	2	0	0	12	1
H8	Jed Sameurn	โรงพยาบาลเจ็ดเสมือน	2	1	1	6	1
H9	Wat Peng	โรงพยาบาลวัดเพลง	2	1	1	3	1
H10	Suan Pung	โรงพยาบาลสวนผึ้ง	2	0	0	5	1
H11	Pa Nu Rang Si	โรงพยาบาลค่ายภาณุรังษี	2	0	0	4	1
			31	37	37	94	28

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B-5 Solution of generic test case for round trip distribution planning

The solutions from all test cases are received from testing on Intel® Core™ 2 Duo CPU P9600@ 2.66 GHz 1.99 GB of RAM computer. The developed program to test the searching result of decision model is using Microsoft Excel's add-in "Solver" to find the optimal solution of Assignment Problem. In test case 4, other approach using Transportation Model is applied to test whether the decision model leads to less travelled distance from supporting hospitals. In test case 6, the current plan of supporting hospitals to all operation sites is used to compare the result from the decision model. Table B-20 presents the current solution from the fiscal year 2008 plan of mobile dentistry service of Ratchaburi Province of the studied organization in assigning supporting hospitals to operation sites with the testing data of test case 6 while Table B-21 shows the solution from Transportation Model approach in test case 4. This designed experiment is to evaluate the efficiency of decision model in finding better solution quality than the current approach of the studied organization and other approach in finding solution. Later on, the calculation of measurements in test case 4, test case 5 and test case 6 is presented.

Table B- 20: Mobile Medical Service Plan of Ratchaburi Province in fiscal year 2008 (Test Case 6)

Hospital	Operation site	Supporting Value					
		Doctor	Dentist	Asst. Dentist	Nurse	Phar	distance
Ratchaburi	Ban Lan Ka	1	1	1	1	1	23
Wat Peng	Ban Lan Ka	1	1	1	1	1	12
Pa Nu Rang Si	Ban Lan Ka	1	1	1	1	1	24
Ratchaburi	Huai Pak	1	2	1	1	1	69
Ban Pong	Huai Pak	1	1	2	1	2	107
Potharam	Pu Ta Kien	1	1	1	1	1	70
Pa Nu Rang Si	Pu Ta Kien	1	1	1	1	1	65
Ban Pong	Pu Ta Kien	1	1	1	1	1	69
Jom Bung	Pong Heng	1	1	1	1	0	40
Suan Pung	Pong Heng	1	1	1	1	1	15
Pa Nu Rang Si	Pong Heng	0	1	1	0	1	62
Ratchaburi	Ratchaburi Prison	1	0	0	0	1	24
Ban Pong	Ratchaburi Prison	0	1	0	0	0	58

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Hospital	Operation site	Supporting Value					
		Doctor	Dentist	Asst. Dentist	Nurse	Phar	distance
Potharam	Ratchaburi Prison	1	0	0	0	0	39
Pak Tor	Ratchaburi Prison	0	0	1	1	0	45
Wat Peng	Ratchaburi Prison	1	0	1	1	1	38
Suan Pung	Ratchaburi Prison	0	1	1	1	0	31
Pa Nu Rang Si	Ratchaburi Prison	0	1	0	0	1	25
Bangpae	Wat Ra Kung Tong	1	1	1	0	1	28
Dum Nern Sa Duk	Wat Ra Kung Tong	0	1	1	1	1	49
Potharam	Wat Ra Kung Tong	1	1	1	1	0	19
Wat Peng	Ban Tri Ngam	1	1	1	0	0	44
Dum Nern Sa Duk	Ban Tri Ngam	1	1	1	1	1	64
Pak Tor	Ban Tri Ngam	0	1	1	1	1	33
Potharam	Rotari Pu Num Ron	1	0	0	1	1	75
Jed Sameurn	Rotari Pu Num Ron	1	0	0	1	1	68
Bangpae	Rotari Pu Num Ron	1	1	1	1	1	103
Ratchaburi	Ban Ta Kor Lang	1	1	1	1	1	80
Suan Pung	Ban Ta Kor Lang	1	1	1	1	1	34
Bangpae	Ban Ta Kor Lang	1	1	1	1	1	103
						Total	1516

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Table B- 21: Transportation Model Approach in selecting supporting hospitals (Test case 6)

วันที่	สถานที่ Site	โรงพยาบาล Hospital	ศักยภาพของโรงพยาบาล(Capacity)					distance
			หมอ (doctor)	ทันตแพทย์ (Dentist)	ทันตพิบาล (Asst. Dentist)	พยาบาล (Nurse)	เภสัช (Phar)	
12/12/2009	Ban Lan Ka	Ratchaburi	0	2	2	0	1	23
12/12/2009	Ban Lan Ka	Pak Tor	2	0	0	3	1	2
12/12/2009	Ban Lan Ka	Wat Peng	1	1	1	0	1	13
12/12/2009	Huai Pak	Ratchaburi	0	2	2	0	0	69
12/12/2009	Huai Pak	Jom Bung	0	1	1	0	2	48
12/12/2009	Huai Pak	Suan Pung	2	0	0	2	1	23
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Table B- 22: Decision Model Approach in Test Case 1

Hospital	Operation Site	Supporting Value					
		Doctor	Dentist	Dentist Assistant	Nurse	Pharmacist	Distance
Pak Tor	Ban Lan Ka	2	0	0	12	1	1.5
Wat Peng	Ban Lan Ka	2	1	1	3	1	12.8
Panurangsi	Ban Lan Ka	2	0	0	4	1	23.6
Dum nern sa duk	Ban Lan Ka	5	8	8	5	4	32.8
Potharam	Ban Lan Ka	3	9	9	8	7	44.4
Bangpae	Ban Lan Ka	2	0	0	9	0	62.7
Ban Pong	Ban Lan Ka	3	0	0	10	1	62.7
Suan Pung	Huai Pak	2	0	0	5	1	23.1
Jom Bung	Huai Pak	3	1	1	10	3	47.9
Ratchaburi	Huai Pak	5	8	8	20	2	68.7
Jed Sa Muern	Huai Pak	2	1	1	6	1	80.8
Bangpae	Huai Pak	0	0	0	2	2	92.3
Ban Pong	Huai Pak	0	9	9	0	3	92.3

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						Total	645.6

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Table B- 23: Decision Model Approach in Test Case 2

hospital	operation site	supporting value					
		doctor	dentist	assistant dentist	Nurse	Pharm.	distance
Potharam	Ban Lan Ka	3	9	8	8	7	44.4
Pak Tor	Ban Lan Ka	2	0	0	12	0	1.5
Wat Peng	Ban Lan Ka	1	0	0	0	0	12.8
Jom Bung	Huai Pak	3	0	1	10	0	47.9
Suan Pung	Huai Pak	2	0	0	5	0	23.1
Ratchaburi	Huai Pak	0	0	3	0	0	68.7
Panurangsi	Huai Pak	2	0	0	4	0	70.5
Jed Sameurn	Huai Pak	1	1	0	1	1	80.8
Wang Peng	Huai Pak	0	1	0	0	1	85.2
Pak Tor	Huai Pak	0	0	0	0	1	85.9
Bang Pae	Huai Pak	0	0	0	0	2	88.3
Ban Pong	Huai Pak	0	4	0	0	0	107
Ban Pong	Pu Ta Kien	3	5	9	10	5	69

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hospital	operation site	supporting value					
		doctor	dentist	assistant dentist	Nurse	Pharm.	distance
Ratchaburi	Pu Ta Kien	0	0	1	0	0	64.4
Potharam	Pu Ta Kien	0	0	1	0	0	69.9
Wat Peng	Pu Ta Kien	0	0	1	0	0	77.8
Bang Pae	Pu Ta Kien	0	0	0	4	0	76.8
Ratchaburi	Pong Heng	5	8	4	20	2	60.6
Jom Bung	Pong Heng	0	1	0	0	3	39.8
Suan Pung	Pong Heng	0	0	0	0	1	15
Panurangsi	Pong Heng	0	0	0	0	1	62.4
Dum Nern Sa Duk	Ratchaburi Prison	5	8	8	5	4	51.2
Jed Sameurn	Ratchaburi Prison	1	0	1	5	0	28.8
Wat Peng	Ratchaburi Prison	1	0	0	3	0	37.8
Bang Pae	Ratchaburi Prison	2	0	0	7	0	46.7
						Total	1416.3

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Table B- 24: Decision Model Approach in Test Case 3

Hospital	Operation Site	Supporting Value					
		Doctor	dentist	assistant dentist	nurse	Phar	distance
Dum Nern Sa Duk	Ban Lan Ka	1	4	4	5	4	32.8
Pak Tor	Ban Lan Ka	1	0	0	10	0	1.5
Wat Peng	Ban Lan Ka	1	0	0	0	0	36.9
Ratchaburi	Huai Pak	0	2	2	13	0	68.7
Suan Pung	Huai Pak	0	0	0	0	1	23.1
Pa Nu Rang Si	Huai Pak	0	0	0	2	1	71
Potharam	Huai Pak	0	0	0	0	1	88.3
Ban Pong	Pu Ta Kien	1	5	5	10	4	69
Potharam	Pong Heng	0	3	3	0	2	80.2
Suan Pung	Pong Heng	1	0	0	5	0	15
Pa Nu Rang Si	Pong Heng	0	0	0	2	0	62.4
Ratchaburi	Ratchaburi Prison	1	4	4	7	2	24.3
Pa Nu Rang Si	Ratchaburi Prison	1	0	0	0	0	25.1

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Hospital	Operation Site	Supporting Value					
		Doctor	dentist	assistant dentist	nurse	Phar	distance
Potharam	Wat Ra Kung Tong	1	6	6	8	4	19.4
Jed Sameurn	Wat Ra Kung Tong	1	0	0	4	0	21.5
Bangpae	Wat Ra Kung Tong	1	0	0	0	0	27.5
Pak Tor	Ban Tri Ngam	0	0	0	2	1	32.6
Wat Peng	Ban Tri Ngam	0	1	1	3	1	43.9
Dum Nern Sa Duk	Ban Tri Ngam	0	4	4	0	0	64
Bangpae	Ban Tri Ngam	0	0	0	2	0	75.8
Jom Bung	Rotari Pu Num Ron	1	1	1	10	3	35.2
Ratchaburi	Rotari Pu Num Ron	0	2	2	0	0	55.7
Jed Sameurn	Rotari Pu Num Ron	0	1	1	2	1	67.8
Ban Pong	Rotari Pu Num Ron	0	1	1	0	0	93.6
Bangpae	Ban Ta Kor Lang	0	0	0	9	2	103
Ban Pong	Ban Ta Kor Lang	0	3	3	0	1	118
						Total	1356.3

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Table B- 25: Decision Model Approach in Test Case 4

hospital	Operation site	Supporting Value					
		Doctor	Dentist	Asst. Dentist	Nurse	Phar	distance
Dum Nern Sa Duk	Ban Lan Ka	3	3	3	3	3	32.8
Ratchaburi	Huai Pak	2	3	3	2	2	68.7
Suan Pung	Huai Pak	0	0	0	0	1	23.1
						Total	124.6

