# การออกแบบระบบสารสนเทศเพื่อการวางแผนการขนส่งสินค้าสำหรับโรงงานผลิตเครื่องนุ่งห่ม

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# INFORMATION SYSTEM DESIGN FOR TRANSPORTATION PLANNING OF A GARMENT FACTORY

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A Thesis Submitted in Partial Fulfillment of the Requirements

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ลีนา เอื้อบำรุงจิต : การออกแบบระบบสารสนเทศเพื่อการวางแผนการขนส่งสินค้าสำหรับโรงงานผลิตเครื่องนุ่งห่ม. (INFORMATION SYSTEM DESIGN FOR TRANSPORTATION PLANNING OF A GARMENT IN FACTORY ) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ.ดร.มานพ เรี่ยวเดชะ, 217 หน้า.

วิทยานิพนธ์ฉบับนี้รายงานการออกแบบระบบสารสนเทศเพื่อสนับสนุนการวางแผนการขนสินค้าสำหรับโรงงานผลิตเครื่องนุ่งห่ม เพื่อให้สามารถดำเนินการรับและส่งสินค้าได้ภายในเวลาที่กำหนด และมีต้นทุนในการขนส่งที่ต่ำ

การออกแบบระบบสารสนเทศแบ่งออกเป็น 5 ส่วน คือ (1) กระบวนการตัดสินใจการวางแผนการขนส่งสินค้า (2) กระบวนการปรับเปลี่ยนแผนการขนส่งสินค้า (3) ฐานข้อมูล (4) หน้าจอการทำงาน และ (5) กระบวนการทำงาน (business process) กระบวนการตัดสินใจการวางแผนการขนส่งสินค้าและการปรับเปลี่ยนแผนการขนส่งสินค้าได้ประยุกต์ใช้เทคนิค nearest neighbor ซึ่งเป็นวิธีการหาคำตอบด้วยวิธีฮิวริสติก (heuristics) เพื่อให้ได้วิธีการหาคำตอบและผลคำตอบที่เหมาะสม โดยคำนึงถึงต้นทุนการขนส่งเป็นหลัก การออกแบบฐานข้อมูล หน้าจอการทำงานและกระบวนการทำงานได้ใช้เครื่องมือ DFD (data flow diagram) และ แผนภาพกระบวนการทำงาน (business flow chart) เพื่อสื่อความคิดของระบบออกมาเป็นรูปธรรม

จากการประเมินระบบพบว่า วิธีการหาคำตอบของโมเดลที่ใช้ในการตัดสินใจเรื่องการจัดเส้นทางการขนส่งที่พัฒนาขึ้นสามารถทำให้ต้นทุนการขนส่งรวมลดลงจากเดิม 46 % ส่วนคำตอบของโมเดลที่ใช้ในการตัดสินใจเรื่องการปรับเปลี่ยนเส้นทางการขนส่งที่พัฒนาขึ้นทำให้ต้นทุนการขนส่งรวมน้อยกว่าคำตอบที่ได้จากประสบการณ์วางแผนของเจ้าหน้าที่วางแผนในปัจจุบันถึง 58 % และสามารถขนส่งสินค้าทั้งหมดได้ทันเวลาที่กำหนด นอกจากนี้ผู้ที่เป็นเป้าหมายเป็นผู้ใช้ระบบสารสนเทศมีความพึงพอใจกับหลักการและแนวคิดของระบบที่ออกแบบขึ้น เพราะสามารถแก้ปัญหาที่เกิดขึ้นในการจัดเส้นทางในปัจจุบัน และลดความยุ่งยากในการตัดสินใจได้ และน่าจะนำไปประยุกต์ใช้ได้จริง

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This thesis reports the design of an information system for supporting transportation planning of a garment factory in order to meet receipts and deliveries in time with low cost of transportation.

The design of the information system consists of 5 parts: (1) the decision making process in delivery planning, (2) the delivery plan changing process, (3) database, (4) computer screens that support delivery planning, and (5) the business process. The nearest neighbor, which is a technique of heuristics, is applied to generate and change transportation plans using the transportation cost as the main criteria. Business flow charts, data flow diagrams, and data schema are used to explain the design of the database, the user interface, and the business process.

The system evaluation shows that the proposed method of decision making process in delivery planning can reduce the transportation cost by 46% from the current method. The proposed delivery plan changing process can reduce the cost of delivery plan changes by 58% comparing to the method generated by the experienced transportation planner. In addition, the users of this information system are satisfied with the concept and the principle of the system, because it can solve present vehicle routing problem, reduce the complexity of making a decision, and practical to implement.

The Regional Centre for Manufacturing System Engineering Student's Signature ..............................

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

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction and statement of problem

Nowadays, every industry in Thailand has grown rapidly and highly competed with each other; therefore, these industries have to improve in every aspect in order to stay competitively. One of the core factors, especially for organisations which have to receive raw materials and send goods to several places, is transportation. These firms must focus on their transportation systems which have ability to respond transportation demand quickly, be in time, and low cost. If they cannot send their goods in time specified in the schedule, it will cause plenty of loss. For example, if the supplier is not able to send raw material to the plant in time, the manufacturing of this plant is stopped and cannot produce any goods. Thus, this plant has to pay the penalty cost to its customer because of lateness.

Transportation cost of garment industry is very expensive, since the plants do not focus on the transportation planning. Although some firms have the delivery planning, these plans have indistinct detail and the inefficient pattern. For instance, each supplier sends its raw material directly to the plant shown in Figure 1, even though these suppliers are located in the same area. If these suppliers coordinate with each other in order to combine the raw material from others and then send it to the plant which is shown in Figure 2, the transportation cost will be decreased. Another alternative, milk run, is shown in Figure 3.

The plant uses its vehicles starting at the plant, then picking up the raw materials from each supplier, and then sending these raw materials to the plant. This method also reduces the transportation cost. Furthermore, milk run method will decrease the number of trucks and increase the utilization of space. [1]

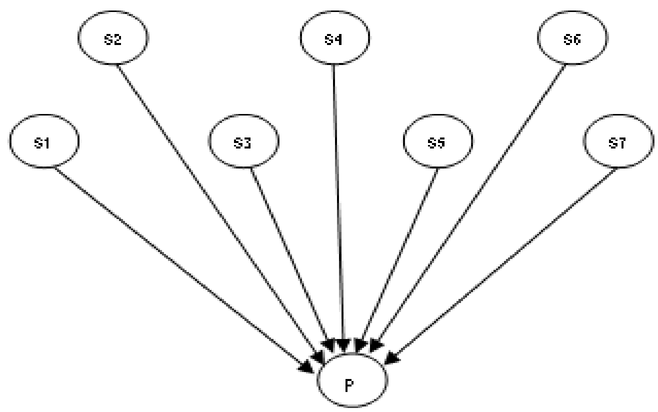



Figure 1 The present delivery method: direct deliver from suppliers to plant (S: Supplier, and P: Plant)

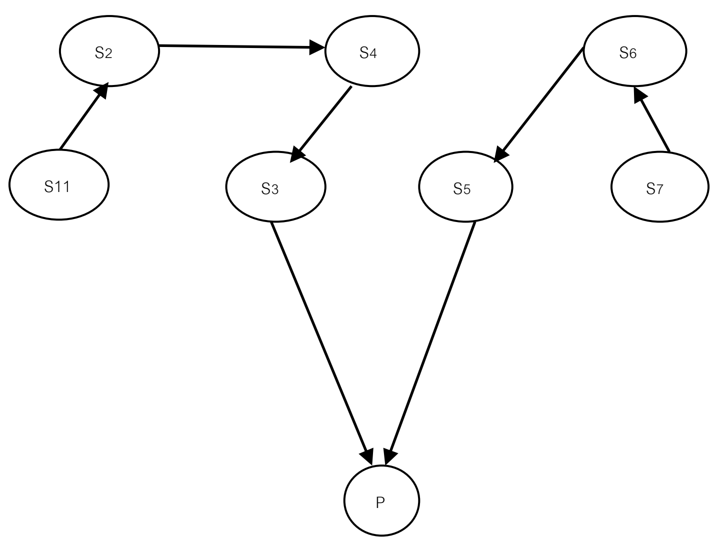



Figure 2 Combining the raw materials in the same area, then sending to the plant

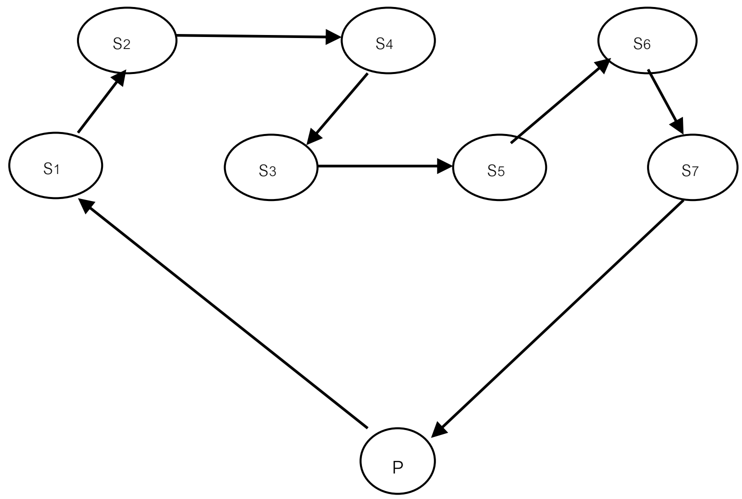



Figure 3 Milk run method by starting and ending at the same point which is a plant

The delivery planning of garment industry, at the present, is managed separately by each department, because these departments have their own vehicles. Sometimes, the different department has the same route and destination, but they do not coordinate. Therefore, the total delivery cost of this plant is very high because of overlapped routing.

Moreover, the transportation demand of garment industry usually changes after releasing the delivery plan such as increasing the transportation demands, putting off the due date, and canceling the transportation demands, so the efficiency of the previous transportation planning is low. For example, it is shown that there are 2 vehicles and the sequence of receiving and sending the goods is shown in Figure 4. After releasing the transportation plan, the transportation demands from some suppliers are changed; that is, the demand from supplier6 is cancelled since there are some problems on production line, and the demand from supplier8 is increased. The plants, at the present, always solve this problem by using new vehicle which is vehicle number 3 in order to pick up the raw material from supplier8 as shown in Figure 5. From this figure, it is shown that the delivery cost is very expensive because of low efficient in planning and no process for changing the transportation plan.

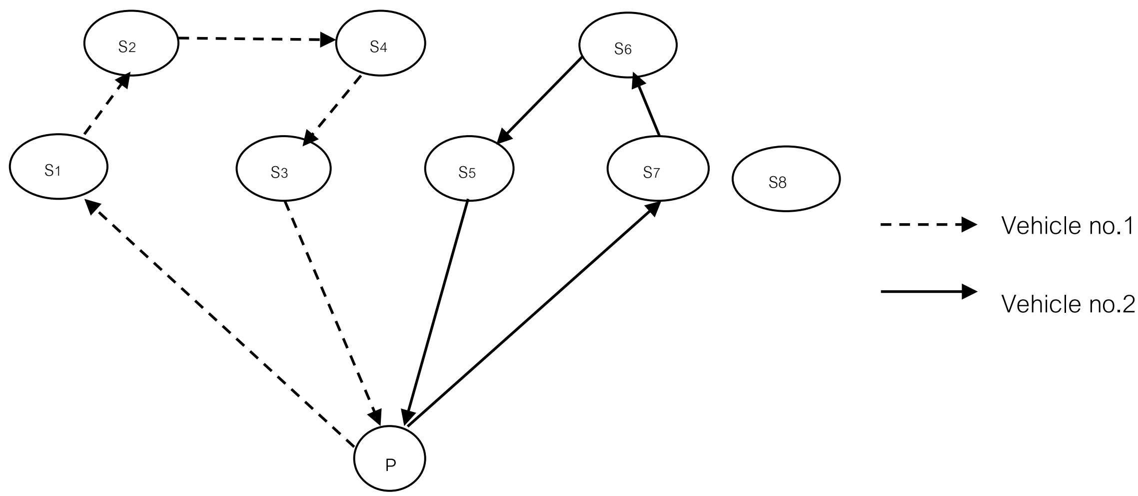



Figure 4 The routing of initial transportation plan

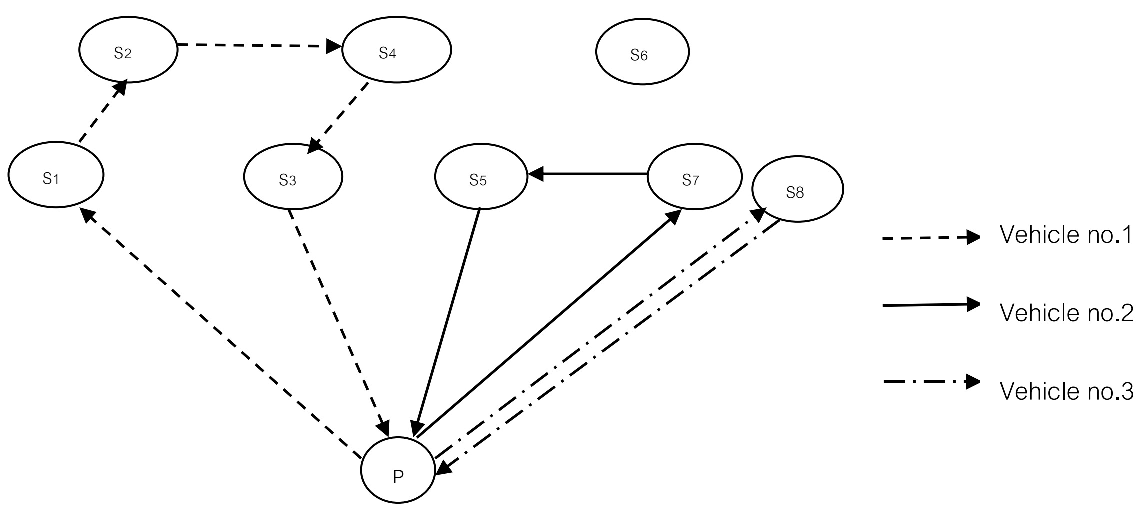



Figure 5 The routing when the transportation demands are changed

These demands are mostly specified in term of period such as receiving and sending the goods (ID 001) since 1/5/2011 until 5/5/2011. Moreover, the transportation demands are sometimes more than the capacity of the vehicles, so these transportation demands have to be operated more than one trip. In addition, each transportation demand has its constraint. For example, some transportation demands cannot operate in the same vehicle as the other demands. All of these things make the planning of transportation more complex.

At the present, the delivery planning is taken responsibility by a planning officer who uses his/her experience to plan and does not have any criteria to make a decision. Furthermore, there is no tool to support his/her decision for planning and no re-plan when the transportation demands are changed.

Therefore, the researcher will develop the decision making process for delivery planning of garment industry including the process of changing the transportation plan in order to pick up and deliver the goods in time with suitable cost. In addition, the decision support system for generating the transportation plan is designed.

## 1.2 Objectives of the research

To design an information system for generating delivery plans for a garment factory in order to meet all demands in time with low cost of transportation.

## 1.3 Research scope

- The information system consists of 5 parts: the decision making process in delivery planning, the delivery plan changing process, user interface or computer screens, database for supporting the process of the system, and the business process. The overview of decision making process for delivery planning and the delivery plan changing process are shown in Figure 6.

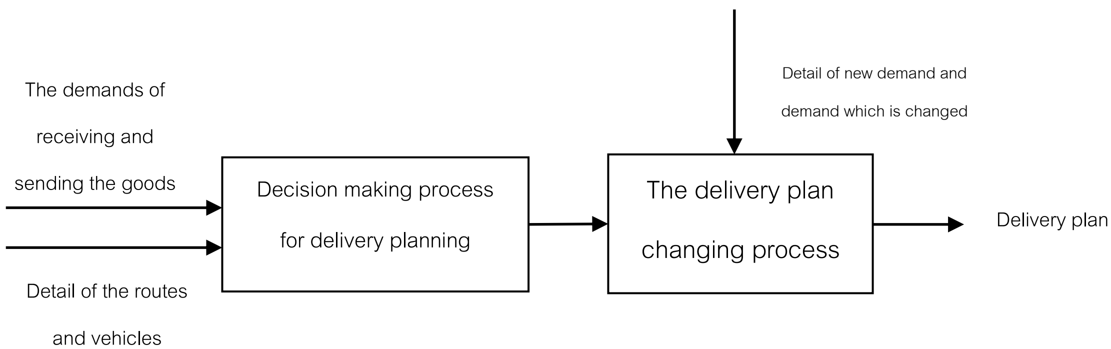



Figure 6 The overview of concept of decision making process for delivery planning and the delivery plan changing process

- Inputs of the decision making process consist of the transportation demands, the detail of the routes, the transportation time between any two points of each vehicle, and the details of vehicles.
- Decision making process is to determine the type of vehicle, routing, and the sequence of receiving and sending the goods for demands that occur after planning time fence.

- Output of decision making process is the delivery plan.
- Inputs of the delivery plan changing process consist of the previous delivery plan, the detail of the routes, the transportation time between any two points of each vehicle, the details of vehicles, and the details of demands chaged which occure in planning time fence.
- The delivery plan changing process is designed for normal situation which excludes the emergency situation such as accident, and breaking down of the vehicles. The plan cannot change while the vehicle is executed.
- Output of delivery plan changing process is the delivery plan which is the same as output of decision making process.
- Any programmers who would like to develop this model to be a programme can use the output of this information system.
- Programme coding and implementation of information system for a garment factory are excluded.
- The delivery plan in this research excludes in house transportation.
- Transportation mode used in this research is road transportation.
- The solution of this system is not guaranteed optimal.
- Goods in this system mean raw materials(R), work in process (WIP), and finished goods (FG). All of these goods are specified in the same units which are kilogramme (kg), and cubic metre ($m^3$).
- Transportation resources in this system are vehicles only, others such as the drivers and the crews are not taken into consideration.

- Nodes in this system consist of several places which are supplier, outsource, plant, distribution center, wholesaler, retailer, and port such as airport, sea port, and train station. Each node has different goods, but they can be receiving and sending points. Moreover, there is one centre point which is the plant.
- The vehicle capacity limitation in this system includes the size of the goods and the weight of goods, but the shape of the goods and the additional equipment for supporting the transportation are not taken into consideration.

The assumptions of this system are shown in Table 1.

Table 1 The assumptions of this system

| Issues | Details of the system |
|---|---|
| Fuel station | – It is assumed that all delivery plans are executable; ignoring problem such as fuel shortage, etc. |
| Node | – The operating time of every node is the same. For example, every node opens at 8 am and closes at 10 pm. |
| Demand | – The planning time fence is specified by the users.<br>– It can be splitted if it is over capacity of the largest vehicle in the system. |
| The conditions of | – Every vehicle has the same starting and ending point; that is, the centre or the plant. |

| Issues | Details of the system |
| --- | --- |
| operating vehicles | – The vehicle has to back to the centre point within the operatation per day which is specified by the users.<br>– There is no transshipment. |
| Vehicle | – The number of in house vehicle is limited.<br>– The number of outsourced vehicle is unlimited.<br>– Each in house vehicle has different maintenance plan. When it is the time of maintenance, this vehicle is sent to the plant in order to repair according to the plan.<br>– There is no maintenance plan for outsourced vehicles.<br>– Transportation cost of each vehicle is known. |
| Time | – Loading and unloading time must be considered.<br>– The transportation time between any two points is different and assumed to be constant and also applicable at any time. It is specified by the user. |
| Transportation cost | – The transportation cost of in house vehicle includes fixed and variable cost which is varied by the distance.<br>– The transportation cost of outsourced vehicle includes fixed cost which is hiring cost per day and variable cost which is varied by the distance. |

| Issues | Details of the system |
| --- | --- |
| Maintenance plan | – The period of maintenance plan is specified in day. |
| Routing | – There is only one routing from node A to node B in this system.<br>– The distance from node A to node B is not equal to node B to node A. |

## 1.4 Methodology

The research can be divided into 2 parts as follows:

### 1.4.1 Design decision making process for delivery planning, and changing the delivery plan process.

The model applied in this part is combining mathematic model and heuristic in order to find the suitable solution.

**1.4.2 Design the decision support system for garment industry including the business process, database, and user interface.**

Since this research focuses on the designing and excludes the programme coding and implementation, the researcher will use business flow chart to explain its idea and Microsoft access for displaying the database.

## 1.5 Research procedure

1. Study garment industry
2. Study the transportation problem
3. Study the literature review related to the vehicle routing problem and solution in order to apply to thesis
4. Design making process for delivery planning
5. Design the delivery plan changing process
6. Design the decision support system
7. Test the information system designed
8. Analyze and conclude the results
9. Prepare report and presentation for thesis

## 1.6 Expected results

- Decision making process for delivery planning of garment industry. The result of this process is the delivery plan which has 2 patterns: the delivery plan arranged by ID of vehicle which is sent to tracking department and outsource in order to operate according to the transportation plan, and the delivery plan arraged by ID of company which is sent to transportation plan department in order to inform the details of receipts and deliveries to each company.
- Changing the delivery plan process for garment industry.
- User Interface
- Database
- Business process

## 1.7 Expected benefits

- Decrease the cost of transportation for garment industry which responds all demand in the system in time.
- Reduce the difficulty and complexity of planning the transportation including the process of changing delivery plan.
- Support the planning officer who has responsibility to plan the transportation and change the transportation plan

# CHAPTER 2
# LITERATURE REVIEW

This chapter explains the theories and literature review related to the problem of information system design for transportation planning, especially the solution of vehicle routing problem. The theories and literature review in this research covers 5 topics as follows:

- Type of distribution planning
- Vehicle routing problem
- Solution techniques
- Heuristics used for solving vehicle routing problem
- Logistics model used at the present

## 2.1 Types of distribution planning

Distribution planning can be divided into 3 levels as follows: strategic planning, tactical planning, and operational planning.

Firstly, it is a strategic planning which is a long term planning. Strategy planning determines the direction of the company or management policy such as the location and capacity of plants and warehouses. Secondly, it is a tactical planning which is a medium term planning. Tactical planning aims to manage and allocate the resource in order to achieve the goals and improve the system's performance. For example, the number of vehicles, the distribution channel, the supplier chosen and the transportation mode have to be determined. Thirdly, it is an operational planning which is a short term planning for day to day activity. Operational planning determines the vehicle routing which consists of the amount of goods transported, and the sequence of picking up and delivery [2].

In conclusion, this research is considered to be an operational planning, because the vehicle routing has to be decided every day.

## 2.2 Vehicle routing problems

Vehicle routing problem can be classified according to the structure of problem as Table 2. [3], [4]

Table 2 Classification of vehicle routing problem (VRP) [3], [4]

| Characteristics | Options |
|---|---|
| Demand | Deterministic<br>Stochastic |
| Size of fleet | One vehicle<br>Multiple vehicles |
| Vehicle capacity | All the same<br>Different<br>Unlimited |
| Housing of vehicle | Single depot<br>Multiple depots |
| Operations | Pick-ups only<br>Deliveries only |

| Characteristics | Options |
|---|---|
| | Pick-ups and deliveries |
| Route time | Same for all vehicles<br>Different for all vehicles<br>Unlimited |
| Costs | Variable cost<br>Fixed cost |
| Objectives | Minimize total distribution time or distance<br>Minimize sum of fixed cost and variable cost<br>Minimize number of vehicles required<br>Minimize total routing cost<br>Maximize utility function based on service or convenience |

This research belongs to the class with deterministic demand and there are several types of vehicle which have limited capacity. Moreover, there is single depot or centre point which is the plant and every vehicle has to back to the centre point within the operatation per day which is specified by the users. The objective of this system is to determine the routing of pick-ups and deliveries for all demands and be in time with suiatable cost consisting fixed and variable cost.

This research determines transportion planning for garment industry with single depot. There are 3 problems which has the same characteristic of research's problem. These three problems are classified according to the level of complication which varies from the simplest to the most difficult.

- Traveling Salesman Problem, TSP
- Multiple Traveling Salesmen Problem, MTSP
- Vehicle Routing Problem, VRP

The details of 3 problems are explained below:

**2.2.1 Travelling salesman problem**

Travelling sales problem is the simplest problem, because the vehicle starts from the single depot, and visits all customers, and then returns to this depot by using one routing. Moreover, there are no time and vehicle's capacity constraints. The output is a routing which starts and ends at the depot or distribution centre, and visits each customer only once time.

Assuming that network $G = [N, A, C]$, where N denotes set of delivery nodes, $A$ denotes set of arcs, and $C = [c_{ij}]$ denotes matrix of transportation cost starting from node i to node j. Moreover, start point and end point is at the distribution centre which is node 1. The model formulation is shown below:

Let $x_{ij}$ = 1 if arc(i, j) belongs to the set of answer. Let $x_{ij}$ = 0 if arc(i, j) does not belong to the set of answer. In addition, X denotes the matrix of $x_{ij}$: therefore, the mathematics model is as follow:

Minimize

$$\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} x_{ij}$$

Equation 1

Subject to

$$\sum_{i=1}^{n} x_{ij} = b_j = 1 \qquad (j = 1,\ldots n)$$

Equation 2

$$\sum_{j=1}^{n} x_{ij} = a_j = 1 \qquad (i = 1,\ldots n)$$

Equation 3

$$X = (x_{ij}) \in S$$

Equation 4

$$x_{ij} = 0$$

Equation 5

S denotes the set for eliminating subtour which is not the needed results of routing, because the subtour does not start and end at the beginning point. Moreover, the subtour can make Equation 2, Equation 3, and Equation 5 to be true; therefore, the subtour has to be eliminated by using following constraints called subtour-breaking constraint (S).

1. $$S = \left\{ (x_{ij}) : \sum_{i \in Q} \sum_{j \notin Q} x_{ij} \geq 1 \right\}$$

Equation 6

Every subset of Q∈ N denotes the eliminating subtour within the routing.

2. $$S = \left\{ (x_{ij}) : \sum_{i \in R} \sum_{j \in R} x_{ij} \leq |R| - 1 \right\}$$

Equation 7

For R ∈ {2,3,..n } denotes that the selected routing does not overlap with other selected routing.

3. $$S = \left\{ (x_{ij}) : y_i - y_j + n x_{ij} \leq n - 1 \right\}$$

Equation 8

For 2 ≤ i ≠ j ≤ n by assuming that $y_i$ = t if the customer i is in the sequence t of routing. If there is other cases, $y_i$ = 0

Fuethermore, there is several models of travelling salesman problem such as Gavish and Graves. This model has assumed flow variables ($y_{ij}$) which denotes the quantity of goods transported from node i to node j. In addition, there is $n$ -1 customers, and starting point is at node 1, and each customer has only one transportation demand. Thus, if there is delivery at the next point, the value of $y_{ij}$ will reduce. The mathematics model is shown below:

Minimise

$$\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} x_{ij}$$

Equation 9

Subject to

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad (j = 1,\ldots n)$$

Equation 10

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad (i = 1,\ldots n)$$

Equation 11

$$\sum_{j=1}^{n} y_{ij} - \sum_{j=1}^{n} y_{ji} = -1 \qquad (i = 2,\ldots n)$$

Equation 12

$$y_{ij} \leq Ux_{ij} \qquad (i = 2,\ldots n)$$

Equation 13

$$x_{ij} = 0 \text{ or } 1, y_{ij} \geq 0$$

Equation 14

$U \geq n - 1$, Equation 10, and Equation 11 means that each node has only one vehicle routing. Equation 13 represents forcing constraint in order to give the value of $y_{ij}$ on arc (i, j) equal to zero, if this arc is not on the needed routing. If $x_{ij}$ is equal to zero, $y_{ij}$ is equal to zero.

### 2.2.2 Multiple travelling salesman problem

Multiple travelling salesman problem is more complicate than travelling salesman problem, because there are several routes to visit all customer. Moreover, there is only depot and there is no time and capacity constraint.

Assuming that M denotes the number of vehicles or routes which deliver the goods to the customers n-1 customers in order to minimize the transportation cost of M routes. The mathmetics model is as follow:

Minimise

$$\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij}$$

Equation 15

**Subject to**

$$\sum_{i=1}^{n} x_{ij} = b_j = \begin{cases} M & if \ \mathbf{j = 1} \\ 1 & if \ \mathbf{j = 2,3,..}n \end{cases}$$

Equation 16

$$\sum_{j=1}^{n} x_{ij} = b_i = \begin{cases} M & if \ i = \mathbf{1} \\ 1 & if \ i = \mathbf{2,3,..}n \end{cases}$$

Equation 17

$$X = (x_{ij}) \in S$$

Equation 18

$x_{ij} = 0$ or 1 $\quad (i,j = 1,\dots n)$

Equation 19

Let S denotes the set for eliminating subtour which uses the same as travelling salesman problem.

### 2.2.3 Vehicle routing problem

Vehicle routing problem is to determine the number of routes and the sequence of delivery the goods from distribution centre to each customer. These routes have to cause the minimum of transportation cost. In addition, there are time and vehicle's capacity constraints.

The mathmetics model of vehicle routing problem which derives from the characteristic of problem such as the function of objective, the constraint of time and capacity is as follows:

Minimise

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{v=1}^{NV} c_{ij} x_{ij}^{v}$$

Equation 20

Subject to

$$\sum_{i=1}^{n}\sum_{v=1}^{NV} x_{ij}^{v} = 1 \qquad (j = 2,\ldots n)$$

Equation 21

$$\sum_{j=1}^{n}\sum_{v=1}^{NV} x_{ij}^{v} = 1 \qquad (i = 2,\ldots n)$$

Equation 22

$$\sum_{i=1}^{n} x_{ip}^{v} - \sum_{j=1}^{n} x_{pj}^{v} = 0 \qquad (v = 1,\ldots NV) \quad (p = 1,\ldots, n)$$

Equation 23

$$\sum_{i=1}^{n} d_i \left( \sum_{j=1}^{n} x_{ij}^{v} \right) \le K_v \qquad (v = 1,\ldots NV)$$

Equation 24

$$\sum_{i=1}^{n} t_i^{v} \sum_{j=1}^{n} x_{ij}^{v} + \sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij}^{v} x_{ij} \le T_v \qquad (v = 1,\ldots NV)$$

Equation 25

$$\sum_{j=2}^{n} x_{1j}^{v} \leq 1 \qquad (v = 1,\ldots NV)$$

Equation 26

$$\sum_{i=2}^{n} x_{i1}^{v} \leq 1 \qquad (v = 1,\ldots NV)$$

Equation 27

$$X \in S$$

Equation 28

$$x_{ij}^{v} = 0 \text{ or } 1 \qquad \textit{for all } i, j, v$$

Equation 29

When;

$n$ = the number of delivery points

$NV$ = the number of vehicles

$K_v$ = capacity of vehicle v

$T_v$ = maximum time for operating vehicle v

$d_i$ = delivery demand at delivery point i

$t_i^v$ = loading time or unloading time at node i operated by vehicle v

$t_{ij}^v$ = travelling time from point i to point j operated by vehicle v

$c_{ij}$ = transportation cost from point i to point j operated by vehicle v

Let $x_{ij}^{v}$ = 1 if arc(i, j) belongs to the set of answer. Let $x_{ij}^{v}$ = 0 if arc(i, j) does not belong to the set of answer. In addition, *X* is the matrix of $x_{ij}^{v} = \sum_{v=1}^{NV} x_{ij}^{v}$ . [5]

## 2.3 Solution techniques

There are two major approaches for solving the vehicle routing problem: exact optimization and heuristics.

### 2.3.1 Exact optimization

This approach can find the optimal answer, but it takes long computational time. There are several techniques for finding the best solution. For example, the liner programming can be used to find the optimal solution; however, this technique can be applied with 42 customers.[6] Another technique is dynamic programming proposed by Bellman [7]. Furthermore, branch and bound can be used to find the best solution.

### 2.3.2 Heuristics

This approach can save the computational time, but the answer is not guaranteed optimal. Heuristics can be classified into 2 groups: classical heuristics and meta heuristics [8].

- Classical heuristics

Classical heuristics can be categories into 3 groups which are route construction methods, two phase method, and route important methods [9].

- Meta heuristics

There are several techniques such as ant colony optimization (ACO), generic algorithm (GA), and simulated annealing. Moreover, tabu search is another example of this group which is proposed by Gehring and Homberger. [10], [11]

The researcher has studied both advantages and disadvantages of exact optimization and heuristics; therefore, the researcher will choose heuristics in order to solve vehicle routing problem in this research. The reason for selecting heuristics as a solution is that there are several nodes and many transportation demands in the system. Thus, heuristics can solve this problem which is complicate and large problem and get the suitable answer with less computational time than using exact optimisation.

## 2.4 Heuristics for solving vehicle routing problem in this research

Nearest neighbor is a technique of heuristion. The concept of this technique is to route by visiting the clostest point. The detail of nearest neighbor is explained below. [12]

Step 1: Searching the next node which has the minimize distance comparing to the current node

Step 2: Visiting the closest node

Step 3: Repeating step 1 and 2 until all nodes are visited

Step 4 Going back to the beginning node

## 2.5 Current logistics models

At the present, there are many distribution models such as direct shipping, milk run, hub and spoke, cross dock, and transshipment. In this research, direct shipping and milk run have been applied in order to generate delivery plan. The details of both models are explained below:

### 2.5.1 Direct shipping model

Direct shipping is the practical model and very popular at the present. The goods are transported from original point to delivery point directly. The distribution centre or warehouse has not been applied in direct shipping model. Therefore, the benefits of using direct shipping are that there is no cost of distribution centre or warehouse such as holding cost of goods. In addition, transportation time is less than other methods, thus it suits for transporting short shelf life product or passenger. However, there are drawbacks of direct shipping. For example, total transportation cost is high, because some routing is overlapped. The model of direct shipping is shown in Figure 7.

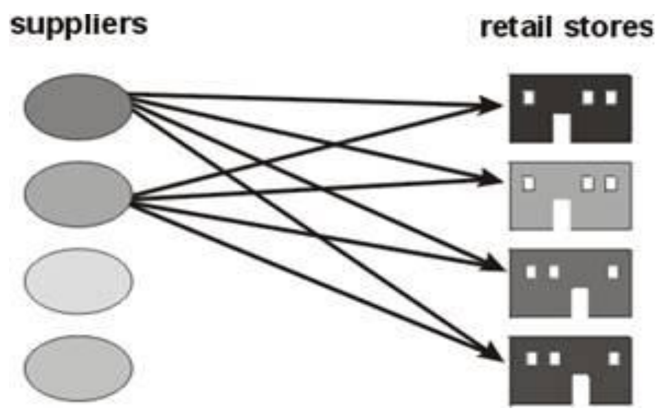



Figure 7 Direct shipping model adapted from Chopra and Meindl [13]

### 2.5.2 Milk run model

Milk run model is assigning a vehicle to travel around in order to pick up raw material, then deliver these raw material at retail stores. There are plenty of benefits for using milk run, for example, the number of vehicles used are fewer than direct shipping model, transportation cost is decreased, and it supports system using just in time (JIT). On the other hand, there are drawbacks of using milk run model as well, for instance, transportation time is higher than other methods, and high skilled planner is required. The model of milk run is shown in Figure 8.

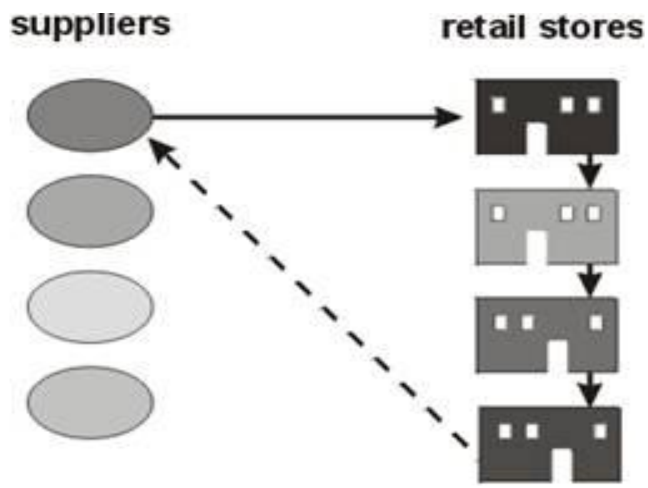



Figure 8 Milk run model adapted from Chopra and Meindl [13]

# CHAPTER 3
# CONCEPTS AND PRINCIPLE

To generate the delivery plan for garment industry, there are several important issues for making a decision: choosing the date of operating transportation demand, type of vehicle which is classified by capacity, group of vehicle used which consists of in house vehicle and outsourced vehicle, method of transportation, routing, and sequence of transporting goods. The objective of generating delivery plan is to meet all demands in time with low cost of transportation. Therefore, the researcher will design an information system for generating delivery plan for a garment factory.

For garment industry, the transportation demand usually changes such as postponing the due date, increasing transportation demand, and cancelling transportation demand. Thus, the process of generating transportation plan created has to be flexible and can change the previous transportation plan in order that all transportation demands in the system are operated in time with low transportation cost.

The process of generating delivery plan can be divided into 2 parts as follow:

Part 1: decision making process for delivery planning

Part 2: changing the delivery plan process

Decision making process for delivery planning and changing the delivery plan process have different process for making a decision, but both 2 parts can use the same database such as the number of in house and outsourced vehicle for each day, routing, distance,’ and transportation time between any two point of each vehicle.