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Table B- 26: Decision Model Approach in Test Case 5

hospital	Operation site	Supporting Value					
		Doctor	Dentist	Asst. Dentist	Nurse	Pharm.	distance
Dum Nern Sa Duk	Ban Lan Ka	3	3	3	3	3	32.8
Ratchaburi	Huai Pak	2	3	3	2	0	68.7
Jom Bung	Huai Pak	0	0	0	0	3	47.9
Ban Pong	Pu Ta Kien	3	3	3	3	3	69
Ratchaburi	Pong Heng	2	3	3	2	2	60.6
Potharam	Ratchaburi Prison	3	3	3	3	3	38.7
						Total	317.7

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Table B- 27: Decision Model Approach in Test Case 6

Hospital	Operation site	Supporting Value					
		Doctor	Dentist	Asst. Dentist	Nurse	Phar	distance
Dum Nern Sa Duk	Ban Lan Ka	3	3	3	3	3	32.8
Suan Pung	Huai Pak	2	0	0	2	1	23.1
Ban Pong	Huai Pak	0	3	3	0	2	107
Ban Pong	Pu Ta Kien	3	3	3	3	3	69
Ratchaburi	Pong Heng	2	3	3	2	0	60.6
Wat Peng	Pong Heng	0	0	0	0	1	77.1
Pa Nu Rang Si	Pong Heng	0	0	0	0	1	62.4
Ratchaburi	Ratchaburi Prison	3	3	3	3	2	24.3
Jed Sameurn	Ratchaburi Prison	0	0	0	0	1	28.8
Potharam	Wat Ra Kung Tong	2	3	3	2	2	19.4
Dum Nern Sa Duk	Ban Tri Ngam	2	3	3	2	1	64
Pak Tor	Ban Tri Ngam	0	0	0	0	1	32.6
Jom Bung	Rotari Pu Num Ron	3	1	1	3	3	35.2

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Potharam	Ban Ta Kor Lang	1	3	3	3	3	99.3
Pa Nu Rang Si	Ban Ta Kor Lang	2	0	0	0	0	81.5
						Total	817.1

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Table B- 28: Calculation of distribution methods' measurements in test case 4

Hospital	Operation site	Direct			
		Distance(km)	No. of vehicle	Time(min)	
Dum Nern Sa Duk	Ban Lan Ka	132.6	3	32.8	
Supply Warehouse	Ban Lan Ka				
		Meeting			
		-	-	-	
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		193.2	2	193.2	
Pick up Route Detail		Dum Nern Sa Duk	Supply Warehouse	Ban Lan Ka	

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Table B- 29: Calculation of distribution methods' measurements in test case 4(continued)

		Direct			
Hospital	Operation site	Distance(km)	No. of vehicle	Time(min)	
Ratchaburi	Huai Pak	215.5	4	65.192308	
Suan Pung	Huai Pak				
Supply Warehouse	Huai Pak	Meeting			
		186.4	2	72.315385	
Meeting point		Ratchaburi			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		193.2	2	193.2	
Pickup Route Detail		Ratchaburi	Supply Warehouse	Suan Pung	Huai Pak

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Table B- 30: Calculation of distribution methods' measurements in test case 5

		Direct			
Hospital	Operation site	Distance(km)	No. of vehicle	Time(min)	
Dum Nern Sa Duk	Ban Larn Ka	88	3	33	
Supply Warehouse	Ban Larn Ka				
		Meeting			
		-	-	-	
Meeting point		-			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		106	2	53	
Pickup Route Detail		Dum Nern Sa Duk	Supply Warehouse	Ban Lan Ka	

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Table B- 31: Calculation of distribution methods' measurements in test case 5(continued)

		Direct			
Hospital	Operation site	Distance(km)	No. of vehicle	Time(min)	
Ratchaburi	Huai Pak	183.6	3	63.9	
Supply Warehouse	Huai Pak				
Jom Bung	Huai Pak	Meeting			
		144.8	2	67.13076923	
Meeting point		Jom Bung			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		147.8	2	67.9	
Pickup Route Detail		Ratchaburi	Supply Warehouse	Jom Bung	Huai Pak

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Table B- 32: Calculation of distribution methods' measurements in test case 5(continued)

Hospital	Operation site	Direct			
		Distance(km)	No. of vehicle	Time(min)	
Ban Pong	Pu Te Kien	201	3	69	
Supply Warehouse	Pu Te Kien				
		Meeting			
		-	-	-	
Meeting point		-			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		208	2	104	
Pickup Route Detail		Ban Pong	Supply Warehouse	Pu Te Kien	

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Table B- 33: Calculation of distribution methods' measurements in test case 5(continued)

Hospital	Operation site	Direct			
		Distance(km)	No. of vehicle	Time(min)	
Ratchaburi	Pong Heng	177	3	61	
Supply Warehouse	Pong Heng				
		Meeting			
		-	-	-	
Meeting point		-			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		114	2	57	
Pickup Route Detail		Ratchaburi	Supply Warehouse	Pong Heng	

Table B- 34: Calculation of distribution methods' measurements in test case 5(continued)

Hospital	Operation site	Direct			
		Distance(km)	No. of vehicle	Time(min)	
Potharam	Ratchaburi prison	101	3	39	
Supply Warehouse	Ratchaburi prison				
		Meeting			
		-	-	-	
Meeting point		-			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		92	2	46	
Pickup Route Detail		Potharam	Supply Warehouse	Ratchaburi prison	

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Table B- 35: Calculation of distribution methods' measurements in test case 6

		Direct			
Hospital	Operation site	Distance(km)	No. of vehicle	Time(min)	
Dum Nern Sa Duk	Ban Larn Ka	88	3	33	
Supply Warehouse	Ban Larn Ka				
		Meeting			
		-	-	-	
Meeting point		-			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		106	2	53	
Pickup Route Detail		Dum Nern Sa Duk	Supply Warehouse	Ban Lan Ka	

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Table B- 36: Calculation of distribution methods' measurements in test case 6(continued)

Hospital	Operation site	Direct			
		Distance(km)	No. of vehicle	Time(min)	
Ban Pong	Huai Pak	197	3	74.69230769	
Supply Warehouse	Huai Pak				
Suan Pung	Huai Pak	Meeting			
		165	2	68.53846154	
Meeting point		Suan Pung			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		386	2	140.0769231	
Pickup Route Detail		Suan Pung	Supply Warehouse	Ban Pong	Huai Pak

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Table B- 37: Calculation of distribution methods' measurements in test case 6(continued)

Hospital	Operation site	Direct			
		Distance(km)	No. of vehicle	Time(min)	
Ban Pong	Pu Te Kien	132	3	69	
Supply Warehouse	Pu Te Kien				
		Meeting			
		-	-	-	
Meeting point		-			
		Pickup route			
		Distance(km)	No. of vehicle	Time(min)	
		208	2	104	
Pickup Route Detail		Ban Pong	Supply Warehouse	Pu Te Kien	

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Table B- 38: Calculation of distribution methods' measurements in test case 6(continued)

Hospital	Operation site	Direct				
		Distance(km)	No. of vehicle	Time(min)		
Ratchaburi	Pong Heng	255	4	62.41666667		
Supply Warehouse	Pong Heng					
Wat Peng	Pong Heng	Meeting				
Pa Nu Rang Si	Pong Heng	130	3	58.16666667		
Meeting point		Supply Warehouse				
		Pickup route				
		Distance(km)	No. of vehicle	Time(min)		
		146	2	58.5		
Pickup Route Detail		Wat Peng	Pa Nu Rang Si	Ratchaburi	Supply Warehouse	Pong Heng

Table B- 39: Calculation of distribution methods’ measurements in test case 6(continued)

Hospital	Operation site	Direct				
		Distance(km)	No. of vehicle	Time(min)		
Jed Sa Meurn	Ratchaburi prison	100	4	24.33333333		
Supply Warehouse	Ratchaburi prison					
Ratchaburi	Ratchaburi prison	Meeting				
		64	2	24.93333333		
Meeting point		Ratchaburi				
		Pickup route				
		Distance(km)	No. of vehicle	Time(min)		
		78	2	25.93333333		
Pickup Route Detail		Jed Sa Meurn	Ratchaburi	Supply Warehouse	Ratchaburi prison	

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Table B- 40: Calculation of distribution methods' measurements in test case 6(continued)

Hospital	Operation site	Direct				
		Distance(km)	No. of vehicle	Time(min)		
Potharam	Wat Ra Kang Tong	68	3	19		
Supply Warehouse	Wat Ra Kang Tong					
		Meeting				
		-	-	-		
Meeting point		-				
		Pickup route				
		Distance(km)	No. of vehicle	Time(min)		
		84	2	19		
Pickup Route Detail		Supply Warehouse	Potharam	Wat Ra Kang Tong		

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Table B- 41: Calculation of distribution methods' measurements in test case 6(continued)

		Direct				
Hospital	Operation site	Distance(km)	No. of vehicle	Time(min)		
Dum Nern Sa Duk	Ban Tri Ngam	211	4	61.41666667		
Supply Warehouse	Ban Tri Ngam					
Pak Tor	Ban Tri Ngam	Meeting				
		150	3	60.5		
Meeting point		Pak Tor				
		Pickup route				
		Distance(km)	No. of vehicle	Time(min)		
		176	2	83.41666667		
Pickup Route Detail		Dum Nern Sa Duk	Supply Warehouse	Pak Tor	Ban Tri Ngam	

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Table B- 42: Calculation of distribution methods' measurements in test case 6(continued)

Hospital	Operation site	Direct				
		Distance(km)	No. of vehicle	Time(min)		
Jom Bung	Rotari Pu Num Ron	124	3	35		
Supply Warehouse	Rotari Pu Num Ron					
		Meeting				
		-	-	-		
Meeting point		-				
		Pickup route				
		Distance(km)	No. of vehicle	Time(min)		
		118	2	35		
Pickup Route Detail		Supply Warehouse	Jom Bung	Rotari Pu Num Ron		

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Table B- 43: Calculation of distribution methods' measurements in test case 6(continued)

		Direct				
Hospital	Operation site	Distance(km)	No. of vehicle	Time(min)		
Jom Bung	Ban Ta Kor Lang	258.8	4	96.92666667		
Supply Warehouse	Ban Ta Kor Lang					
Ratchaburi	Ban Ta Kor Lang	Meeting				
		204	3	98.2		
Meeting point		Supply Warehouse				
		Pickup route				
		Distance(km)	No. of vehicle	Time(min)		
		202	2	98.2		
Pickup Route Detail		Ratchaburi	Supply Warehouse	Jom Bung	Ban Ta Kor Lang	

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Appendix C

Appendix C: Seminar detail

C-1 Seminar details

SEMINAR DETAIL

SEMINAR TOPIC: SUPPORING SYSTEM FOR MOBILE MEDICAL SERVICE OPERATION

MANAGEMENT

OBJECTIVE: To present initial conclusions of mobile medical service operation support system in planning, operation and management including aggregation of comments, opinions and recommendation from involving agents in mobile medical service to conclude the research leading to further development and application.

PRESENTATION TOPIC:

1. Previous research and development
2. Overview of the research
    a. Background of problem
    b. Objectives of the research
    c. Research Scope
3. Research Methodology
    a. Information System for operation management of mobile medical service
    b. Medical staffs and medical supplies distribution planning
    c. Process in forecasting of medical staffs and supplies
4. Simulation of operation support system for mobile medical service
5. Conclusion of research
    a. Information System for mobile medical service
    b. Reports from operation support system
    c. Logic in operation routing and medical staffs and supplies distribution
    d. Process in forecasting medical staffs and supplies

SEMINAR LOCATION AND SCHEDULE:

Friday 16th October 2009 from 8:30 a.m. – 12:00 p.m. at Thantong fl.1 Montien Riverside Bangkok with the seminar schedule:

8.30 a.m.	Registration
9.00 a.m.	Inauguration Ceremony
10.30 a.m.	Break
10.45 a.m.	Program Simulation
11.30 a.m.	Discussion
12.00 a.m.	Lunch

SEMINAR ATTENDEES:

Vice Dean of Research Affairs Faculty of Engineering Chulalongkorn University:

Associate Professor Siriporn Dumrongsakkul , Ph.D.

Researchers:

Asst.Prof. Rein Boondiskulchok, D.Eng.	Head of Researchers
Siravit Swangnop	
Krongsin Somprasonk	
Piyakit Kittitulakanon	Research Assistant
Dusadee Chansuko	

Attendees:

Auxiliary	Name
Fort Somdet Pharanaresuan maharat hospital	Dr. Puwadon Verapan
Red Cross	Dr. Thitima Sukkasaem
	Sunan Klaitum
	Jubsiri Anatporntakoon
	Siriporn Valbusawa
	Arasa Petchkong

Thailand Princess Mother Medical Volunteer Foundation	Dr.Yuth Potharamic
	Vorawan Dechagraisaya
	Usa Siwalen
	Benyatip Norbida
	Viseth Intan
Ratchaburi Provincial Public Health office	Dr. Mantana Chavunkul
	Somchit Thanakullapan
	Ungkana Panitchitta
	Chiravat Chiravattananukoon
	Mantana Chavunkul
	Suwanna Atthachot
Ratchaburi Hospital	Naraporn Pengthumkerdphol
Suanpeng Local Public Health Office	Varee Sainaha
	Vinaiphol Pongthong

C-2 Questionnaires

SATISFACTION EVALUATION FORM

Of

"SUPPORING SYSTEM FOR MOBILE MEDICAL SERVICE OPERATION MANAGEMENT"

Friday 16th October 2009 from 9:00 a.m. to 12:00 p.m. at Montien Riverside Hotel

RESPONSE DETAIL:

Auxiliary Associate……………………………………………………………………………

Position…………………………………………………………………………………………

Authority……………………………………………………………………………………..

Operation Location……………………………………………………………………………

Frequency in mobile medical service:……………………………………………..time/year

Experience in mobile medical service

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TOPIC	EVALUATION MARK				
	1 Disagree	2 Quite disagree	3 Generally agree	4 Quite agree	5 Totally agree
Medical staffs and supplies distribution planning ROUNDTRIP 1. Are the concepts and principle in the research can solve the problem					
2. Are the concepts and principle in the research is correct, appropriate and versatile					
3. Input data is required in planning					
4. Output data is necessary for planning					
5. Constraints are adequate					
ONE-DAY TRIP 6. Are the concepts and principle in the research can solve the problem					
7. Input data is correct, appropriate and versatile					
8. Output data is necessary for planning					
9. Concepts can be realistically implemented					
10. Constraints are adequate					
11. Possibilities in operation of distribution method: - Direct from hospital - Meeting Point - Pickup route					

Additional Comment:………

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Appendix D

Appendix D: Graphic User Interface (GUI)

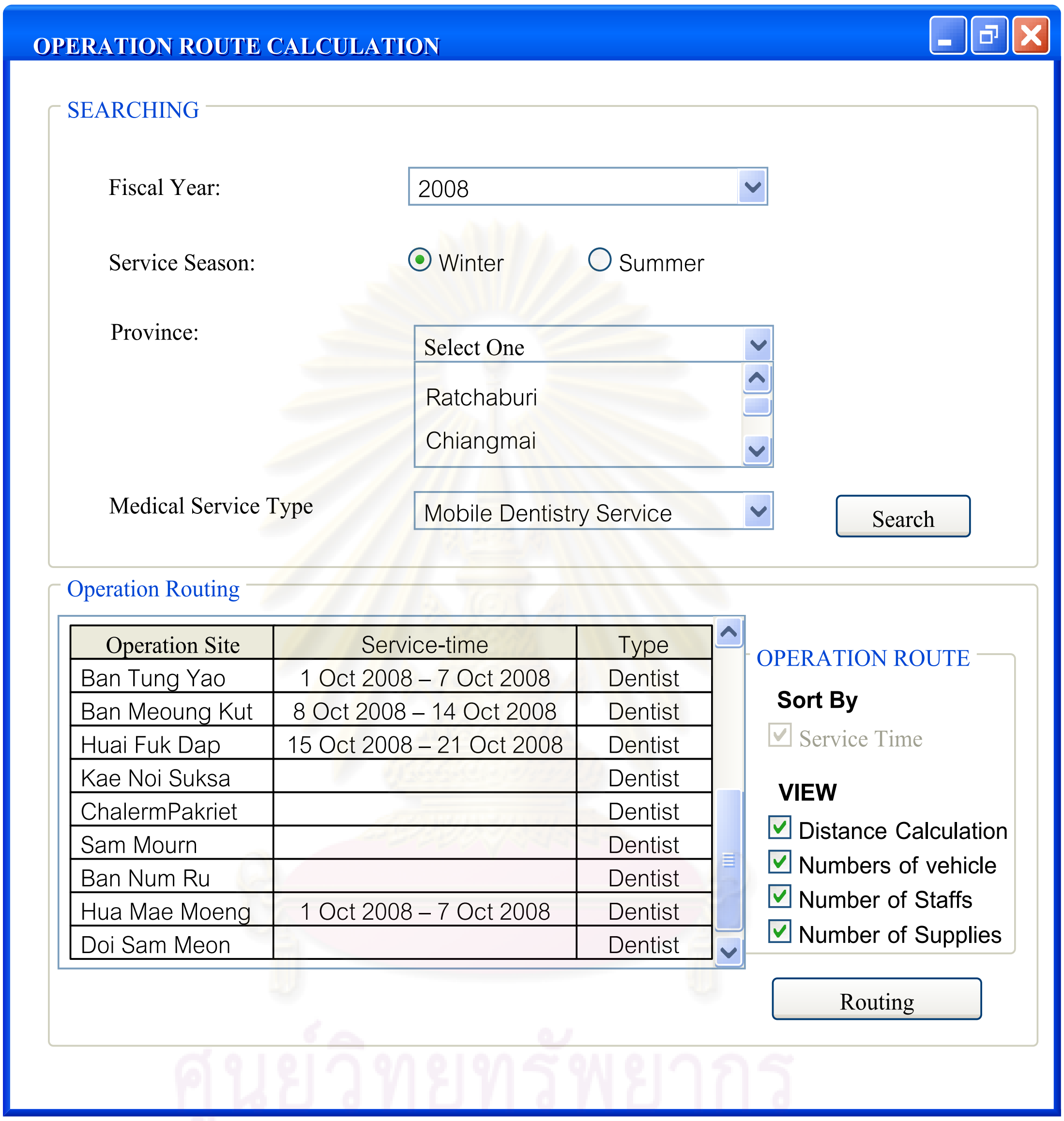


Figure D- 1 Input Data for Round trip planning

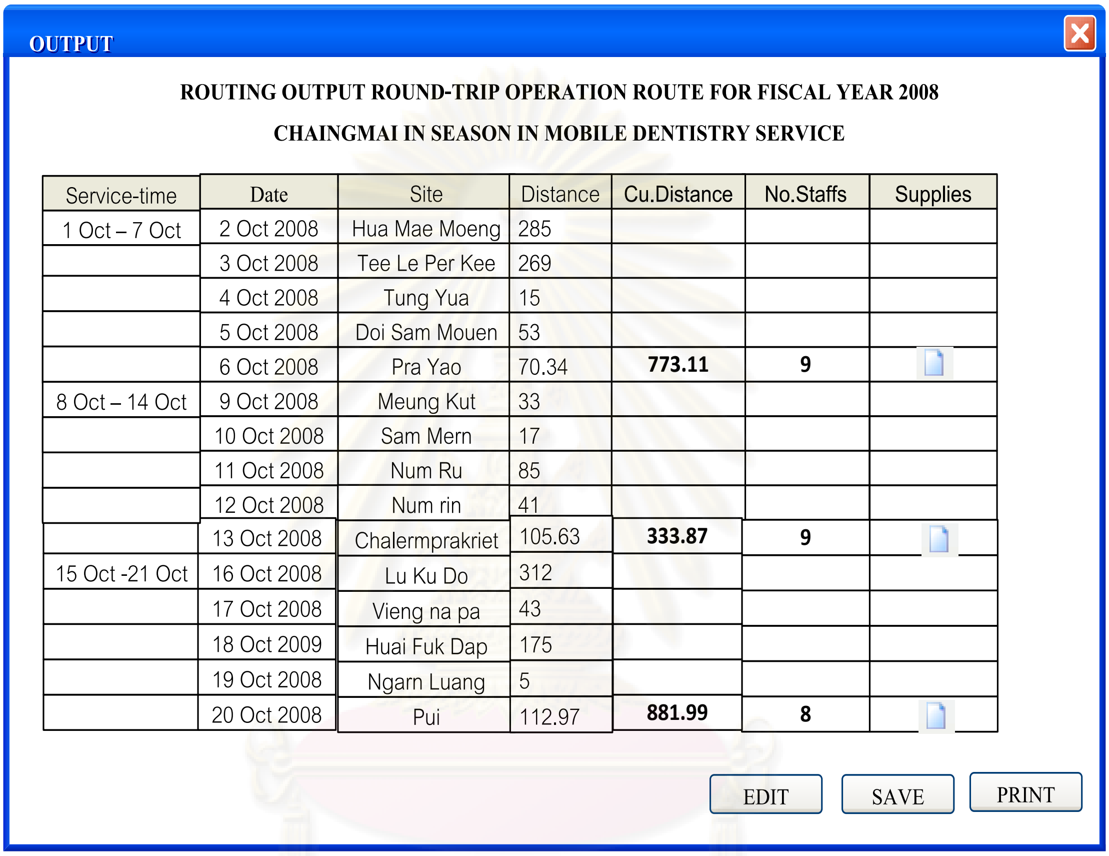
Objective: To retrieve input data into the system for calculation process

Instruction:

1. Select fiscal year in order to start the operation routing of the selected fiscal year plan
2. Choose the season for operation since the operation season leads to the different demand of medical staff
3. Select the planning province to retrieve the operation requisition for calculation

4. Select type of medical service resulting in the open of medical volunteer registration

5. Push “Search” button to retrieve the data into the system for calculation: after push the button all data in the selected field above will appear. User can select different sorting views including data fields to be seen.