## 3.1 Concepts and principle of decision making process for delivery planning

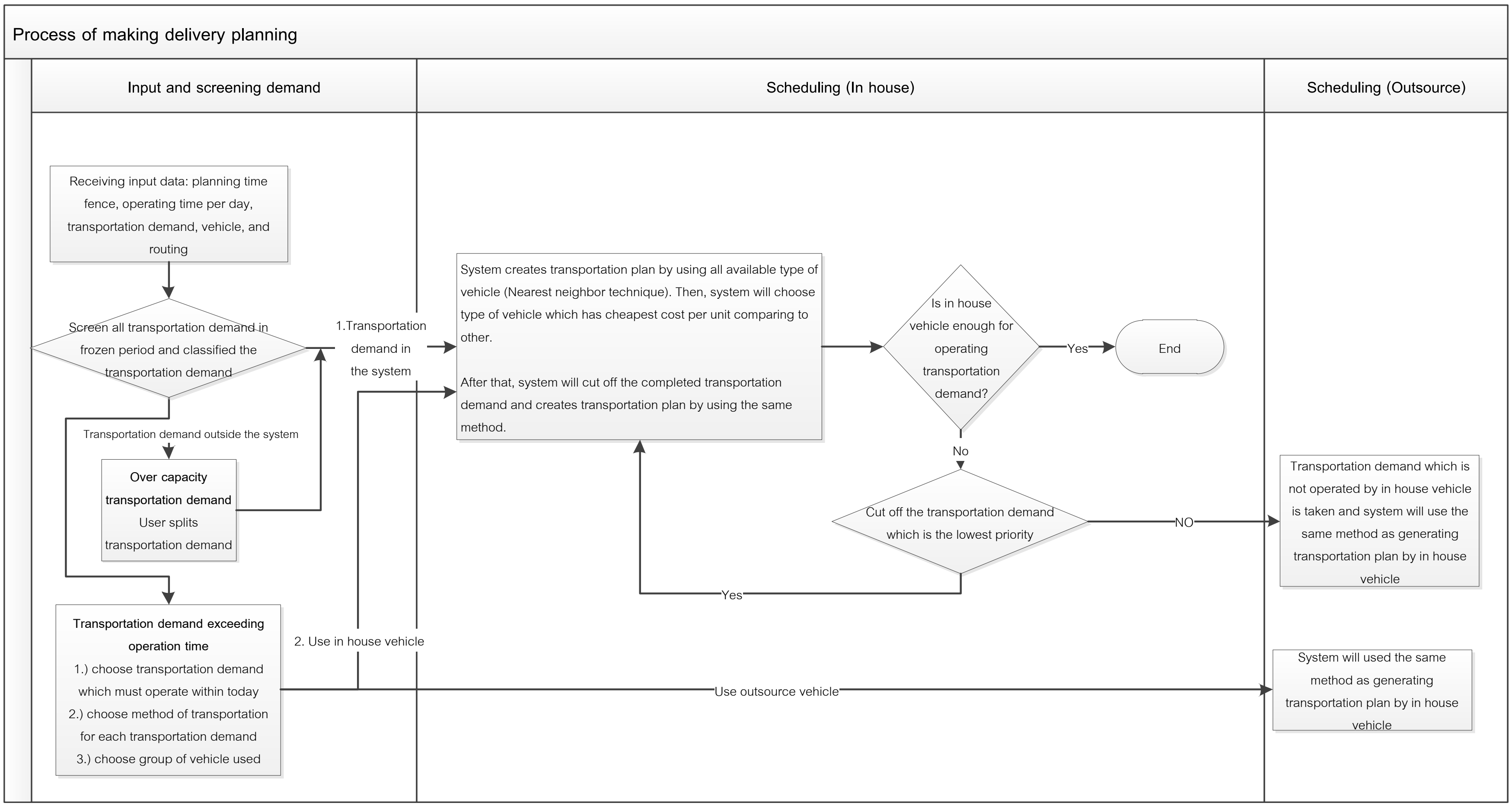



Figure 9 The overview concept of decision making process

The overview concept of decision making process is shown in Figure 9. It starts from recieiving input data consisting of planning time fence, operating time per day, transportation demand, in house and outsourced vehicle, and routing. Then, the system will screen all transportation demands in planning time fence and classify which transportation demand is in the system or outside the system. There are 2 conditions of classifying transportation demand. The first condition is that the quantity of transportation demand has to be less than or equal to the largest vehicle's capacity in the system. The second condition is that the operating time of transportation demand is less than or equal to operating time per day. After classifying the transportation demand, it can be divided into 3 groups as follows:

- Group 1: over capacity transportation demand. The system will solve this problem by splitting the quantity of transportation demand into several batches. It will be divided by user. After that, the system will check that transportation demand splitted can be operated by vehicle in the system or not.
- Group 2: transportation demand exceeding operaton time per day. The system will solve this problem as following steps:
    - Choose transportation demand which must be operated within today.
    - Choose method of transportation for each transportation demand. There are 2 methods: direct shipping and milk run. The reason for having 2 methods is that each method has its advantages and disadvantages; therefore, the system creates the options in order that users can select the appropriate option and suit with his/her business.

- Choose group of vehicle used. There are 2 groups: in house and outsourced vehicle. If in house vehicle is chosen, transportation demand exceeding operation time per day will be operated before transportation demand in the system. On the other hand, if outsourced vehicle is chosen, this transportation demand will be routed with the same process and techniques as in house vehicle routing; that is, nearest neighbor. Moreover, the constraints of capacity and time have to be considered when routing. After that, the type of vehicle which has cheapest cost per unit will be selected and will operate transportation plan. Transportation plan will be generated every day starting from the first day to last day of planning time fence.

- Group 3: transportation demand in the system. All demands in the system will be routed by all available types of in house vehicle, and using nearest neightbor technique which has 2 constraints: capacity in term of weight and volume as well as time constraint. Then, the type of vehicle which has cheapest cost per unit will be chosen. After that, system will cut off the completed transportation demand and use the same steps with transportation demand left. Transportation plan will be generated every day starting from the first day to the last day of planning time fence.

The reason for choosing all transportation demands is that it will give the good answer which has low transportation cost. In addition, nearest neighbor is selected because it can give the answer which generates low distance affecting on transportation cost. Furthermore, choosing the type of vehicle which has the cheapest transportation cost per unit will affect on low transportation cost as well.

The system tries to do and choose the method affecting on low transportation cost which means that the system tries to achieve the objective.

After generating transportation plan, the system will consider all in house vehicles and ask that the number of in house vehicle is enough for operating all transportation demands or not. If the number of in house vehicle is enough, the system will conclude all transportation plans. On the contrary, if the number of in house vehicle is not enough, either system or user will cut off one transportation demand which has the lowest priority and this demand will be operated other day. Then, transportation demand left will be routed again by using the same process. Furthermore, if all transportation demands cannot be cut off or have to be operated only today, the system will select transportation demands left from generating by in house vehicle and route it by using outsourced vehicle which uses the same process as routing by in the house vehicle.

## 3.2 Concepts and principle of changing the delivery plan process

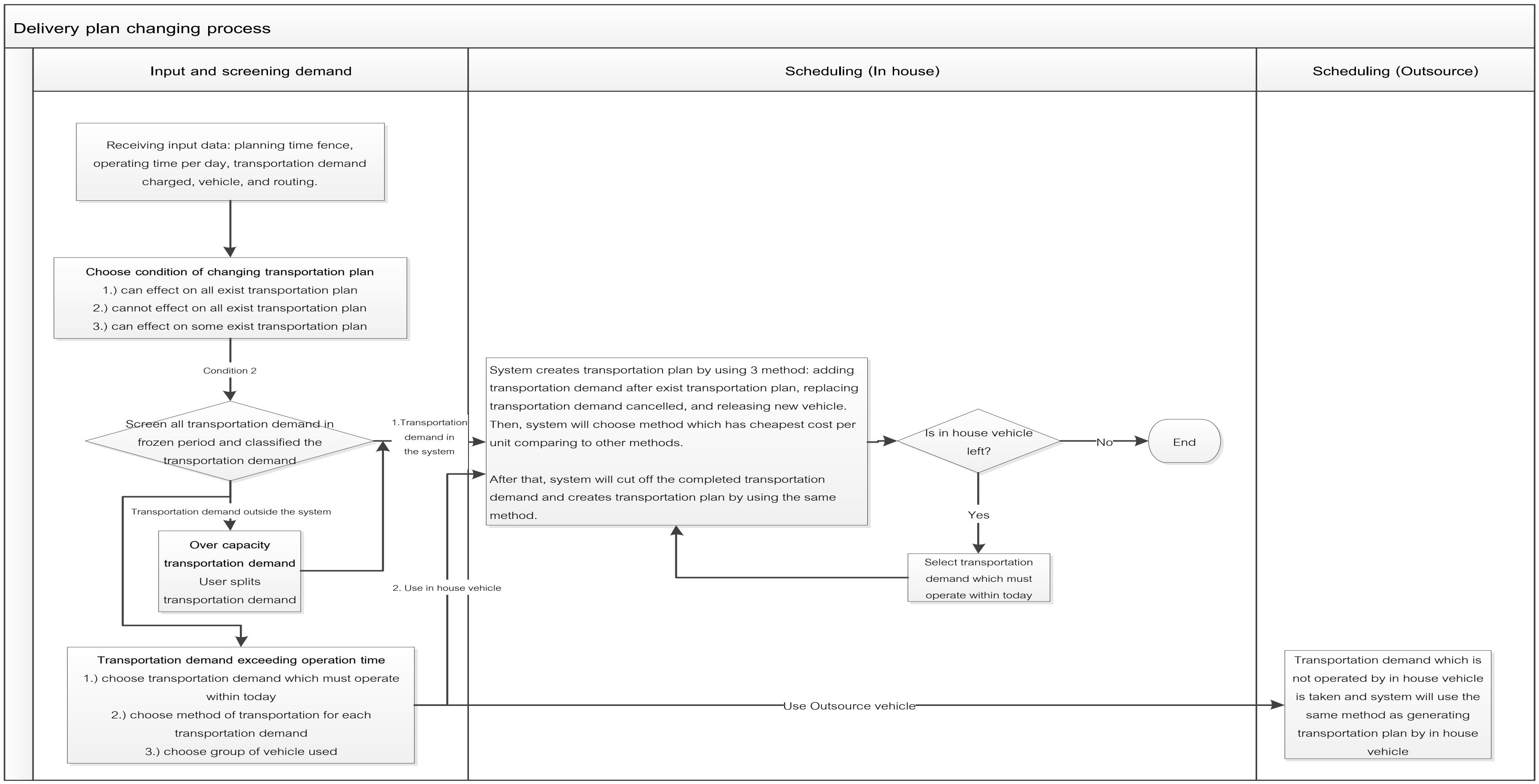



Figure 10 The overview concept of changing the delivery plan process

The overview concept of delivery plan changing process is shown in Figure 10. It starts from receiving input data consisting of planning time fence, operating time per day, transportation demand changed, vehicle, previous transportation plan, and routing. Then, user has to select the condition of changing transportation plan by considering constraint of changing previous transportation plan; therefore, user can select the appropriate condition with fit for the industry or factory. There are 3 conditions of changing transportation plan as follows:

- Condition 1: Changing transportation plan can effect on all previous transportation plans.

  System will combine transportation demand changed and all previous transportation demands, then create transportation plan following Figure 9.

- Condition 2: Changing transportation plan cannot effect on all previous transportation plans.

  System will start considering all transportation demands in planning time fence and classify the transportation demand by using the same method as making delivery planning process. After that, transportation demands will be divided into 3 groups and operated by the same method except group 3.

  - Group 3: transportation demand in the system. All demands in the system will be routed by using 3 following methods:
    - Adding transportation demand after the previous transportation plan.
    - Replacing new transportation demand in period of transportation demand cancelled.

- Releasing new vehicle which has the same process as making delivery planning.

After that, system will select the method which has cheapest transportation cost per unit. Then, system will cut the completed transportation demand off and use the same process with transportation demand left. After generating transportation plan, system will consider the number of in house vehicle left. If there is no in house vehicle left, system will conclude all transportation plans. In contrast, if there is available in house vehicle, either system or user will select transportation demand which must be operated within today and be routed by the same process.

The reason for adding transportation demand to operate today in case of having available in house vehicle is utilizing the in house vehicle. Even though in house vehicle is used or not, the fixed cost of in house vehicle is always paid.

Moreover, user can change transportation plan by his/herself. Then, system will check availability of the method selected by user. The important issues checked are capacity in term of weight and volume, and time limitation. Therefore, user can generate transportation plan which suits to his/her industry or plant.

- Condition 3: changing transportation plan can effect on some previous transportation plans.

There are 2 tasks for users if method 3 is selected. Firstly, user selects transportation plan which can be effected on both time confirmed with customer and type of vehicle operated. Transportation plan selected is arranged by ID of vehicle. Secondly, users select the condition of changing for each transportation demand. There are 2 conditions: condition 1 (changing transportation plan can effect on a previous transportation plans), and condition 2 (transportation plan cannot effect on all previous transportation plans). After completing 2 tasks, the system will operated according to the process of condition 1, and 2.

# CHAPTER 4
# DETAILS OF THE DESIGNED SYSTEM

This chapter explains the details of the system designed which can be divided into 2 following topics:

- The business process and fundamental of input data
- Decision support

## 4.1 Business process and fundamentals of input data

There are 2 business processes in this system: business process of decision making process for delivery planning, and business process of changing the delivery plan process. Business process will explain receiving and sending data among departments which are related to the processes. Moreover, the frequency of receiving and sending information will be specified in this topic.

### 4.1.1 Business process and fundamentals of input data of decision making process for delivery planning

This part will explain business process of decision making process for delivery planning which has the detail as Figure 11.

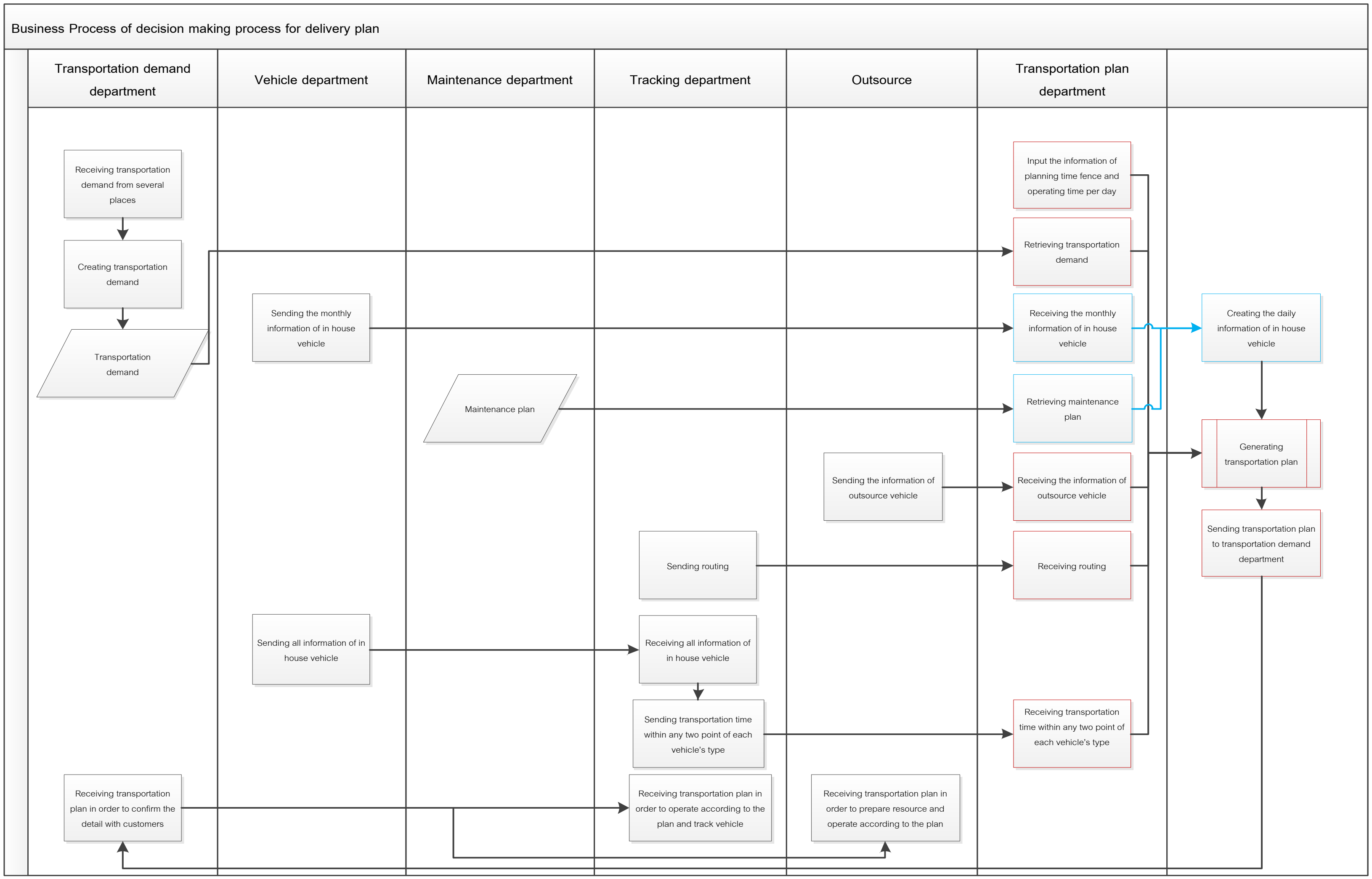



Figure 11 Business process of decision making process

The fundamental of input data of decision making process for delivery planning has the details as below:

<u>Fill in planning time fence and operating time per day</u>

Planning time fence is the period of planning transportation ahead and it is specified in days. For instance, accordind to Figure 12, if today is 1/6/2011, 6 days of planning time fence mean that the system is going to retrieve transportation demand since 1/6/2011 till 5/6/2011 and the system will generate transportation plan. Then, if today is 2/6/2011, the system will retrieve transportation demand and generate transportation plan from 2/6/2011 to 7/6/2011.

Planning time fence is filled in by user when using information system the first time. This data is a set up data and will be used as an input of generating delivery plan process.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Day | 1/6/2011 | 2/6/2011 | 3/6/2011 | 4/6/2011 | 5/6/2011 | 6/6/2011 | 7/6/2011 |

Planning time fence = 5 days

Figure 12 Example of transportation plan which has 6 days of planning time fence

Operating time per day is the maximum time that each vehicle is able to operate within one day. It starts counting since the vehicle leaves from centre plant and visits several places until the vehicle returns to centre plant.

Operating time per day is specified in hours by user when using information system the first time. This data is a set up data and will be used as an input of generating delivery plan process. Furthermore, this data is a time constraint of this system.

<u>Retrieve transportation demand</u>

Transportation demand is retrieved from transportation demand department. This department has to receive transportation demand from several places such as main plant, supplier, other plant, oursource, distribution centre, wholesales, retailer, sea port, airport, and train station. All of transportations of this research are concluded in Table 3.

Table 3 Scope of transportation

| To / From | Supplier | Main plant | Other plant | Outsource | Distribution centre | Wholesaler | Retailer | Port/Sea port/ Train Station |
|---|---|---|---|---|---|---|---|---|
| Supplier | - | R | R | R | - | - | - | - |
| Main plant | R | - | R /W | R/ W | F | F | F | F |
| Other plant | R | R /W | - | R/ W | F | F | F | F |
| Outsource | R | R /W | R /W | R/ W | F | F | F | F |
| Distribution centre | - | F | F | F | - | - | - | - |
| Wholesaler | - | F | F | F | - | - | - | - |
| Retailer | - | F | F | F | - | - | - | - |
| Port/Sea port/Train Station | - | F | F | F | - | - | - | - |

Assumption In house transportation is not taken into consideration.

Note Letter R represents raw material.

Letter W represents work in process.

Letter F represents finished goods.

The system will retrieve transportation demand every day and use as an input of generating delivery plan process. The detail of transportation demand is explained below:

- ID of transportation demand which has the characteristics as Figure 13 and has the details as follow:
  - Digit 1: pick up point which can be classified into 5 following groups:
    - F represents factory.
    - S represents supplier.
    - O represents outsource.
    - C represents distribution centre, wholesaler, retailer, sea port, airport, and train station.
    - E represents other points which cannot be grouped into 4 above groups.
  - Digit 2: delivery point which can be classified into 5 following groups:
    - F represents factory.
    - S represents supplier.
    - O represents outsource.
    - C represents distribution centre, wholesaler, retailer, sea port, airport, and train station.
    - E represents other points which cannot be grouped into 4 above groups.
  - Digit 3: type of goods transported which can be classified into 4 following groups:
    - R represents raw material.
    - W represents work in process.
    - F represents finished goods.
    - E represents other goods which cannot be grouped into 3 above groups.

- Digit 4 to 7: Running number such as 0001
- Digit 8 to 9: divided batch number which shows in the parentheses round brackets such as 01

| Pick up point | Delivery point | Type of goods | Running number | Divided batch number |
|---|---|---|---|---|
| F/S/O/C/E | F/S/O/C/E | R/W/F/E | 0000 | (00) |

Figure 13 The characteristics of transportation demand's ID

- Period of time that can pick up and deliver goods. It is specified in days, for example, the transportation demand can be operated since 10/7/2011 untill 12/7/2011.
- Name of pick up and delivery point
- Quantity of goods specified in 2 dimensions: weight (kg), and volume ($m^3$)
- The constraint of transporting goods. This information sometimes receives from transportation demand department. Sometimes, the user or the transportation planer has to make the decision about the constraint by his/herself.
    - This transportation demand has to be separated from other transportation demands or not.
    - This transportation demand has to operate the same day as other transportation demands or not. If yes, the user must assign the demand to each group, assuming that the transportation demand in the same group will operate the same day. For example, ID OCF0003(01) and SFM0004(01) are in group 1, thus it means that both OCF0003(01) and SFM0004(01) are operated the same day.
- Type of goods which can be classified into 4 groups.
- Loading time and unloading time.

  <u>Assumption of loading and unloading time</u>

  Loading time is equal to unloading time if it is the same ID of transportation demand.

Table 4 shows the details of transportation demand.

Table 4 Example of transportation demand

| Transportation demand_ID | Today | 13/7/2011 | 14/7/2011 | 15/7/2011 | Seperated demand | Group for transportating | Goods_type | Loading time (min) |
|---|---|---|---|---|---|---|---|---|
| FOW0001(01) | A- B (300kg., 2.4$m^3$) | | | | No | No | W | 60 |
| OCF0002(01) | A- D (500 kg., 3.9 $m^3$) | | | | Yes | No | F | 100 |
| OCF0003(01) | D-C (200kg.,1.6 $m^3$) | | | | No | Yes/ group 1 | F | 50 |
| SFM0004(01) | B - D (100 kg., 0.4 $m^3$) | | | | No | Yes/group 1 | R | 70 |

If the user cannot fill in loading time and unloading time, or transportation demand department does not give this information, the system will calculate both loading and unloading time according to [1].

Receive the monthly in house vehicle

There are 2 types of in house vehicle in the system: vehicle bought by factory, and vehicle rented more than 1 month by the factory. This data receives from vehicle department. This department has evalulated aggregate plan to determine the number of vehicle required in each month, then generated the vehicle renting plan, then prepared the vehicle by renting according to the plan, respectively.

The detail of the monthly in house vehicle is as follow:

Vehicle bought by the factory

- Month consisting of 12 months since January until December
- ID of vehicle’s type. The criterion for classifying vehicle is capacity. The characteristic of ID of vehicle’s type consists of 3 digits which are running number.

Assumption of in house vehicle’s variable cost

In house vehicle which has the same capacity has the same variable cost.

- Capacity of vehicle which is specified in 2 dimensions: weight (kg), and volume ($m^3$)
- Fix cost which comes from depreciation

Assumption of in house vehicle's fixed cost (Vehicle bought by the factory)

Fixed cost of in house vehicle bought by the factory is always paid, even though it is operated or not.

- Variable cost which comes from fuel cost varied by distance
- The number of in house vehicle

Table 5 shows the detail of monthly in house vehicle bought by factory.

Table 5 Example of the detail of monthly in house vehicle bought by factory

| Month | Vehicle's type_ID | Capacity (kg.) | Capacity ($m^3$) | Fixed cost (Baht/month) | Variable cost (Baht/km.) | Number of vehicle (unit) |
|---|---|---|---|---|---|---|
| June | 001 | 1,000 | 4 | 9,000 | 3 | 5 |
| | 002 | 5,000 | 30 | 15,000 | 8 | 5 |
| July | 001 | 1,000 | 4 | 9,000 | 3 | 4 |
| | 002 | 5,000 | 30 | 15,000 | 8 | 6 |

**Vehicle rented more than one month by the factory**

- Month consisting of 12 months since January until December
- ID of vehicle's type. The criterion for classifying vehicle is capacity. The characteristic of ID of vehicle's type consists of 3 digits which are running number.
- Capacity of vehicle which is specified in 2 dimensions: weight (kg), and volume ($m^3$)
- Average fix cost which comes from the average hiring cost per month

<u>Assumption of in house vehicle's fixed cost (Vehicle rented more than one month by the factory)</u>

Fixed cost of in house vehicle rented more than one month by the factory is always paid, even though it is operated or not.

- Variable cost which comes from fuel cost varied by distance
- The number of in house vehicle

Table 6 shows the detail of monthly in house vehicle rented more than one month by the factory.

Table 6 Example of the detail of monthly in house vehicle rented more than one month by the factory

| Month | Vehicle's type_ID | Capacity (kg.) | Capacity ($m^3$) | Average fixed cost (Baht/month) | Variabel cost (Baht/km.) | Number of vehicle (unit) |
|---|---|---|---|---|---|---|
| June | 001 | 1,000 | 4 | 20,000 | 3 | 10 |
| | 002 | 5,000 | 30 | 55,000 | 8 | 10 |
| July | 001 | 1,000 | 4 | 20,000 | 3 | 10 |
| | 002 | 5,000 | 30 | 55,000 | 8 | 15 |

This information has received every year and used as an input in order to determine the number of in house in each day.

<u>Retrieve maintenance plan</u>

Maintenance plan is retrieved from maintenance department. The details of maintenance plan of each vehicle which is explained below will know ahead about 1 month.

The detail of maintenance plan is as follow:

- ID of maintenance plan which consists of 6 digits which has the detail as follow and shown in Figure 14.
    - Digit 1: type of vehicle classified by physical shape. There are 6 following groups.
        - A represents car.
        - B represents 4 wheeled pick up truck.
        - C represents 4 wheeled van
        - D represents 6 wheeled truck
        - E represents 10 wheeled truck
        - F represents other vehicles which have different physical shape from 5 above groups.
    - Digit 2 to 6 which is running number

| Physical shape of vehicle | Running number |
|---|---|
| A/B/C/D/E/F | 00000 |

Figure 14 Characteristic of vehicle's ID

- Car registration
- ID of vehicle's type
- Start date of maintenance vehicle
- End date of maintenance vehicle

Table 7 shows the detail of maintenance plan

Table 7 example of maintenance plan

| Maintenance plan_ID | Vehicle_ID | Car registration | Vehicle type_ID | Start date (D/M/Y) | End date (D/M/Y) |
|---|---|---|---|---|---|
| D00001 | D00001 | 65-1234 | 001 | 6/6/2011 | 8/6/2011 |
| B00002 | B00001 | วฮ-3456 | 002 | 7/6/2011 | 10/6/2011 |

The system will retrieve maintenance plan every month in order to use as an input and determine the number of vehicle in each day.

<u>Receive outsourced vehicle information</u>

Outsourced vehicle considered in this system is vehicle which has only hiring cost per day or short term contract. This data comes from outsource and has the detail as below:

- Date consisting day, month, and year, respectively.
- Vehicle's type ID which uses the same criteria for classifying type of vehicle.

  <u>Assumption of outsourced vehicle's variable cost</u>

  Outsourced vehicle which has the same capacity will have the same variable cost
- Capacity which is specified in 2 dimensions: weight(kg), and volume($m^3$)
- Fixed cost which comes from hiring cost per day
- Variable cost which comes from fuel cost varied by distance
- The number of vehicle in each day

  <u>Assumption of the number outsource</u>

  The number of outsourced vehicle is unlimited

  Table 8 shows the details of outsourced vehicle information in each day

Table 8 Example of outsourced vehicle information in each day

| Date (D/M/Y) | Vehicle's type_ID | Capacity (kg.) | Capacity ($m^3$) | Fixed cost (Baht/day) | Variable cost (Baht/km.) | Number of vehicle (unit) |
|---|---|---|---|---|---|---|
| 1/6/2011 | 001 | 1,000 | 4 | 1,000 | 3 | unlimited |
| | 002 | 5,000 | 30 | 4,500 | 8 | unlimited |
| 2/6/2011 | 001 | 1,000 | 4 | 1,000 | 3 | unlimited |
| | 002 | 5,000 | 30 | 4,500 | 8 | unlimited |

This information receives from outsource everyday and uses as an input of generating transportation plan.

<u>Receive routing information</u>

Routing information receives from tracking vehicle department which comes from the data of tracking vehicle in the real suitation. The distance from A to B is not necessary to equal to the distance from B to A. Thus, this data is very pratical and has the detail as shown in Table 9. Moreover, all distances between any two points cannot be known easily in the real practice, hence the distance between two points which is specidifed in Table 3 has to be known and recorded in the database. The reason is that it is a transportation occurring in the system.

Table 9 Example of routing information

| From / To | A (km.) | B (km.) | C (km.). | D (km.) |
|---|---|---|---|---|
| A (km.) | | 20 | 50 | 30 |
| B (km.) | 20 | | 15 | 70 |
| C (km.) | 55 | 20 | | 30 |
| D (km.) | 35 | 60 | 30 | |

This data is changed according to the information from tracking vehicle department; therefore, the transportation planning used this data is more accurate and pratical. This information is used as an input of generating transportation plan.

Receive transportation time between any two points of each vehicle's type

The information of transportation time between any two points of each vehicle receives from tracking vehicle department which comes from the data of tracking vehicle in the real suitation. The transportation time from A to B is not necessary to equal to the transportation time from A to B. In addition, the transportation time does not need to depend on the distance operated. Hence, this information is very pratical.

Table 10 and Table 11 display the detail of transportation time between any two points. Furthermore, transportation time classified by the vehicle's type is very pratical, since different type of vehicle uses diffent travelling time on the same route in the real suitation.

Table 10 Example of transportation time between any two points of vehicle's type ID 001

| From / To | A (min) | B (min) | C (min) | D (min) |
|---|---|---|---|---|
| A (min) | | 50 | 125 | 75 |
| B (min) | 55 | | 40 | 175 |
| C (min) | 100 | 50 | | 75 |
| D (min) | 70 | 170 | 75 | |

Table 11 Example of transportation time between any two points of vehicle's type ID 002

| From / To | A (min) | B (min) | C (min) | D (min) |
|---|---|---|---|---|
| A (min) | | 30 | 75 | 45 |
| B (min) | 30 | | 22 | 105 |
| C (min) | 60 | 30 | | 45 |
| D(min) | 40 | 105 | 55 | |

This information is changed according to the information from tracking vehicle department. Hence, the transportation planning used this information is more accurate and pratical. This data is used as an input of generating transportation plan.

<u>Calculate the number of in house vehicle in each day</u>

The number of in house vehicle in each day is calculated from the number of in house vehicle in each month and maintenance plan, according to Equation 30.

$$NH_{km}^{v} = NH_{m}^{v} - NHM_{km}^{v}$$

Equation 30

When;

$NH_{km}^{v}$ represents the number of in house vehicle type v which is ready for operating on day k, month m.

$NH_{m}^{v}$ represents the number of in house vehicle type in month m. It comes from the total number of in house vehicle bought by factory and vehicle rented more than 1 month by factory.

$NHM_{km}^{v}$ represents the number of in house vehicle type v which is repaired on day k, month m.

k represents date

v represents type of vehicle

m represents month

Assumption of maintenance plan

The period of maintenance plan is specified in day; that is, even though the vehicle is repaired less than one day, the system will assume that this vehicle cannot operate on the maintenance day. This assumption has both advantages and disadvantages as follows:

The advantage is that it is easy for determining the number of vehicle in each day. However, the disadvantage is that it is not practical, because the vehicle can operate after repairing in the real suitation.

The detail of in house vehicle in each day is shown as below:

- Date consisting of day, month, and year
- Type of vehicle. The criterion for classifying is capacity.
- Capacity of vehicle which is specified in 2 dimensions: weight(kg), and volume($m^3$)
- Fix cost
- Variable cost which comes from the fuel cost varied by the distance
- The number of vehicle in each day

Table 12 displays the details of in house vehicle in each day

Table 12 Example of the details of in house vehicle in each day

| Date | Vehicle's type_ID | Capacity (kg.) | Capacity ($m^3$) | Fixed cost (Baht/day) | Variable cost (Baht/km) | Number of vehicle (unit) |
|---|---|---|---|---|---|---|
| 1/6/2011 | 001 | 1,000 | 4 | 15,000 | 3 | 14 |
| | 002 | 5,000 | 30 | 40,000 | 8 | 13 |
| 2/6/2011 | 001 | 1,000 | 4 | 15,000 | 3 | 12 |
| | 002 | 5,000 | 30 | 40,000 | 8 | 11 |

The system will calculate the number of in house in each day every month. This information will be used as an input of generating transportation plan.

<u>Decision making process</u>

Decision making process starts from recieiving planning time fence, operating time per day, transportation demand, in house and outsourced vehicle, routing, and transportation time as input data in order to generate the transportation plan.

There are several following issues that have to be made a decision when generating delivery plan.

- Choose transportation demand operated in each day
- Choose type of vehicle
- Chooose routing and the sequence of transporting goods

This transportation planning aims to meet all demands in time with low cost of transportation.

<u>Send delivery plan to transportation demand department</u>

After generating transportation plan, the system will send this plan to transportation demand department every day. There are 2 patterns of transportation plan which is explained below:

Pattern 1 is transportation plan which is arraged by ID of vehicle in order to operate according to the plan. It will be assigned to tracking vehicle department and outsource by transportation demand department. The detail of transportation plan arraged by ID of vehicle is as follows:

- ID of vehicle
- Car registration
- ID of vehicle’s type

- Time
- Details in each period of time *(OTW mens on the way)*
- Place where the vehicle operates
- ID of transportation demand
- Quantity of transportation demand
- Capacity left
- Total distance
- Transportation cost

Table 13 displays the detail of transportation plan arraged by ID of vehicle

Table 13 Example of transportation plan arraged by ID of vehicle B00001 with car resigtration วฮ-3456

| Vehicle's type_ID | Time | Detail | Place | Transportation demand_ID | Weight (kg.) | Volume ($m^3$) | Weight left (kg.) | Volume left ($m^3$) |
|---|---|---|---|---|---|---|---|---|
| 002 (In house) | 9.00 | Leave | P | | | | 1,000 | 4 |
| | 9.00-10.00 | OTW | | | | | 1,000 | 4 |
| | 10.00 | Arrive | A | | | | 1,000 | 4 |
| | 10.00-11.00 | Loading | A | FOW0001 | 300 | 2.4 | 700 | 1.6 |
| | 11.00 | Leave | A | | | | 700 | 1.6 |
| | 11.00 - 12.00 | OTW | | | | | 700 | 1.6 |
| | 12.00 | Arrive | B | | | | 700 | 1.6 |
| | 12.00-13.00 | Unloading | B | FOW0001 | 300 | 2.4 | 1,000 | 4 |
| | 13.00 | Leave | B | | | | 1,000 | 4 |

| Vehicle's type_ID | Time | Detail | Place | Transportation demand_ID | Weight (kg.) | Volume ($m^3$) | Weight left (kg.) | Volume left ($m^3$) |
|---|---|---|---|---|---|---|---|---|
| | 13.00-15.00 | OTW | | | | | 1,000 | 4 |
| | 15.00 | Arrive | A | | | | 1,000 | 4 |
| | 15.00-16.00 | Loading | A | OCF0002 | 500 | 3.9 | 500 | 0.1 |
| | 16.00 | Leave | A | | | | 500 | 0.1 |
| | 16.00-18.00 | OTW | | | | | 500 | 0.1 |
| | 18.00 | Arrive | D | | | | 500 | 0.1 |
| | 18.00-19.00 | Unloading | D | OCF0002 | 500 | 3.9 | 1,000 | 4 |
| | 19.00 | Leave | D | | | | 1,000 | 4 |
| | 19.00-21.00 | OTW | | | | | 1,000 | 4 |
| | 21.00 | Arrive | P | | | | 1,000 | 4 |
| Total distance = 425 km | | | | | | | | |
| Variable cost = 425 km X 3 baht/km. = 1,275 km | | | | | | | | |
| Fixed cost = 500 baht | | | | | | | | |
| Total transportation cost = 1,775 baht | | | | | | | | |

Pattern 2 is transportation plan which is arraged by ID of company in order to inform the detail of transportation plan to every company related to the plan.The detail of transportation plan arraged by ID of company is as follows

- ID of company
- Name of company
- ID of transportation demand
- Detail
- Time

- Weight
- Volume
- ID of vehicle
- Car registration

Table 14displays the detail of transportation plan arraged by ID of company.

Table 14 Example of transportation plan arraged by ID of company F0001 (Company A)

| Transportation demand_ID | Detail | Time | Weight (kg.) | Volume ($m^3$.) | Vehicel_ID | Car registration |
|---|---|---|---|---|---|---|
| FOW0001 | Pick up | 10.00-11.50 | 300 | 2.4 | B00001 | วฮ-3456 |

### 4.1.2 Business process and fundamentals of input data of changing the delivery plan process

This part will explain business process of delivery plan changing process which has the detail as Figure 15

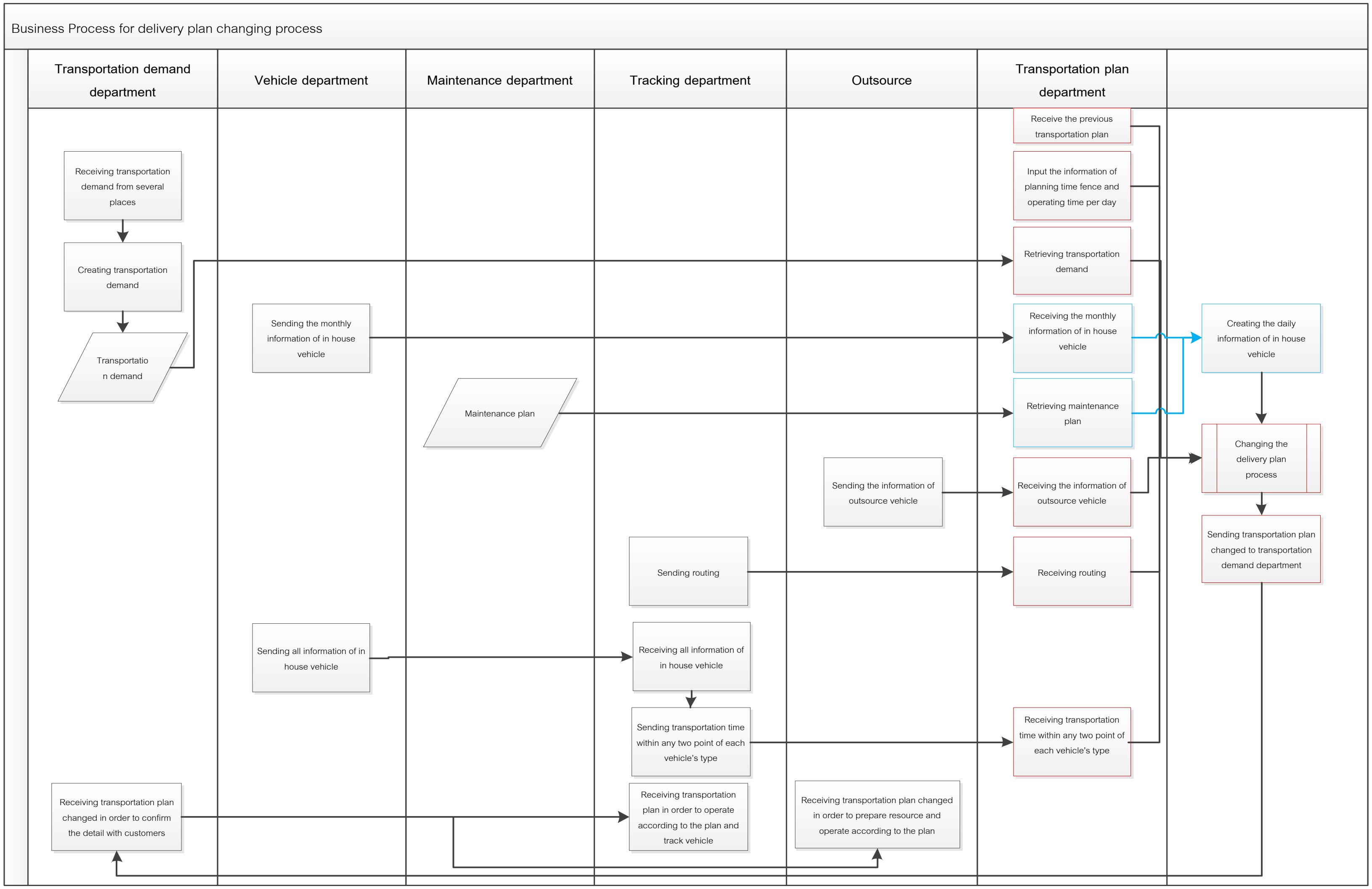



Figure 15 Business process of changing the delivery plan process

The fundamental of input data of of changing the delivery plan process has the detail as below

<u>Receive the previous transportation plan</u>

The previous transportation plan is received every day and uses as a constraint of changing the delivery plan.