Service-time	Date	Site	Distance	Cu.Distance	No.Staffs	Supplies
1 Oct – 7 Oct	2 Oct 2008	Hua Mae Moeng	285			
	3 Oct 2008	Tee Le Per Kee	269			
	4 Oct 2008	Tung Yua	15			
	5 Oct 2008	Doi Sam Mouen	53			
	6 Oct 2008	Pra Yao	70.34	**773.11**	**9**	
8 Oct – 14 Oct	9 Oct 2008	Meung Kut	33			
	10 Oct 2008	Sam Mern	17			
	11 Oct 2008	Num Ru	85			
	12 Oct 2008	Num rin	41			
	13 Oct 2008	Chalermprakriet	105.63	**333.87**	**9**	
15 Oct -21 Oct	16 Oct 2008	Lu Ku Do	312			
	17 Oct 2008	Vieng na pa	43			
	18 Oct 2009	Huai Fuk Dap	175			
	19 Oct 2008	Ngarn Luang	5			
	20 Oct 2008	Pui	112.97	**881.99**	**8**	

Figure D- 2 Routing result for Round trip planning

Objective: To present the operation routing result from the DSS computation including

- Details of operation route
- Cumulative total distance
- Numbers of medical staffs required in each service-time period
- Medical supplies required in each service-time period

Instruction: After the planners are satisfied with the result calculated by the DSS, he/she can edit the detail of the route by pushing “EDIT” button and can save the operation route data for the creation of operation plan by pushing “SAVE” button. Moreover, planners can documentarily save the operation route result from the DSS by pushing "PRINT" button.

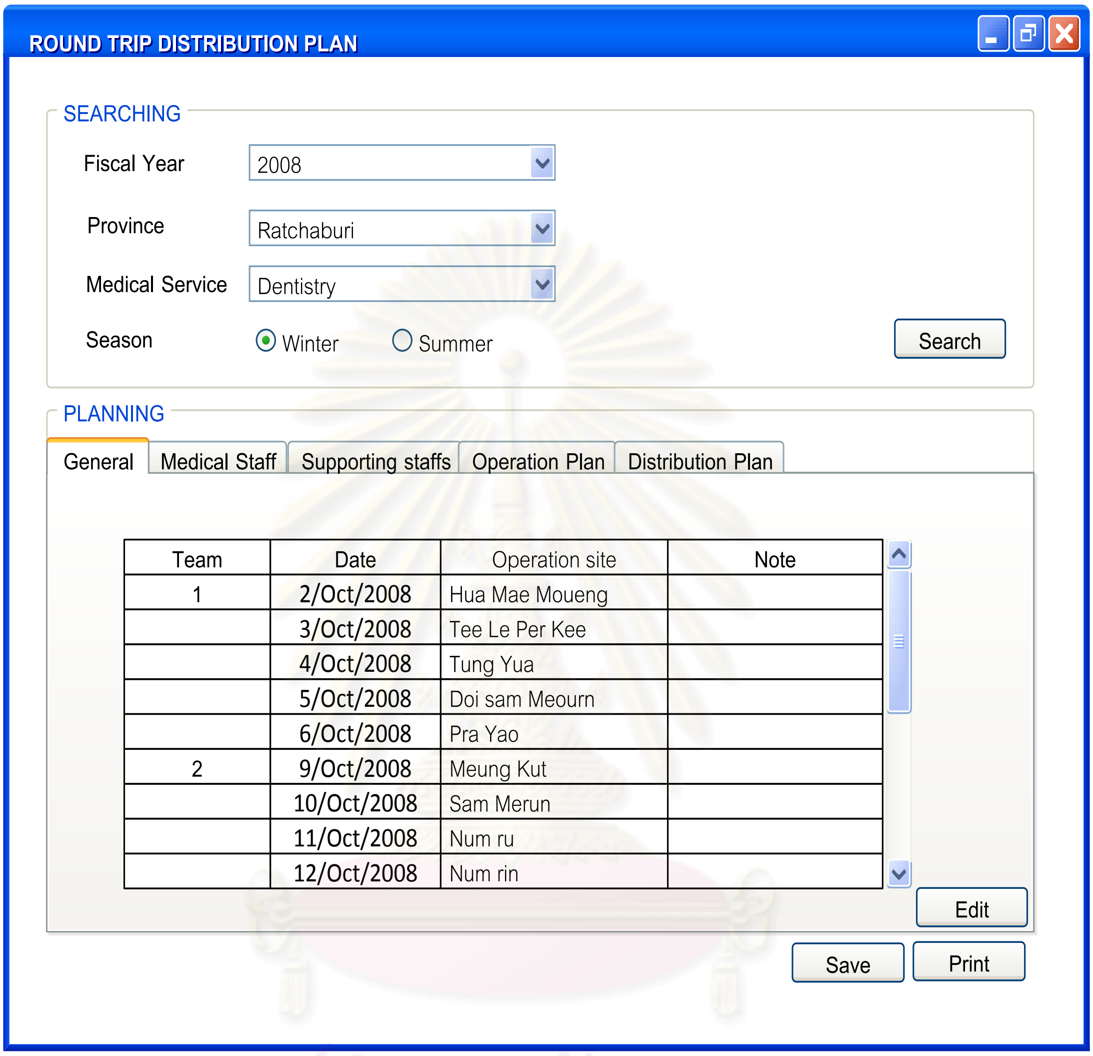


Figure D- 3 General operation plan for Round trip planning

Objective: To create overall operation plan for round-trip distribution

Instruction: There are many tabs in the GUI of creating operation plan

In Figure D-3: the general plan for Round trip planning is the tab that retrieves operation route data that planners decided to keep in the database of the DSS to generate operation plan. Detail of operation route is shown again for revision (optional) by clicking "Edit" button; however, if planners are satisfied with the result, he/she can do both "Save" the data for generating operation plan and entering the next tab to further create overall plan or he/she can "Print" the result of general plan for revision.

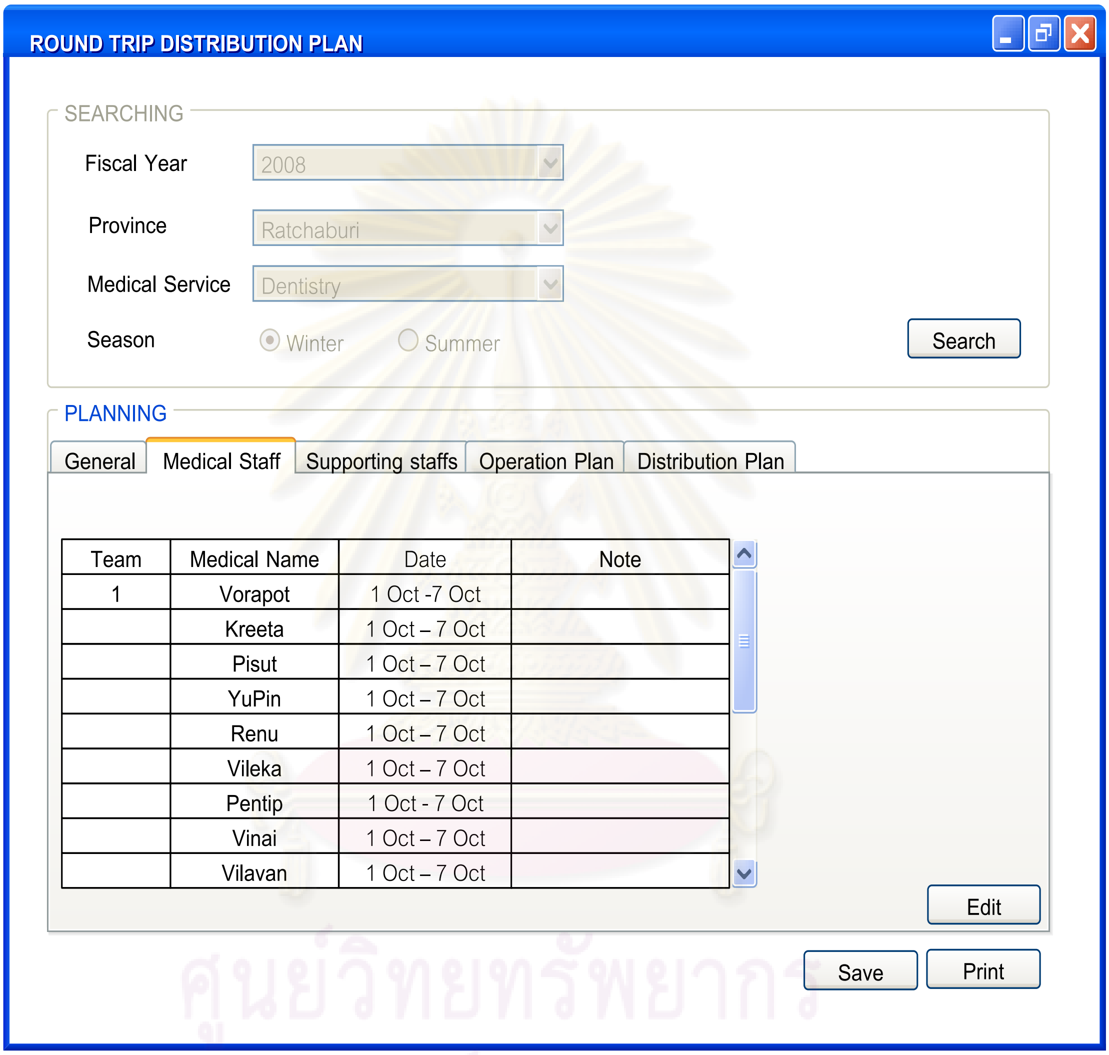
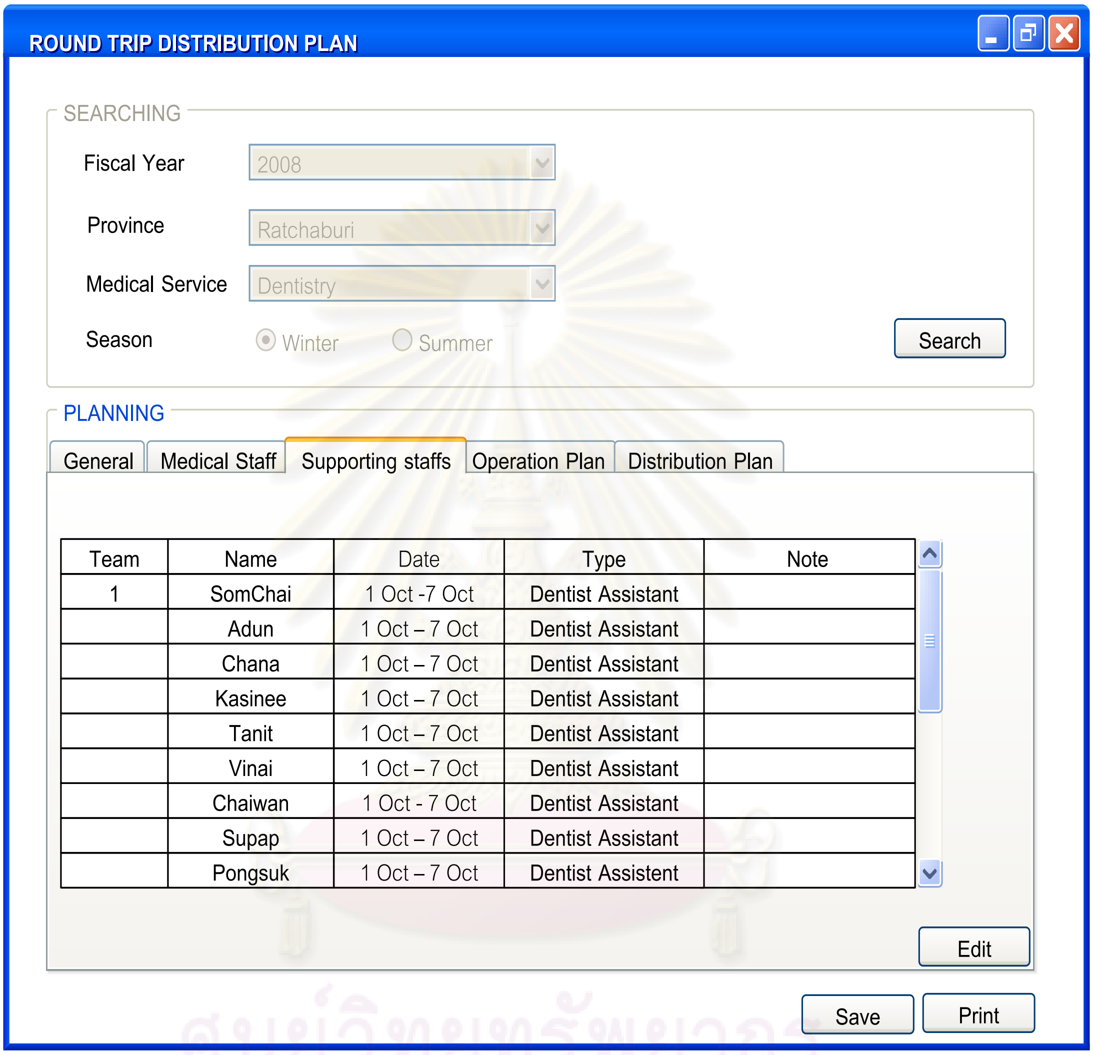


Figure D- 4 Medical staff Plan for Round trip planning

Objective: To present the details of medical staffs in each medical team

Instruction: The list of medical staffs registered to operate at the operation site according to operation route of each service-time period that has already passes through the screening process of Personnel Registration are shown in this information tab. Users can edit the information of names, surnames or individual information of medical staffs by clicking "Edit" button; however, if planners are satisfied with the result, he/she can do both “Save” the data and enter to the next tab to further create overall plan or he/she can “Print” the result of general plan for revision.

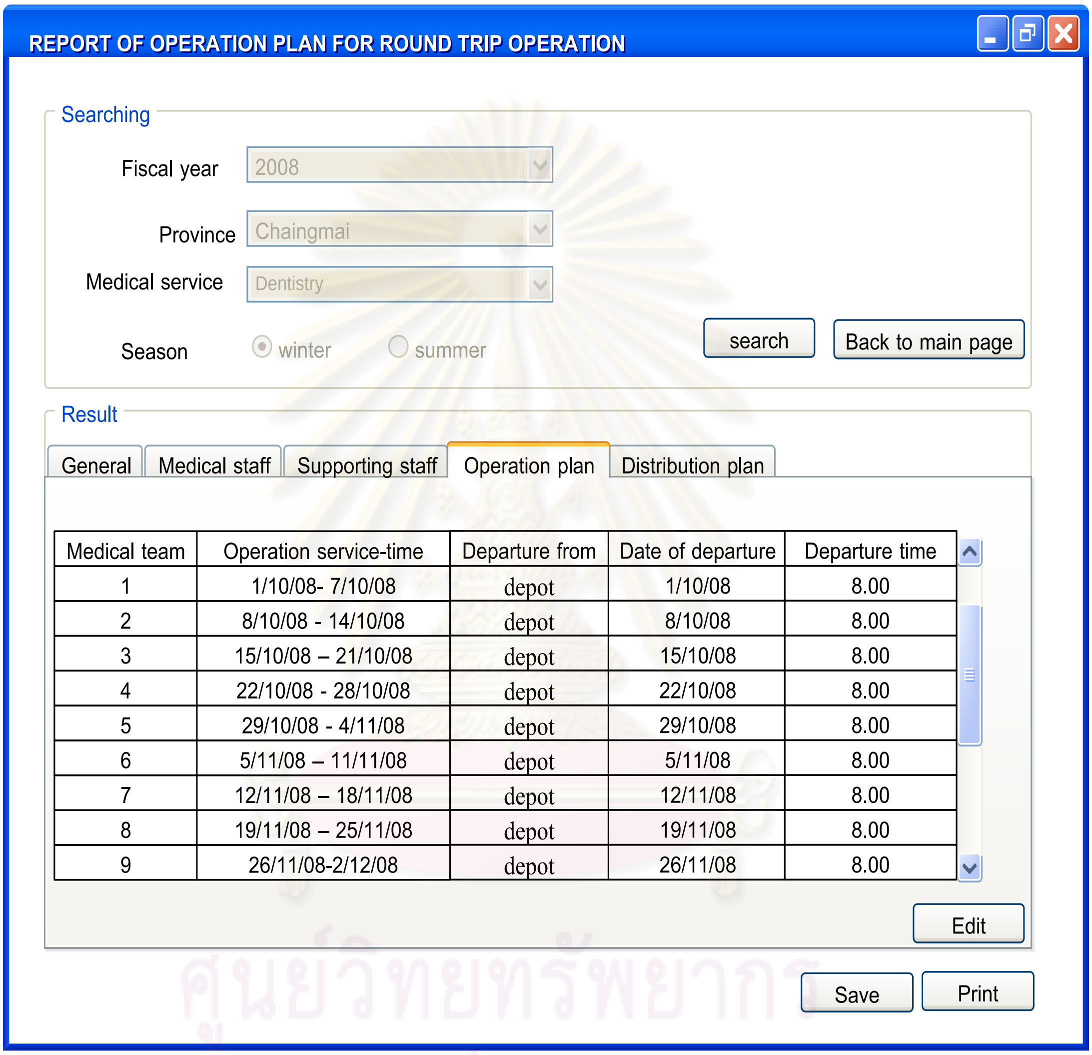


Team	Name	Date	Type	Note
1	SomChai	1 Oct -7 Oct	Dentist Assistant	
	Adun	1 Oct – 7 Oct	Dentist Assistant	
	Chana	1 Oct – 7 Oct	Dentist Assistant	
	Kasinee	1 Oct – 7 Oct	Dentist Assistant	
	Tanit	1 Oct – 7 Oct	Dentist Assistant	
	Vinai	1 Oct – 7 Oct	Dentist Assistant	
	Chaiwan	1 Oct - 7 Oct	Dentist Assistant	
	Supap	1 Oct – 7 Oct	Dentist Assistant	
	Pongsuk	1 Oct – 7 Oct	Dentist Assistent	

Figure D- 5 Supporting Staff plan for Round trip planning

Objective: To present the details of supporting medical staffs in each medical team; the supporting staffs are nurses, pharmacists and dentist assistants who are not directly provide medical treatment to patients or customers.

Instruction: The list of supporting medical staffs registered to operate at the operation site according to operation route of each service-time period that has already passes through the screening process of Personnel Registration are shown in this information tab. Users can edit the information of names, surnames or individual information of supporting medical staffs by clicking “Edit” button; however, if planners are satisfied with the result, he/she can do both “Save” the data and enter to the next tab to further create overall plan or he/she can “Print” the result of general plan for revision.