<u>Fill in planning time fence and operating time per day</u>

See more details in page 41.

<u>Retrieve transportation demand changed</u>

Transportation demand changed is retrieved from transportation demand department. Transportation demand considered is in planning time fence only.

Transportation demand changed has 2 following types:

Type 1: Transportation demand added

Type 2: Transportation demand cancelled

For transportation demand postponed the due date, the system will automatically cancel the previous transportation demand which has the old due date, and add new transportation demand which has the new due date.

The system will retrieve transportation demand changed every time that it occurs and use it as an input of changing the delivery plan process. The detail of transportation demand changed is as below:

- ID of transportation demand which has the characteristic as Figure 13
- Period of time that can pick up and delivery goods
- Name of pick up and delivery point
- Quantity of goods specified in 2 dimensions: weight (kg), and volume ($m^3$)
- The constraint of transporting goods

- Type of goods which can be classified into 4 groups
- Loading time and unloading time
- Status of transportation demand changed

Table 15 displays the detail of transportation demand changed.

Table 15 Example of transportation demand changed

| Transportation demand_ID | Today | 13/7/2011 | Seperated transportation demand | Group for transporting | Goods_type | Loading time (min) | Transportation demand_status |
|---|---|---|---|---|---|---|---|
| FOW0001(01) | A-B(300kg., 2.4m$^3$) | | No | No | W | 60 | cancel |
| OCF0002(01) | A- D (300 kg., 2.4 m$^3$) | | Yes | No | F | 100 | add |

In case of no loading time data, see more details in page 66.

<u>Recieve the monthly in house vehicle information</u>

See more details in page 46.

<u>Retrieve maintenance plan</u>

See more details in page 48.

<u>Recieve the outsourced vehicle information</u>

See more details in page 50.

<u>Recieve routing information</u>

See more details in page 51.

<u>Recieve information of transportation time between any two point of each vehicle</u>

See more details in page 52.

<u>Recieve the daily in house vehicle information</u>

See more details in page 53.

<u>Changing the delivery plan process</u>

Changing the delivery plan process starts from recieiving the previous transportation plan, planning time fence, operating time per day, transportation demand changed, in house and outsourced vehicle, routing, and transportation time as input data in order to generate the transportation plan. There are several following issues that have to be made a decision when transportation demand changed.

- Choose transportation demand operated in each day
- Choose type of vehicle and group of vehicle
- Choose routing and the sequence of transporting goods

This transportation plan changed aims to meet all demand in time with low cost of transportation. Moreover, there are many conditions of changing the transportation plan, for example, changing transportation plan cannot effect on the previous transportation plan both time, and vehicle used. Hence, the user can choose the suitable condition which is fit to the nature of the business.

<u>Sending delivery plan to transportation demand department</u>

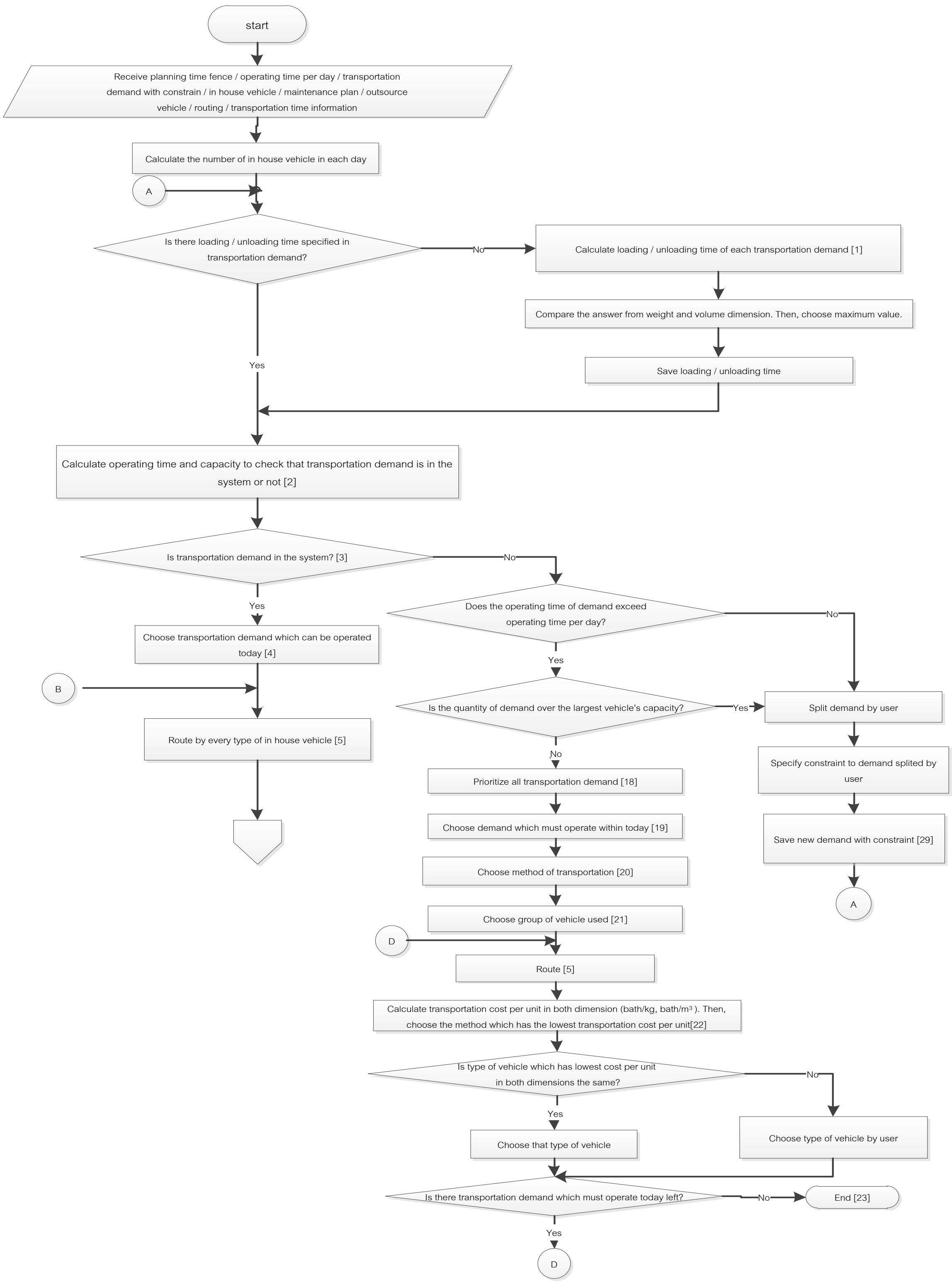
See more details in page 55.

## 4.2 Decision support

### 4.2.1 Decision making process for delivery planning

In this part, the detail of decision making process for delivery plannig will be explained step by step. Moreover, the assumption of each step will be stated in this part.

Figure 16 shows the detail of decision making process for delivery planning.


start
Receive planning time fence / operating time per day / transportation demand with constrain / in house vehicle / maintenance plan / outsource vehicle / routing / transportation time information
Calculate the number of in house vehicle in each day
A
Is there loading / unloading time specified in transportation demand?
No
Calculate loading / unloading time of each transportation demand [1]
Compare the answer from weight and volume dimension. Then, choose maximum value.
Save loading / unloading time
Yes
Calculate operating time and capacity to check that transportation demand is in the system or not [2]
Is transportation demand in the system? [3]
No
Yes
Choose transportation demand which can be operated today [4]
B
Route by every type of in house vehicle [5]
Does the operating time of demand exceed operating time per day?
No
Yes
Is the quantity of demand over the largest vehicle's capacity?
Yes
Split demand by user
Specify constraint to demand splited by user
Save new demand with constraint [29]
A
No
Prioritize all transportation demand [18]
Choose demand which must operate within today [19]
Choose method of transportation [20]
Choose group of vehicle used [21]
D
Route [5]
Calculate transportation cost per unit in both dimension (bath/kg, bath/m³ ). Then, choose the method which has the lowest transportation cost per unit[22]
Is type of vehicle which has lowest cost per unit in both dimensions the same?
No
Yes
Choose that type of vehicle
Choose type of vehicle by user
Is there transportation demand which must operate today left?
No
End [23]
Yes
D

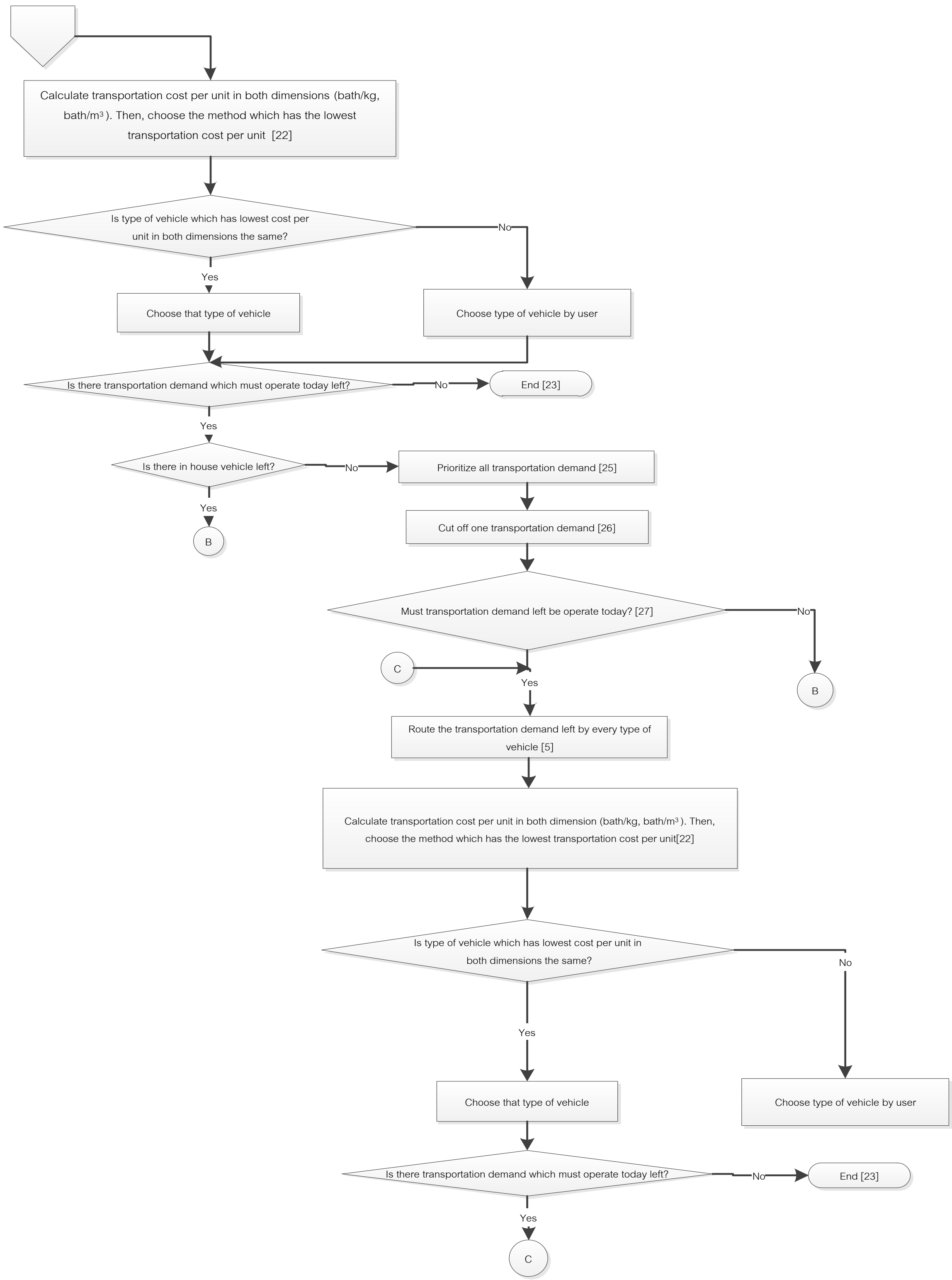



Figure 16 The detail of decision making process

The detail of each step is explained below:

**[1] Calculate loading and unloading time of each transportation demand**

Loading and unloading time of each transportation demand are calculated according to Equation 31 and Equation 32.

$$TLW_i = TUW_i = tlw_j \times W_i$$

Equation 31

$$TLV_i = TUV_i = tlv_j \times V_i$$

Equation 32

When;

$TLW_i$ represents loading time of transportation demand ID i which is calculated from weight dimension (unit: min).

$TUW_i$ represents unloading time of transportation demand ID i which is calculated from weight dimension (unit: min).

$tlw_j$ represents loading time per weight of goods' type j which is different according to the type of goods. (unit: $\frac{min}{kg}$)

$W_i$ represents weight of transportation demand ID i (unit: kg.)

$TLV_i$ represents loading time of transportation demand ID i which is calculated from volume dimension (unit: min).

$TUV_i$ represents unloading time of transportation demand ID i which is calculated from volume dimension (unit: min).

$tlv_j$ represents loading time per volume of goods' type j which is different according to the type of goods. (unit: $\frac{min}{m^3}$)

$V_i$ represents volume of transportation demand ID i (unit: $m^3$)

i represents ID of transportation demand.

j represents type of goods.

After calculating loading time according to Equation 31 and Equation 32, the system will compare these two answers and choose the maxmimum answer as a loading and unloading time of each transportation demand. In other words, loading time is selected according to Equation 33.

$$TL_i = TU_i = \mathrm{Max}(TLW_i, TLV_i)$$

Equation 33

When;

$TL_i$ represents loading time of transportation demand ID i (unit: min).

$TU_i$ represents unloading time of transportation demand ID i (unit: min).

[2] Calculate operating time and capacity in term of weight and volume of every transportation demand in order to check which transportation demand is in the system.

Equation 34 is used for calculating the operating time of each transportation demand comparing to the operating time per day. If the demand can make Equation 34 come true, it means that this demand can operate within the operating time per day. Moreover, Equation 35 and Equation 36 are used to calculate and check that quantity of each transportation demand can be operated by the vehicle in the system or not.

$$T^{v}_{h->p(i)} + TL_{i} + T^{v}_{p(i)->d(i)} + TU_{i} + T^{v}_{d(i)->h} \leq TO \quad ; \quad \text{All } v$$

Equation 34

$$W_i \leq CW^{v} \quad ; \quad v \text{ represents the largest type of vehicle.}$$

Equation 35

$$V_i \leq CV^{v} \quad ; \quad v \text{ represents the largest type of vehicle.}$$

Equation 36

When;

$T^{v}_{h->p(i)}$ represents travelling time of vehicle type v from home to pick up point of transportation demand ID i.

$T^{v}_{p(i)->d(i)}$ represents travelling time of vehicle type v from pick up point to delivery point of transportation demand ID i.

$T^{v}_{d(i)->h}$ represents travelling time of vehicle type v from delivery point of transportation demand ID i to home.

TO represents operating time per day (unit: min).

$CW^{v}$ represents capacity of vehicle type v in term of weight (unit:kg.).

$CV^v$ represents capacity of vehicle type v in term of volume (unit: $m^3$)

p(i) represents pick up point of transportation demand ID i.

d(i) represents delievery point of transportation demand ID i.

h represents home.

**[3] Is this transportation demand in the system?**

The transportation demand in the system has to make Equation 34, Equation 35, and Equation 36 come true. It means as follows:

Operating time of this transportation demand has to be less than or equal to operating time per day at lease one type of vehicle; in other words, at lease one type of vehicle can make Equation 34 come true.

The quantity of transportation demand in term of weight and volume has to be less than the capacity of the largest vehicle in the system. The vehicle considered is both in house and outsourced vehicle. In other words, Equation 35 and Equation 36 are true.

**[4] Choose transportation demand which can be operated today**

There are 2 methods of choosing transportation demand which can be operated today as follows:

1. System chooses transportation demand which can be operated today

   The system will select all transportation demands that can be operated today; however, the total quantity transported has to be less than the capacity of all in house vehicles.

- The reasons that operate all transportataion demands as fast as possible are as follows:
    - It is suitable with the nature of garment industry which has the details as below:

      The number of transportation demand is usually decreased at the beginning of planning time fence, since the transportation demand is cancelled or postponed. Hence, the transportation demand is increased at the following period or day.

      The main reasons of cancelling and postponing the demand are as follows:

        - Supplier cannot produce raw material such as bolt as specifying in the schedule.
        - Plant cannot product finished goods as specifying in the schedule.

      Therefore, operating transporting demand since the beginning of the period will increase the number of available vehicle in the following day. Then, the efficiency of generating transportation plan will be high and the number of outsourced vehicle rented will be reduced as well. Thus, the total transportation cost will be decreased.

      This method is suitable with the factory which the transportation demand is usually cancelled at the beginning of planning time fence or postponed to the other date. In addition, the transportation plan is already generated and the companies related to this plan know the details of transportation plan. Furthermore, this method is suitable with the factory which transportation demand is increased at the following period or day and the companies already prepare vehicle for transportation.

This method is not suitable with the factory which the transportation demand is usually added at the beginning of planning time fence, since the companies related to this plan know the details of transportation plan. Thus, it is hard to change transportation plan and also difficult to generate the effective plan. However, this characteristic does not occur in garment industry.

- It is utilize the in house vehicle, since the factory has to pay for fixed cost of in house vehicle, even thogh it is used or not.

2. User chooses transportation demand which can be operated today

**[5] Route by every type of in house and outsourced vehicle**

Heuristices that is applied in this research is nearest neighbor. In addition, the model of transporting applied in this research is milk run model which has both advantages and disadvanges as below:

The advantage of milk run model is reducing cost of transportation, since there is no overlapped routing. On the other hand, the disadvantage of milk run model is taking long travelling time, thus it is not suit for short shelf life goods. However, there is no effect on goods in garment industry.

**Routed by every type of in house vehicle**

Transportation demand chosen will be routed according to process specified in Figure 17.

**Routed by every type of outsourced vehicle**

Transportation demand left which the in house vehicle cannot operate will be selected in order to be routed by outsourced vehicle. Transportation demand chosen will be routed according to process specified in Figure 17.Table 16 is the example of transportation demand with group of vehicle used.

Table 16 Example of transportation demand with group of vehicle used

| Transportation demand_ID | Today | Seperated demand | Goods_ type | Loading time (min) | Group of vehicle |
|---|---|---|---|---|---|
| FOW0001(1) | A - B (300 kg., 2.4 $m^3$) | N | W | 60 | In house |
| OCF0002(1) | A - D (500 kg., 3.9 $m^3$) | Y | F | 100 | In house |
| OCF0003(1) | D - C (200 kg., 1.6 $m^3$) | N | F | 50 | In house |
| SFM0004(1) | B - D (100 kg., 0.4 $m^3$) | N | R | 70 | Outsource |

From Table 16, it is shown that there are 4 transportation demands which must be operated within today. In house vehicle can operate transportation demand ID FOW0001(1) OCF0002(1), and OCF0003(1); therefore, outsourced vehicle will operate transportation demand left which is transportation demand ID SFM0004(1).

**[6] Calculate maximum time at any point of time**

Maximum time is the maximum travelling time from any point to pick up or delivery point. This value depends on the status of each transportation demand, and also type of vehicle used.

<u>Calculation method</u>

1. Consider transportation demand which has status 1 and 2. The status of transportation demand can be divided into 3 statuses as follows:

Status 1: Transportation demand which has not picked up and delivered.

Status 2: Transportation demand which has picked up, but has not delivered.

Status 3: Transportation demand which has picked up, and delivered.

Table 17 shows the status of each transportation demand.

Table 17 Status of each transportation demand

| Transportation demand_ID | Today | Seperated demand | Goods_type | Loading time (min) | Status |
|---|---|---|---|---|---|
| FOW0001(1) | A - B (300 kg., 2.4 $m^3$) | N | W | 60 | 1 |
| OCF0002(1) | A - D (500 kg., 3.9 $m^3$) | Y | F | 100 | 1 |
| OCF0003(1) | D - C (200 kg., 1.6 $m^3$) | N | F | 50 | 1 |
| SFM0004(1) | B - D (100 kg., 0.4 $m^3$) | N | R | 70 | 1 |

2. Consider pick up and delivery point of transportation demand which has status 1, and delivery point of transportation demand which has status 2.

Table 18 Points considered in order to calculate maximum time

| Transportation demand_ID | Today | Seperated demand | Goods_ type | Loading time (min) | Status | Points considered |
|---|---|---|---|---|---|---|
| FOW0001(1) | A - B (300 kg., 2.4 $m^3$) | N | W | 60 | 1 | A B |
| OCF0002(1) | A - D (500 kg., 3.9 $m^3$) | Y | F | 100 | 1 | A D |
| OCF0003(1) | D - C (200 kg., 1.6 $m^3$) | N | F | 50 | 1 | D C |
| SFM0004(1) | B - D (100 kg., 0.4 $m^3$) | N | R | 70 | 1 | B D |

From Table 18, there are 4 points considered which are A, B, C, and D.

3. Find maximum time from any point to A, B, C, and D from table of transportation time between any two points. For example, the maximum time from any point to A, B, C, and D of vehicle's type ID 003 which is shown below can be found from Table 19.
   Maximum time from any point to A is 100 minutes.
   Maximum time from any point to B is 170 minutes.
   Maximum time from any point to C is 125 minutes.
   Maximum time from any point to D is 175 minutes.

Table 19 Transportation time between any two points of vehicle's type ID 003

| From / To | A (min) | B (min) | C (min) | D (min) |
|---|---|---|---|---|
| A (min) | | 50 | 125 | 75 |
| B (min) | 55 | | 40 | 175 |
| C (min) | 100 | 50 | | 75 |
| D (min) | 70 | 170 | 75 | |

**[7] Calculate minimum time of each transportation demand**

Minimum time of each transportation demand is the minimum operating time for picking up and delivery the goods. This value depends on the current point and type of vehicle. Moreover, minimum time can be calculated from Equation 37.

$$T^{vx}_{min(i)} = T^{vx}_{this\ point \rightarrow p(i)} + TL_i + T^{vx}_{p(i) \rightarrow d(i)} + TU_i + T^{vx}_{d(i) \rightarrow h}$$

Equation 37

When;

$T^{vx}_{min(i)}$ represents the minimum operating time for picking up and delivery transportation demand ID I by vehicle type v, vehicle ID x.

$T^{vx}_{this\ point->p(i)}$ represents travelling time from the current point or this point to pick up point of transportation demand ID I by vehicle type v, vehicle ID x.

$T^{vx}_{h->p(i)}$ represents travelling time from home to pick up point of transportation demand ID I by vehicle type v, vehicle ID x.

this point represents the point that vehicle is operated at the present.

X represents ID of vehicle.

**[8] Choose the closet point which has the minimum distance comparing to home**

The closet point which has the minimum distance comparing to home can be found from Table 20. For example, if point A is assumed to be home, the closet point which has the minimum distance comparing to home is B located far from home 20 kilometres.

Table 20 Routing

| From/ To | A (km.) | B (km.) | C (km.) | D (km.) |
|---|---|---|---|---|
| A (km.) | | 20 | 50 | 30 |
| B (km.) | 20 | | 15 | 70 |
| C (km.) | 55 | 20 | | 30 |
| D (km.) | 35 | 60 | 30 | |

[9] Calculate operating time for all delivery goods, weight, and volume.

Calculation method of operating time of sending the goods

$$\sum_{\forall i \in setB} \mathrm{TD}^{\mathrm{vx}}_{\mathrm{max(i)}} = T^{v}_{\text{this point->d(i)}} + \sum_{\forall i \in setB} \mathrm{TU_i} + \mathrm{Max}(T^{v}_{\text{set A->h}})$$

Equation 38

When;

Set A — represents pick up and delivery point of transportation demand which has status 1, and delivery point of transportation demand which has status 2.

Set B — represents transportation demand delivered at the current point or delivery point of transportation demand ID i.

$\sum_{\forall i \in setB} \mathrm{TD}^{\mathrm{vx}}_{\mathrm{max(i)}}$ — represents total operating time of delivery goods until returning home of transportation demand ID i by vehicle type v, vehicle ID x.

$\sum_{\forall i \in setB} \mathrm{TU_i}$ — represents total unloading time of transportation demand ID i.

$\mathrm{Max}(T^{v}_{\text{set A->h}})$ — represents the maximum travelling time from any point in set A to home by vehicle type v.

Calculation method of quantity of transportation demand

$$\text{Weight (kg.)} = \sum_{\forall i \in setB} \mathrm{W_i}$$

Equation 39

$$\text{Volume } (m^3) = \sum_{\forall i \in setB} V_i$$

Equation 40

When;

$\sum_{\forall i \in setB} W_i$ represents total weight of transportation demand delivered at d(i) (unit: kg.)

$\sum_{\forall i \in setB} V_i$ represents total volume of transportation demand delivered at d(i) (unit: $m^3$.)

**[10] Can transportation demand delivered or picked up operate under constraint?**

Transportation demand that can be operated by this system has to pass all 3 constraints as follows:

Constraint 1: $TO^{vx}_{max(i)} \leq TO^{vx}_{left}$

Constraint 2: Weight constraint

<u>Case of delivery</u>

$$\sum_{\forall i \in setC} W_i - \sum_{\forall i \in setB} W_i \leq CW^v$$

<u>Case of receipt</u>

$$\sum_{\forall i \in setC} W_i + \sum_{\forall i \in setB} W_i \leq CW^v$$

Constraint 3: Capacity constraint

Case of delivery

$$\sum_{\forall i \in setC} V_i \quad - \quad \sum_{\forall i \in setB} V_i \quad \leq \quad CV^v$$

Case of receipt

$$\sum_{\forall i \in setC} V_i \quad + \quad \sum_{\forall i \in setB} V_i \quad \leq \quad CV^v$$

When,

$\sum_{\forall i \in setC} W_i$ represents total weight of transportation demand on vehicle. (Unit: kg)

$\sum_{\forall i \in setC} V_i$ represents total volume of transportation demand on vehicle. (Unit: $m^3$)

Set C represents transportation demand which has status 2 and operated by vehicle type v, vehicle ID x.

$TO^{vx}_{max(i)}$ represents operating time of transportation demand ID I which calculates from maximum time, and is operated by vehicle type v, vehicle ID x.

$TO^{vx}_{left}$ represents operating time left of vehicle type v, vehicle ID x.

**[11] Calculate and update operating time left, weight left, volume left, maximum time, and minimum time**

Calculation method of operating time left

$$TO^{vx}_{left} = TO - TO^{vx}_{max(i)} + \sum_{\forall i \in setD} (TO_{max(i)} - TO^{vx}_{real(i)})$$

Equation 41

Set D represents transportation demand which has status 3 and is operated by vehicle type v, vehicle ID x.

$TO^{vx}_{real(i)}$ represents operating time used for transporting transportation demand ID i by vehicle type v, vehicle ID x.

Calculation method of weight and volume left (on truck)

$$CW^{vx}_{left} = CW^{v} - \sum_{\forall i \in setC} W_i$$

Equation 42

$$CV^{vx}_{left} = CV^{v} - \sum_{\forall i \in setC} V_i$$

Equation 43

When,

$CW^{vx}_{left}$ represents capacity left which is specified in term of weight of vehicle type v, vehicle ID x (unit:kg.)

$CV^{vx}_{left}$ represents capacity left which is specified in term of volume of vehicle type v, vehicle ID x (unit:$m^3$)

Calculation method of maximum time

See more detail in [6]

Calculation method of Minimum time

See more detail in [7]

**[12] Calculate operating time for picking up all goods, weight, and volume.**

Calculation method of operating time of picking up and sending the goods

$$\sum_{\forall i \in setE} \mathrm{TO}^{\mathbf{vx}}_{\mathbf{max(i)}} = T_{\text{this point->p(i)}} + \sum_{\forall i \in setE} \mathrm{TL_i} + \sum_{\forall i \in setE} \mathrm{Max}(T^{vx}_{\text{set A->d(i)}}) + \sum_{\forall i \in setE} \mathrm{TU_i} + \mathrm{Max}(T^{vx}_{\text{set A->h}})$$

Equation 44

When;

Set E represents transportation demand picked up at pick up point of transportation demand ID i by vehicle type v, vehicle ID x.

$\sum_{\forall i \in setE} \mathrm{TO}^{\mathbf{vx}}_{\mathbf{max(i)}}$ represents total operating time of transportation demand ID i in set E, by vehicle type v, vehicle ID x.

$\sum_{\forall i \in setE} \mathrm{Max}(T^{vx}_{\text{set A->d(i)}})$ represents total maximum travelling time of set E from any point in set A to delivery point of transportation demand ID i by vehicle type v, vehicle ID x.

$T_{\text{this point->p(i)}} = 0$, because the vehicle is at pick up point. Therefore, operating time of picking up and sending the goods can calculate according Equation 45.

$$\sum_{\forall i \in setE} TO^{vx}_{max(i)} = \sum_{\forall i \in setE} TL_i + \sum_{\forall i \in setE} Max(T^{vx}_{set\ A \to d(i)}) + \sum_{\forall i \in setE} TU_i + Max(T^{vx}_{set\ A \to h})$$

Equation 45

Calculation method of quantity of transportation demand

$$\text{Weight (kg.)} = \sum_{\forall i \in setE} W_i$$

Equation 46

$$\text{Volume } (m^3) = \sum_{\forall i \in setE} V_i$$

Equation 47

**[13] End**

The transportation plan consisting of sequenvce of routing, total distance, total time, total weight, and volume will be shown. Table 21 shows the example of transportation plan.

Table 21 Example of transportation plan

| **Vehicle_ID** | **Time** | **Detail** | **Place** | **Transportation demand_ID** | **Weight (kg)** | **Volume ($m^3$)** | **Weight left (kg)** | **Volume left($m^3$)** |
|---|---|---|---|---|---|---|---|---|
| B00002 (In house) | 9.00 | Leave | P | | | | 1,000 | 4 |
| | 9.00-10.00 | OTW | | | | | 1,000 | 4 |
| | 10.00 | Arrive | A | | | | 1,000 | 4 |
| | 10.00-11.00 | Loading | A | FOW0001 | 300 | 2.4 | 700 | 1.6 |
| | 11.00 | Leave | A | | | | 700 | 1.6 |
| | 11.00 -12.00 | OTW | | | | | 700 | 1.6 |

| Vehicle_ID | Time | Detail | Place | Transportation demand_ID | Weight (kg) | Volume ($m^3$) | Weight left (kg) | Volume left($m^3$) |
|---|---|---|---|---|---|---|---|---|
| B00002 (In house) | 12.00 | Arrive | B | | | | 700 | 1.6 |
| | 12.00-13.00 | Unloading | B | FOW0001 | 300 | 2.4 | 1,000 | 4 |
| | 13.00 | Leave | B | | | | 1,000 | 4 |
| | 13.00-15.00 | OTW | | | | | 1,000 | 4 |
| | 15.00 | Arrive | A | | | | 1,000 | 4 |
| | 15.00-16.00 | Loading | A | OCF0002 | 500 | 3.9 | 500 | 0.1 |
| | 16.00 | Leave | A | | | | 500 | 0.1 |
| | 16.00-18.00 | OTW | | | | | 500 | 0.1 |
| | 18.00 | Arrive | D | | | | 500 | 0.1 |
| | 18.00-19.00 | Unloading | D | OCF0002 | 500 | 3.9 | 1,000 | 4 |
| | 19.00 | Leave | D | | | | 1,000 | 4 |
| | 19.00-21.00 | OTW | | | | | 1,000 | 4 |
| | 21.00 | Arrive | P | | | | 1,000 | 4 |
| Total distance = 425 km | | | | | | | | |
| Variable cost = 425 km. X 3 Baht/km. = 1,275 Baht | | | | | | | | |
| Fixed cost = 500 Baht | | | | | | | | |
| Total transportation cost = 1,775 Baht | | | | | | | | |

[14] Is time left more than minimum time?

If the operating time left is more than minimum time of any transportation demand operated by vehicle type v, vehicle ID x at lease one demand, it means there is time left.

**[15] Calculate operating time for picking up goods, weight, and volume.**

Calculation method of operating time for picking up goods

$$TO^{vx}_{max(i)} = T^{vx}_{this\ point \to p(i)} + TL_i + Max(T^{vx}_{set\ A \to d(i)}) + TU_i + Max(T^{vx}_{set\ A \to h})$$

Equation 48

Calculation method of quantity of transportation demand

$$\text{Weight (kg.)} = W_i$$

Equation 49

$$\text{Volume } (m^3) = V_i$$

Equation 50

**[16] Find the feasible solution of picking up all transportation demands by considering the constraint of separated transportation demand**

There are at least 2 feasible solutions as follows:

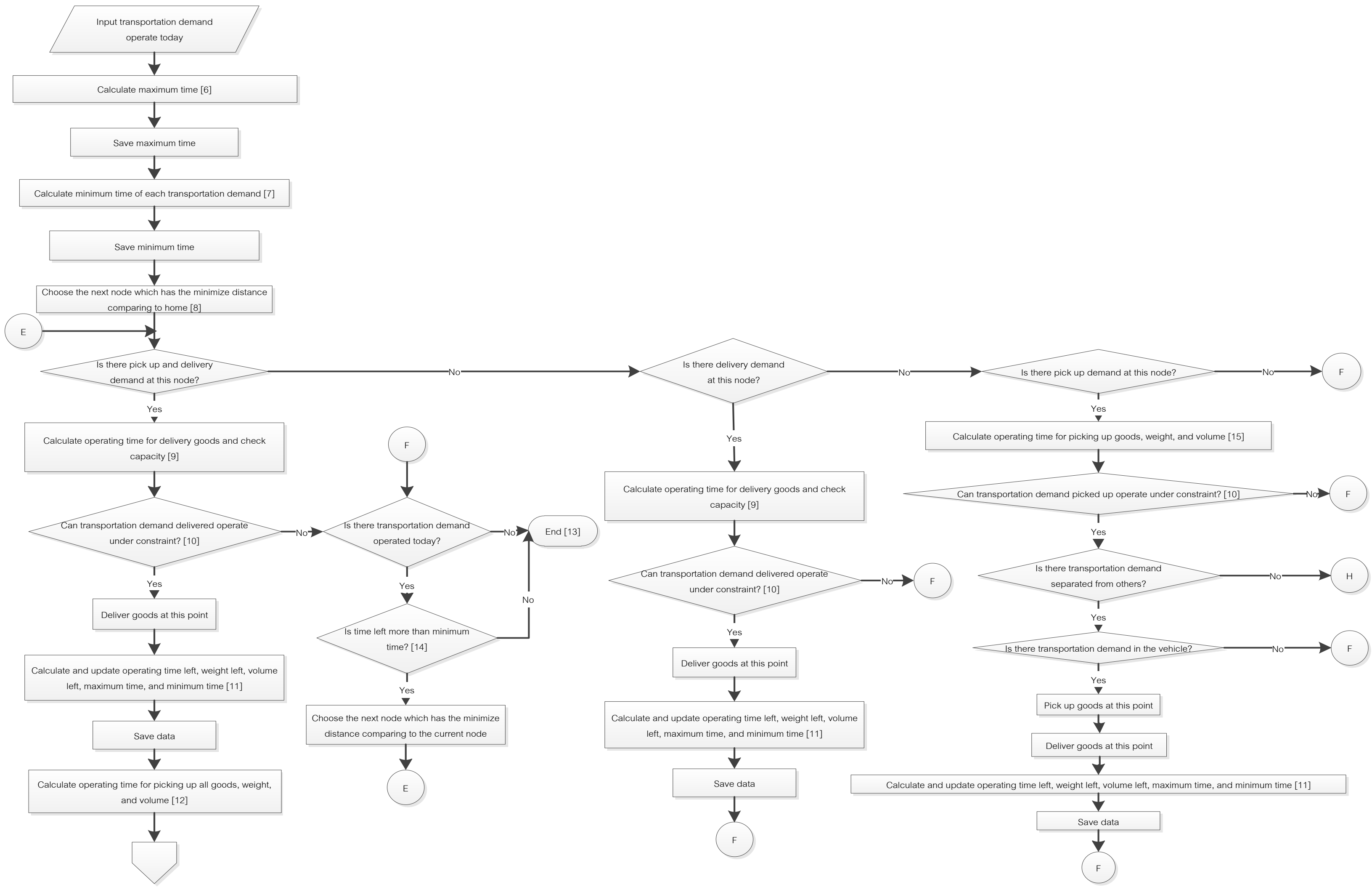
Solution 1: Picking up only separated transportation demand

Solution 2: Picking up all transportation demands except separated transportation demand

If the vehicle cannot operate all transportation demands at this point, the system will pick up as much as possible.

**[17] Find the feasible solution of picking up all transportation demands**

There are several feasible solutions. The system will find the feasible solution by assuming that the system will pick up as much as possible.


Input transportation demand operate today
Calculate maximum time [6]
Save maximum time
Calculate minimum time of each transportation demand [7]
Save minimum time
Choose the next node which has the minimize distance comparing to home [8]
E
Is there pick up and delivery demand at this node?
No
Yes
Calculate operating time for delivery goods and check capacity [9]
Can transportation demand delivered operate under constraint? [10]
No
Yes
Deliver goods at this point
Calculate and update operating time left, weight left, volume left, maximum time, and minimum time [11]
Save data
Calculate operating time for picking up all goods, weight, and volume [12]
F
Is there transportation demand operated today?
No
End [13]
Yes
Is time left more than minimum time? [14]
No
Yes
Choose the next node which has the minimize distance comparing to the current node
E
Is there delivery demand at this node?
No
Yes
Calculate operating time for delivery goods and check capacity [9]
Can transportation demand delivered operate under constraint? [10]
No
F
Yes
Deliver goods at this point
Calculate and update operating time left, weight left, volume left, maximum time, and minimum time [11]
Save data
F
Is there pick up demand at this node?
No
F
Yes
Calculate operating time for picking up goods, weight, and volume [15]
Can transportation demand picked up operate under constraint? [10]
No
F
Yes
Is there transportation demand separated from others?
No
H
Yes
Is there transportation demand in the vehicle?
No
F
Yes
Pick up goods at this point
Deliver goods at this point
Calculate and update operating time left, weight left, volume left, maximum time, and minimum time [11]
Save data
F

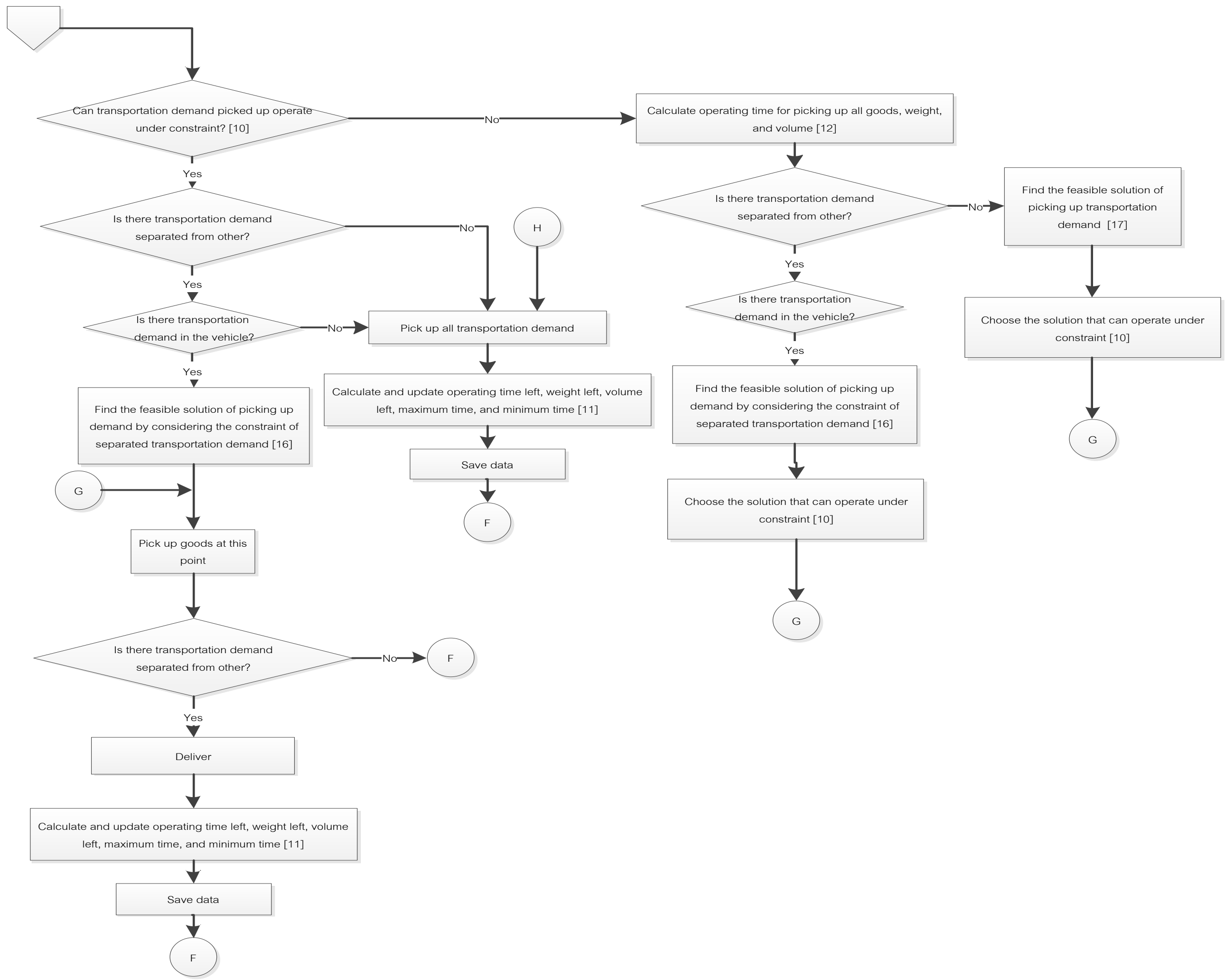



Figure 17 The detail of routing by in house and outsourced vehicle

**[18] Prioritising all transportation demands exceeding operating time per day**

There are 2 methods of prioritising transportation demand exceeding operating time per day as follows:

1. System prioritizes transportation demand exceeding operating time per day according to equation below:

$$N_{left(i)} = N_i - NP_i - (NO_i - 1)$$

Equation 51

$$P_i = N_{left(i)} + 1$$

Equation 52

When;

$N_i$ represents total number of days that can operate transportation demand ID i

$NP_i$ represents number of daypassed including today that can operate transportation demand ID i

$NO_i$ represents the number of days operating transportation demand ID i.

$P_i$ represents priority of transportation demand ID i.

$N_{left(i)}$ represents number of days left that can operate transportation demand ID i.

2. User prioritizes transportation demand exceeding operating time per day.

**[19] Select transportation demand that must be operated today**

There are 2 methods of choosing transportation demand which must be operated today as follows:

1. System chooses transportation demand which must be operated today.

The system will choose transportation demand which has priority =1.

2. User chooses transportation demand which must be operated today.

**[20] Choose method of transportation**

User has to select the method of transportation to each demand. There are 2 methods: direct shipping and milk run. Each method has its advantages and disadvantages. For example, the advantage of direct shipping is using less transportation time than milk run. However, there is disadvantage of direct shipping such as high transportation cost.

If the user selects milk run method, the user has to specify group for transporting. The demand in the same group will be operated on the same day. Table 22 displays transportation demand with method of transporting.

Table 22 Transportation demand with method of transporting.

| **Transportation demand_ID** | **Method of transporting** |
|---|---|
| FOW0001(01) | direct shipping |
| OCF0002(01) | milk run /Group 1 |
| OCF0003(01) | milk run / Group 1 |

From Table 22, it is concluded that there are 2 vehicles used. The first vehicle will operate transportation demand ID FOW0001(01) by direct shipping. The second vehicle will operate transportation demand ID OCF0002(01) and OCF0003(01) by milk run.

Assumption of transportation demand exceeding operating time per day is that it can operate only in the period of operating time.

**[21] Select group of vehicle**

User has to select group of vehicle used: in house and outsourced vehicle.

**[22] Calculate transportation cost per unit in both dimensions: weight (Baht//kg.) and volume (Baht/$m^3$) and select the type of vehicle or method that has the lowest transportation cost per unit**

In house vehicle group

The system will select the type of in house vehicle that has the lowest transportation cost per unit ($\frac{\text{Baht}}{\text{kg.}}$ or $\frac{\text{Baht}}{m^3}$). Transportation cost per unit can calculate from Equation 53 and Equation 54.

$$CPW^{vx} = \frac{\sum_{\forall i \in setD} \mathrm{d_i} \ \ \mathrm{x}\ \mathrm{VC^v}}{\sum_{\forall i \in setD} \mathrm{W_i}}$$

Equation 53

$$CPV^{vx} = \frac{\sum_{\forall i \in setD} \mathrm{d_i} \ \ \mathrm{x}\ \mathrm{VC^v}}{\sum_{\forall i \in setD} \mathrm{V_i}}$$

Equation 54

When;

| | |
|---|---|
| $CPW^{vx}$ | represents variable cost per total weight operated by vehicle type v, vehicle ID x. (unit:$\frac{\text{Baht}}{\text{kg.}}$) |
| $\sum_{\forall i \in setD} \mathrm{d_i}$ | represents total distance of operating transportation demand ID i in set D by vehicle type v, vehicle ID x. |
| $VC^v$ | represents variable cost of vehicle type v (unit: $\frac{\text{Baht}}{\text{kg.}}$) |
| $\sum_{\forall i \in setD} \mathrm{W_i}$ | represents total weight of transportation demand ID i in set D (unit:kg.) |

$CPV^{vx}$ represents variable cost per total volume operated by vehicle type v, vehicle ID x. (unit:: $\frac{\text{Baht}}{m^3}$)

$\sum_{\forall i \in setD} \mathrm{V_i}$ represents total volume of transportation demand ID i in set D (unit: $m^3$)

Outsourced vehicle group

The system will select the type of outsourced vehicle that has the lowest transportation cost per unit ($\frac{\text{Baht}}{\text{kg.}}$ or $\frac{\text{Baht}}{m^3}$). Transportation cost per unit can calculate from Equation 55 and Equation 56.

$$CPW^{vx} = HC^{v} \times NHC^{v} + \frac{\sum_{\forall i \in setD} \mathrm{d_i} \ \mathrm{x\,VC^v}}{\sum_{\forall i \in setD} \mathrm{W_i}}$$

Equation 55

$$CPV^{vx} = HC^{v} \times NHC^{v} + \frac{\sum_{\forall i \in setD} \mathrm{d_i} \ \mathrm{x\,VC^v}}{\sum_{\forall i \in setD} \mathrm{V_i}}$$

Equation 56

When;

$HC^{vx}$ represents renting cost per day of vehicle type v, vehicle ID x. (unit: Baht)

$NHC^{vx}$ represents the number of day renting outsourced vehicle type v, vehicle ID x (unit: day)

[23] End

The system will update the number of in house vehicle left in each type, and outsourced vehicle used, and display transportation plan.

[24] The system saves new transportation demand and constraint

The system saves new transportation demand and constraint of transporting such as separated transportation demand and group for transporting.

[25] Prioritising all transportation demands in the system

There are 2 methods of prioritising transportation demand in the system as follows:

1. System prioritizes transportation demand in the system according to equation below:

$$N_{left(i)} = N_i - NP_i$$

Equation 57

$$P_i = N_{left(i)} + 1$$

Equation 58

The reason of choosing due date or $N_{left}$ as criteria to give priority for each demand is that there will cause lots of effect such as penalty cost, if the goods cannot be transported on time.

Table 23 Transportation demand with N left

| Transportation demand_ID | Today | 13/7/2011 | 14/7/2011 | 15/7/2011 | N left (days) |
|---|---|---|---|---|---|
| FOW0001(01) | A- B(300 kg., 2.4m$^3$) | | | | 0 |
| OCF0002(01) | A- D (500 kg., 3.9 m$^3$) | | | | 1 |
| OCF0003(01) | D-C (200 kg.,1.6 m$^3$) | | | | 0 |
| SFM0004(01) | B - D (100 kg., 0.4 m$^3$) | | | | 3 |

2. User prioritizes transportation demand in the system

[26] Cut off one transportation demand

There are 2 methods of cutting transportation demand in the system as follows:

1. System cuts off one transportation demand in the system which is the lowest priority. If there is more than one transportation demand which is the lowest priority, the user has to select which demand should be cut off. In addition, if transportation demand cut off has the group for transporting, the system will cut off all demands in this group.
2. User cuts off one transportation demand in the system

**[27] Must all transportation demands left be operated today?**

There are 2 methods of considering transportation demand in order to operate today as follows:

1. System will consider transportation demand left. If all demands have priority equal to 1, all demands will be operated today
2. User will consider transportation demand left in order to determine which demand should be operated today.

### 4.2.2 Process for changing delivery plan

In this part, the detail of changing the delivery plan process will be explained step by step. Moreover, the assumption of each step will be stated in this part.

displays the details of changing the delivery plan process.

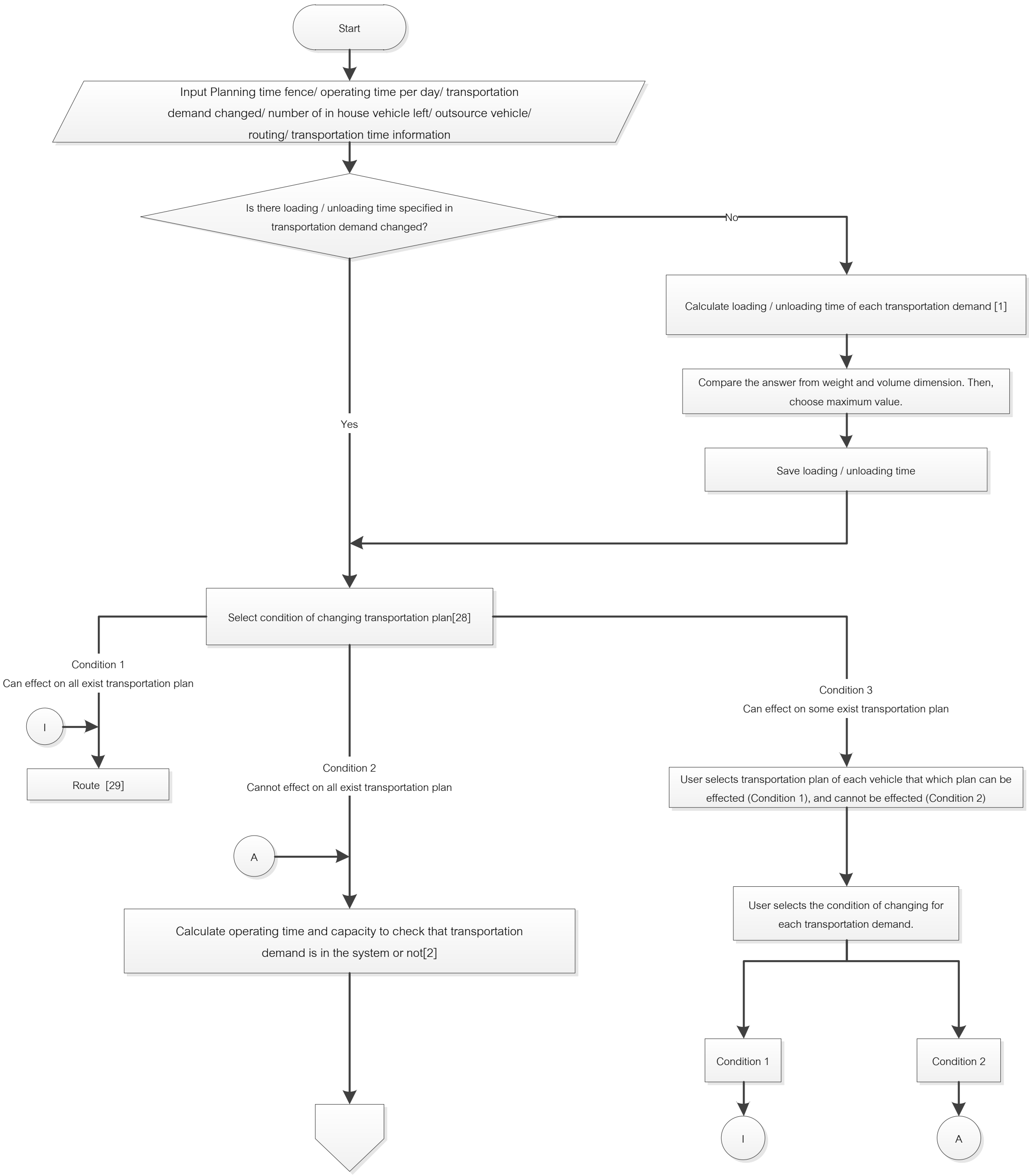

Start
Input Planning time fence/ operating time per day/ transportation demand changed/ number of in house vehicle left/ outsource vehicle/ routing/ transportation time information
Is there loading / unloading time specified in transportation demand changed?
No
Calculate loading / unloading time of each transportation demand [1]
Compare the answer from weight and volume dimension. Then, choose maximum value.
Save loading / unloading time
Yes
Select condition of changing transportation plan[28]
Condition 1
Can effect on all exist transportation plan
I
Route [29]
Condition 2
Cannot effect on all exist transportation plan
A
Calculate operating time and capacity to check that transportation demand is in the system or not[2]
Condition 3
Can effect on some exist transportation plan
User selects transportation plan of each vehicle that which plan can be effected (Condition 1), and cannot be effected (Condition 2)
User selects the condition of changing for each transportation demand.
Condition 1
Condition 2
I
A


Figure 18 The detail of changing the delivery plan process

**[28] User selects the condition of changing transportation plan by considering constraint of changing previous transportation plan**

In this step, user has to select only one condition of changing transportation plan. There are 3 conditions of changing transportation plan as follows:

<u>Condition 1: changing transportation plan can effect on all previous transportation plans</u>.

If user selects this condition, the previous transportation will be changed both time and ID of vehicle; however, the demand will be operated in the same day as the previous transportation plan.

This condition is suitable with company that has high flexibility in receiving and delivery time.

<u>Condition 2: changing transportation plan cannot effect on all previous transportation plan.</u>

If user selects this condition, the previous transportation cannot be changed both time and ID of vehicle operated. This condition is suitable with company that has low flexibility in receiving and delivery time.

<u>Condition 3: changing transportation plan can effect on some previous transportation plans.</u>

If user selects this condition, some previous transportation plans can be changed both time and ID of vehicle which is the same as condition 1. Some previous transportation plans or some transportation demands cannot be changed both time and ID of vehicle which is the same as condition 2. Moreover, the previous transportation plan is arraged by ID of vehicle, and there is an assumption of fixed transportation demand “transportation plan which consists of fixed transportation demand cannot be changed.”

For example, there are 2 previous transportation plans operated by B00001and B00002 shown in Table 24 and Table 25. If the previous transportation plan operated by B00001 can be changed, time of picking up and delivery of transportation demand ID FOW0001 and OCF0002 will be changed and vehicle operated will be changed as well. On the other hand, the previous transportation plan operated by B00002 or transportation demand ID OCF0003 cannot be changed, time of picking up and delivery transportation demand ID OCF0003 will be the same and operated by vehicle ID B00002.

Table 24 Previous transportation plan operated by B00001

| Vehicle's type_ID | Time | Details | Place | Demand_ID | Weight (kg) | Volume ($m^3$) | Weight left (kg) | Volume left ($m^3$) |
|---|---|---|---|---|---|---|---|---|
| 002 (In house) | 9.00 | Leave | P | | | | 1,000 | 4 |
| | 9.00-10.00 | OTW | | | | | 1,000 | 4 |
| | 10.00 | Arrive | A | | | | 1,000 | 4 |
| | 10.00-11.00 | Loading | A | FOW0001 | 300 | 2.4 | 700 | 1.6 |
| | 11.00 | Leave | A | | | | 700 | 1.6 |
| | 11.00 -12.00 | OTW | | | | | 700 | 1.6 |
| | 12.00 | Arrive | P | | | | 700 | 1.6 |
| | 12.00-13.00 | Unloading | P | FOW0001 | 300 | 2.4 | 1,000 | 4 |
| | 13.00 | Leave | P | | | | 1,000 | 4 |
| | 13.00-15.00 | OTW | | | | | 1,000 | 4 |
| | 15.00 | Arrive | B | | | | 1,000 | 4 |
| | 15.00-16.00 | Loading | B | OCF0002 | 500 | 3.9 | 500 | 0.1 |
| | 16.00 | Leave | B | | | | 500 | 0.1 |
| | 16.00-18.00 | OTW | | | | | 500 | 0.1 |
| | 18.00 | Arrive | C | | | | 500 | 0.1/ |
| | 18.00-19.00 | Unloading | C | OCF0002 | 500 | 3.9 | 1,000 | 4 |
| | 19.00 | Leave | C | | | | 1,000 | 4 |
| | 19.00-21.00 | OTW | | | | | 1,000 | 4 |
| | 21.00 | Arrive | P | | | | 1,000 | 4 |
| Total distance = 425 km | | | | | | | | |

Table 25 Previous transportation plan operated by B00002

| Vehicle's type_ID | Time | Details | Place | Demand_ID | Weight (kg) | Volume ($m^3$) | Weight left (kg) | Volume left ($m^3$) |
|---|---|---|---|---|---|---|---|---|
| 002 (In house) | 9.00 | Leave | P | | | | 1,000 | 4 |
| | 9.00-10.00 | OTW | | | | | 1,000 | 4 |
| | 10.00 | Arrive | C | | | | 1,000 | 4 |
| | 10.00-11.00 | Loading | C | OCF0003 | 200 | 1.6 | 800 | 2.4 |
| | 11.00 | Leave | C | | | | 800 | 2.4 |
| | 11.00 -12.00 | OTW | | | | | 800 | 2.4 |
| | 12.00 | Arrive | P | | | | 800 | 2.4 |
| | 12.00-13.00 | Unloading | P | OCF0003 | 200 | 1.6 | 1,000 | 4 |
| | 13.00 | End | P | | | | 1,000 | 4 |
| Total distance = 200 km | | | | | | | | |

[29] Route

The step of roting is as follows:

1. Update all transportation demands consisting of transportation demand changed and added.
2. Combine transportation demand changed and all previous transportation deamands, then create transportation plan according to Figure 17.

[30] End

The system will update the number of in house vehicle left, the number of outsourced vehicle used, and transportation plan changed.

**[31] Update transportation plan by considering transportation demand cancelled**

The system will update transportation plan by considering transportation demand cancelled and calculate transportation cost according to [22].

**[32] Routing transportation demand added**

Before routing transportation demand added, the user has to select the method of changing such as system or user.

Changing transportation plan by system

The step of changing transportation plan by system is as follows:

1. The system will find all possible solutions from 3 following methods:

   1.1 Adding transportation demand after every previous transportation plan

   Assumption of adding transportation demand

   Picking up and delivery have to be operated continuously in every transportation demand.

   The step of adding transportation demand is as follows:

   1.1.1) Find the nearest point comparing to the final point in the previous transportation plan by considering the distance. For example, according to Table 24, the final point is C.

   1.1.2) Check that there is transportation demand at this point or not.

   - Have transportation demand at this point: do 1.1.3
   - Do not have transportation demand at this point: find the next nearest point, then do 1.1.2.

   1.1.3) Check that this demand can be operated under constraint or not

   Equation 59 is used for checking time constraint

$$T^{vx}_{\text{this point->p(i)}} + TL_i + T^{vx}_{p(i)\to d(i)} + TU_i + T^{vx}_{d(i)\to h} \leq TO^{vx}_{left}$$

Equation 59

   - If Equation 59 is true, this demand can be operated under time constraint. Hence, do 1.1.4.
   - If Equation 59 is false, this demand cannot be operated under time constraint. Hence, find the next nearest point, then do 1.1.2.

   1.1.4) Pick up or delivery

1.1.5) update $TO^{vx}_{left}$ ,$CW^{vx}_{left}$, $CV^{vx}_{left}$ , and transportation plan

1.1.6) check demand left that must be operated today and operating time per day left. Then, operating time per day left is compared with operating time of each demand.

The method of check demand left: If there is status 1 of transportation demand, there is demand left.

The method of check time left: use Equation 60

- If Equation 60 is true, time left is enough to operate other demand.
- If Equation 60 is false, time left is not enough to operate other demand.

$$TO^{vx}_{left} \geq T^{vx}_{min(i)}$$

Equation 60

The method of finding $T^{vx}_{min(i)}$ is specified in [7].

- If there is demand left and enough time to operate, the system will find the next nearest point and then do 1.1.2.
- If there is no demand left or time left is not enough time to operate, the system will conlude the routing, transportation demand operated, and transportation cost.

1.2 Replacing transportation demand cancelled method.

Assumption of replacing transportation demand cancelled method.

There are 2 patterns of assumption:

- Pattern 1: picking up and delivery has to be operated continuously.
- Pattern 2: picking up and delivery has not operated continuously.

If the system can do both patterns, pattern 1 will always be selected.

The step of replacing transportation demand cancelled is as follows:

1.2.1) Find the nearest point comparing to the final point before transportation demand cancelled period. For example, the details of Table 24 can be drawn as Figure 19. Then, transportation demand ID OCF0002 is cancelled shown in Figure 20, thus final point of transportation demand cancelled period is P.

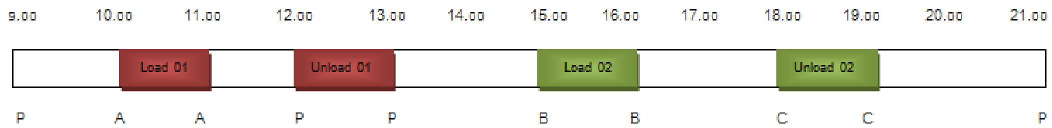



Figure 19 The previous transportation plan operated by vehicle_ID B00001

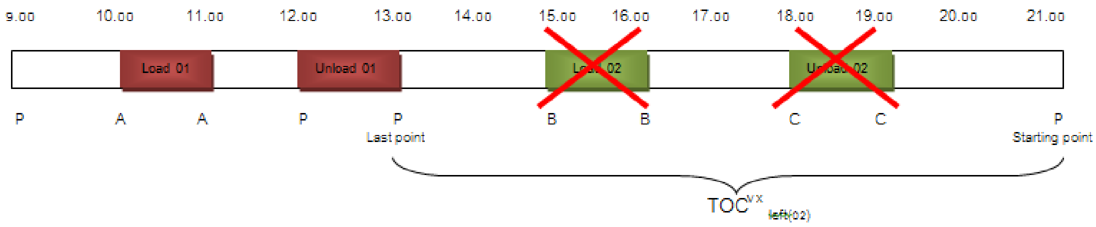



Figure 20 The transportation plan after cancelling OCF0002 operated by vehicle_ID B00001

1.2.2) Check that there is transportation demand at this point or not.

- Have transportation demand at this point: do 1.2.3
- Do not have transportation demand at this point: find the next nearest point, then do 1.2.2.

1.2.3) Check that this demand can be operated under constraint or not

<u>Pattern 1</u>

Equation 61 is used for checking time constraint of pattern 1.

$$T^{vx}_{last\ point->p(i)} + TL_i + T^{vx}_{p(i)->d(i)} + TU_i + T^{vx}_{d(i)->starting\ point} \leq TOC^{vx}_{left(i)}$$

Equation 61

When;

Last point — represents final point before transportation demand cancelled period (pattern 1), such as last point is P, according to Figure 20.

Starting point — represents the beginning point after transportation demand cancelled period (pattern 1), such as starting point is P, according to Figure 20.

$T^{vx}_{last\ point->p(i)}$ — represents travelling time from final point before transportation demand cancelled period to pick up point point of transportation demand ID i by vehicle type v, vehicle ID x .

$T^{vx}_{d(i)->starting\ point}$ — represents travelling time from delivery point of transportation demand ID i to beginning point after transportation demand cancelled period by vehicle type v, vehicle ID x .

$TOC^{vx}_{left(i)}$ — represents total operating time left of transportation demand ID i cancelled by vehicle type v, vehicle ID x .For example, from Figure 20, $TOC^{vx}_{left(i)}$ of $TOC^{002,\ B0001}_{left(02)}$ is 8 hours starting from 21.00 to 13.00.

<u>Pattern 2</u>

Equation 62 and Equation 63 is used for checking time constraint of pattern 2.

$$T^{vx}_{last\ point1\text{->}p(i)} + TL_i + T^{vx}_{p(i)\ \text{->}starting\ point1} \leq TOC^{vx}_{left1(i)}$$

Equation 62

and

$$T^{vx}_{last\ point2\text{->}d(i)} + TU_i + T^{vx}_{d(i)\ \text{->}\ starting\ point2} \leq TOC^{vx}_{left2(i)}$$

Equation 63

When;

Last point1 represents final point before transportation demand cancelled period (pattern 2: picking up period), such as last point1 is C, according to Figure 22.

Starting point1 represents the beginning point after transportation demand cancelled period (pattern 2: picking up period), such as starting point1 is B, according to Figure 22.

Last point2 represents final point before transportation demand cancelled period (pattern 2: delivery period), such as last point2 is B, according to Figure 22.

Starting point2 represents the beginning point after transportation demand cancelled period (pattern 2: delivery period), such as starting point2 is P, according to Figure 22.

$T^{vx}_{last\ point1->p(i)}$ represents travelling time from final point before transportation demand cancelled period (pattern 2: picking up period) to pick up point of transportation demand ID i by vehicle type v, vehicle ID x .

$T^{vx}_{p(i)->starting\ point1}$ represents travelling time from pick up point of transportation demand ID i to the beginning point after transportation demand cancelled period (pattern 2: picking up period) by vehicle type v, vehicle ID x .

$TOC^{vx}_{left1(i)}$ represents total operating time left of transportation demand ID i cancelled (pattern 2: picking up period) by vehicle type v, vehicle ID x .For example, from Figure 22 $TOC^{vx}_{left1(i)}$ of $TOC^{vx}_{left1(04)}$ is 4 hours starting from 15.00 to 11.00.

$T^{vx}_{last\ point2->d(i)}$ represents travelling time from final point before transportation demand cancelled period (pattern 1: delivery period) to delivery point of transportation demand ID i by vehicle type v, vehicle ID x.

$T^{vx}_{d(i)->starting\ point2}$ represents travelling time from delivery point of transportation demand ID i to the beginning point after transportation demand cancelled period (pattern 2: delivery period) by vehicle type v, vehicle ID x .

$TOC^{vx}_{left2(i)}$ represents total operating time left of transportation demand ID i cancelled (pattern 2: delivery period) by vehicle type v, vehicle ID x .For example, from Figure 22, $TOC^{vx}_{left2(i)}$ of $TOC^{vx}_{left2(04)}$ is 5 hours strating from 21.00 to 16.00.

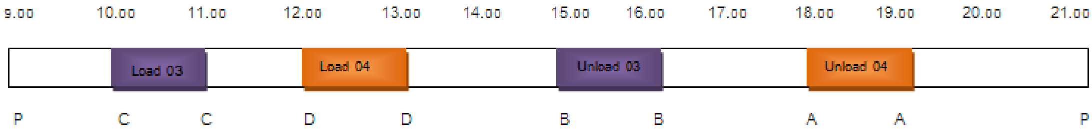



Figure 21 The previous transportation plan

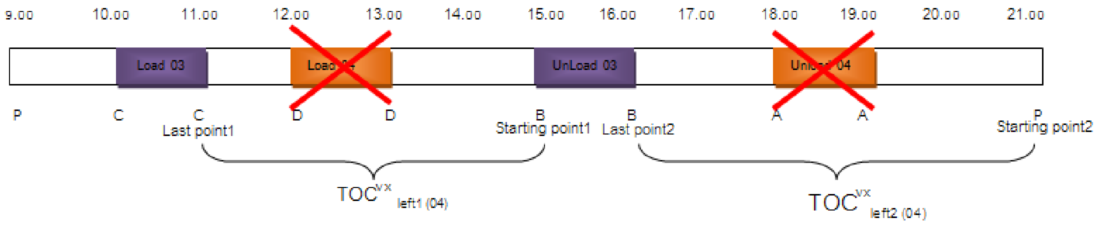



Figure 22 The transportation plan after cancelling SFM0004 operated

Equation 64 and Equation 65 are used for checking capacity constraint in term of weight, and volumn, respectively.

$$\sum_{\forall i \in set F} \mathrm{W}_{\mathrm{i}} \leq \mathrm{W}^{vx}_{\mathrm{cancel(i)}} \text{ (kg.)}$$

Equation 64

$$\sum_{\forall i \in set F} V_{\mathrm{i}} \leq \mathrm{V}^{vx}_{\mathrm{cancel(i)}} \text{ (m}^3\text{)}$$

Equation 65

When;

Set F represents transportation demand replaced in cancelling period operated by vehicle type v, vehicle ID x.

$\sum_{\forall i \in set F} \mathrm{W}_{\mathrm{i}}$ represents total weight of transportation demand ID i in set F

$\sum_{\forall i \in setF} V_i$ represents total volume of transportation demand ID i in set F

$W^{vx}_{cancel(i)}$ represents weight of transportation demand cancelled ID i operated by vehicle type v, vehicle ID x. (unit: kg.)

$V^{vx}_{cancel(i)}$ represents volume of transportation demand cancelled ID i operated by vehicle type v, vehicle ID x. (unit: $m^3$)

- If the demand has no problem about time constraint which has the detail as Table 26, and no problem about capacity constraint (Equation 64 and Equation 65 is true), it means that the system can operate this transportation. Hence, do 1.2.4. with pattern 1.

Table 26 Result of time constraint that can operate demand with pattern1

| Equation 61 | Equation 62 | Equation 63 |
|---|---|---|
| True | True | True |
| True | True | False |
| True | False | True |
| True | False | False |

- If the demand has no problem about time constraint which has the detail as Table 27 and no problem about capacity constraint (Equation 64 and Equation 65 is true), it means that the system can operate this transportation. Hence, do 1.2.4. with pattern 2.

Table 27 Result of time constraint that can operate demand with pattern2

| Equation 61 | Equation 62 | Equation 63 |
|---|---|---|
| False | True | True |

- If the demand has problem about time constraint which has the detail as Table 28 or has problem about capacity constraint (Equation 64 or Equation 65 is false), it means that the system cannot operate this transportation. Hence, find the next closet point. Then, do 1.2.2.

Table 28 Result of time constraint that cannot operate demand

| Equation 61 | Equation 62 | Equation 63 |
|---|---|---|
| False | True | False |
| False | False | True |
| False | False | False |

1.2.4) Pick up and delivery goods

- Pattern 1: Pick up or delivery the goods continuously
- Pattern2: Pick up the goods in transportation demand cancelled period (picking up period), and deliver the goods in transportation demand cancelled period (delivery period).

1.2.5) update $TOC^{vx}_{left(i)}$ ,$TOC^{vx}_{left1(i)}$ ,$TOC^{vx}_{left2(i)}$ , set F , last point1 , last point 2 , and transportation plan

1.2.6) check demand left that must be operated today and operating time left. Then, operating time left is compared with operating time of each demand.

The method of check demand left: If there is status 1 of transportation demand, there is demand left.

The method of check time left: Equation 66 , Equation 67 , and Equation 68 are used for checking time left.

- If the result has the same as Table 29, time left is enough to operate other demand
- If the result has the same asTable 30, time left is not enough to operate other demand.

Table 29 Result of time left constraint that can operate other demand

| Equation 66 | Equation 67 | Equation 68 |
|---|---|---|
| True | True | True |
| True | True | False |
| True | False | True |
| True | False | False |
| False | True | True |

Table 30 Result of time left constraint that can operate other demand

| Equation 66 | Equation 67 | Equation 68 |
|---|---|---|
| False | True | False |
| False | False | True |
| False | False | False |

$$TOC^{vx}_{left(i)} \geq T^{vx}_{min(i)}$$

Equation 66

or

$$TOC^{vx}_{left1(i)} \geq TP^{vx}_{min(i)}$$

Equation 67

and

$$TOC^{vx}_{left2(i)} \geq TD^{vx}_{min(i)}$$

Equation 68

When;

The method of calculating $T^{vx}_{min(i)}$ is explained in [7]

$TP^{vx}_{min(i)}$ represents operating time for picking up demand of transportation demand ID i, operated by vehicle type v, vehicle ID x. This value can be calculated according to Equation 69.

$TD^{vx}_{min(i)}$ represents operating time for delivery demand of transportation demand ID i, operated by vehicle type v, vehicle ID x. This value can be calculated according to Equation 70.

$$TP^{vx}_{min(i)} = T^{vx}_{last\ point1 \to p(i)} + TL_i + T^{vx}_{p(i) \to starting\ point1}$$

Equation 69

$$TD^{vx}_{min(i)} = T^{vx}_{last\ point2 \to d(i)} + TU_i + T^{vx}_{d(i) \to starting\ point2}$$

Equation 70

- If there is demand left and enough time to operate, the system will find the next nearest point and then do 1.2.2.
- If there is no demand left or time left is not enough time to operate, the system will conlude the routing, transportation demand operated, and transportation cost.

1.3 Releasing new vehicle method which has the same process of making delivery plan.

Assumption of releasing new vehicle method

Ousource vehicle will be used if there is no in house vehicle left.

The step of releasing new vehicle is as follows:

In step of choosing group of vehicle, in house vehicle will be operated first. Then, it is a step of routing which has the details as Figure 16.

2. Calculate transportation cost per unit in both dimensions: weight (Baht//kg.) and volume (Baht/m$^3$)

Adding transportation demand after the previous transportation plan and replacing in transportation demand cancelled periof method

$$CPW^{vx} = \frac{TC_{new}^{vx} - TC_{old}^{vx}}{W_{new}^{vx} - W_{old}^{vx}}$$

Equation 71

$$CPV^{vx} = \frac{TC_{new}^{vx} - TC_{old}^{vx}}{V_{new}^{vx} - V_{old}^{vx}}$$

Equation 72

When;

$TC_{new}^{vx}$ represents transportation cost of transportation plan changed operated by vehicle type v, vehicle ID x.(unit:baht.)

$TC_{old}^{vx}$ represents transportation cost of old transportation plan operated by vehicle type v, vehicle ID x.(unit: baht.)

$W_{new}^{vx}$ represents total weight of transportation demand after changing plan operated by vehicle type v, vehicle ID x.(unit:kg.)

$W_{old}^{vx}$ represents total weight of transportation demand before changing plan operated by vehicle type v, vehicle ID x.(unit:kg.)

$V_{new}^{vx}$ represents total volume of transportation demand after changing plan operated by vehicle type v, vehicle ID x.(unit:$m^3$.)

$V_{old}^{vx}$ represents total volume of transportation demand before changing plan operated by vehicle type v, vehicle ID x.(unit: $m^3$.)

Releasing new vehicle: The method of calcution is explained in [22].

3. Select the method or answer that has the lowest transportation cost per weight($\frac{Baht}{kg.}$) and volume ($\frac{Baht}{m^3}$). Sometimes, the method which has lowest transportation cost per weight and transportation cost per volume is the different method or answer.

   3.1 If the lowest transportation cost per weight and transportation cost per volume is the same method or answer, the system will automatically choose that method or answer.

   3.2 If the lowest transportation cost per weight and transportation cost per volume is different method or answer, the user has to choose the method or answer needed.

4. Cut off transportation demand operated. Then, repeat step 1 to 4 until no transportatation demand changed which must be operated today.

Changing transportation plan by user

The step of changing transportation plan by user is as follows:

1. User has to select the method to each transportation demand change. Therer are 3 methods:

- Adding transportation demand.
- Replacing transportation demand cancelled method.
- Releasing new vehicle method which has the same process of making delivery planning.