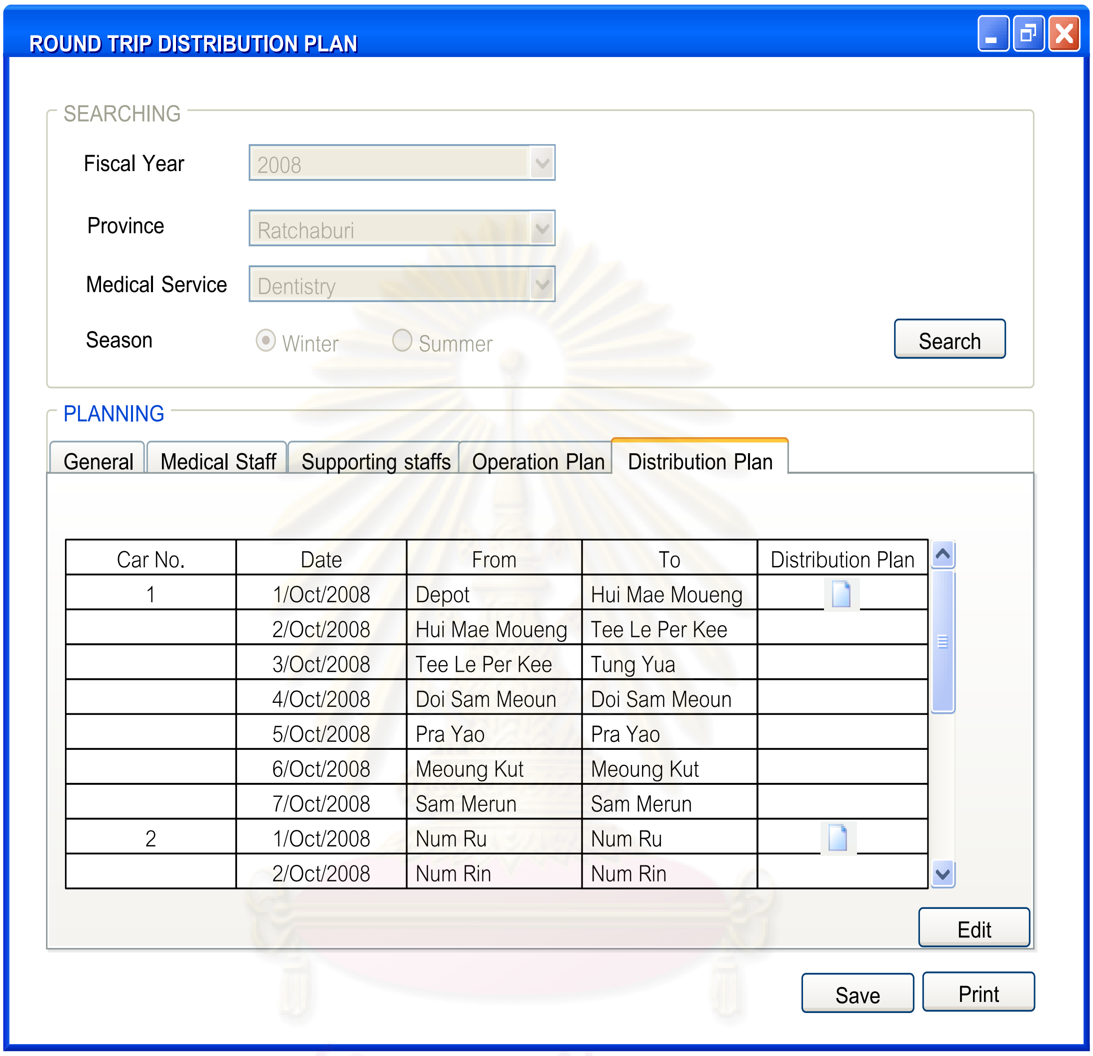


Medical team	Operation service-time	Departure from	Date of departure	Departure time
1	1/10/08- 7/10/08	depot	1/10/08	8.00
2	8/10/08 - 14/10/08	depot	8/10/08	8.00
3	15/10/08 – 21/10/08	depot	15/10/08	8.00
4	22/10/08 - 28/10/08	depot	22/10/08	8.00
5	29/10/08 - 4/11/08	depot	29/10/08	8.00
6	5/11/08 – 11/11/08	depot	5/11/08	8.00
7	12/11/08 – 18/11/08	depot	12/11/08	8.00
8	19/11/08 – 25/11/08	depot	19/11/08	8.00
9	26/11/08-2/12/08	depot	26/11/08	8.00

Figure D- 6 Operation Plan for Round trip planning

Objective: To present the overall plan of operation plan in medical team responsible in each service-time, the departure-return location, and departure schedule in order that all involving personnel mutually realizes and perceive important details of the operation plan.

Instruction: Users can edit the information of the departure-return location, and time by clicking “Edit” button; however, if planners are satisfied with the result, he/she can do both “Save” the data and enter to the next tab to further create overall plan or he/she can “Print” the result of general plan for revision.

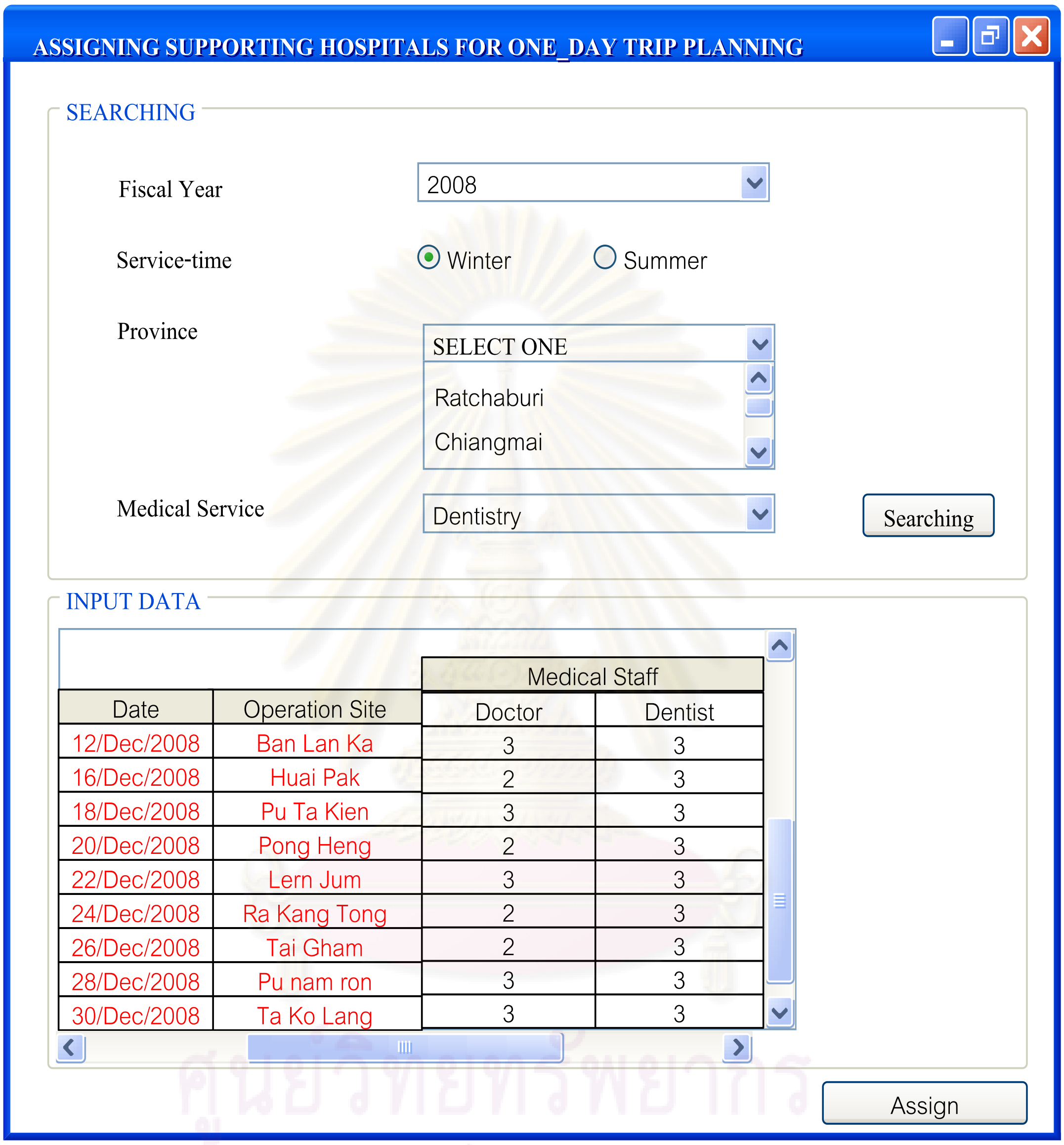


Car No.	Date	From	To	Distribution Plan
1	1/Oct/2008	Depot	Hui Mae Moueng	
	2/Oct/2008	Hui Mae Moueng	Tee Le Per Kee	
	3/Oct/2008	Tee Le Per Kee	Tung Yua	
	4/Oct/2008	Doi Sam Meoun	Doi Sam Meoun	
	5/Oct/2008	Pra Yao	Pra Yao	
	6/Oct/2008	Meoung Kut	Meoung Kut	
	7/Oct/2008	Sam Merun	Sam Merun	
2	1/Oct/2008	Num Ru	Num Ru	
	2/Oct/2008	Num Rin	Num Rin	

Figure D- 7 Distribution plan for Round trip planning

Objective: To present the detail of distribution for vehicles

Instruction: This tab is the management of vehicle in pickup point and delivery point including the must-carried item needed to be transported to operation site. Users can edit the information of the departure-return location, and time of each individual car to be more appropriate in real practice by clicking “Edit” button; however, if planners are satisfied with the result, he/she can do both “Save” the data and enter to the next tab to further create overall plan or he/she can “Print” the result of general plan for revision. By clicking is to view and manage the detail of must-carried medical supplies in each vehicle.



Date	Operation Site	Medical Staff	
		Doctor	Dentist
12/Dec/2008	Ban Lan Ka	3	3
16/Dec/2008	Huai Pak	2	3
18/Dec/2008	Pu Ta Kien	3	3
20/Dec/2008	Pong Heng	2	3
22/Dec/2008	Lern Jum	3	3
24/Dec/2008	Ra Kang Tong	2	3
26/Dec/2008	Tai Gham	2	3
28/Dec/2008	Pu nam ron	3	3
30/Dec/2008	Ta Ko Lang	3	3

Figure D- 8 Data Retrieving for one-day trip planning

To retrieve input data into the system for calculation process

Instruction:

1. Select fiscal year in order to start the operation routing of the selected fiscal year plan

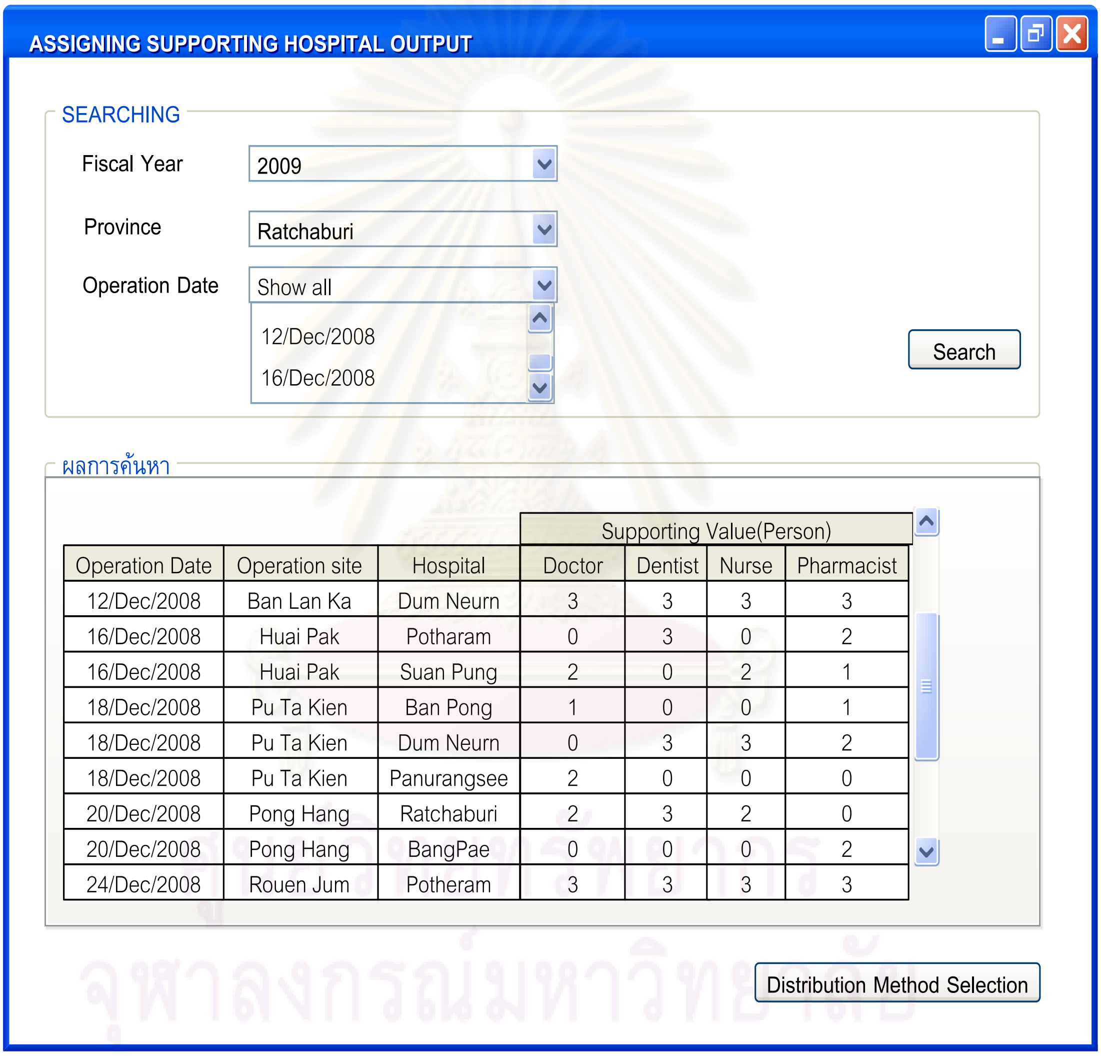
2. Choose the season for operation since the operation season leads to the different demand of medical staff

3. Select the planning province to retrieve the operation requisition for calculation

4. Select type of medical service resulting in the open of medical volunteer registration

5. Push “Search” button to retrieve the data into the system for calculation: after push the button all data in the selected field above will appear including the demand of medical staffs in each type at each operation site.