2. The system will check availability of the method selected by user; in other words, the system will check that the selected method by user can operate or noy by checking capacity in term of weight and volume, and time limit Checking availability of each method has the details as below:

2.1 Adding transportation demand method

Checking time constraint: Equation 59

Checking weight constraint: No need to check

Checking volume constraint: No need to check

2.2 Replacing transportation demand cancelled method.

<u>Pattern 1</u>

Checking time constraint: Equation 61

Checking weight constraint: Equation 64

Checking volume constraint: Equation 65

<u>Pattern 2</u>

Checking time constraint: Equation 62 and Equation 63

Checking weight constraint:Equation 64

Checking volume constraint:Equation 65

2.3 Releasing new vehicle method

This method is divided into 2 following patterns:

- Pattern 1: Pick up and delivery the goods have to do continuously each demand by demand.
- Pattern 2: Pick up and delivery the goods do not need to operate continuously each demand by demand.

Therefore, the process of checking time, weight, and volume constraint of each pattern is explained below:

Pattern 1

Checking time constraint: Equation 59

Checking weight constraint: No need to check

Checking volume constraint: No need to check

Pattern 2

Time, weight, and volume constraint of this pattern can be checked after the sequence of picking up and delivery are specified clearly. The system will show the capacity of vehicle left and time used at each move. Thus, the user will know when it is over capacity and over time.

3. Show the results of selected method and conclude that it can operate or not.

   If the selected method can operate, do step 4.

   If the selected method cannot operate, the user has to select new method. Then, the system will calculate and repear since step2.

4. Cut off transportation demand fit into transportation plan. Then, update $TO^{vx}_{left}$ ,$TOC^{vx}_{left(i)}$ ,$TOC^{vx}_{left1(i)}$ ,$TOC^{vx}_{left2(i)}$ ,setF ,$CW^{vx}$, $CV^{vx}$ and transportation plan.

5. Repeat step 1 to 4 until no transportatation demand changed which must be operated today.

# CHAPTER 5

# INFORMATION SYSTEM

This chapter explains the details of the information system designed which can be divided into 2 following topics:

- Database
- User interface

## 5.1 Database

Database of this system can be classified into 10 parts as follows:

### 5.1.1 Transportation time between any two points of each vehicle

The details of transportation time between any two points of each vehicle database are as follows:

- Transportation time_ID
- Starting point_ID
- Destination point_ID
- Starting point_name
- Destination point_name
- Vehicle's type_ID
- Transportation time

### 5.1.2 Node

The details of node database are as follows:

- Company_ID
- Company_name
- Company_contact number
- Representative_name
- Representative_contact number
- Company_type
- Address
- Latitude
- Longitude
- Opening time
- Closing time

### 5.1.3 Routing

The details of routing database are as follows:

- Routing_ID
- Starting point_ID
- Destination point_ID
- Starting point_name
- Destination point_name
- Distance

### 5.1.4 Maintenance plan

The details of maintenance plan database are as follows:

- Maintenance plan_ID
- Vehicle_ID
- Car registration
- Vehicle’s type_ID
- Start date
- End date
- Maintenance plan_status
- Information_Status

### 5.1.5 Transportation plan

The details of transportation plan database are as follows:

- Transportation plan_ID
- Date
- Vehicle_ID
- Vehicle’s type_ID
- Car registration
- Time
- Details
- Place_name
- Transportation demand_ID
- Weight
- Volume

- Weight left
- Volume left
- Total distance
- Fixed cost
- Variable cost
- Transportation cost
- Created date
- Last update

### 5.1.6 Loading time per unit

The details of loading time per unit database are as follows:

- Goods' type_ID
- Goods_type
- Loading time per kg
- Loading time per $m^3$

### 5.1.7 Availability of vehicles

The details of availability of vehicle database are as follows:

- Date
- In house vehicle_ID
- Outsourced vehicle_ID
- Maintenance plan_status

### 5.1.8 Transportation demand

The details of transportation demand database are as follows:

- Transportation demand_ID
- Picking up point_name
- Delivery point_name
- Start date
- End date
- Retrieved date
- Seperated transportation demand
- Group for transporting
- Weight
- Volume
- Goods_Type
- Loading time
- Transportation demand_status
- Changing transportation demand_status

### 5.1.9 In house vehicle

The details of in house vehicle database are as follows:

- In house vehicle_ID
- Car registration
- Vehicle classified by physical shape_type
- Brand
- Model

- Colour
- Vehicle’s type_ID
- Maximum capacity in term of weight
- Maximum capacity in term of volume
- Fixed cost
- Variable cost
- Start date
- End date

### 5.1.10 Outsourced vehicle

The details of outsourced vehicle database are as follows:

- Outsourced vehicle_ID
- Car registration
- Vehicle classified by physical shape_type
- Brand
- Model
- Colour
- Vehicle’s type_ID
- Maximum capacity in term of weight
- Maximum capacity in term of volume
- Fixed cost
- Variable cost
- Start date
- End date

Relation between 10 databases in the system is shown in Figure 23.

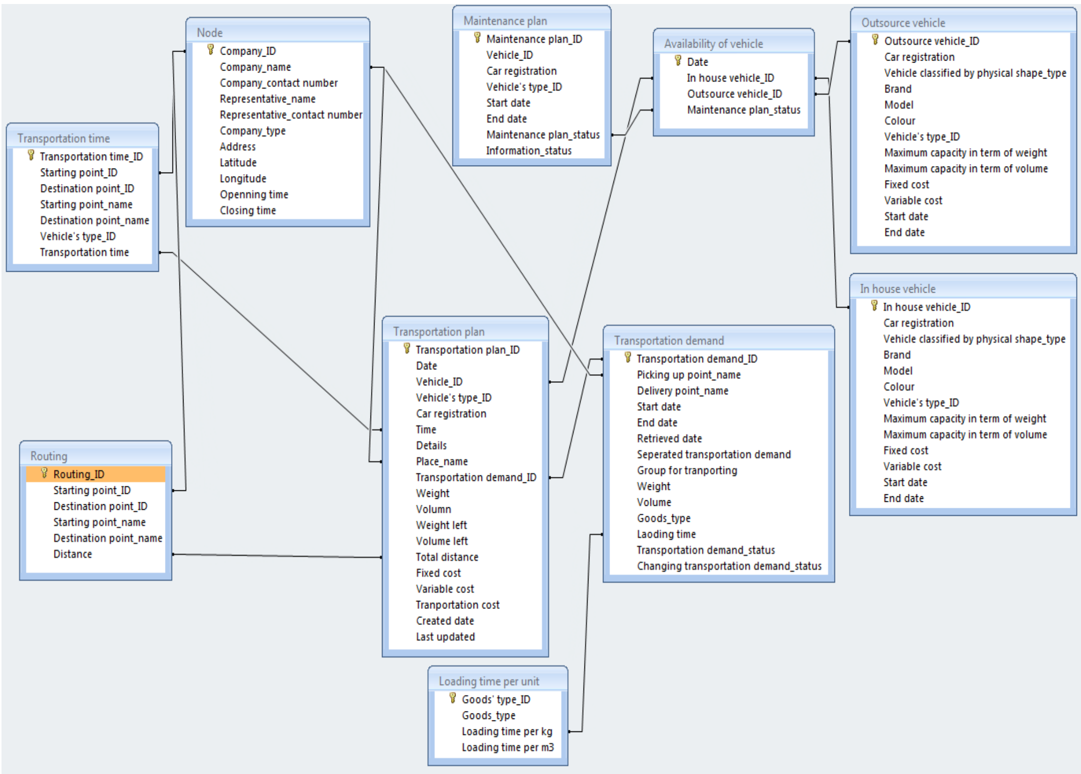


Figure 23 Relation between 10 databases in the system

## 5.2 User interfaces

Use interface, which is the computer screen that support delivery planning, can be divided into 4 sections: set up, decision making process for delivery planning, changing the delivery plan process, and report sections.

### 5.2.1 Set up

5.2.1.1 Setting up data and information of generating delivery plan

The user interface desgined for setting up data and information of generating delivery plan is shown below in Figure 24.

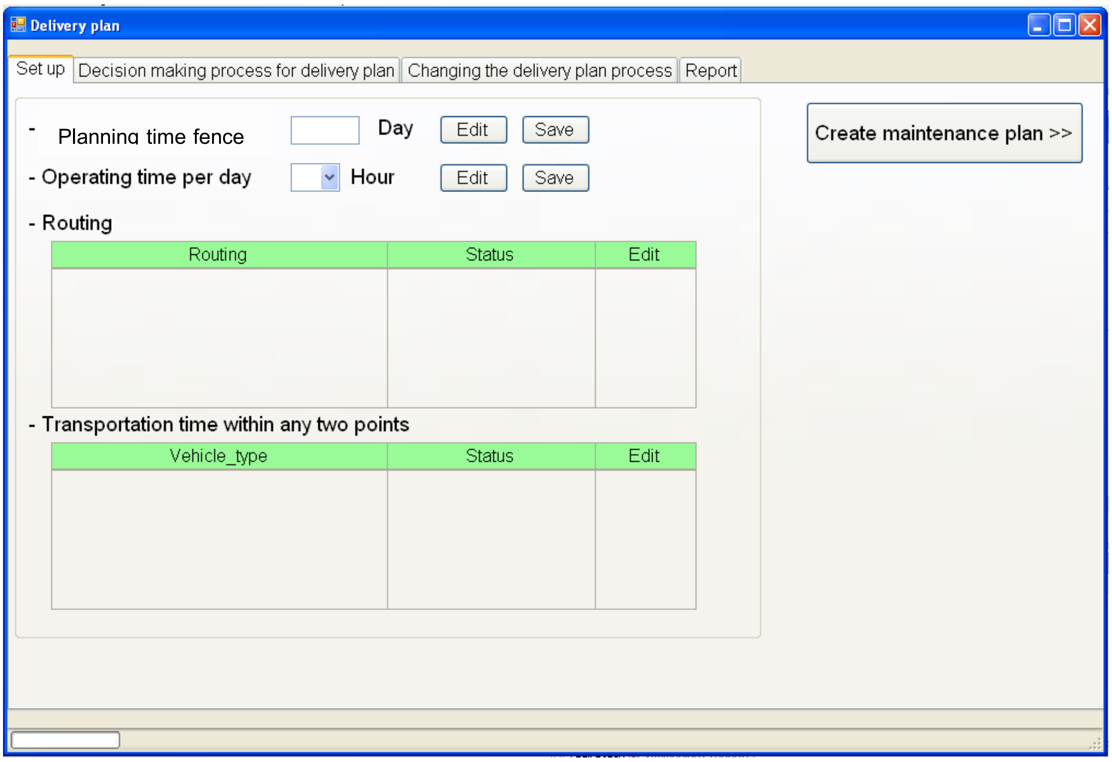



Figure 24 User interface for setting up data and information of generating delivery plan

Objective

To set up planning time fence and operating time per day in order to use as an input of generating transportation.

To retrieve the routing information and transportation time between any two point of each vehicle from tracking vehicle department in order to use as an input of generating transportation.

Instruction

Only transportation planning officer can access this user interface. The details of set up data and all input are stated below:

- Planning time fence

  Planning time fence is specified in day. User has to fill in planning time fence in the blank. The user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button.

- Operating time per day

  The unit of operating time per day is hour. The user can select the number of operating time per day which has the data since 0 untill 24 hours. The user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button.

- Routing information

  Routing information can be retrieved by clicking “Browse” button in edit column. The user can see the status of routing information such as no information, and the date updating the information.

- Transportation time between any two points of each vehicle

  Transportation time between any two points of each vehicle can be retrieved by clicking “Browse” button in edit column. The user can see the status of transportation time such as no information, and the date updating the information.

Moreover, user can fill in or add the maintenance plan by clicking “Create maintenance plan” buttom.

5.2.1.2 Input of maintenance plan

The user interface desgined for for creating maintenance plan is shown below in Figure 25.

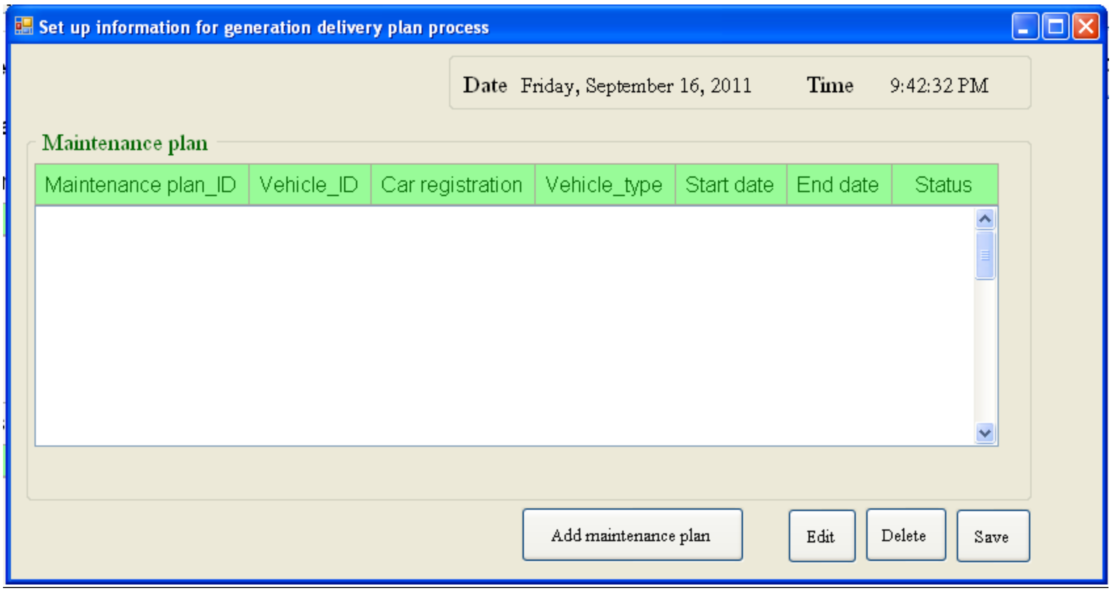



Figure 25 User interface for creating maintenance plan

Objective

To retrieve maintenance plan in order to calculate the number of in house vehicle in each day.

Instruction

Only maintenance officer can access this user interface. The details of maintenance plan are stated below:

- ID of maintenance plan
- ID of vehicle
- Car registration
- Vehicle's type
- Start date of maintenance

- End date of maintenance
- Status of information such as no information, and the date updating the information.

Maintenance officer will fill in the maintenance data. The user can save the data by pushing "Save" button, and can edit the data by pushing "Edit" button. In addition, the user can delete the information by pushing "Delete" button, and can add the data by clicking "Add maintenance plan".

### 5.2.2 Decision making process for delivery planning

5.2.2.1 Retrieving transportation demand for decision making process for delivery planning.

The user interface desgined for retrieving transportation demand for decision making process for delivery planning is shown below in Figure 26.

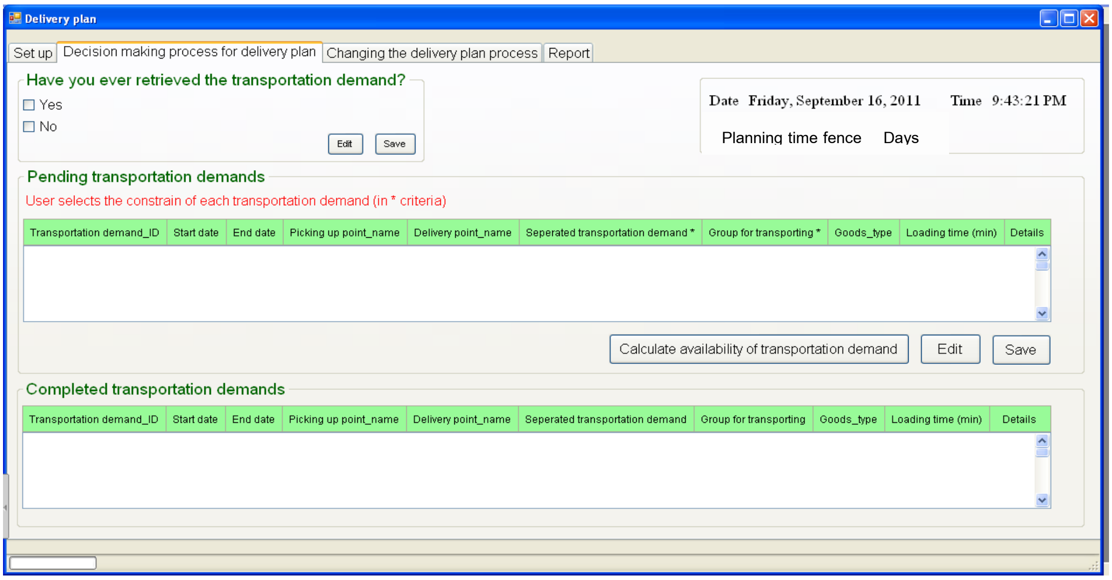



Figure 26 User interface for retrieving transportation demand for decision making process for delivery planning

<u>Objective</u>

To retrieve transportation demand and calculate the availability of all transportation demand in order to check which demand is in the system.

<u>Instruction</u>

Only transportation planning officer can access this user interface. This user inferface presents pending transportation demands; in other words, the demand that has not been considered in order to generate transportation plan. Furthermore, it presents completed transportation demand which is fit into transportation plan.

The user can edit the constraint of each transportation demand by pushing "Edit" button. The information that the user can edit is as follows:

- Seperated transportation demand
- Group for transporting

After that, the user can save the data by pushing "Save" button. After completing all constraint of the demand, the user can click "calculate availability of transportation demand" in order to check which demand is in the system and out of the system.

5.2.2.2 Dividing overy capacity transportation demand

The user interface desgined for dividing overy capacity transportation demand is shown below in Figure 27.

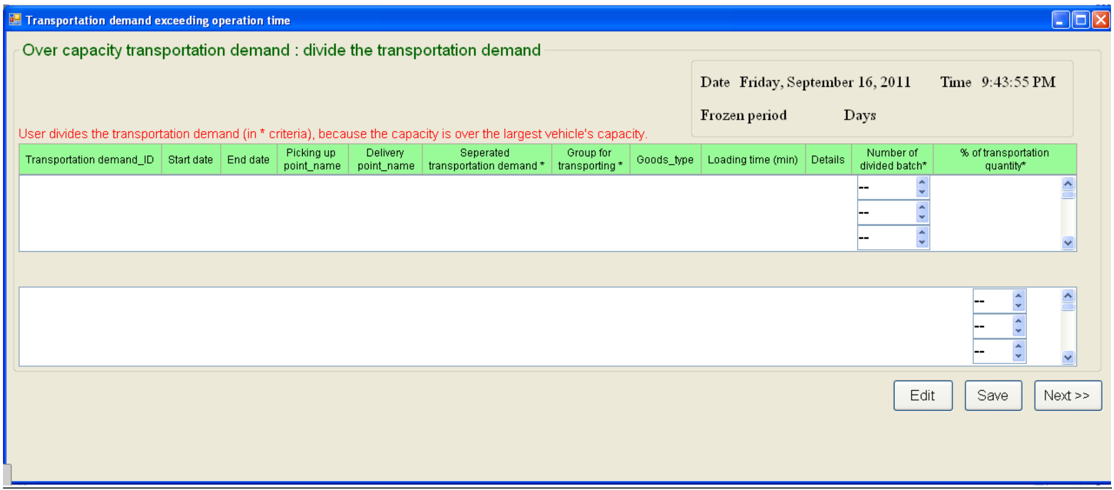



Figure 27 User interface for dividing overy capacity transportation demand

<u>Objective</u>

To divide overy capacity transportation demand which is over the largest vehicle’s capacity in order that this demand can be operated by vehicle in the system.

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to split the transporation demand by selecting the number of divided batch. Then, the user has to select the percent of transportation quantity to each divided demand. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button.

5.2.2.3 Selecting the method of prioritising transportation demand exceeding operation time

The user interface desgined for selecting the method of prioritising transportation demand exceeding operation time is shown below in Figure 28.

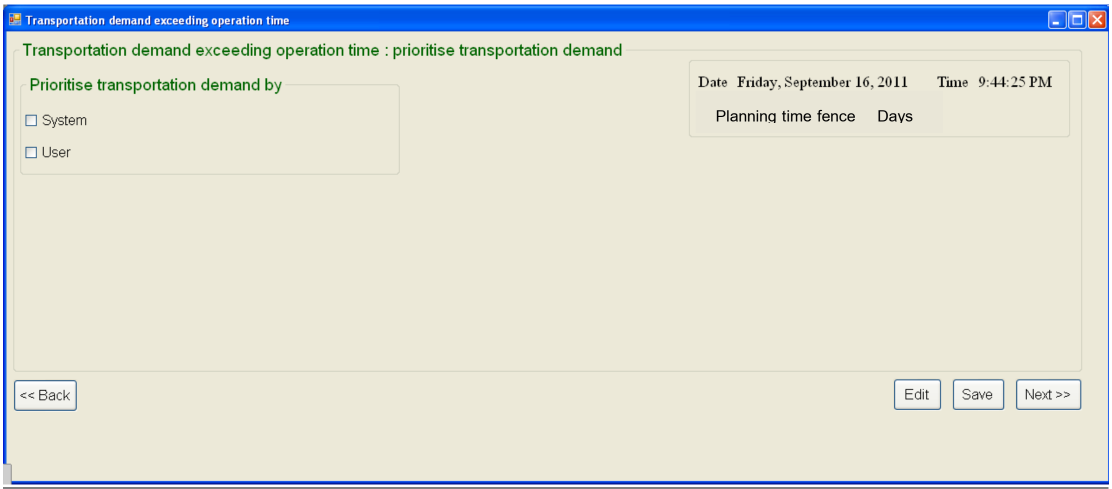



Figure 28 User interface for selecting the method of prioritising transportation demand exceeding operation time

Objective

To select the method of prioritising transportation demand exceeding operation time

Instruction

Only transportation planning officer can access this user interface. The user has to select the method of prioritising transportation demand exceeding operation time by selecting in front of the method needed. There are 2 methods: system prioritizing, and user prioritizing. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.4 Displaying the priority of each transportation demand exceeding operation time prioritized by system

The user interface desgined for displaying the priority of each transportation demand exceeding operation time prioritized by system is shown below in Figure 29.

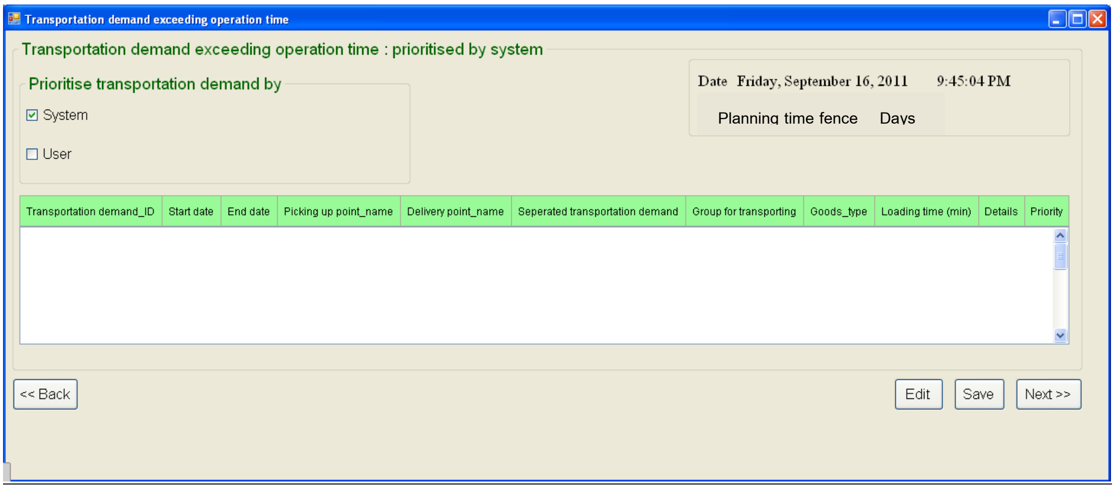



Figure 29 User interface for displaying the priority of each transportation demand exceeding operation time prioritized by system

<u>Objective</u>

To display the priority of each transportation demand exceeding operation time prioritized by system

<u>Instruction</u>

Only transportation planning officer can access this user interface. This user interface will present the priority of each transportation demand exceeding operation time. Then, the user can save the data by pushing “Save” button if the user agrees with the system priorizing. However, if the user would like to edit the data, the user can edit by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.5 Prioritising transportation demand exceeding operation time by user

The user interface desgined for prioritising transportation demand exceeding operation time by user is shown below in Figure 30.

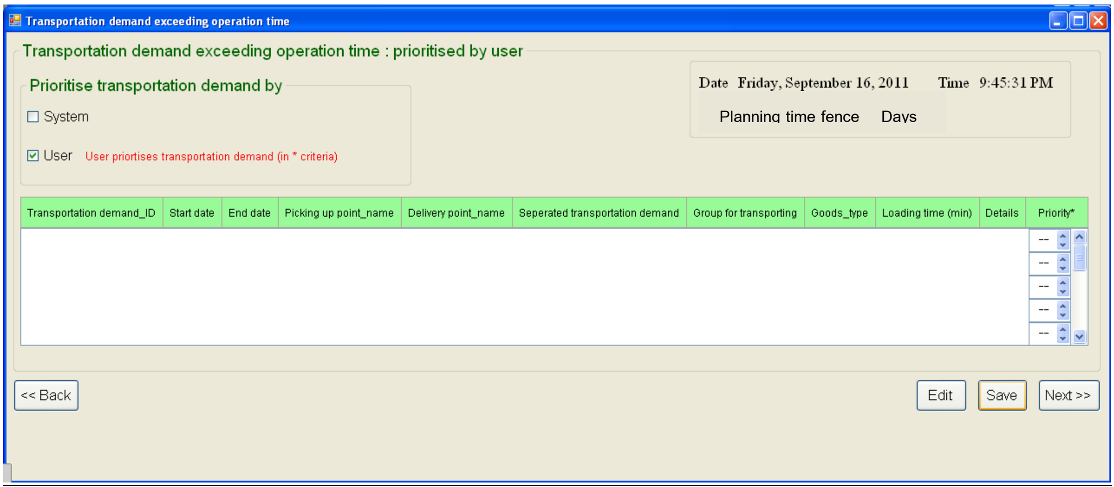



Figure 30 User interface for prioritising transportation demand exceeding operation time by user

Objective

To prioritise transportation demand exceeding operation time by user

Instruction

Only transportation planning officer can access this user interface. The user has to prioritise transportation demand exceeding operation time by selection the priority in priority column. Then, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.6 Selecting the method of choosing transportation demand exceeding operation time which must be operated within today

The user interface desgined for selecting the method of choosing transportation demand exceeding operation time which must be operated within today is shown below in Figure 31.

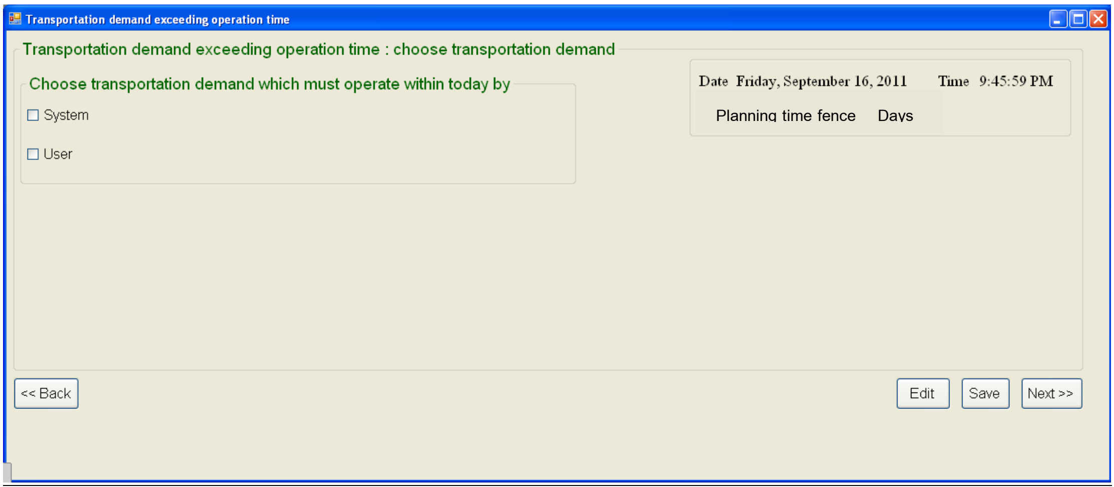



Figure 31 User interface for selecting the method of choosing transportation demand exceeding operation time which must be operated within today

Objective

To select the method of choosing transportation demand exceeding operation time which must be operated within today.

Instruction

Only transportation planning officer can access this user interface. The user has to select the method of choosing transportation demand exceeding operation time which must be operated within today by selecting in front of the method needed. There are 2 methods: chosen by system, and user. After that, the user can save the data by pushing "Save" button, and can edit the data by pushing "Edit" button. In addition, the user can move to the next page by pushing "Next" button. On the other hand, the user can go the previos page by pushing "Back" button.

5.2.2.7 Displaying the transportation demand exceeding operation time which must be operated within today chosen by system

The user interface desgined for displaying the transportation demand exceeding operation time which must be operated within today chosen by system is shown below in Figure 32.

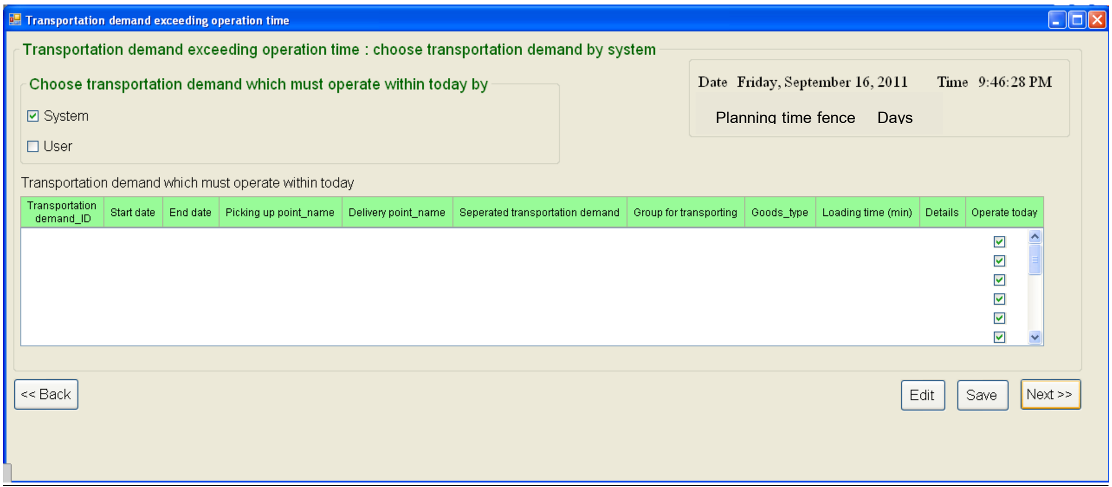



Figure 32 User interface for displaying the transportation demand exceeding operation time which must be operated within today chosen by system

Objective

To display the transportation demand exceeding operation time which must be operated within today chosen by system.

Instruction

Only transportation planning officer can access this user interface. This user interface will present the transportation demand exceeding operation time which must be operated within today chosen by system. Then, the user can save the data by pushing "Save" button if the user agrees with the system. However, if the user would like to edit the data, the user can edit by pushing "Edit" button. In addition, the user can move to the next page by pushing "Next" button. On the other hand, the user can go the previos page by pushing "Back" button.

5.2.2.8 Choosing the transportation demand exceeding operation time which must be operated within today chosen by user

The user interface desgined for choosing the transportation demand exceeding operation time which must be operated within today chosen by user is shown below in Figure 33.

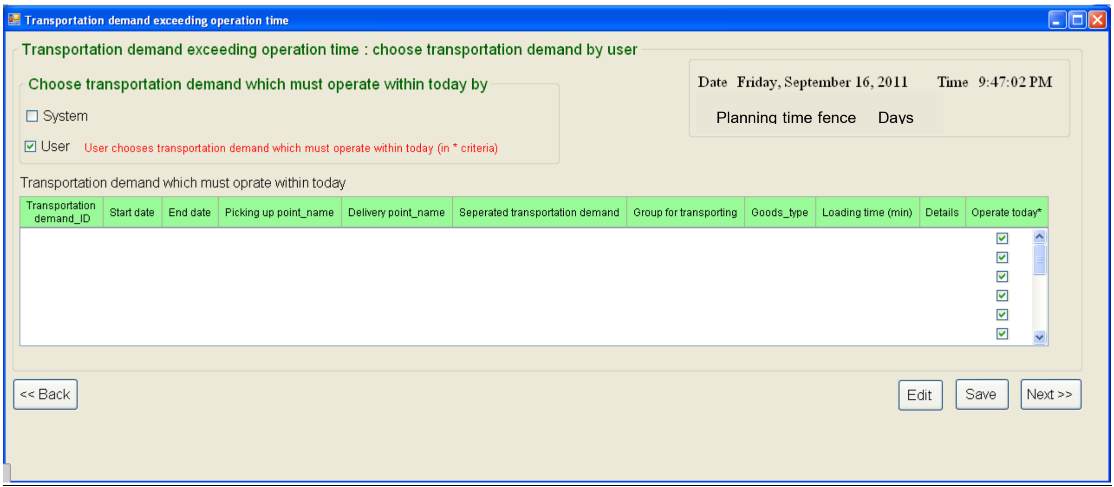



Figure 33 User interface for choosing the transportation demand exceeding operation time which must be operated within today chosen by user

Objective

To choose the transportation demand exceeding operation time which must be operated within today by user.

Instruction

Only transportation planning officer can access this user interface. The user has to choose the transportation demand exceeding operation time which must be operated within today by selection the column of operate today. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.9 Choosing the method of transportation to each transportation demand exceeding operation time

The user interface desgined for choosing the method of transportation to each transportation demand exceeding operation time is shown below in Figure 34.

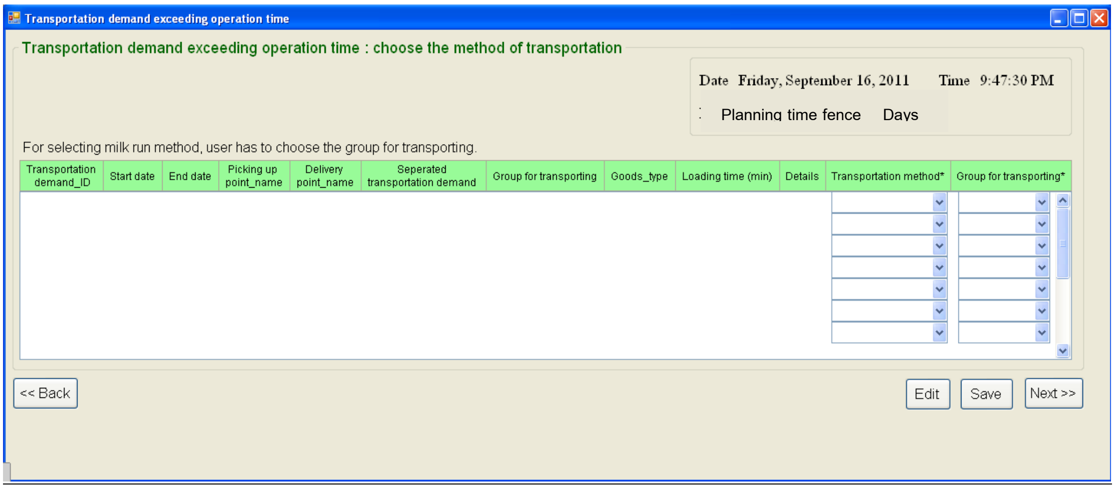



Figure 34 User interface for choosing the method of transportation to each transportation demand exceeding operation time

<u>Objective</u>

To choose the method of transportation to each transportation demand exceeding operation time

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to choose the method of transportation to each transportation demand exceeding operation time by selecting in transportation method column. There are 2 methods: dircect shipping, and milk run. In case of milk run method, the user has to select the group for transporting in the column of group for transporting as well in order to operate in the same day. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.10 Selecting the group of vehicle which operates transportation demand exceeding operation time

The user interface desgined for selecting the group of vehicle which operates transportation demand exceeding operation time is shown below in Figure 35.

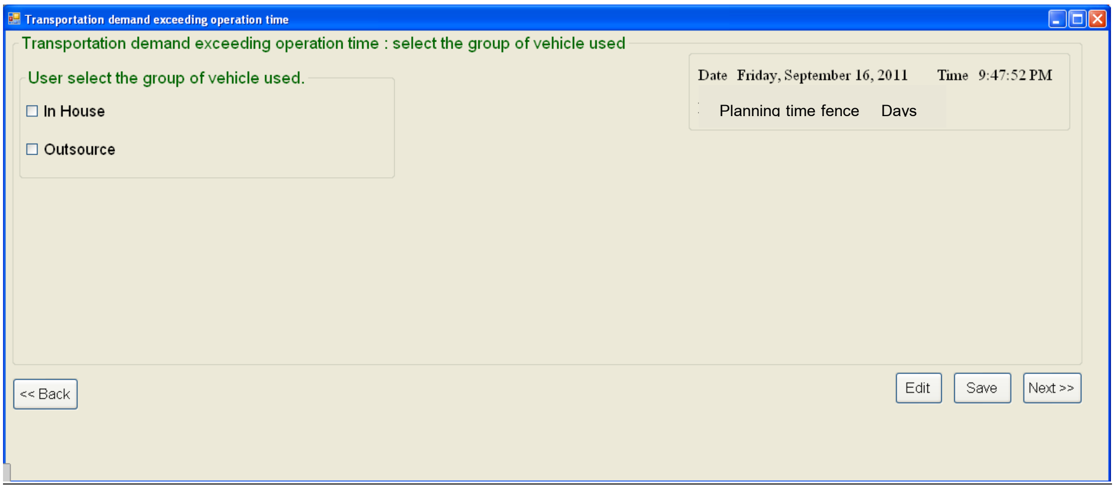



Figure 35 User interface for selecting the group of vehicle which operates transportation demand exceeding operation time

Objective

To select the group of vehicle which operates transportation demand exceeding operation time

Instruction

Only transportation planning officer can access this user interface. The user has to select the group of vehicle which operates transportation demand exceeding operation time by selecting in front of group needed. There are 2 groups: in house vehicle, and outsourced vehicle. Then, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.11 Displaying all available of transportation plan and selecting the transportation plan for transportation demand exceeding operation time

The user interface desgined for displaying all available of transportation plan and selecting the transportation plan for transportation demand exceeding operation time is shown below in Figure 36.

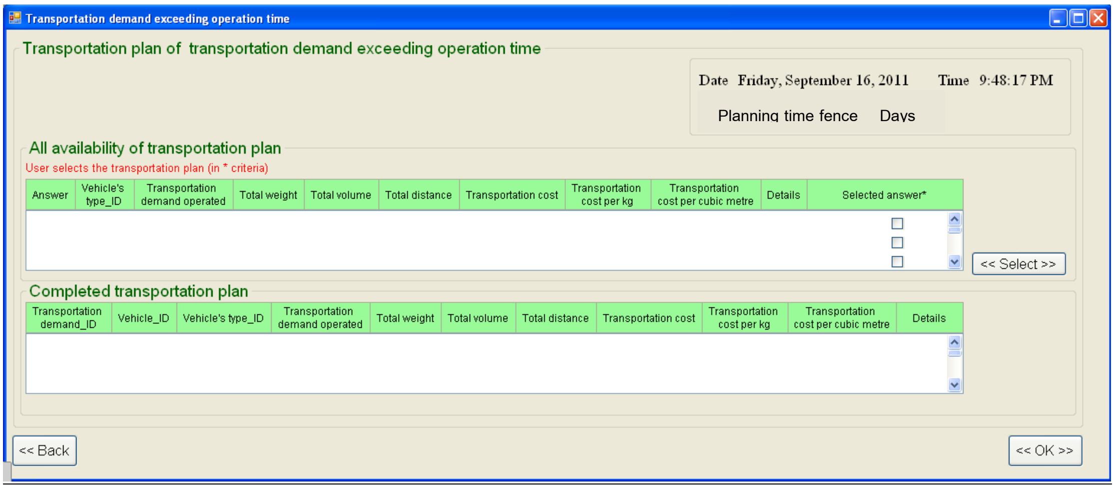



Figure 36 User interface for displaying all available of transportation plan and selecting the transportation plan for transportation demand exceeding operation time

Objective

To display all available of transportation plan and select the transportation plan for transportation demand exceeding operation time.

Instruction

Only transportation planning officer can access this user interface. The user has to select the transportation plan for transportation demand exceeding operation time by selecting in the column of selected answer. Then, the user clicks the “Select” button. After selecting the transportation plan, the user can move to the next page by pushing “OK” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.12 Selecting the method of choosing transportation demand in the system which can be operate today

The user interface desgined for selecting the method of choosing transportation demand in the system which can be operated today is shown below in Figure 37.

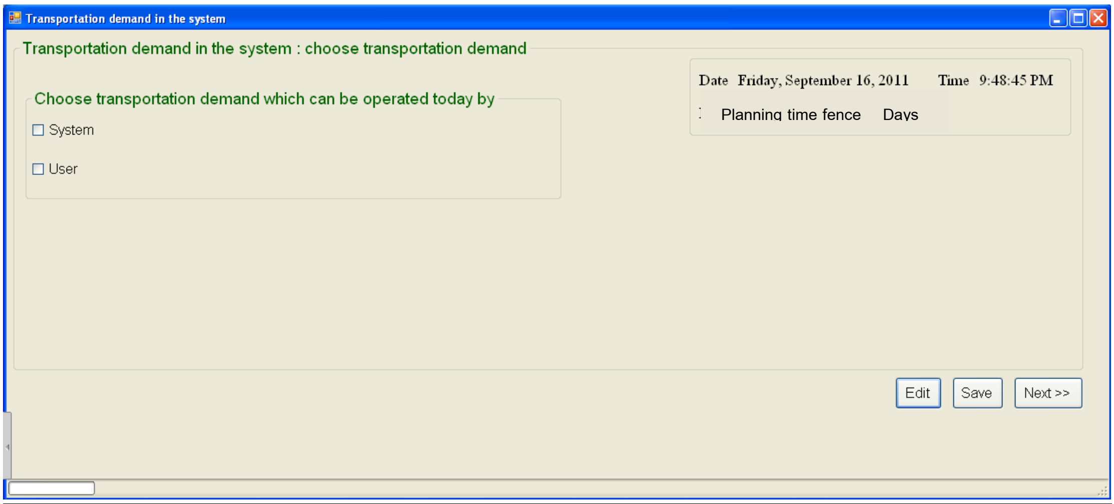



Figure 37 User interface for selecting the method of choosing transportation demand in the system which can be operated today

<u>Objective</u>

To select the method of choosing transportation demand in the system which can be operated today.

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to select the method of choosing transportation demand in the system which can be operated today by selecting in front of group needed. There are 2 methods: chosen by system and user. Then, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button.

5.2.2.13 Displaying transportation demand in the system which can be operated today chosen by system

The user interface desgined for displaying transportation demand in the system which can be operated today chosen by system is shown below in Figure 38.

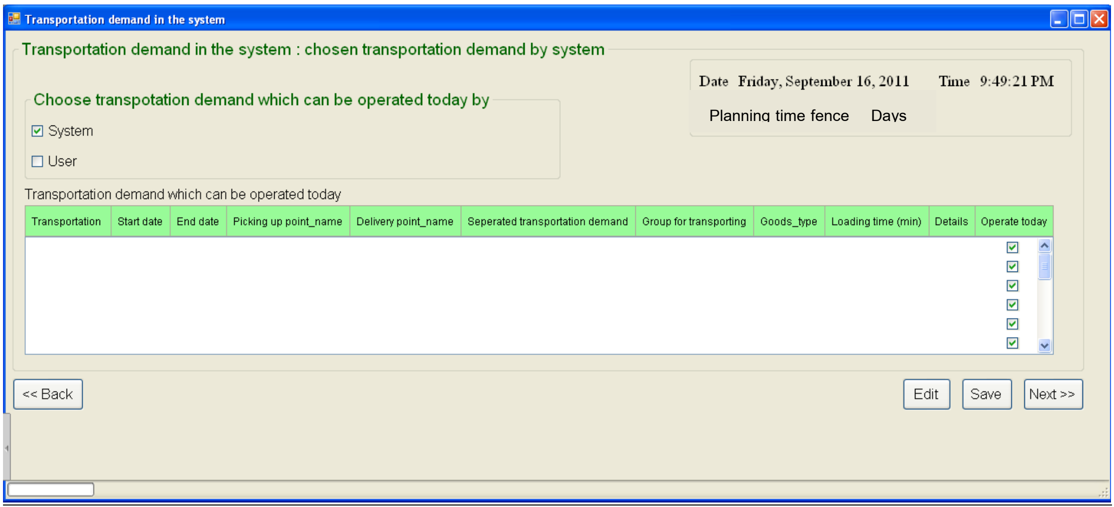



Figure 38 User interface for displaying transportation demand in the system which can be operated today chosen by system

<u>Objective</u>

To display transportation demand in the system which can be operated today chosen by system.

Instruction

Only transportation planning officer can access this user interface. This user interface will present transportation demand in the system which can be operated today chosen by system. Then, the user can save the data by pushing “Save” button if the user agrees with the system. However, if the user would like to edit the data, the user can edit by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.14 Selecting transportation demand in the system which can be operated today chosen by user

The user interface desgined for selecting transportation demand in the system which can be operated today chosen by user is shown below in Figure 39.

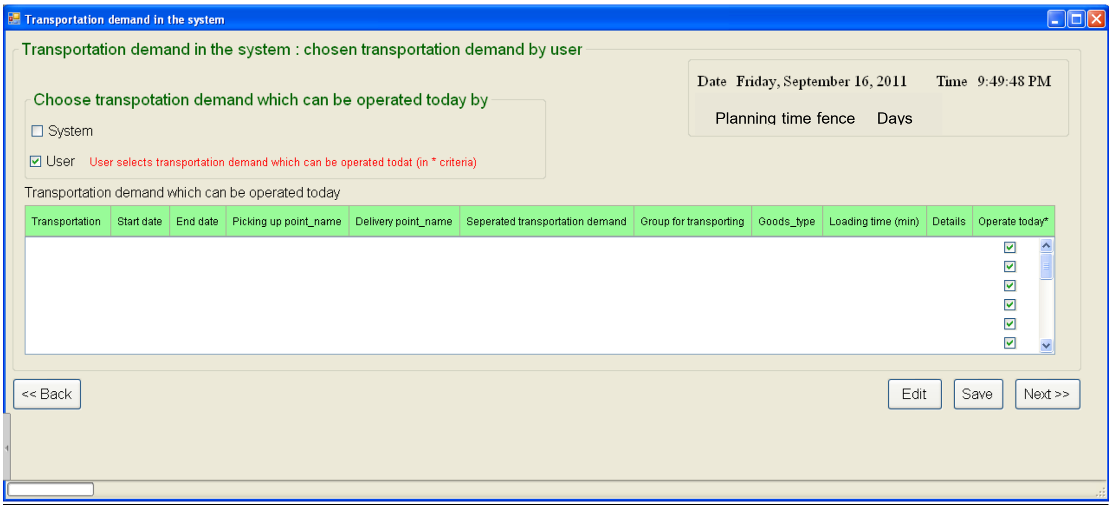



Figure 39 User interface for selecting transportation demand in the system which can be operated today chosen by user

Objective

To select transportation demand in the system which can be operated today chosen by user.

Instruction

Only transportation planning officer can access this user interface. The user has to select transportation demand in the system which can be operated today chosen by user by selection the column of operate today. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.15 Displaying all available of transportation plan and selecting the transportation plan for transportation demand in the system

The user interface desgined for displaying all available of transportation plan and selecting the transportation plan for transportation demand in the system is shown below in Figure 40.

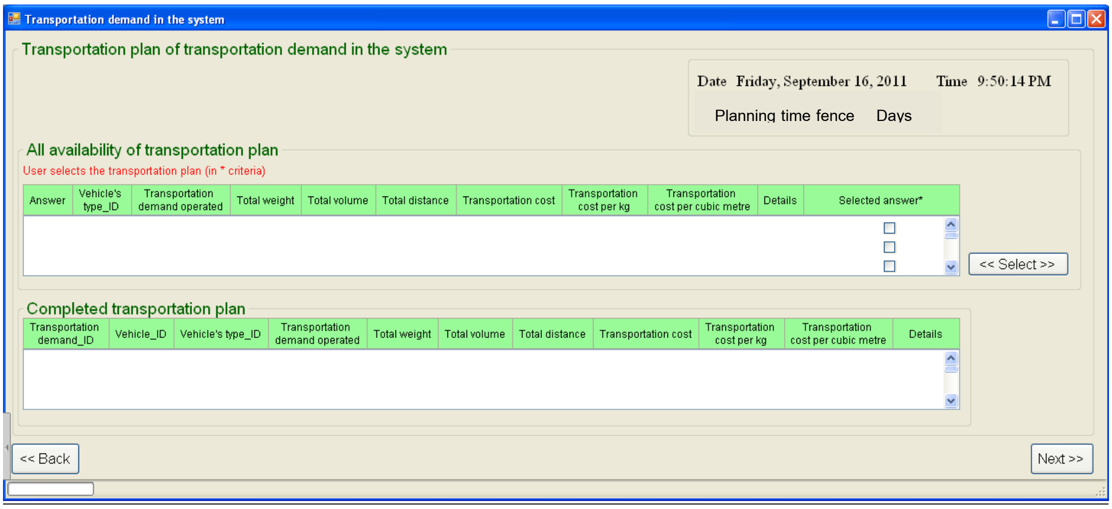



Figure 40 User interface for displaying all available of transportation plans and selecting the transportation plan for transportation demand in the system

Objective

To display all available of transportation plans and select the transportation plan for transportation demand in the system

Instruction

Only transportation planning officer can access this user interface. The user has to select the transportation plan for transportation demand in the system by selecting in the column of selected answer. Then, the user clicks the “Select” button. After selecting the transportation plan, the user can move to the next page by pushing “OK” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.16 Selecting the method of cutting off transportation demand in the system which does not operate today

The user interface desgined for selecting the method of cutting off transportation demand in the system which does not operate today is shown below in Figure 41.

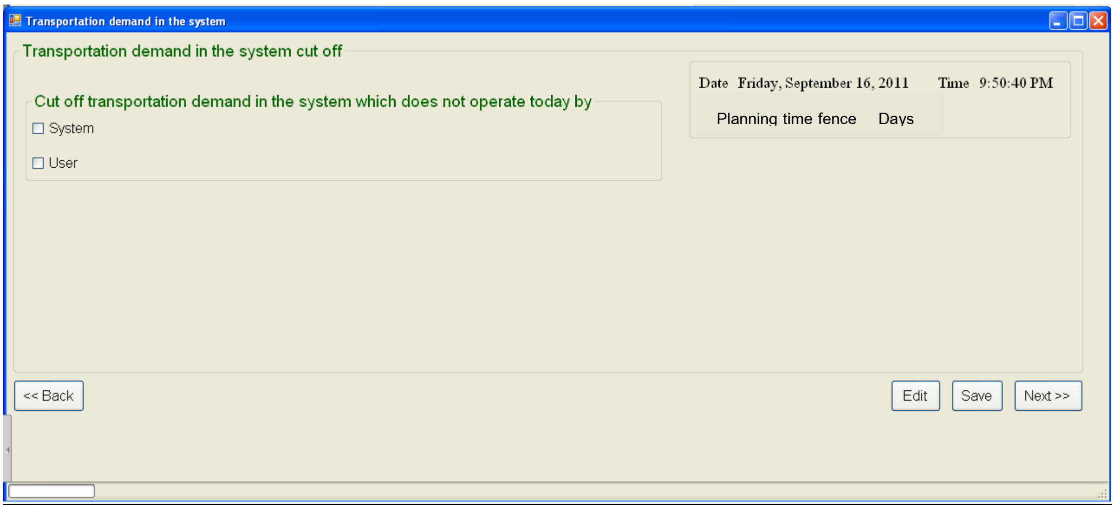



Figure 41 User interface for selecting the method of cutting off transportation demand in the system which does not operate today

Objective

To select the method of cutting off transportation demand in the system which does not operate today

Instruction

Only transportation planning officer can access this user interface. The user has to select the method of cutting off transportation demand in the system which does not operate today by selecting in front of the method needed. There are 2 methods: cut by system, and user. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.17 Displaying transportation demand in the system cut off by system

The user interface desgined for displaying transportation demand in the system cut off by system is shown below in Figure 42.

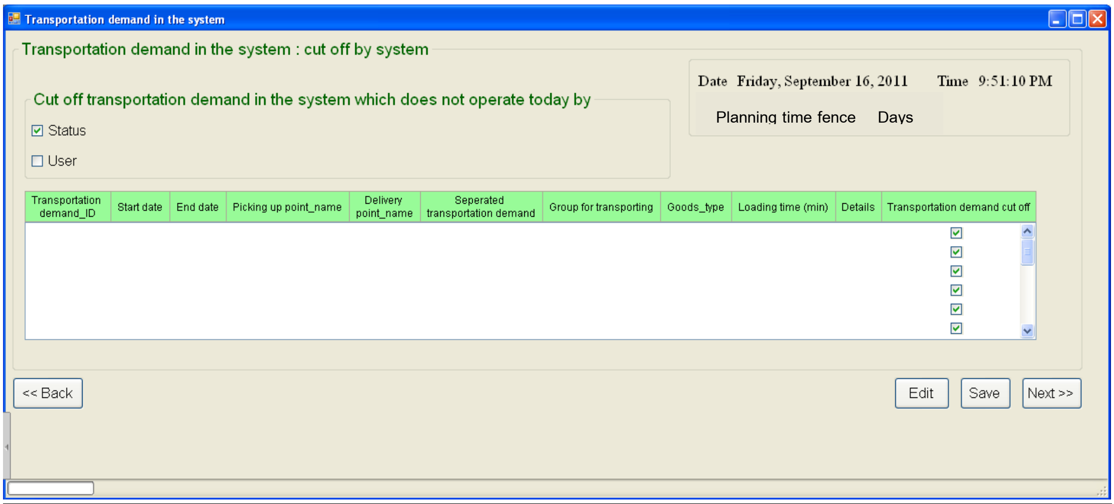



Figure 42 User interface for displaying transportation demand in the system cut off by system

<u>Objective</u>

To display transportation demand in the system cut off by system.

Instruction

Only transportation planning officer can access this user interface. This user interface will display transportation demand in the system cut off by system. Then, the user can save the data by pushing “Save” button if the user agrees with the system. However, if the user would like to edit the data, the user can edit by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.2.18 Cutting off transportation demand in the system which does not operate today by user

The user interface desgined for cutting off transportation demand in the system which does not operate today by user is shown below in Figure 43.

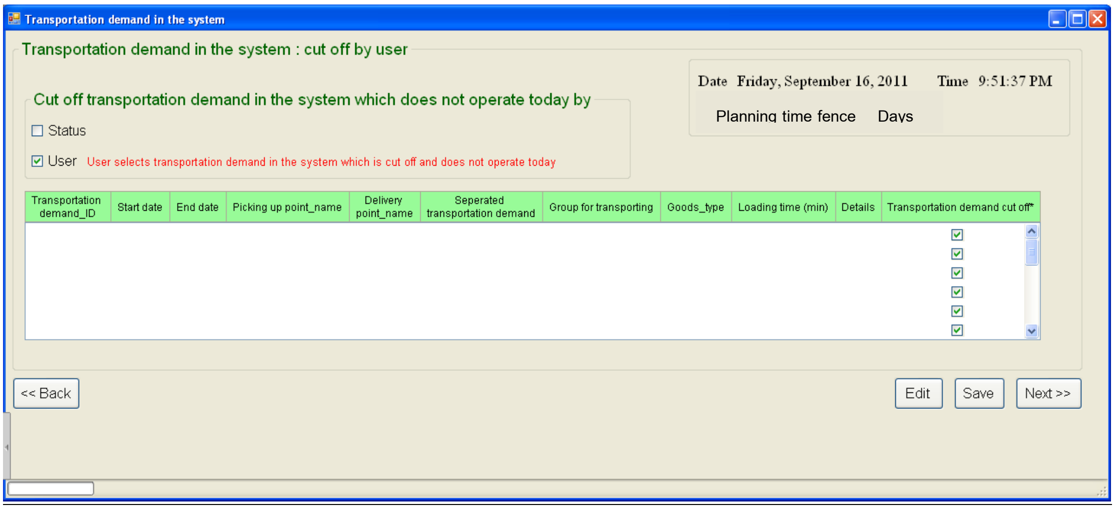



Figure 43 User interface for cutting off transportation demand in the system which does not operate today by user

<u>Objective</u>

To cut off transportation demand in the system which does not operate today by user.

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to cut off transportation demand in the system which does not operate today. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

### 5.2.3 Changing the delivery plan process

5.2.3.1 Retrieving transportation demand changed for changing the delivery plan

The user interface desgined for retrieving transportation demand changed for changing the delivery plan process is shown below in Figure 44.

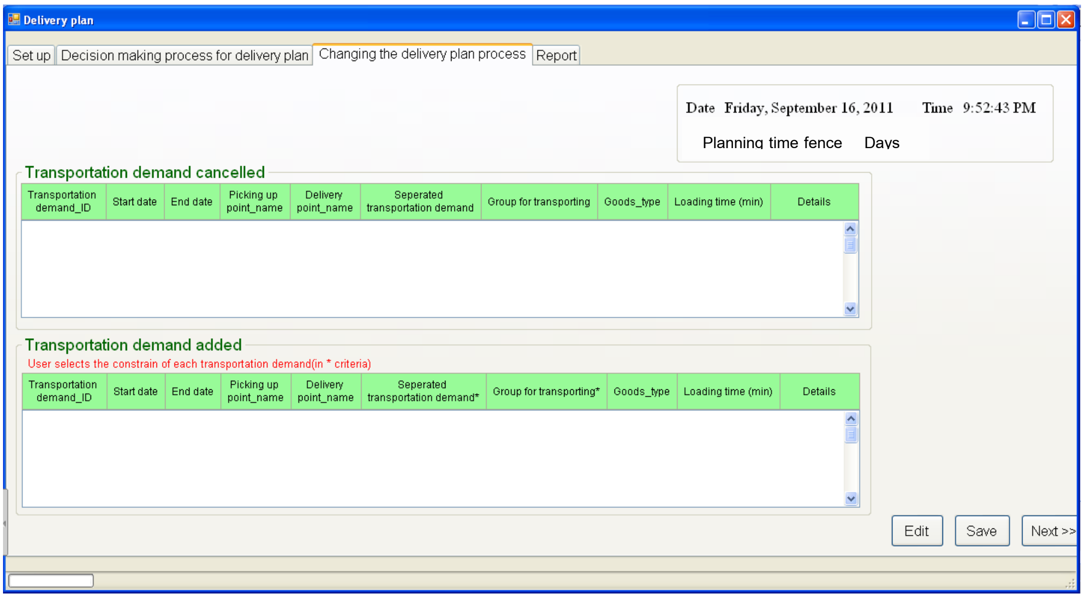



Figure 44 User interface for retrieving transportation demand changed for changing the delivery plan process

Objective

To retrieve transportation demand changed for changing the delivery plan process.

Instruction

Only transportation planning officer can access this user interface. This user inferface presents transportation demands cancelled and transportation demand added in planning time fence.

The user has to edit the constraint of each transportation demand added by pushing “Edit” button. The information that the user can edit is as follows:

- Seperated transportation demand

– Group for transporting

After that, the user can save the data by pushing "Save" button, and can move to the next page by pushing "Next" button.

5.2.3.2 Selecting the condition of changing the transportation plan

The user interface desgined for selecting the condition of changing the transportation plan is shown below in Figure 45.

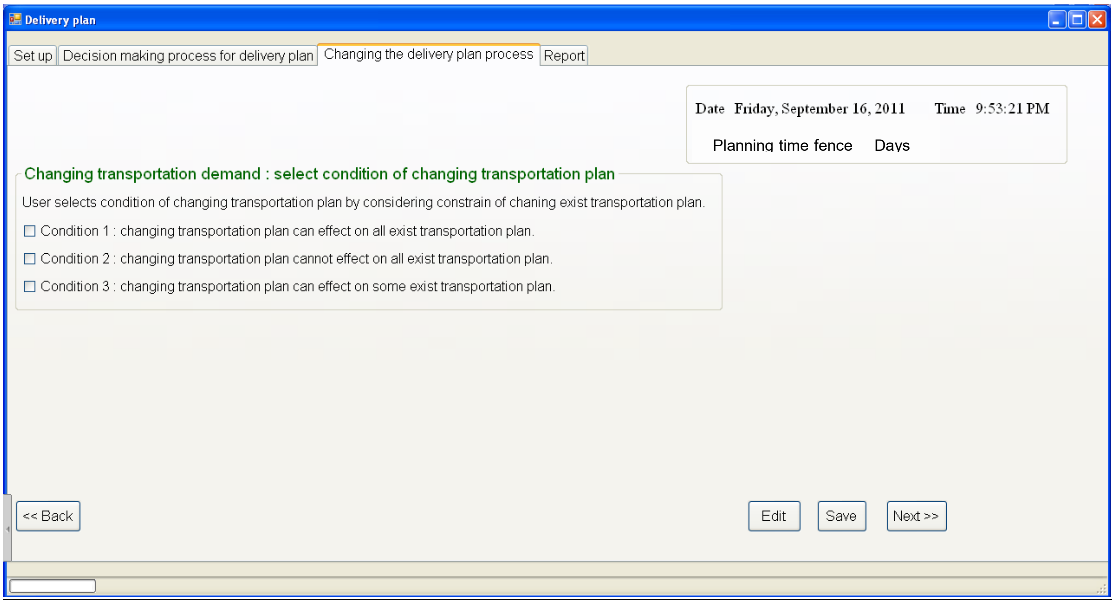



Figure 45 User interface for selecting the condition of changing the transportation plan

<u>Objective</u>

To selecte the condition of changing the transportation plan.

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to select the condition of changing the transportation plan by selecting in front of the condition. Then, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.3.3 Selecting the method of choosing transportation demand changed which must be operated within today (changing the delivery plan by condition 1)

The user interface desgined for selecting the method of choosing transportation demand changed which must be operated within today (changing the delivery plan by condition 1) is shown below in Figure 46.

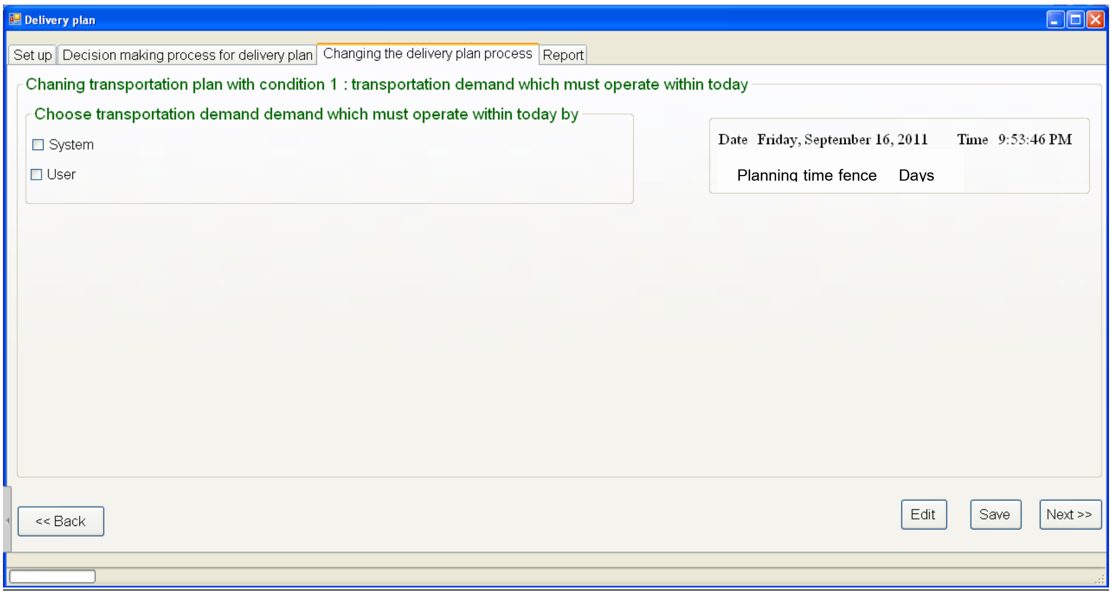



Figure 46 User interface for selecting the method of choosing transportation demand changed which must be operated within today (changing the delivery plan by condition 1)

<u>Objective</u>

To select the method of choosing transportation demand changed which must be operated within today (changing the delivery plan by condition 1)

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to select the method of choosing transportation demand changed which must be operated within today (changing the delivery plan by condition 1) by selecting in front of the method needed. There are 2 methods: chosen by system, and user. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.3.4 Displaying transportation demand changed which must be operated within today chosen by system (changing the delivery plan by condition 1)

The user interface desgined for displaying transportation demand changed which must be operated within today chosen by system (changing the delivery plan by condition 1) is shown below in Figure 47.

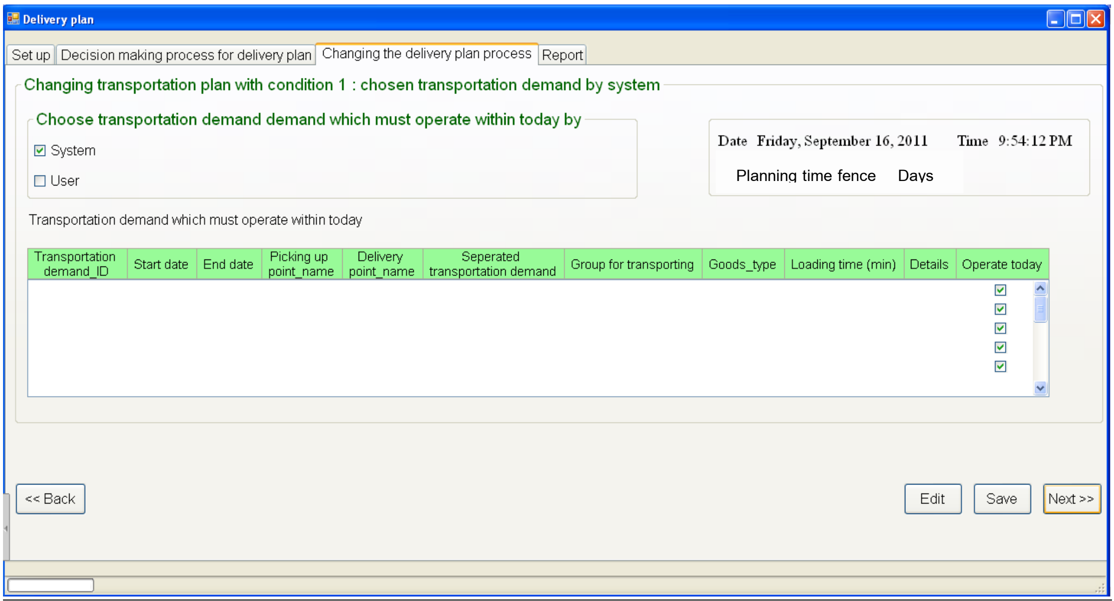



Figure 47 User interface for displaying transportation demand changed which must be operated within today chosen by system (changing the delivery plan by condition 1)

<u>Objective</u>

To display transportation demand changed which must be operated within today chosen by system (changing the delivery plan by condition 1)

<u>Instruction</u>

Only transportation planning officer can access this user interface. This user interface will present the transportation changed which must be operated within today chosen by system (changing the delivery plan by condition 1) chosen by system. Then, the user can save the data by pushing “Save” button if the user agrees with the system. However, if the user would like to edit the data, the user can edit by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.3.5 Choosing transportation demand changed which must be operated within today by user (changing the delivery plan by condition 1)

The user interface desgined for choosing transportation demand changed which must be operated within today by user (changing the delivery plan by condition 1) is shown below in Figure 48.

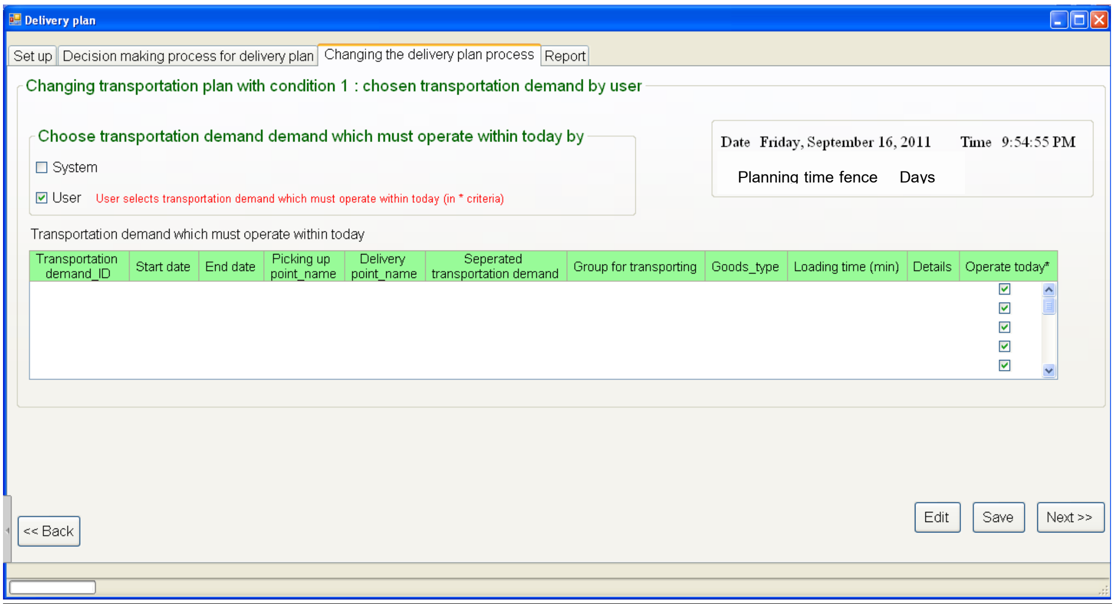



Figure 48 User interface for choosing transportation demand changed which must be operated within today by user (changing the delivery plan by condition 1)

<u>Objective</u>

To choose transportation demand changed which must be operated within today by user (changing the delivery plan by condition 1).

Instruction

Only transportation planning officer can access this user interface. The user has to choose transportation demand changed which must be operated within today by user (changing the delivery plan by condition 1) by selection the column of operate today. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.3.6 Displaying transportation demand added (changing the delivery plan condition 2)

The user interface desgined for displaying transportation demand added (changing the delivery plan by condition 2) is shown below in Figure 49.

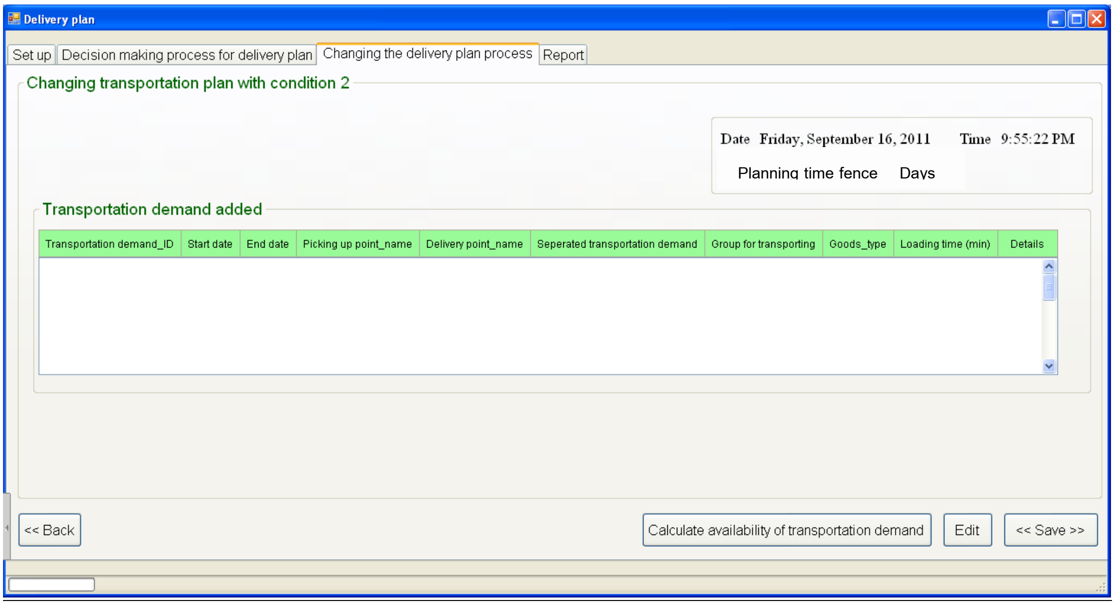



Figure 49 User interface for displaying transportation demand added (changing the delivery plan by condition 2)

Objective

To display transportation demand added (changing the delivery plan by condition 2).

Instruction

Only transportation planning officer can access this user interface. This user interface shows transportation demand added (changing the delivery plan by condition 2).

The user can edit the constraint of each transportation demand by pushing “Edit” button. The information that the user can edit is as follows:

- Seperated transportation demand
- Group for transporting

After that, the user can save the data by pushing “Save” button. After completing all constraint of the demand, the user can click “calculate availability of transportation demand” in order to check which demand is in the system and out of the system.

5.2.3.7 Selecting the method of changing the previous transportation plan (changing the delivery plan by condition 2)

The user interface desgined for selecting the method of changing the previous transportation plan (changing the delivery plan by condition 2) is shown below in Figure 50.

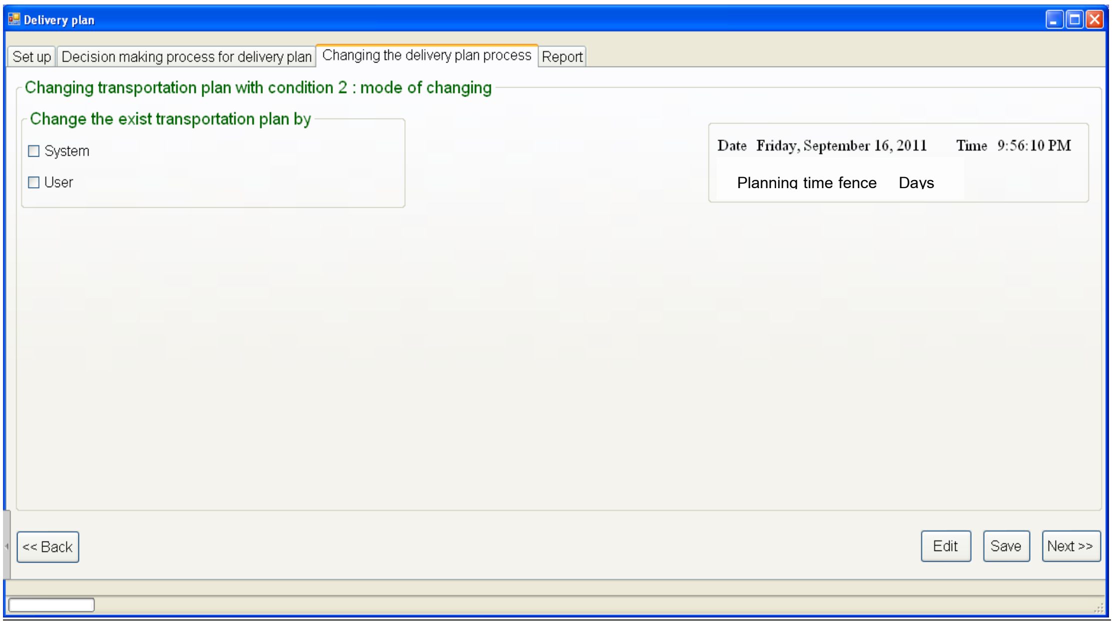



Figure 50 User interface for selecting the method of changing the previous transportation plan (changing the delivery plan by condition 2)

<u>Objective</u>

To select the method of changing the previous transportation plan (changing the delivery plan by condition 2)

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to select the method of of changing the previous transportation plan (changing the delivery plan by condition 2) by selecting in front of the method needed. There are 2 methods: changed transportation plan by system, and user. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.3.8 Displaying all available of transportation plan and selecting the transportation plan for transportation demand changed (changing the delivery plan by condition 2)

The user interface desgined for displaying all available of transportation plan and selecting the transportation plan for transportation demand changed (changing the delivery plan by condition 2) is shown below in Figure 51.