6. By clicking the “Assign” button lead to the calculation process of DSS which result in the assigning hospital solution presented in Figure D-9



Operation Date	Operation site	Hospital	Supporting Value(Person) Doctor	Dentist	Nurse	Pharmacist
12/Dec/2008	Ban Lan Ka	Dum Neurn	3	3	3	3
16/Dec/2008	Huai Pak	Potharam	0	3	0	2
16/Dec/2008	Huai Pak	Suan Pung	2	0	2	1
18/Dec/2008	Pu Ta Kien	Ban Pong	1	0	0	1
18/Dec/2008	Pu Ta Kien	Dum Neurn	0	3	3	2
18/Dec/2008	Pu Ta Kien	Panurangsee	2	0	0	0
20/Dec/2008	Pong Hang	Ratchaburi	2	3	2	0
20/Dec/2008	Pong Hang	BangPae	0	0	0	2
24/Dec/2008	Rouen Jum	Potheram	3	3	3	3

Figure D- 9 Display Result for one-day trip planning

Objective: To present the assignment result from the DSS computation including

- Type of supporting personnel by each hospital to each operation site
- Numbers of supporting personnel by each hospital to each operation site

Instruction: After the planners are satisfied with the result calculated by the DSS, he/she should select the most appropriate distribution method by pushing “Distribution Method Selection” button to enter into the next pop-up GUI presented in Figure D-10

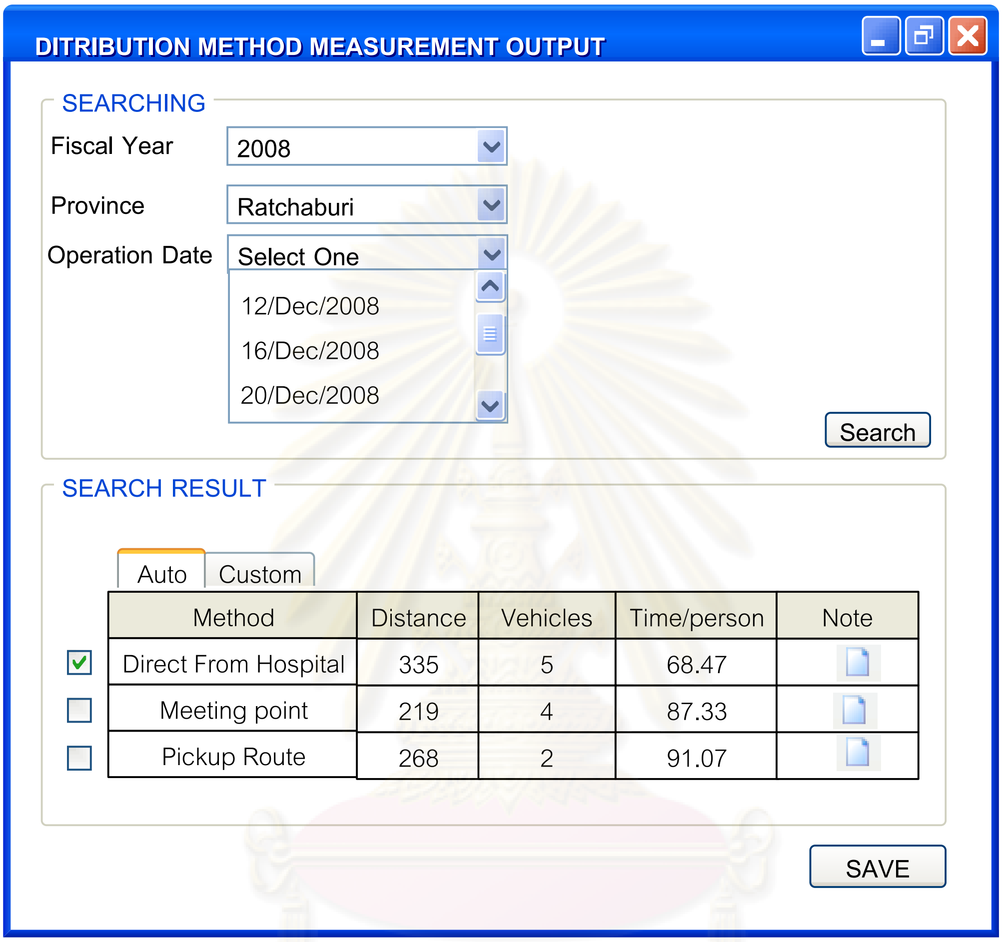


Figure D- 10 Selection of distribution method for one-day trip planning

Objective: Selection of distribution method of medical staff to operation site

Instruction: Users can select the most appropriate distribution method by choosing only one method in each operation date by clicking in the space provided In front of each method. The measurements of each method is presented as decision support information for planners to make a decision on the most appropriate distribution method depending on each planner individual prioritized measurement.

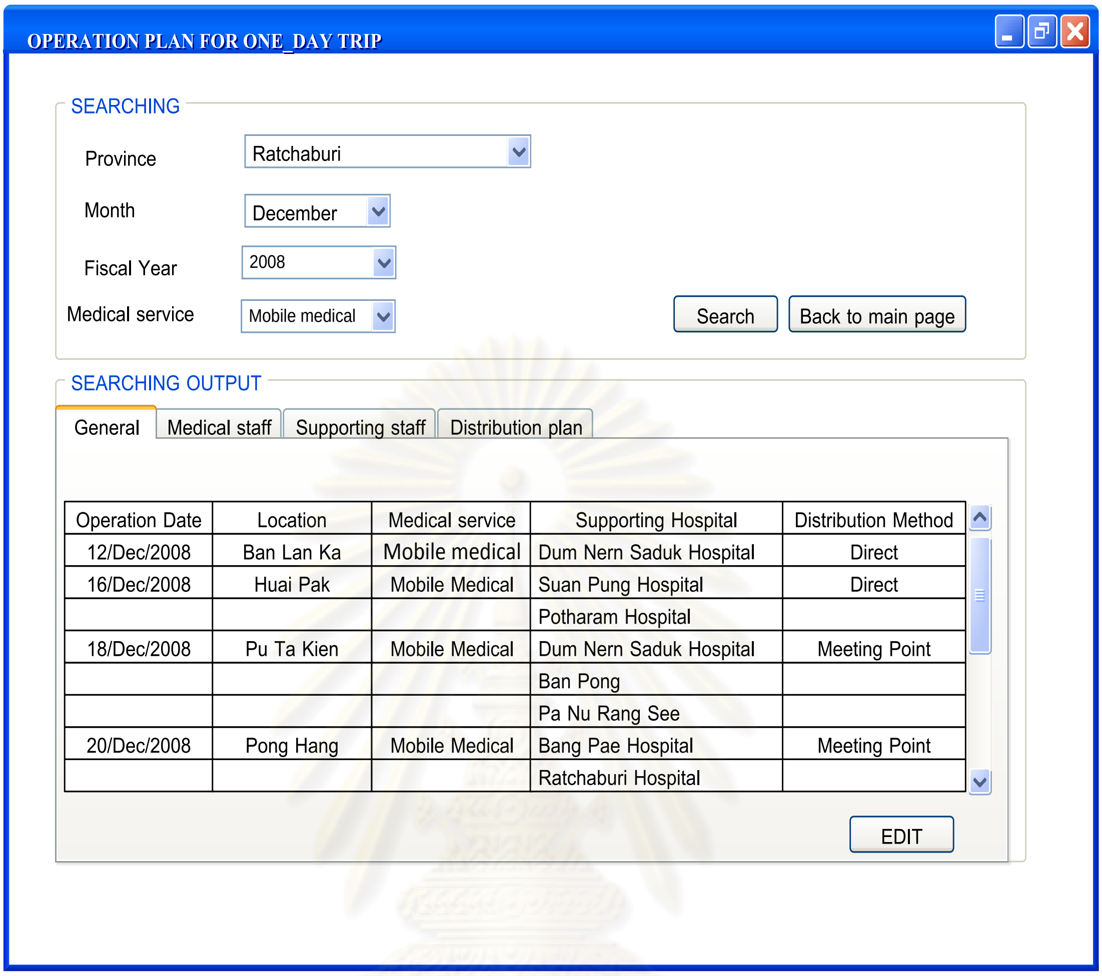


Figure D- 11 General Plan for one-day trip planning

Objective: To create overall operation plan for one-day trip distribution

Instruction: There are many tabs in the GUI of creating operation plan

In Figure D-11: the general plan for one day trip planning is the tab that retrieves all information required in distribution of medical staffs to operation sites including location of operation site, type of medical service , lists of supporting hospitals, and distribution method. These are overviews of operation plan and important information to communicate with other involving agents in mobile medical service. The detail of operation plan as shown can be revised by clicking “Edit” button; however, if planners are satisfied with the result, he/she can do both “Save” the data for generating operation plan and entering the next tab to further create overall plan or he/she can “Print” the result of general plan for revision.