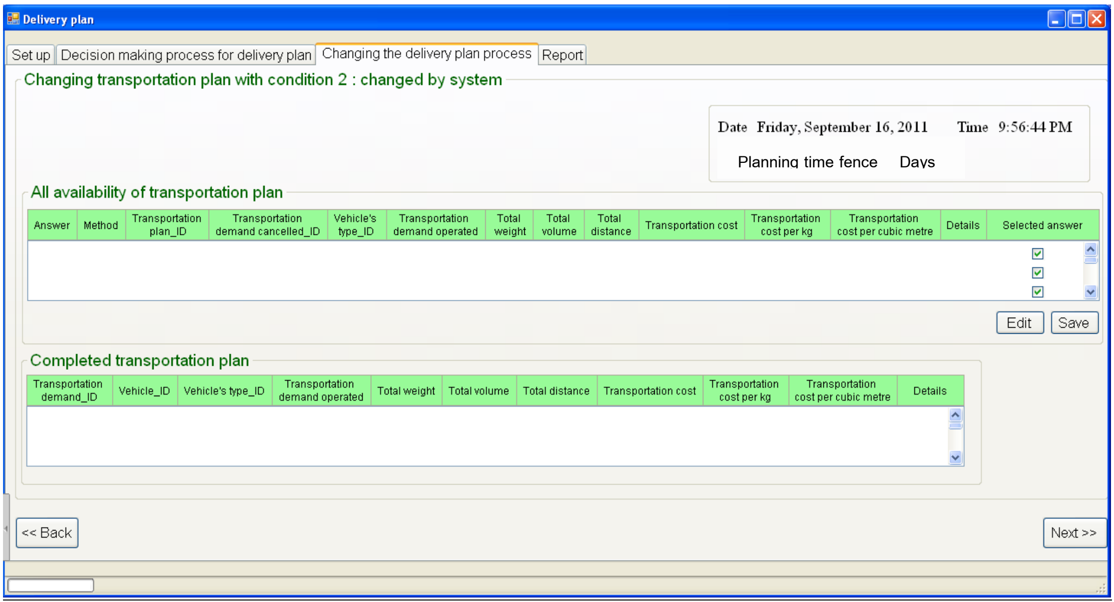



Figure 51 User interface for displaying all available of transportation plan and selecting the transportation plan for transportation demand changed (changing the delivery plan by condition 2)

<u>Objective</u>

To display all available of transportation plan and selecte the transportation plan for transportation demand changed (changing the delivery plan by condition 2)

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to select the transportation plan for transportation demand changed (changing the delivery plan by condition 2) by selecting in the column of selected answer. Then, the user clicks the “Save” button. Moreover, the user can edit the selected answer by pushing “Edit” button After selecting the transportation plan, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.3.9 Checking availability of transportation plan changed by user (changing the delivery plan by condition 2)

The user interface desgined for checking availability of transportation plan changed by user (changing the delivery plan by condition 2) is shown below in Figure 52.

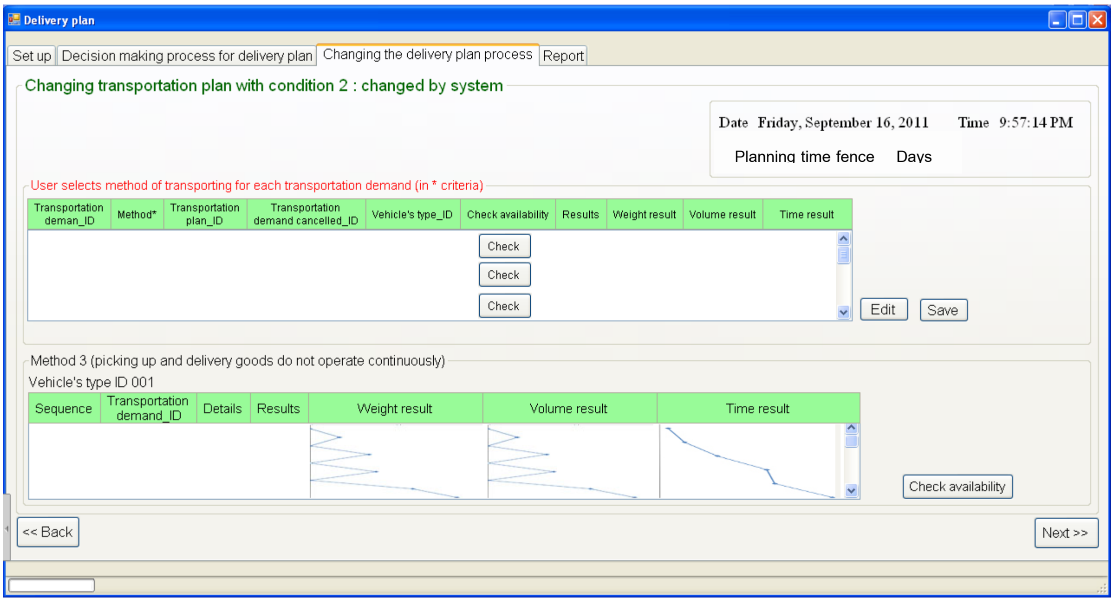



Figure 52 User interface for checking availability of transportation plan changed by user (changing the delivery plan by condition 2)

Objective

To check availability of transportation plan changed by user (changing the delivery plan by condition 2)

Instruction

Only transportation planning officer can access this user interface. The user has to select the method for transportation demand added. There are 3 methods: adding transportation demand after previous transportation plan, replacing transportation demand cancelled, releasing new vehicle method.

If the users choose adding transportation demand after previous transportation plan method, the user has to select ID of the previous transportation plan. If the user chooses replacing transportation demand cancelled method, the user has to select ID of transportation demand cancelled. If the user chooses releasing new vehicle method which the pick up and delivery goods operates continuously, the user has to select type of vehicle operated as well. After selecting the method to each demand, the user must save the data by pushing “Save” button first. Then, the user can check the availability of the selected method that it can operate or not by clicking “Check” button. The system will check all of the limitation of the sytem consisting opertating time constraint, and capacity of vehicle constraint by considering both weigh, and volumn dimension. Then, the system will display the result of selected method and conclude that it can operate or not.

For releasing new vehicle method which the pick up and delivery goods does not operate continuously, the system is able to chek if the user choose the sequence of picking up and delivery. After selecting the sequence, the user can click “Check availability” buttom. Then, the system will show the results as well. Furthemore, the user can edit the method to each transportation demand by pushing "Edit" button. In addition, the user can move to the next page by pushing "Next" button. On the other hand, the user can go the previos page by pushing "Back" button.

5.2.3.10 Displaying transportation demand added (changing the delivery plan by condition 3)

The user interface desgined for displaying transportation demand added (changing the delivery plan by condition 3) is shown below in Figure 53.

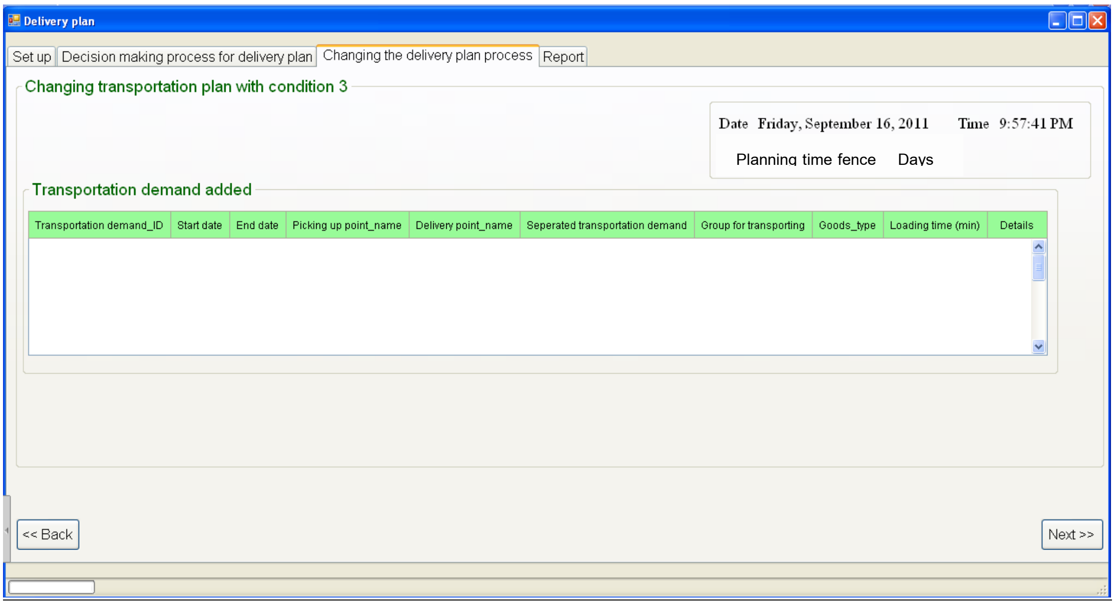



Figure 53 User interface for displaying transportation demand added (changing the delivery plan by condition 3)

<u>Objective</u>

To display transportation demand added (changing the delivery plan by condition 3)

<u>Instruction</u>

Only transportation planning officer can access this user interface. This user interface presents transportation demand added, and the user cannot change any information. After that, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

5.2.3.11 Selecting which transportation plan arranged by vehicle’s ID can be effected (changing the delivery plan by condition 3)

The user interface desgined for selecting which transportation plan arranged by vehicle’s ID can be effected (changing the delivery plan by condition 3) is shown below in Figure 54.

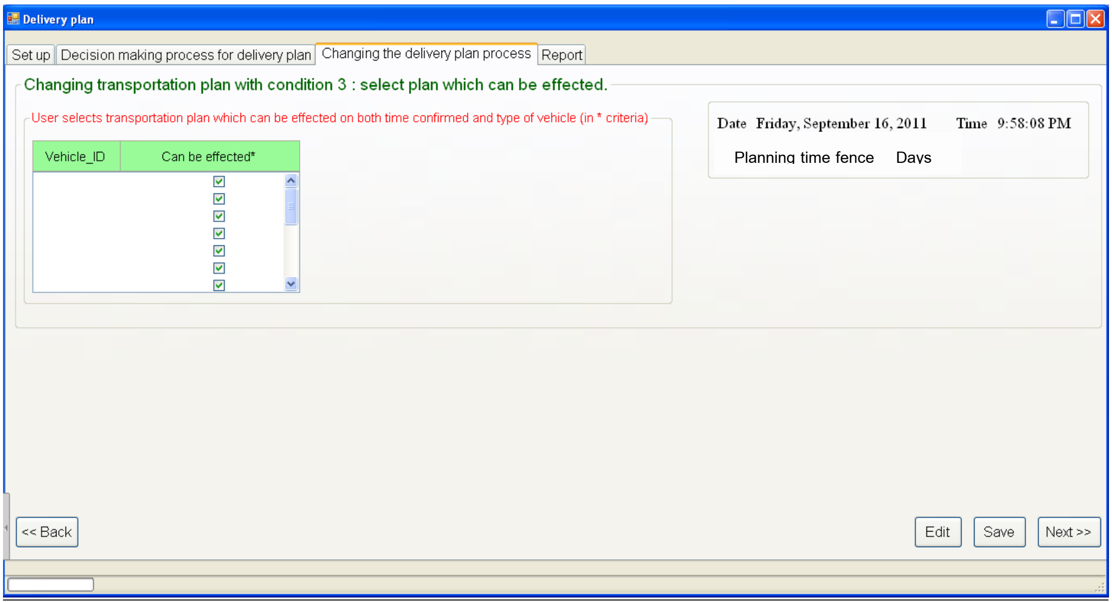



Figure 54 User interface for selecting which transportation plan arranged by vehicle’s ID can be effected (changing the delivery plan by condition 3)

Objective

To select which transportation plan arranged by vehicle's ID can be effected (changing the delivery plan by condition 3)

Instruction

Only transportation planning officer can access this user interface. The user has to choose which transportation plan arranged by vehicle's ID can be effected (changing the delivery plan by condition 3) by selecting the column of can be effected. After that, the user can save the data by pushing "Save" button, and can edit the data by pushing "Edit" button. In addition, the user can move to the next page by pushing "Next" button. On the other hand, the user can go the previos page by pushing "Back" button.

5.2.3.12 Selecting the condition of changing for each transportation demand (changing the delivery plan by condition 3)

The user interface desgined for selecting the condition of changing for each transportation demand (changing the delivery plan by condition 3) is shown below in Figure 55

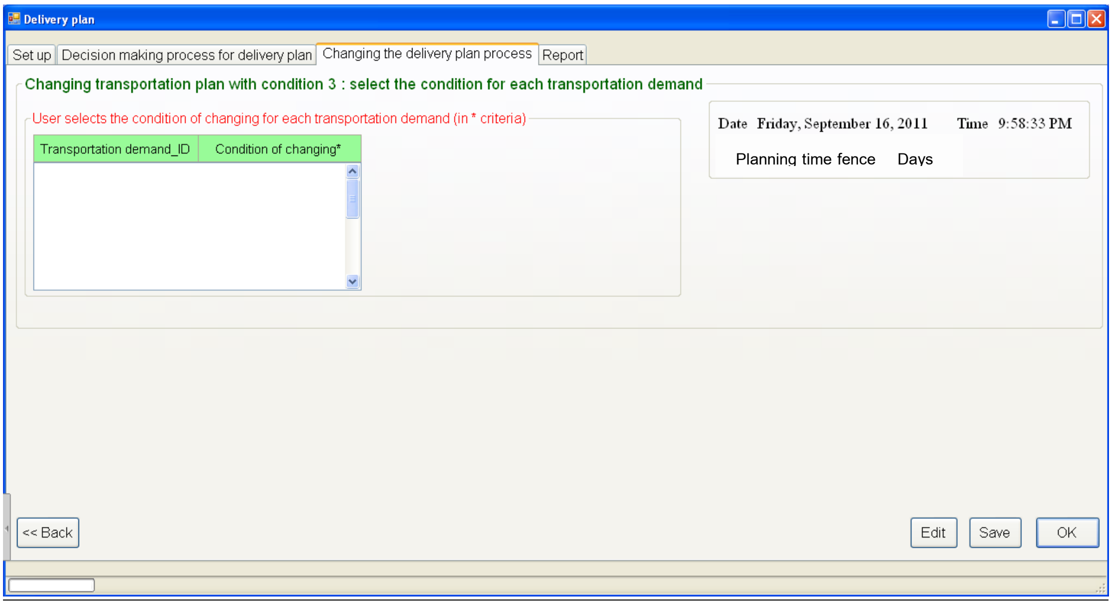



Figure 55 User interface for selecting the condition of changing for each transportation demand (changing the delivery plan by condition 3)

<u>Objective</u>

To select the condition of changing for each transportation demand (changing the delivery plan by condition 3)

<u>Instruction</u>

Only transportation planning officer can access this user interface. The user has to select the condition of changing for each transportation demand (changing the delivery plan by condition 3) by selecting the column of condition of changing. After that, the user can save the data by pushing “Save” button, and can edit the data by pushing “Edit” button. In addition, the user can move to the next page by pushing “Next” button. On the other hand, the user can go the previos page by pushing “Back” button.

## 5.2.4 Report

### 5.2.4.1 Displaying the results of generating transportation

The user interface desgined for displaying the results of generating transportation is shown below in Figure 56.

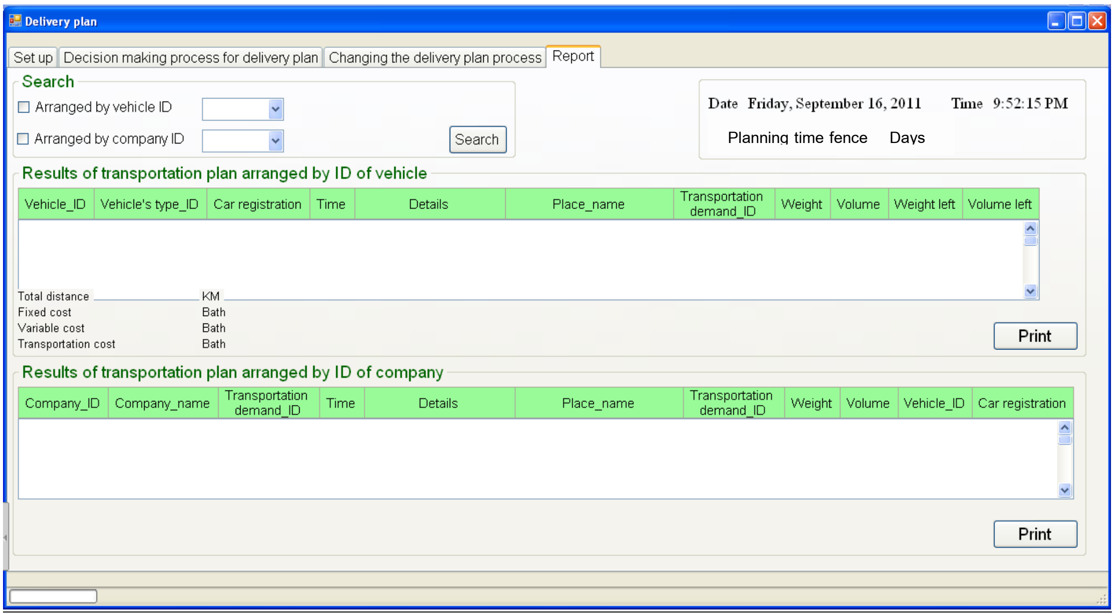



Figure 56 User interface for displaying the results of generating transportation

Objective

To present the results of generating transportation arranged by ID of vehicle and ID of company.

Instruction

Only transportation planning officer can access this user interface. The user has to select the pattern of transportation plan by selecting in front of the pattern. There are

2 patterns: transportation plan arraged by ID of vehicle and ID of company. If the user would like transportation plan arraged by ID of vehicle, the user has to select the ID of vehicle. On the other hand, if the user would like transportation plan arraged by ID of company, the user has to select the ID of company as well. After selecting the pattern and ID, the user has to click "search" button in order that the system will retrieve transportation plan from the database. Moreover, the user can print this plan by pushing "Print" button.

# CHAPTER 6

# SYSTEM EVALUATION

This chapter explains the evaluation of the system designed which can be divided into 2 following topics:

- Evaluation of the correctness and completeness of the designed information system
- Evaluation of the efficiency of information system result

## 6.1 Evaluation of the correctness and completeness of the designed information system

The research designed is evaluated the correctness and completeness by interviewing officer working in garment industry and related to transportation planning such as transportation planner. The researcher has interviewed 2 garment factories which are located in Bangkok, Thailand. The, these two factories have evaluated the concept of information system desgined which is didived into 3 sections: evaluation of the correctness and completeness of decision making process for delivery planning, evaluation of the correctness and completeness of changing the delivery plan process, and decision support system evaluation. The detail of each section is explained below:

### 6.1.1 Evaluation of the correctness and completeness of decision making process for delivery planning

- The capability of solving the current problem.

According to the interview of transportation planners, mostly planner said that proposed decision making process can solve the problem at the present. For example, the overlap routing is reduce, and also the transportation cost is decrease. The main reson that can solve the problem is milk run model which can decrease both distance and number of vehicle used.

Furthemore, transportation planner has suggested that milk run model is not suit for transportation demand which has long distance, because it may cause more distance than direct shipping model. However, the system designed has already solved this problem by choosing either milk run or direct shipping method when transportation demand is operated more than one day or located far from home.

- Concept and principle for finding the solution

According to the interview of transportation planners, they said that the concept is correct, and appropriate such as giving the priority to each transportation demand by using due date as a criteria, using milk run model in order to reduce the transportation cost, using outsourced vehicle in order to operate transportation when it is the due date, using cost per unit in order to select transportation plan. Moreover, planner from one factory has recommended that sometimes using outsourced vehicle is cheaper than using in house vehicle, because using in house vehicle has several costs apart from depreciation, and fuel cost. It is maintance cost, and driver salary. Thus, it should have process in order to trade off between using in house and outsourced vehicle.

- Input information

Input information of decision making process is adequate and appropriate, especially the data of transportation time between any two points of each vehicle. It will genetate delivery plan more accurately.

Nowadays, there is no record of input information, but the planner can give the information by using his/her experice. However, it is the estimation number. In addition, there is no transportation demand which has the due date specified in range of days. All demand s has specified in the exactly date.

- Output of decision making process

Planner of the garment factory told that the output of decision making process is enough and appropriate for transporting goods. There are many details in transportation plans which are very goods such as the arriving time, the leaving time, weight left, and volume left. Furthermore, transportation plan arranged by ID of company is very good idea, because every company related to this plan will know the details aheaf, then the resource inclucing loding and unloading staff will be prepared.

- Constraint of decision making process

According to the interview of transportation planners, every transportation planner said that the constraint in the system design is adequate and very practical such as separating transportation demant. The example of the real situation is that finish goods transported to port has to be separated, and mixed with other brands or transportation demand.

- Number of options

According to the interview of transportation planners, every transportation planner said that there are many options in the system and very flexible such as choosing the transportion plan needed, and transportion demand which must be operated within today.

- Possibility in implementing the decision making process to the real situation

  The decision making process designed is high possibility in impleting to the real situation; however, there are several uncertainty in garment industry. For example, the supplier has told the date of sending raw material, then the supplier cannot produce or find raw material on time on the specified date. Another example is that the factory has rented the 6 wheel truck and it is already confirmed that it is availble, but there is no 6 wheel truck on the specified date.

### 6.1.2 Evaluation of the correctness and completeness of changing the delivery plan process

- The capability of solving the current problem.

  According to the interview of transportation planners, mostly planner said that changing the delivery plan process designed can solve the problem at the present by reducing number of vehicle used, and transportation cost. The main reson that can solve the problem is that the system uses several methods apart from releasing new vehicle such as the method of adding transportation demand after the previous transportation plan, and replacing transportation demand cancelled. All of these methods cause decreasing of the number of vehicle and cost of transportation.

- Concept and principle for finding the solution

According to the interview of transportation planners, they said that the concept is correct, and appropriate such as changing transportation plan by considering the consition of the previous transportation plan.

Moreover, the planners have supported the method of replacing transportation demand cancelled, but they saild that the information of the system has to be vey accurately such as loading time, and transportation time between any two points. Then, this method will be a practical solution.

- Input information

Input information of changing the delivery plan process is adequate and appropriate. Nowadays, there is no record of input information, but the planner can give the information by using his/her experice. However, it is the estimation number. In addition, there is no transportation demand which has the due date specified in range of days. All demand s has specified in the exactly date.

- Output of changing the delivery plan process

Planner of the garment factory told that the output of changing the delivery plan process is enough and appropriate for transporting goods.

- Constraint of changing the delivery plan process

According to the interview of transportation planners, every transportation planner said that the constraint in the system design is adequate and very practical.

- Number of options

According to the interview of transportation planners, every transportation planner said that there are many options in the system and very flexible such as selecting either system or user in order to change transportation plan.

- Possibility in impleting the changing the delivery plan process to the real situation

  Possibility in impleting the changing the delivery plan process to the real situation is medium because of high uncertainty in garment industry and changing transportation demand after vehicle releasing. The system designed cannot change transportation plan after releasing the vehicle.

### 6.1.3 Decision support system evaluation

- Linkage and coherence of user interface

  According to the interview, the user who relates to user interface such as transportation planner, and mainternance officer said that the linkage and coherence of user interface is good. Moreover, they have suggested that the manual of using the programme will help the user understand programme more quickly.

- User friendly

  According to the interview, the user who relates to user interface said that this user interface is easy for use, because there is a message in every user interface. For example, the user has to fill in the constraint of each transportation demand in*criteria. Hence, it can be called user frienfly.

- Reduce the complexity of planning the transportation plan

  According to the interview, the user related to user interface said that this user interface can reduce the complexity of planning transportation time, and uses less than user to generate the plan .In addition, it supports the user to know which transportation demand is important.

## 6.2 Evaluation results of the efficiency of information system

To evaluation the efficiency of information system result, the real case will be used. Then, the answer from the proposed method of the system which uses heuristics and the current method which plans by the experienced transportation planner will be compared. The system testing consists of the evaluatation of routing and choosing the type of vehicle operated. In addition, the process of selecting transportation demand in order to operate in each day cannot be evaluated, since there is no input which is transportation demand specified in the range of transportation date in the real suitataion at the present; in other words, transportation demand input, nowadays, is specified the exactly transportation date.

Evaluation of the efficiency of information system result is divided into 2 following parts:

– Evaluation of the efficiency of decision making process result
– Evaluation of the efficiency of changing the delivery plan process result

### 6.2.1 Evaluation result of the efficiency of decision making process

The details of input for decision making process which comes from the real case are as follows: Table 31 shows transportation demand (1/8/2011) of a garment factory located in Bangkok, Thailand, Table 32 displays the information of in hosue vehicle on 1/8/2011, Table 33 displays the information of outsorce vehicle on 1/8/2011, Table 34 presents the routing data, Table 35 displays transportation time between any two points of vehicle's type ID 001, and Table 36 presents transportation time between any two points of vehicle's type ID 002. Furthermore, operating time per day is 24 hours or 1440 minutes.

The characteristic of generating transportation plan at the the present is as follows:

In hosue vehicle type ID 002 which has only 1 unit always operate transportation demand between the main plant and other plant. The other demands will be operated by outsourced vehicle starting from the pick up point, and going to the delivery point, and then back to the pick up point; in order words, direct shipping is applied. Moreover, each department or each node has operated its own demands, so there is some overlapped route. In addition, there is no home base in the real practice. The details of transportation plan generated bythe experienced planner are shown in Table 37 and Table 38.

The processes of proposed model are displayed in Figure 16, and Figure 17 by giving F0001 to be home base.

The details of transportation plan generated bythe proposed model are shown in Table 39 and Table 40. Table 39 is the transportation plan of transportation demand in the system, and Table 40 is the transportation plan of transportation demand exceeding the opertation time.

Table 31 Transportation demand (1/8/2011) of a garment factory located in Bangkok, Thailand

| Demand_ID | Pick up point_ID | Delivery point_ID | Seperated transportation demand | Group for transporting | Goods_type | Loading time (min) | Volume ($m^3$) | Weight (kg) |
|---|---|---|---|---|---|---|---|---|
| SMR0001 | S0001 | F0001 | N | N | RM | 70 | 7 | 2,000 |
| SFR0002 | S0002 | F0001 | N | N | RM | 40 | 4 | 1,000 |
| SFR0003 | S0003 | F0001 | N | N | RM | 40 | 4 | 1,000 |
| SFR0004 | S0004 | F0002 | N | N | RM | 100 | 11 | 3,000 |
| SFR0005 | S0005 | F0002 | N | N | RM | 40 | 4 | 1,000 |
| SFR0006 | S0006 | F0003 | N | N | RM | 40 | 4 | 1,000 |
| FFW0007 | F0001 | F0002 | N | N | WIP | 80 | 20 | 2,560 |
| FOW0008 | F0001 | O0001 | N | N | WIP | 10 | 1 | 100 |
| FOW0009 | F0001 | O0002 | N | N | WIP | 15 | 1 | 120 |
| OFW0010 | O0002 | F0001 | N | N | WIP | 15 | 1 | 150 |
| FCF0011 | F0001 | C0001 | N | N | FG | 30 | 3 | 385 |
| FCF0012 | F0001 | C0002 | N | N | FG | 15 | 2 | 200 |
| FCF0013 | F0001 | C0003 | N | N | FG | 15 | 2 | 180 |
| FCF0014 | F0001 | C0005 | N | N | FG | 15 | 1 | 120 |
| FFF0015 | F0002 | F0001 | N | N | FG | 30 | 3 | 300 |
| FFF0016 | F0003 | F0001 | N | N | FG | 35 | 3 | 400 |
| FCF0017 | F0001 | C0006 | Y | N | FG | 35 | 4 | 520 |
| FCF0018 | F0001 | C0007 | Y | N | FG | 35 | 3 | 380 |
| FCF0019 | F0001 | C0008 | N | N | FG | 15 | 2 | 190 |
| FCF0020 | F0001 | C0009 | Y | N | FG | 20 | 2 | 220 |

Table 32 In house vehicle information

| Date (D/M/Y) | Vehicle's type_ID | Weight (kg.) | Volume ($m^3$) | Fixed cost (Baht/day) | Variable cost (Baht/km.) | Number of vehicle (unit) |
|---|---|---|---|---|---|---|
| 1/8/2011 | 002 | 5,000 | 30 | 500 | 8 | 1 |

Table 33 Outsourced vehicle information

| Date(D/M/Y) | Vehicle's type_ID | Weight (kg.) | Volume ($m^3$) | Fixed cost (Baht/day) | Variable cost (Baht/km.) | Number of vehicle(unit) |
|---|---|---|---|---|---|---|
| 1/8/2011 | 001 | 1,000 | 4 | 1,000 | 3 | Unlimited |
| | 002 | 5,000 | 30 | 4,500 | 8 | Unlimited |

Table 34 Routing information

| From/ To | F0001 | F0002 | F0003 | C0001 | C0002 | C0003 | C0004 | C0005 | S0001 | S0002 | S0003 | S0004 | S0005 | S0006 | O0001 | O0002 | C0006 | C0007 | C0008 | C0009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F0001 | 0 | 175 | 682 | 6 | 10 | 190 | 706 | 271 | 15 | 20 | 25 | 22 | 9 | 30 | 10 | 27 | 16 | 140 | 38 | 160 |
| F0002 | 175 | 0 | 755 | 180 | 185 | 120 | 830 | 198 | 200 | 210 | 215 | 222 | 207 | 240 | 230 | 240 | 230 | 130 | 150 | 140 |
| F0003 | 682 | 755 | 0 | 670 | 665 | 780 | 180 | 920 | 670 | 675 | 677 | 680 | 660 | 670 | 650 | 661 | 630 | 780 | 620 | 770 |
| C0001 | 6 | 180 | 670 | 0 | 3 | 183 | 699 | 264 | 8 | 13 | 18 | 15 | 2 | 23 | 3 | 20 | 9 | 133 | 31 | 153 |
| C0002 | 10 | 185 | 665 | 3 | 0 | 180 | 696 | 261 | 5 | 10 | 15 | 12 | 3 | 20 | 5 | 17 | 6 | 130 | 28 | 150 |
| C0003 | 190 | 120 | 780 | 183 | 180 | 0 | 850 | 130 | 117 | 123 | 129 | 125 | 115 | 140 | 117 | 130 | 120 | 15 | 130 | 10 |
| C0004 | 706 | 830 | 180 | 699 | 696 | 850 | 0 | 980 | 740 | 742 | 744 | 749 | 730 | 750 | 740 | 750 | 740 | 830 | 720 | 820 |
| C0005 | 271 | 198 | 920 | 264 | 261 | 130 | 980 | 0 | 250 | 254 | 257 | 259 | 262 | 262 | 261 | 253 | 250 | 140 | 220 | 148 |
| S0001 | 15 | 200 | 670 | 8 | 5 | 117 | 740 | 250 | 0 | 10 | 18 | 15 | 20 | 25 | 14 | 17 | 20 | 112 | 20 | 120 |
| S0002 | 20 | 210 | 675 | 13 | 10 | 123 | 742 | 254 | 10 | 0 | 16 | 13 | 18 | 23 | 12 | 15 | 18 | 110 | 18 | 118 |
| S0003 | 25 | 215 | 677 | 18 | 15 | 129 | 744 | 257 | 18 | 16 | 0 | 18 | 23 | 28 | 17 | 20 | 23 | 115 | 23 | 123 |
| S0004 | 22 | 222 | 680 | 15 | 12 | 125 | 749 | 259 | 15 | 13 | 18 | 0 | 22 | 27 | 16 | 19 | 22 | 114 | 22 | 122 |
| S0005 | 9 | 207 | 660 | 2 | 3 | 115 | 730 | 262 | 20 | 18 | 23 | 22 | 0 | 37 | 26 | 29 | 32 | 124 | 32 | 132 |
| S0006 | 30 | 240 | 670 | 23 | 20 | 140 | 750 | 262 | 25 | 23 | 28 | 27 | 37 | 0 | 19 | 22 | 25 | 117 | 25 | 125 |
| O0001 | 10 | 230 | 650 | 3 | 5 | 117 | 740 | 261 | 14 | 12 | 17 | 16 | 26 | 19 | 0 | 27 | 30 | 122 | 30 | 130 |
| O0002 | 27 | 240 | 661 | 20 | 17 | 130 | 750 | 253 | 17 | 15 | 20 | 19 | 29 | 22 | 27 | 0 | 33 | 125 | 33 | 133 |
| C0006 | 16 | 230 | 630 | 9 | 6 | 120 | 740 | 250 | 20 | 18 | 23 | 22 | 32 | 25 | 30 | 33 | 0 | 180 | 30 | 185 |
| C0007 | 140 | 130 | 780 | 133 | 130 | 15 | 830 | 140 | 112 | 110 | 115 | 114 | 124 | 117 | 122 | 125 | 180 | 0 | 39 | 140 |
| C0008 | 38 | 150 | 620 | 31 | 28 | 130 | 720 | 220 | 20 | 18 | 23 | 22 | 32 | 25 | 30 | 33 | 30 | 39 | 0 | 170 |
| C0009 | 160 | 140 | 770 | 153 | 150 | 10 | 820 | 148 | 120 | 118 | 123 | 122 | 132 | 125 | 130 | 133 | 185 | 140 | 170 | 0 |

Table 35 Transportation time between any two points of vehicle's type ID 001

| From/To | F0001 | F0002 | F0003 | C0001 | C0002 | C0003 | C0004 | C0005 | S0001 | S0002 | S0003 | S0004 | S0005 | S0006 | O0001 | O0002 | C0006 | C0007 | C0008 | C0009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F0001 | 0 | 159 | 620 | 5 | 9 | 173 | 642 | 246 | 14 | 18 | 23 | 20 | 8 | 27 | 9 | 25 | 15 | 127 | 35 | 145 |
| F0002 | 159 | 0 | 686 | 164 | 168 | 109 | 755 | 180 | 182 | 191 | 195 | 202 | 188 | 218 | 209 | 218 | 209 | 118 | 136 | 127 |
| F0003 | 620 | 686 | 0 | 609 | 605 | 709 | 164 | 836 | 609 | 614 | 615 | 618 | 600 | 609 | 591 | 601 | 573 | 709 | 564 | 700 |
| C0001 | 5 | 164 | 609 | 0 | 3 | 166 | 635 | 240 | 18 | 23 | 18 | 23 | 9 | 21 | 14 | 18 | 27 | 121 | 28 | 139 |
| C0002 | 9 | 168 | 605 | 3 | 0 | 164 | 633 | 237 | 14 | 18 | 27 | 23 | 9 | 23 | 14 | 27 | 23 | 118 | 25 | 136 |
| C0003 | 173 | 109 | 709 | 166 | 164 | 0 | 773 | 118 | 106 | 112 | 117 | 114 | 105 | 127 | 106 | 118 | 109 | 14 | 118 | 27 |
| C0004 | 642 | 755 | 164 | 635 | 633 | 773 | 0 | 891 | 673 | 675 | 676 | 681 | 664 | 682 | 673 | 682 | 673 | 755 | 655 | 745 |
| C0005 | 246 | 180 | 836 | 240 | 237 | 118 | 891 | 0 | 227 | 231 | 234 | 235 | 238 | 238 | 237 | 230 | 227 | 127 | 200 | 135 |
| S0001 | 14 | 182 | 609 | 18 | 14 | 106 | 673 | 227 | 0 | 27 | 36 | 18 | 18 | 23 | 45 | 36 | 18 | 102 | 18 | 109 |
| S0002 | 18 | 191 | 614 | 23 | 18 | 112 | 675 | 231 | 27 | 0 | 27 | 27 | 27 | 36 | 18 | 27 | 36 | 100 | 18 | 107 |
| S0003 | 23 | 195 | 615 | 18 | 27 | 117 | 676 | 234 | 36 | 27 | 0 | 18 | 45 | 45 | 18 | 18 | 21 | 105 | 45 | 112 |
| S0004 | 20 | 202 | 618 | 23 | 23 | 114 | 681 | 235 | 18 | 27 | 18 | 0 | 23 | 27 | 27 | 36 | 32 | 104 | 27 | 111 |
| S0005 | 8 | 188 | 600 | 9 | 9 | 105 | 664 | 238 | 18 | 27 | 45 | 23 | 0 | 18 | 27 | 36 | 45 | 113 | 29 | 120 |
| S0006 | 27 | 218 | 609 | 21 | 23 | 127 | 682 | 238 | 23 | 36 | 45 | 27 | 18 | 0 | 32 | 27 | 23 | 106 | 23 | 114 |
| O0001 | 9 | 209 | 591 | 14 | 14 | 106 | 673 | 237 | 45 | 18 | 18 | 27 | 27 | 32 | 0 | 25 | 27 | 111 | 27 | 118 |
| O0002 | 25 | 218 | 601 | 18 | 27 | 118 | 682 | 230 | 36 | 27 | 18 | 36 | 36 | 27 | 25 | 0 | 30 | 114 | 30 | 121 |
| C0006 | 15 | 209 | 573 | 27 | 23 | 109 | 673 | 227 | 18 | 36 | 21 | 32 | 45 | 23 | 27 | 30 | 0 | 164 | 27 | 168 |
| C0007 | 127 | 118 | 709 | 121 | 118 | 14 | 755 | 127 | 102 | 100 | 105 | 104 | 113 | 106 | 111 | 114 | 164 | 0 | 35 | 127 |
| C0008 | 35 | 136 | 564 | 28 | 25 | 118 | 655 | 200 | 18 | 18 | 45 | 27 | 29 | 23 | 27 | 30 | 27 | 35 | 0 | 155 |
| C0009 | 145 | 127 | 700 | 139 | 136 | 27 | 745 | 135 | 109 | 107 | 112 | 111 | 120 | 114 | 118 | 121 | 168 | 127 | 155 | 0 |

Table 36 Transportation time between any two points of vehicle's type ID 002

| From/To | F0001 | F0002 | F0003 | C0001 | C0002 | C0003 | C0004 | C0005 | S0001 | S0002 | S0003 | S0004 | S0005 | S0006 | O0001 | O0002 | C0006 | C0007 | C0008 | C0009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F0001 | 0 | 175 | 682 | 6 | 10 | 190 | 706 | 271 | 15 | 20 | 25 | 22 | 9 | 30 | 10 | 27 | 16 | 140 | 38 | 160 |
| F0002 | 175 | 0 | 755 | 180 | 185 | 120 | 830 | 198 | 200 | 210 | 215 | 222 | 207 | 240 | 230 | 240 | 230 | 130 | 150 | 140 |
| F0003 | 682 | 755 | 0 | 670 | 665 | 780 | 180 | 920 | 670 | 675 | 677 | 680 | 660 | 670 | 650 | 661 | 630 | 780 | 620 | 770 |
| C0001 | 6 | 180 | 670 | 0 | 3 | 183 | 699 | 264 | 20 | 25 | 20 | 25 | 10 | 23 | 15 | 20 | 30 | 133 | 31 | 153 |
| C0002 | 10 | 185 | 665 | 3 | 0 | 180 | 696 | 261 | 15 | 20 | 30 | 25 | 10 | 25 | 15 | 30 | 25 | 130 | 28 | 150 |
| C0003 | 190 | 120 | 780 | 183 | 180 | 0 | 850 | 130 | 117 | 123 | 129 | 125 | 115 | 140 | 117 | 130 | 120 | 15 | 130 | 30 |
| C0004 | 706 | 830 | 180 | 699 | 696 | 850 | 0 | 980 | 740 | 742 | 744 | 749 | 730 | 750 | 740 | 750 | 740 | 830 | 720 | 820 |
| C0005 | 271 | 198 | 920 | 264 | 261 | 130 | 980 | 0 | 250 | 254 | 257 | 259 | 262 | 262 | 261 | 253 | 250 | 140 | 220 | 148 |
| S0001 | 15 | 200 | 670 | 20 | 15 | 117 | 740 | 250 | 0 | 30 | 40 | 20 | 20 | 25 | 50 | 40 | 20 | 112 | 20 | 120 |
| S0002 | 20 | 210 | 675 | 25 | 20 | 123 | 742 | 254 | 30 | 0 | 30 | 30 | 30 | 40 | 20 | 30 | 40 | 110 | 20 | 118 |
| S0003 | 25 | 215 | 677 | 20 | 30 | 129 | 744 | 257 | 40 | 30 | 0 | 20 | 50 | 50 | 20 | 20 | 23 | 115 | 50 | 123 |
| S0004 | 22 | 222 | 680 | 25 | 25 | 125 | 749 | 259 | 20 | 30 | 20 | 0 | 25 | 30 | 30 | 40 | 35 | 114 | 30 | 122 |
| S0005 | 9 | 207 | 660 | 10 | 10 | 115 | 730 | 262 | 20 | 30 | 50 | 25 | 0 | 20 | 30 | 40 | 50 | 124 | 32 | 132 |
| S0006 | 30 | 240 | 670 | 23 | 25 | 140 | 750 | 262 | 25 | 40 | 50 | 30 | 20 | 0 | 35 | 30 | 25 | 117 | 25 | 125 |
| O0001 | 10 | 230 | 650 | 15 | 15 | 117 | 740 | 261 | 50 | 20 | 20 | 30 | 30 | 35 | 0 | 27 | 30 | 122 | 30 | 130 |
| O0002 | 27 | 240 | 661 | 20 | 30 | 130 | 750 | 253 | 40 | 30 | 20 | 40 | 40 | 30 | 27 | 0 | 33 | 125 | 33 | 133 |
| C0006 | 16 | 230 | 630 | 30 | 25 | 120 | 740 | 250 | 20 | 40 | 23 | 35 | 50 | 25 | 30 | 33 | 0 | 180 | 30 | 185 |
| C0007 | 140 | 130 | 780 | 133 | 130 | 15 | 830 | 140 | 112 | 110 | 115 | 114 | 124 | 117 | 122 | 125 | 180 | 0 | 39 | 140 |
| C0008 | 38 | 150 | 620 | 31 | 28 | 130 | 720 | 220 | 20 | 20 | 50 | 30 | 32 | 25 | 30 | 33 | 30 | 39 | 0 | 170 |
| C0009 | 160 | 140 | 770 | 153 | 150 | 30 | 820 | 148 | 120 | 118 | 123 | 122 | 132 | 125 | 130 | 133 | 185 | 140 | 170 | 0 |

Table 37 The details of transportation plan by the experienced planner

| Transportation demand_ID | Vehicle_type | Fixed cost (Baht/day) | Variable cost (Baht/km) | Total Fixed Cost(Baht) | Total Variable Cost (Baht) | Number of vehicle(Unit) | Total distance (km) | Total time (min) |
|---|---|---|---|---|---|---|---|---|
| SMR0001 | OS001 | 1,000 | 3 | 2,000 | 180 | 2 | 60 | 168 |
| SFR0002 | OS001 | 1,000 | 3 | 1,000 | 120 | 1 | 40 | 116 |
| SFR0003 | OS001 | 1,000 | 3 | 1,000 | 150 | 1 | 50 | 126 |
| SFR0004 | OS002 | 4,500 | 8 | 4,500 | 3,552 | 1 | 444 | 644 |
| SFR0005 | OS002 | 4,500 | 8 | 4,500 | 3,312 | 1 | 414 | 494 |
| SFR0006 | OS002 | 4,500 | 8 | 4,500 | 10,720 | 1 | 1,340 | 1,420 |
| FFW0007 | IH002 | 500 | 8 | 500 | 1,400 | 1 | 175 | 335 |
| FOW0008 | OS001 | 1,000 | 3 | 1,000 | 60 | 1 | 20 | 38 |
| FOW0009 | OS001 | 1,000 | 3 | 1,000 | 81 | 1 | 27 | 55 |
| OFW0010 | OS001 | | 3 | 0 | 81 | | 27 | 55 |
| FCF0011 | OS001 | 1,000 | 3 | 1,000 | 36 | 1 | 12 | 73 |
| FCF0012 | OS001 | 1,000 | 3 | 1,000 | 60 | 1 | 20 | 48 |
| FCF0013 | OS001 | 1,000 | 3 | 1,000 | 1,140 | 1 | 380 | 376 |
| FCF0014 | OS001 | 1,000 | 3 | 1,000 | 1,626 | 1 | 542 | 522 |
| FFF0015 | IH002 | | 8 | 0 | 1,400 | | 175 | 235 |
| FFF0016 | OS002 | 4,500 | 8 | 4,500 | 10,912 | 1 | 1,364 | 1,434 |
| FCF0017 | OS001 | 1,000 | 3 | 1,000 | 96 | 1 | 32 | 100 |
| FCF0018 | OS002 | 4,500 | 8 | 4,500 | 2,240 | 1 | 280 | 350 |
| FCF0019 | OS001 | 1,000 | 3 | 1,000 | 228 | 1 | 76 | 100 |
| FCF0020 | OS002 | 4,500 | 8 | 4,500 | 2,560 | 1 | 320 | 360 |

Table 38 The transportation cost of model generated by the experienced planner

| Transportation demand_ID | Fixed cost (Baht/day) | Number of operating day (day) | Variable cost (Baht/km) | Total fixed cost (Baht) | Total variable cost(Baht) |
|---|---|---|---|---|---|
| SMR0001 | 1,000 | 1 | 3 | 2,000 | 180 |
| SFR0002 | 1,000 | 1 | 3 | 1,000 | 120 |
| SFR0003 | 1,000 | 1 | 3 | 1,000 | 150 |
| SFR0004 | 4,500 | 1 | 8 | 4,500 | 3,552 |
| SFR0005 | 4,500 | 1 | 8 | 4,500 | 3,312 |
| SFR0006 | 4,500 | 1 | 8 | 4,500 | 10,720 |
| FFW0007 | 500 | 1 | 8 | 500 | 1,400 |
| FOW0008 | 1,000 | 1 | 3 | 1,000 | 60 |
| FOW0009 | 1,000 | 1 | 3 | 1,000 | 81 |
| OFW0010 | | 1 | 3 | 0 | 81 |
| FCF0011 | 1,000 | 1 | 3 | 1,000 | 36 |
| FCF0012 | 1,000 | 1 | 3 | 1,000 | 60 |
| FCF0013 | 1,000 | 1 | 3 | 1,000 | 1,140 |
| FCF0014 | 1,000 | 1 | 3 | 1,000 | 1,626 |
| FFF0015 | | 1 | 8 | 0 | 1,400 |
| FFF0016 | 4,500 | 1 | 8 | 4,500 | 10,912 |
| FCF0017 | 1,000 | 1 | 3 | 1,000 | 96 |
| FCF0018 | 4,500 | 1 | 8 | 4,500 | 2,240 |
| FCF0019 | 1,000 | 1 | 3 | 1,000 | 228 |
| FCF0020 | 4,500 | 1 | 8 | 4,500 | 2,560 |

Table 39 The details of transportation plan in the system by proposed model

| Round | Vehicle_type | Fixed cost (Baht) | Variable cost (Baht/km) | Total distance (km) | Total weight operated(kg) | Total volume operated($m^3$) | Total transportation cost per weight (Baht/kg) | Total transportation cost per volume (Baht/$m^3$) | Demand operated |
|---|---|---|---|---|---|---|---|---|---|
| 1 | IH002 | 500 | 8 | 52 | 620 | 5 | 1.47 | 183.20 | FOW0008/FCF0017 |
| 2 | OS001 | 1,000 | 3 | 162 | 895 | 8 | 1.66 | 185.75 | FCF0011/FCF0012/ FOW0009/FCF0019 |
| 3 | OS001 | 1,000 | 3 | 280 | 380 | 3 | 4.84 | 613.33 | FCF0018 |
| 4 | OS001 | 1,000 | 3 | 320 | 220 | 2 | 8.91 | 980 | FCF0020 |
| 5 | OS001 | 1,000 | 3 | 380 | 180 | 2 | 11.89 | 1070 | FCF0013 |
| 6 | OS001 | 1,000 | 3 | 391 | 1,000 | 4 | 2.17 | 543.28 | SFR0005 |
| 7 | OS001 | 1,000 | 3 | 94 | 1,150 | 5 | 1.15 | 256.40 | SFR0002/OFW0010 |
| 8 | OS001 | 1,000 | 3 | 50 | 1,000 | 4 | 1.15 | 287.50 | SFR0003 |
| 9 | OS002 | 4,500 | 8 | 922 | 4,980 | 31 | 2.39 | 383.10 | SMR0001/FFW0007/ FFF0015/FCF0014 |
| 10 | OS002 | 4,500 | 8 | 419 | 3,000 | 10 | 2.17 | 785.20 | SFR0004 |

Table 40 The details of transportation plan exceeding operation time by proposed model

| Transportation demand_ID | Vehicle's type_ID | Fixed cost (baht) | Variable cost (baht/km) | Total distance (km) | Total time (min) | Total transportation cost (baht) |
|---|---|---|---|---|---|---|
| SFR0006 | OS001 | 1,000 | 3 | 1,387 | 1,336 | 5,161 |
| FFF0016 | OS001 | 1,000 | 3 | 1,364 | 1,310 | 5,092 |

After generating transportation from 2 methods, the result is summarized according to Table 41. In addition, the researcher has calaulated percenr of improving the answer from Equation 73.

$$\text{\% of improving the answer} = \frac{\mathrm{AM}-\mathrm{AP}}{AP}\, x\ 100$$

Equation 73

When;

AM denotes the answer from the proposed method.

AP denotes the answer from the experienced planner.

Table 41 The efficiency of decision making process result

| Issues | Answer from the proposed method | Answer from the experienced planner | % of improving the answer |
|---|---|---|---|
| Total transportation cost (Baht) | 42,928 | 79,454 | -45.97 |
| Fixed cost (Baht) | 18,500 | 39,500 | -53.16 |
| Total number of vehicle used (Unit) | 12 | 19 | -36.84 |
| Number of vehicle type 001 (Unit) | 9 | 12 | -25.00 |
| Number of vehicle type 002 (Unit) | 3 | 7 | -57.14 |
| Variable cost (Baht) | 24,428 | 39,954 | -38.86 |
| Total distance (km) | 5,821 | 5,798 | 0.40 |

From Table 41, it is shown that the proposed method of decision making process in delivery planning can reduce the transportation cost consisting of fixed and variable cost by 45.971% comparing to the current method with the same case of a garment factory in Bangkok. The main reduction comes from fixed cost which depends on the number of vehicle used, and variable cost coming from distance and type of vehicle used, so it can achieve the objective of the research and also increase the competitive advantage to the garment factory. Moreover, it can decrease the complexity of transportation planning by using calculation time about 1 second to 3 minutes depending on the size of problem, while the efficiency of the transportation is better. At the present, generating transportation plan takes about 20 to 45 minutes

From testing, it is shown that total distance of proposed model ismore than total distance of current method. The reason is that there are some nodes located very far from home, but there is transportation demand which has little quantity and is not related with the home point. Moreover, every vehicle has to be back to home base every time, so it causes more distance than the current method which is no home base and operates by direct shipping model. Therefore, it can be concluded that transportation demand which is very far from home and not related to home suits with no home base system.

Furhermore, Equation 34 which is used in order to check which transportation is in the system may not work in some case, some demand, especially demand which has the pick up or delivery point far from home takes time nearly operation time per day and can make Equation 34 come true such as SFR0006 and FFF0016. Both these 2 demands have effect on calculating maxmum time process, thus the demand left cannot be operate. Therefore, the researcher has recommended that Equation 34 should have allowance time in order to be able find every transportation plan.

### 6.2.2 Evaluation result of the efficiency of changing the delivery plan process

The details of input for changing the delivery plan process which comes from the real case are as follows: Table 42 shows transportation demand changed (1/8/2011) of a garment factory located in Bangkok, Thailand, Table 43 displays the information of in hosue vehicle on 1/8/2011 including the number of vehicle left, Table 33 displays the information of outsorce vehicle on 1/8/2011, Table 33 displays the information of outsorce vehicle on 1/8/2011, Table 34 presents the routing data, Table 35 displays transportation time between any two points of vehicle's type ID 001, Table 36 presents transportation time between any two points of vehicle's type ID 002, and the previous transportation plan. Furthermore, operating time per day is 24 hours or 1440 minutes.

The previous transportation plan is given to operate only 2 transportation demands which are FOW0008 and FCF0017. The detail of the previous transportation plan generated by the experienced planner is shown in Table 44, and the details of the previous transportation plan generated by proposed model is shown in Table 45. This plan comes from decision making process.

At the the present, there is no changing delivery plan processs. When transportation demand is cancelld, the planner will ignore it. On the other hand, when transportation demand is added, the planner will always assign new vehicle to operate demand added. From the test case, there is transportation demand; that is, transportation demand ID FOW0008 is cancelled, and transportation demand ID SFR0021 is added. The planner will solve this problem by ignoring transportation demand cancelled and assigning new vehicle type 002 in order to operate transportation demand ID SFR0021. The detail of transportation plan changed by experienced planner is shown in Table 46.

The processes of proposed model are displayed in Figure 18.

The condition 2 of changing transportation plan, changing transportation plan cannot effect on both time and vehicle used, is selected. Moreover, the system will make all decision. The details of transportation plan changed by the proposed model are shown in Table 47.

Table 42 Transportation demand changed

| Transportation demand_ID | Pick up point_name | Delivery point_name | Seperated demand | Group for transporting | Goods_type | Loading tme (min) | Volume ($m^3$) | Weight (kg) | Status |
|---|---|---|---|---|---|---|---|---|---|
| FOW0008 | F0001 | O0001 | N | N | RM | 10 | 0.78 | 100 | Cancel |
| SFR0021 | F0001 | F0002 | N | N | WIP | 80 | 20 | 2,500 | Add |

Table 43 In house vehicle

| Date (D/M/Y) | Vehicle's type_ID | Capacity (kg.) | Capacity ($m^3$) | Fixed cost (Baht/day) | Variable cost (Baht /km.) | Number of vehicle (unit) |
|---|---|---|---|---|---|---|
| 1/8/2011 | 002 | 5,000 | 30 | 500 | 8 | 0 |

Table 44 The previous transportation plan generated by transportation planner

| Transportation plan_ID | Transportation demand_ID | Vehicle's type_ID | Total fixed cost (Baht) | Total variable cost (Baht) | Number of vehicle (unit) | Total distance (km.) | Total time (min) | Routing |
|---|---|---|---|---|---|---|---|---|
| 00001 | FOW0008 | OS001 | 1,000 | 60 | 1 | 20 | 38 | F0001 > O0001 > F0001 |
| 00002 | FCF0017 | OS001 | 1,000 | 96 | 1 | 32 | 100 | F0001 > C0006 > F0001 |

Table 45 The previous transportation plan generated by proposed model

| Transportation plan_ID 00001 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Vehicle's type_ID | Time | Details | Place | Demand_ID | Weight (kg) | Volume ($m^3$) | Weight left (kg) | Volume left($m^3$) |
| IH002 | 8.00-8.10 | Loading | F0001 | FOW0008 | 100 | 0.78 | 4,900 | 29.22 |
| | 8.10 | Leave | F0001 | | | | 4,900 | 29.22 |
| | 8.10-8.20 | OTW | | | | | 4,900 | 29.22 |
| | 8.20 | Arrive | O0001 | | | | 4,900 | 29.22 |
| | 8.20-8.30 | Unloading | O0001 | FOW0008 | 100 | 0.78 | 4,900 | 29.22 |
| | 8.30 | Leave | O0001 | | | | 5,000 | 30 |
| | 8.30-8.40 | OTW | | | | | 5,000 | 30 |
| | 8.40 | Arrive | F0001 | | | | 5,000 | 30 |
| | 8.40-9.15 | Loading | F0001 | FCF0017 | 520 | 4 | 4,680 | 26 |
| | 9.15 | Leave | F0001 | | | | 4,680 | 26 |
| | 9.15-9.31 | OTW | | | | | 4,680 | 26 |
| | 9.31 | Arrive | | | | | 4,680 | 26 |
| | 9.31-10.06 | Unloading | C0006 | FCF0017 | 520 | 4 | 5,000 | 30 |
| | 10.06 | Leave | | | | | 5,000 | 30 |
| | 10.06-10.22 | OTW | | | | | 5,000 | 30 |
| | 10.22 | Arrive | F0001 | | | | 5,000 | 30 |

Table 46 The transportation plan changed by transportation planner

| Plan_ID | Demand_ID | Vehicle 's type_ID | Fixed cost (baht/day) | Varibel cost (baht/km) | Total fixed cost(baht) | Total variable cost(baht) | Number of vehicle(unit) | Total distance (km) | Total time (min) | Routing |
|---|---|---|---|---|---|---|---|---|---|---|
| 00003 | SFR0021 | OS002 | 4,500 | 8 | 4,500 | 2,800 | 1 | 350 | 510 | F0001 > F002 > F0001 |
| 00002 | FCF0017 | OS001 | 1,000 | 3 | 1,000 | 96 | 1 | 32 | 100 | F0001 > C0006 > F0001 |

Table 47 The transportation plan changed by proposed model

| Transportation plan_ID 00001 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Vehicle's type_ID | Time | Details | Place | Demand_ID | Weight (kg) | Volume ($m^3$) | Weight left (kg) | Volume left($m^3$) |
| IH002 | 8.00-8.40 | FOW0008 is canclled | | | | | 5,000 | 30 |
| | 8.40 | Arrive | F0001 | | | | 5,000 | 30 |
| | 8.40-9.15 | Loading | F0001 | FCF0017 | 520 | 4 | 4,680 | 26 |
| | 9.15 | Leave | F0001 | | | | 4,680 | 26 |
| | 9.15-9.31 | OTW | | | | | 4,680 | 26 |
| | 9.31 | Arrive | | | | | 4,680 | 26 |
| | 9.31-10.06 | Unloading | C0006 | FCF0017 | 520 | 4 | 5,000 | 30 |
| | 10.06 | Leave | | | | | 5,000 | 30 |
| | 10.06-10.22 | OTW | | | | | 5,000 | 30 |

| Transportation plan_ID 00001 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Vehicle's type_ID | Time | Details | Place | Demand_ID | Weight (kg) | Volume ($m^3$) | Weight left (kg) | Volume left($m^3$) |
| | 10.22 | Arrive | F0001 | | | | 5,000 | 30 |
| | 10.22-11.42 | Loading | F0001 | SFR0021 | 2500 | 20 | 2,500 | 20 |
| | 11.42 | Leave | F0001 | | | | 2,500 | 20 |
| | 11.42-14.37 | OTW | | | | | 2,500 | 20 |
| | 14.37 | Arrive | F0002 | | | | 2,500 | 20 |
| | 14.37-15.57 | Unloading | F0002 | SFR0021 | 2500 | 20 | 5,000 | 30 |
| | 15.57 | Leave | F0002 | | | | 5,000 | 30 |
| | 15.57-18.52 | OTW | | | | | 5,000 | 30 |
| | 18.52 | Arrive | F0001 | | | | 5,000 | 30 |

Table 48 The efficiency of changing the delivery plan process

| Issues | Answer from the proposed method | | | Answer from the experienced planner | | |
|---|---|---|---|---|---|---|
| | Previous transportation plan | Transportation plan changed | Diff. | Previous transportation plan | Transportation plan changed | Diff. |
| Total transportation cost (Baht) | 916 | 3,556 | 2,640 | 2,156 | 8,396 | 6,240 |
| Fixed cost (Baht) | 500 | 500 | 0 | 2,000 | 5,500 | 3,500 |
| Total number of vehicle used (Unit) | 1 | 1 | 0 | 2 | 2 | 0 |
| Number of vehicle type 001 (Unit) | 0 | 0 | 0 | 2 | 1 | 1 |
| Number of vehicle type 002 (Unit) | 1 | 1 | 0 | 0 | 1 | 1 |
| Varaible cost (Baht) | 416 | 3,056 | 2,640 | 156 | 2,896 | 2,740 |
| Total distance (km) | 52 | 382 | 330 | 52 | 382 | 330 |

From Table 48, it is shown that the proposed method of the delivery plan changing process can decrease the transportation cost consisting of fixed and variable cost by 57.69% or 3,600 baht comparing to the current method with the same case of a garment factory in Bangkok. The main reduction cost comes from fixed cost by decreasing the number of vehicle operated, so it can be achieved according to the objective of the research which is to design an information system for generating delivery plans for a garment factory in order to meet all demands in time with low cost of transportation.

# CHAPTER 7

# CONCLUSION

This chapter shows the conclusion of the research which can be divided into 4 following topics:

- Conclusion of the research
- Limitation of the system
- Problem and obstacle during the research time
- Suggestion for further studies

## 7.1 Conclusion of the research

This thesis reports the details of an information system design for transportation planning of a garment factory. The objective of this research is to design an information system for generating delivery plans for a garment factory in order to meet all demands in time with low cost of transportation. The researcher has applied nearest neighbor which is a technique of heuristics in order to generate and change the transportation plan which is a suitable answer. The answer from this model uses the transportation cost as the main criteria. In addition, the business flow chart, data flow diagram, and Microsoft access are used in order to explain and show the idea of decision support system consisting of database, user interface, and business process.

The steps of doing research starts from studying garment industry, the transportation problem, the literature review related the vehicle routing problem method in order to apply to thesis. After that, the researcher has design making process for delivery planning, the delivery plan changing process, and decision support system, respectively. After designing process, the information system designed is tested. The testing process can be divided into 2 parts. The fist tesing is an evaluation of the correctness and completeness of information system by interviewing the staff related to the system. According to the interviewing, the user of this information system are satisfied with the concept and principle of the system, because it can solve vehicle routing problem which happens at the present, reduce the complexity of making a decision, and apply the concept and implement to the real practice. The second testing is an evaluation of the efficiency of information system result. The system testing shows that the proposed method of decision making process in delivery planning can reduce the transportation cost consisting of fixed and variable cost by 45.97% comparing to the current method. Another system testing, the delivery plan changing process, displays that the transportation cost is decreased by 57.69% comparing to the method generated by the experienced transportation planner. After that, the research has analysed and concluded the results of this research.

The outputs of information system are the decision making process in delivery planning, the delivery plan changing process, user interface, database, and the business process.

## 7.2 Limitations of the system

- Information system is desgined for normal situation which excludes the emergency situation such as accident, and breaking down of the vehicles.
- The transportation plan cannot change while the vehicle is executed.
- The solution of this system is not guaranteed optimal.

- Transportation resources in this system are vehicles only, others such as the drivers, and the crew are not considered.
- There is single depot which is plant.
- The period of maintenance plan is specified in day.
- Outsorce vehicle has one renting type which is one day contract.
- Transportation demand can be splitted if it is over capacity of the largest vehicle in the system.
- The operating time of every node is the same.
- There is no transshipment in the system designed

## 7.3 Problems and obstacles in conducting research

- In the evaluation of the efficiency of information system result, the reseacher can evaluate only some processes which are routing and choosing the type of vehicle operated, but the researcher cannot evaluate the process of selecting transportation demand in order to operate in each day. The reason is that input of transportation demand, at the present, is specified the exactly transportation date and does not specified in the range of transportation date as an input of this research.
- Observation of real practice and collecting data takes lots of time than the schedule, because some companies are not able to give the information on the date specified in the schedule.
- Some companies cannot give the internal information that is necessary for doing research, because it is a secret of company.

## 7.4 Suggestions for further studies

- Comparison and trading off between buy in house vehicle and renting outsourced vehicle
- Study the method of loading goods by considering the sequence of routing and utilizing the space
- Study vehicle routing problem by adding the fuel station, for example, the vehicle should add fuel before operating or add the fuel while operating.
- Study the density of vehicle in each routing in different time in order to generate transportation more accurately. For instance, the density of routing which comes from A to B is very low on 9.00-15.00.

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# APPENDICES

# APPENDIX A

| | |
|---|---|
| Record of interview | Company A |
| Date of interview | 4 April 2011 |

1. General Information

Company A has produced many popular international sport brands, and worked as a sub-contractor, and then exported the product to other countries. There are 3 plants of company A in Thailand: two plants are located in Bangkok, and one plant is located in Ubonratchatani. The company, at the present, has already expanded the production to China. Moreove, company A has a plan to expand its production line to Vietnam.

Yearly aggregate plan is dealed between the contractor and the plant in order that the plant will evaluate the production capacity needed for each year and plan for support that demand. When the real demand is known in each month, the company has to produce according to the required number. In case of the production capacity cannot meet the customer requirement; the company will consider outsourcing for the exceeding demand.

2. Transportation Information

There are transportation resources as follows:

| | |
|---|---|
| 6 wheeled truck | 2 units |
| Pick-up truck | 6 units |
| KIA truck | 1 unit |

The transportation planning will be generated every day. It is divided into two rounds; morning and afternoon round. The vehicles are shared among divisions in the company in order to utilize the resources. However, transportation division has the first priority for using vehicle. In the maintenance aspect, the company has a credit with many garages for maintainanace the vehicle. The process of choosing the garage is based on quotation. Moreover, the company will assign specific driver to each vehicle, and provide budget for general maintenance and wash his/her own vehicle.

3. Characteristics of transporting goods

Transportation of company A is divided into following categories;

Tranportation of raw material: For transporting raw material, supplier will manage every thing in orde to send the material to the plant. Thus, the company will not consider of transporting raw material.

Transportation of raw material between Bangkok and Ubonratchatani plant: Two 6 wheeled trucks will be used in order to transporte raw material within these plants. There are two rounds per week and each round takes time about 3 days. the vehicle will leave from Bangkok plant at 7 pm on first day and go to Ubonratchatani. Then, the vehicle will arrive at Ubonratchatani plant in the morning on second day, and the whole day is used for loading and unloading the goods. After loading and unloading, the vehicle will leave from Ubonratchatani plant at the evening on second day and arrive at Bangkok plant in the morning on third day.

Transportation of raw material between the two Bangkok plants: Pick-up truck will be used for transporting raw material within these two Bangkok plants. Warehouse at the main plant is major warehouse. When sub plant needs any raw material, it will be transported from this warehose to sub plant.

Transportation of finished goods to port: There are two main ports for transporting finished goods: Ladkrabang and Bangprakong port. Transporting finished goods to port needs high level of control. The reason is that if finished good is losted, the company has to pay for the penalty cost which is very high due to the regulation of intellectual property. Moreover, transporting good to the port has to reserve space and specific time. Normally, the company will hire a sub-contract transportation company in order to pick-up finished goods from plant and delivery to ports. These sub-contractors will be evaluated and must be met the requirements, and then the contract will be signed for transportation with a fixed rate of transportation cost per trip. On the other hand, the two 6 wheeled trucks may be used for transportation of finished good when they're availble.

Record of interview Company B

Date of interview 11 April 2011

1. General Information

Company B has provided production for popular international sport brands and worked as a sub-contractor and exported the product to other countries. There are 2 plants of company B: one is located in Bangkok, and the other one is located in Mahasarakham.

The core business of company B is the production for foreign customer by using Bangkok plant as a main plant and Mahasarakham plant as a sub plant. Bangkok plant has a respondsibility for managing every thing, while Mahasarakham plant has a respondsibility for only producing goods. In other words, Bangkok plant will produce the more complex products than Mahasarakham plant due to the high performance of labor.

2. Transportation Information

There are transportation resources as follows:

| | |
|---|---|
| 6 wheeled truck | 2 units |
| Pick-up truck | unknown |

Network LAN will be used for showing the available time of each vehicle and booking vehicle. Person who would like to use vehicle can book via this system. Moreover, maintenance plan will be managed by the transportation division, and each vehicle has it own driver.

3. Characteristics of transporting goods

Transportation of company B is divided into following categories;

Raw material: Due to the high level of safety sepcified by foreign customers, raw material and supplier will be chosen by the customer. Thus, the suppliers will be deliver raw material to the company. Therefore, the company has no responsibility for this transportation.

Transportation of raw material between Bangkok and Mahasarakham plant: 6 wheeled truck will be operated for transportating within these 2 plants. There are 2 rounds per week which leaves from Bangkok plant on every Tuesday and Friday. In addition, the backhaul from Mahasarakham plant to Bangkok will transport the finished goods as well.

Transportation of finished good to port: There are two major ports: Ladkrabang and Klongtoey port. Transporting finished goods to port needs high level of control. The reason is that if finished good is losted, the company has to pay for the penalty cost which is very high due to the regulation of intellectual property. Moreover, transporting good to the port has to reserve space and specific time. Normally, the company will hire a sub-contract transportation company in order to pick-up finished goods from plant and delivery to ports. All products have to be finished by Wednesday in order to deliver finished goods in time on every Thursday.

Record of interview Company C

Date of interview 29 April 2011

1. General Information

Company C has produced the goods for both domestic and international customer. The company has 5 own plants located in Bangkok, Lampoon, Kabinburi, Maesod and Sriracha. Each plant has its different skill.

2. Transportation Information

There are transportation resources as follows:

| | |
|---|---|
| 6 wheeled truck | 1 unit |

Only one vehicle in this plant is used for transporting raw material from Bangkok to Kabinburi. The vehicle will leave from Bangkok plant once a week. Because of having a few in house vehicle, the company has not focused on transportation plan.

3. Characteristics of transporting goods

Transportation of company C is divided into following category;

Raw material: The responsibility for transporting raw material from supplier to the main plant in Bangkok is a supplier. Raw material will be transported before production plan about one week, because the company has policy that any material cannot stock in the warehouse more than 15 days. Thus, supplier has to stock the material and deliver it when company C needs

Transportation of raw material between Bangkok and Kabinburi plant: This route will be opreated by 6 wheeled truck once per week. Kabinburi plant will order any material needed for production from main plant, then main plant has to pick-up all the material in the warehouse, load into the truck, and delivery it to Kabinburi plant. On backhauling, finished good will be sent back to main plant for inspecting and selling.

Transportation of finished goods: Because the domestic customer is the department store, there is high level of variety of products. Thus, Bankok plant has to pack finished good into a box containing each order for each department store. Then, there will be vehicle to pick up all finished goods in order to send to the customers every morning.

| | |
|---|---|
| Record of interview | Company D |
| Date of interview | 22 April 2011 |

1. General Information

Company D has provided a transportation service including renting vehicle. The service of this company is very vary such as renting vehicle service, renting vehicle with driver, hiring vehicle for one trip of transportation. Moreover, the company has a truck installing HIAB crane which is suitable for delivery heavy goods or needs to move by the crane.

2. Transportation Information

There are transportation resources as follows:

| | |
|---|---|
| 6 wheeled and 10 wheeled truck | unknow |
| Container truck | ≈ 28 units |
| Pick-up truck | ≈ 6 units |

Due to the company business, the management will be varied to each type of service. However, the company has its own garage for maintenance the vehicle which causes lower maintenance cost comparing to the competitors.

3. Characteristics of transporting goods

Transportation of company D is divided into following category;

Short period rental (less than one year): Vehicle will be send to customer site under the control contract. There are several optional prices for customers such as including driver service, and including the fuel cost. All of this causes the differentiation of rental cost.

Long period rental (more than one year): Vehicle will be sent to customer site under the control contract and has the same characteristics as short period rental. Moreover, there is 15% discount for this type of renting.

Trip base hiring: Vehicle will be at transportation base and waiting for transportation requirement from customer. When the requirement comes, the truck will pick up goods at the pick up point and and delivery it at destination point. If the distance is short or both two destinations are located in around Bangkok area, one truck can operate about 2 trips per day. On the other hand, if the distance is far, one truck can operate about 1 trip per day.

Whole day renting: Vehicle will be rent for each day. The customer may consider that there are many transportation requirements for one day and renting the vehicle for whole day will be cheaper than trip base hiring.

Record of interview Company E

Date of interview 27 April 2011

1. General Information

Company E has provided full logistics service. The company will responsible for whole transportation activity which help the customers reduce their transportation task. The company is experted in the logistics field which can make lower transportation cost than other company, because of economy of scale and many distribute channels.

2. Transportation Information

There are transportation resources as follows:

| | |
|---|---|
| Transportation vehicle | $\approx$ 400 units |

The transportation policy of this company is very interesting. All the vehicles of the company are owned by driver and the company supports financial problem. Since all drivers act as owner, they have to manage their own vehicles. The company will feed the transportation job for each driver that is fixed in each area. Moreover, each driver lives in the area that they work, so they are expert in the routing. The payment will be made on job base system which can stimulate the driver to be hard-working. On the other hand, maintenance will be made by each driver, so the transportation cost is low. For all above reasons, the company has no need to install any vehicle monitoring and tracking system.

3. Characteristics of transporting goods

Transportation of company E is divided into following categories;

Managing the tranportation for specific customer: The company will provide overall transportation service. The company will start working by evaluating the transportation cost. Then, the company will buy new vehicle in orde to operate only the customer's works. Sometimes, there is customer's logo on vehicle. When transportation demand is place, the company has to operate according the demand.

Delivery general goods: The characteristics is same as DHL; that is, when the demand is placed, the company will pick up and delivery goods according to the transportation demand.

# APPENDIX B

The details of transportation plan from the proposed model according to 6.1.2 (the evaluation of the answer from the proposed model which generates the transportation plan) are shown below:

## Round 1

Table 49 The deatils of transportation plan from the proposed model (round 1)

| ID of transportation plan 00001 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| IH002 | F0001 | Loading | FOW0008 |
| | F0001 | Leave | |
| | | OTW | |
| | O0001 | Arrive | |
| | O0001 | Unloading | FOW0008 |
| | O0001 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Loading | FCF0017 |
| | F0001 | Leave | |
| | | OTW | |
| | C0006 | Arrive | |
| | C0006 | Unloading | FCF0017 |
| | C0006 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

Round 2

Table 50 The deatils of transportation plan from the proposed model (round 2)

| ID of transportation plan 00002 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS001 | F0001 | Loading | FCF0011 |
| | F0001 | Leave | |
| | | OTW | |
| | C0001 | Arrive | |
| | C0001 | Unloading | FCF0011 |
| | C0001 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Loading | FCF0012 |
| | F0001 | Leave | |
| | | OTW | |
| | | Arrive | |
| | C0002 | Unloading | FCF0012 |
| | | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Loading | FOW0009 |
| | F0001 | Leave | |
| | | OTW | |
| | O0002 | Arrive | |
| | O0002 | Unloading | FOW0009 |
| | O0002 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Loading | FCF0019 |

| ID of transportation plan 00002 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| | F0001 | Leave | |
| | | OTW | |
| | C0008 | Arrive | |
| | C0008 | Unloading | FCF0019 |
| | C0008 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

Round 3

Table 51 The deatils of transportation plan from the proposed model (round 3)

| ID of transportation plan 00003 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS0001 | F0001 | Loading | FCF0018 |
| | F0001 | Leave | |
| | | OTW | |
| | C0007 | Arrive | |
| | C0007 | Unloading | FCF0018 |
| | C0007 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

Round 4

Table 52 The deatils of transportation plan from the proposed model (round 4)

| ID of transportation plan 00004 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS0001 | F0001 | Loading | FCF0020 |
| | F0001 | Leave | |
| | | OTW | |
| | C0009 | Arrive | |
| | C0009 | Unloading | FCF0020 |
| | C0009 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

Round 5

Table 53 The deatils of transportation plan from the proposed model (round 5)

| ID of transportation plan 00005 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS001 | F0001 | Loading | FCF0013 |
| | F0001 | Leave | |
| | | OTW | |
| | C0003 | Arrive | |
| | C0003 | Unloading | FCF0013 |
| | C0003 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

Round 6

Table 54 The deatils of transportation plan from the proposed model (round 6)

| ID of transportation plan 00001 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS001 | F0001 | Leave | |
| | | OTW | |
| | S0005 | Arrive | |
| | S0005 | Loading | SFR0005 |
| | S0005 | Leave | |
| | | OTW | |
| | F0002 | Arrive | |
| | F0002 | Unloading | SFR0005 |
| | F0002 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

Round 7

Table 55 The deatils of transportation plan from the proposed model (round 7)

| ID of transportation plan 00007 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS001 | F0001 | Leave | |
| | | OTW | |
| | S0002 | Arrive | |
| | S0002 | Loading | SFR0002 |
| | S0002 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Unloading | SFR0002 |
| | F0001 | Leave | |
| | | OTW | |
| | O0002 | Arrive | |
| | O0002 | Loading | OFW0010 |
| | O0002 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Unloading | OFW0010 |

Round 8

Table 56 The deatils of transportation plan from the proposed model (round 8)

| ID of transportation plan 00008 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS001 | F0001 | Leave | |
| | | OTW | |
| | S0003 | Arrive | |
| | S0003 | Loading | SFR0003 |
| | S0003 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Unloading | SFR0003 |

Round 9

Table 57 The deatils of transportation plan from the proposed model (round 9)

| ID of transportation plan 00009 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS002 | F0001 | Loading | FFW0007/ FCF0014 |
| | F0001 | Leave | |
| | | OTW | |
| | S0001 | Arrive | |
| | S0001 | Loading | SFR0001 |
| | S0001 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Unloading | SFR0001 |
| | F0001 | Leave | |
| | | OTW | |
| | F0002 | Arrive | |
| | F0002 | Unloading | FFW0007 |
| | F0002 | Loading | FFF0015 |
| | F0002 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |
| | F0001 | Unloading | FFF0015 |
| | F0001 | Leave | |
| | | OTW | |
| | C0005 | Arrive | |
| | C0005 | Unloading | FCF0014 |
| | C0005 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

Round 10

Table 58 The deatils of transportation plan from the proposed model (round 10)

| ID of transportation plan 00010 | | | |
|---|---|---|---|
| Vehicle's type_ID | Place | Details | Transportation demand_ID |
| OS002 | F0001 | Leave | |
| | | OTW | |
| | S0004 | Arrive | |
| | S0004 | Loading | SFR0004 |
| | S0004 | Leave | |
| | | OTW | |
| | F0002 | Arrive | |
| | F0002 | Unloading | SFR0004 |
| | F0002 | Leave | |
| | | OTW | |
| | F0001 | Arrive | |

# BIOGRAPHY

Leena Uabumrungjit was born on 21th January 1988, Bangkok, Thailand. She was graduted from Chulalongkorn University, faculty of Engineering, majoring in Industrial Engineering in 2010. She continued Master degree in Engineering Management at Regional Centre for Manufacturing System Engineering (RCMSE), a dual master's degree programme of Chulalongkorn University in Thailand which cooperates with University of Warwick in United Kingdom. While she was studying Master degree, she was a researcher at ROM unit (Intergration Development of Performance & Company for Resources and Operations System in Manufacturing & Service Organization).