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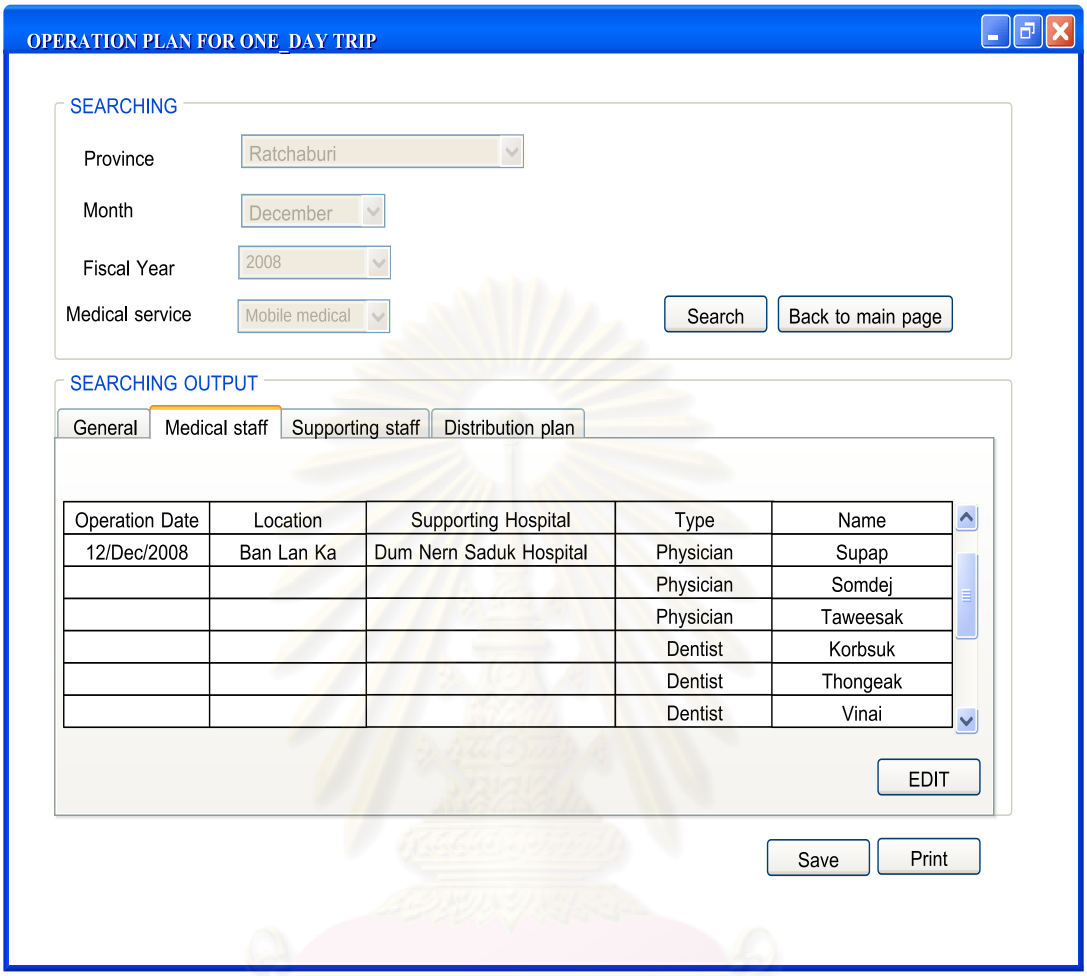

Figure D- 12 Medical staff Collaborative Plan for one-day trip planning

Objective: To present the details of medical staffs in each operation date

Instruction: The list of medical staffs registered to operate at the operation site according to operation route of each operation date from each supporting hospitals that has already passes through the screening process of Personnel Registration are shown in this information tab. Users can edit the information of names, surnames or individual information of medical staffs by clicking “Edit” button; however, if planners are satisfied with the result, he/she can do both “Save” the data and enter to the next tab to further create overall plan or he/she can “Print” the result of general plan for revision.

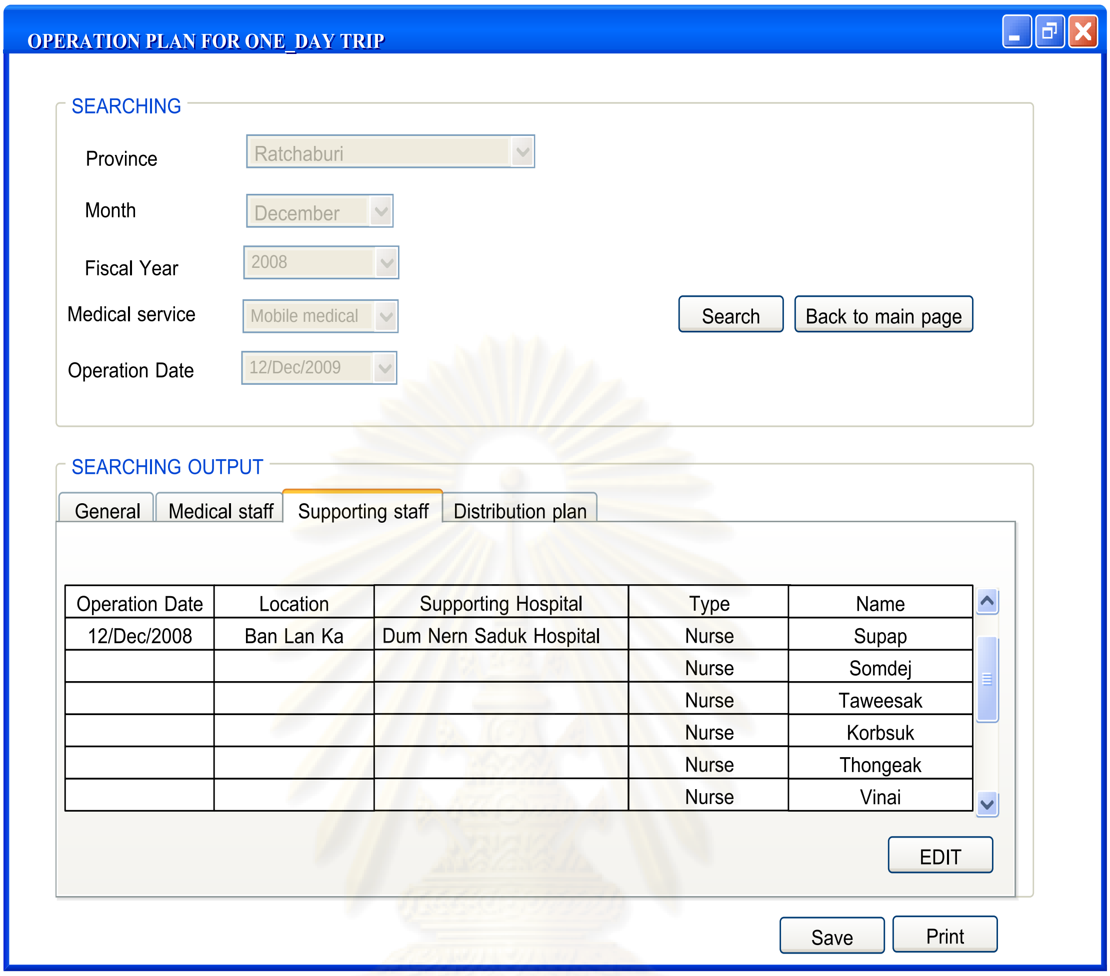

Figure D- 13 Medical staff Collaborative Plan for one-day trip planning (continued)

Objective: To present the details of supporting medical staffs in each operation date; the supporting staffs are nurses, pharmacists and dentist assistants who are not directly provide medical treatment to patients or customers.

Instruction: The list of supporting medical staffs registered to operate at the operation site according to each operation site requirement and result from assigning supporting hospitals that has already passes through the screening process of Personnel Registration are shown in this information tab. Users can edit the information of names, surnames or individual information of supporting medical staffs by clicking “Edit” button; however, if planners are satisfied with the result, he/she can do both “Save” the data and enter to the next tab to further create overall plan or he/she can “Print” the result of general plan for revision.

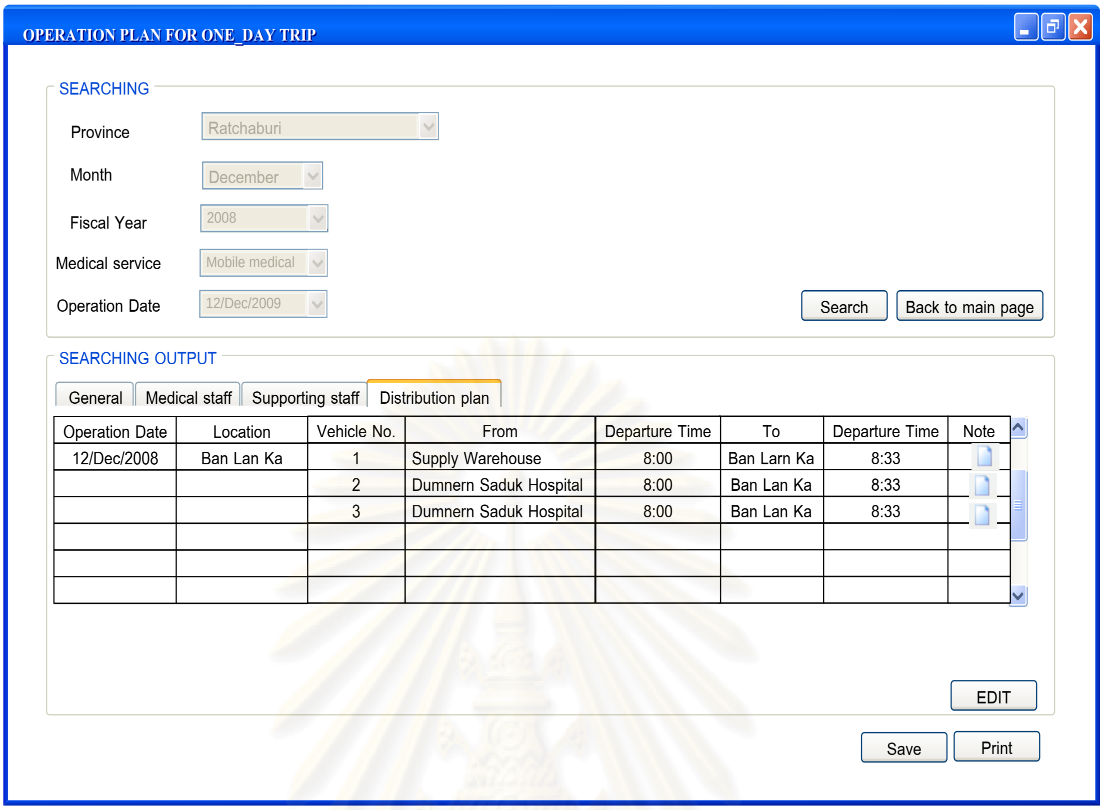

Figure D- 14 Distribution plan for one-day trip planning

Objective: To present the detail of distribution for vehicles

Instruction: This tab is the management of vehicle in pickup point and delivery point including the must-carried item: staffs and supplies needed to be transported to each operation site from different supporting hospitals according the to the selected distribution method. Users can edit the information of the departure-return location, and time of each individual car to be more appropriate in real practice by clicking “Edit” button; however, if planners are satisfied with the result, he/she can do both “Save” the data and enter to the next tab to further create overall plan or he/she can “Print” the result of general plan for revision. By clicking  is to view and manage the detail of must-carried medical supplies in each vehicle.

BIOGRAHPHY

Krongsin Somprasonk completed her undergraduate studies in 2007 with the Bachelor's Degree of Engineering 2nd class honor with the major of Industrial Engineer at the Department of Industrial Engineering, Chulalongkorn University. During the same year of graduation, she enrolled in the dual Master's Degree Program of Chulalongkorn University, Thailand and University of Warwick, UK to strengthen her studies in engineering business management at the Regional Center for Manufacturing Systems Engineering, Chulalongkorn University.