ABSTRACT
A Milk Collection Center (MCC) is a facility for collecting raw milk supplied by a dairy farmer based on the demand of a milk manufacturer. Raw milk of each MCC is supplied from the dairy farm where is located within 20 kilometers length from the MCC. Raw milk collection is one of logistics activities. A reduction in the cost of collecting raw milk is one of the goals of effectively managing raw milk supply chain. Some farmers presently self-deliver raw milk to MCC. In this situation, therefore, the transportation cost is increased as supply chain management view point.
This research aims to reduce transportation cost of collecting raw milk paid by dairy farmer. Geographic Information System (GIS) is used to input, store, retrieve, manipulate, analyze and output geographically referenced data in order to support decision making. GIS database is constructed to store input data such as road network, road section’s lengths, farm locations, raw milk quantity of each farm and other relevant data. Then, GIS software is used to determine the routing networks of raw milk collection from dairy farms to MCC.
The results showed that the total distance of all routes in the network was reduced by 54.8 % and transportation cost was reduced by 37.9 %.

KEY WORDS
GIS, Network Analysis, Transportation Cost

1. Introduction
Dairy Farming Promotion Organization of Thailand (D.P.O.) was established by Thai government as a state enterprise since 1971. In response to the government’s policy, the D.P.O. buys raw milk from the farmers who are the D.P.O. members to promote the raising the number of dairy farmers and dairy cows. The D.P.O. (lower northern region) owns 1 raw-milk processing plant where are located in Sukhothai province and 5 Milk Collection Centers (MCC) where are located in Sukhothai and Pichit province. These MCCs are facilities for collecting and inspecting raw milk from the dairy farmers prior to supply to the D.P.O.’s milk processing plant where is converting raw milk into U.H.T. milk and pasteurized milk. Raw milk is usually perishable and can remain in inventory for a limited time. Some dairy farmers self-deliver raw milk to the MCC and other pay third-party hauler for delivering raw milk. Glenn et al. [1] presented that a delivery schedule of supplying raw milk to a fluid milk processing plant impacts on transfer costs which include transportation, storage, transaction, and management costs. Changing from a five day to seven day delivery schedule decreases the transfer costs. Butler et al. [2] presented that transportation costs are a major component of total cost in milk collection industry. In supply chain management view point, transportation cost of raw milk between a farmer and a MCC stages may be decreased by using the third-party hauler. Ioannou et al. [3] proposed Map-Route, a vehicle routing approach, coupled with GIS for solving intra-city product delivery routing problems. GIS based systems also were applied for hazardous material truck routing problems (Frank et al. [4]). Ioannou [5] presented the method to redesign the distribution network of sugar industry. MapInfo, GIS software, was used to estimate the actual distances among nodes as an input data for the transportation model. After performing an activity-based costing analysis, the author concluded that transportation cost is the largest cost contributor, accounting for 37% of the total distribution cost. In this research, raw-milk collecting routes from groups of dairy farms to MCC are studied by comparing the transportation costs between the dairy farmer self-delivering raw milk to a MCC and the third party hauler collecting raw milk from dairy farmer. Moreover, the appropriate route of milk collection for each truck without overlapping is determined. This will help the hauler’s decision making process which dairy farms are in the group for each route of a truck for collecting milk to reducing the transportation cost, and help the dairy farmers to decide either self-delivering or paying for third party hauler collecting raw milk.
2. Methodology

First, maps, digitized drawings (maps), and geographic data are collected from secondary sources, such as Department of Highways and Department of Public Works and Town & Country Planning. Geographic data consisting of the locations and road network of dairy farms and MCCs, and their corresponding attributes such as the raw-milk production capacity of each farm, raw-milk storage capacity of each MCC, directions, road types, and length are collected from dairy farmers and D.P.O.’s officers.

Not all locations of dairy farms, especially in the rural area are appeared on the maps. Therefore, to fulfill incomplete road network on maps, information technology tools such as internet and satellite geographic information are very useful in this phase. PointAsia.com application [6], which is an application of 3D digital map obtained from satellite imagery of IKONOS commercial earth observation satellite, is used to observe the road networks as shown in Fig. 1, and measure the distance of road in some areas that are not appeared on the incomplete maps. Therefore, the routes, location of dairy farms are filled on the digital maps completely with supporting of satellite images from PointAsia.com as shown in Fig. 2.

Then ArcView, GIS software, is used to integrate digital maps and relational databases for analyzing network problems. ArcView provides an extension tool (or add-on program) such as network analyst to determine the best route of collecting raw milk from each dairy farm group. Find best route is a specialized function of network analyst to solve this problem (ESRI [7]). In this research, assumptions consist of as follows: (1) a fleet of trucks are only one type of truck with the same capacity and conditions, (2) each truck is assigned to one route per cycle per shift, (3) milk collection for each truck is two times a day, and (4) the amount of raw milk supplied to MCC is deterministic.

3. Results and Discussion

In this paper, 54 dairy farmers who are the members of the D.P.O. (lower northern region) and supply raw milk to MCC located in Srinakorn city, Sukhothai province are selected to illustrate the result of study. 54 dairy farms marked on digital maps are grouped by concerning geographical location, road condition and, road network. Network analyst is used to analyze a milk collection network. The function named find best route is used to determine a route for each truck to collect raw milk. A constraint is the limited capacity of a truck. A maximum number of 50 liter-buckets loaded on the truck are assumed to be twelve. 54 dairy farms are divided to 7 groups for milk collecting network that satisfy the constraint and obtain the minimum distances for seven trucks (Table 1). As seen in Table 1, the distances of each group and all groups for raw milk self-delivery by using
motorcycle are longer than that for third party hauler. The transportation cost of group no.1, 3, and 4 of self-delivering raw milk is lower than that of third party hauler. However, the total transportation cost of all groups paying for third party hauler is lower than that of self-delivering. The results showed that the total distance of all routes in the network was reduced by 54.8% and transportation cost was reduced by 37.9% when third party haulers were selected for milk collection.

Table 1: The Results of Grouping Dairy Farmers Who Supply Raw Milk to Srinakorn MCC

<table>
<thead>
<tr>
<th>Group no.</th>
<th>Number</th>
<th>Distance for self-delivery (m.)</th>
<th>Distance for third-party hauler (m.)</th>
<th>Cost of self-delivery (฿)</th>
<th>Cost of third-party hauler(฿)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>66,854</td>
<td>65,899</td>
<td>83</td>
<td>84</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>104,292</td>
<td>46,091</td>
<td>129</td>
<td>84</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>60,874</td>
<td>27,011</td>
<td>75</td>
<td>84</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>35,178</td>
<td>19,302</td>
<td>42</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>140,323</td>
<td>39,578</td>
<td>174</td>
<td>77</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>150,927</td>
<td>56,264</td>
<td>187</td>
<td>56</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>124,666</td>
<td>54,707</td>
<td>155</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td>683,114</td>
<td>308,852</td>
<td>846</td>
<td>525</td>
</tr>
</tbody>
</table>

The best route for collecting raw milk of third party hauler for the first dairy farmer group (consisting of 9 farms) that is started from MCC, then, location no.1, 2,…, 9 respectively, and returned to the origin point, MCC, is shown in Fig. 3.

Figure 3: One-Route Milk Collection of A Truck From The 1st Farmer group at Srinakorn City, Sukhothai.

4. Conclusion

The appropriate route of milk collection for each truck without overlapping is determined and illustrated by the graphical presentation. This will help the hauler’s decision making process to select which dairy farms are in the group for each route of a truck for collecting milk to reducing the transportation cost. The dairy farmers may select to pay for third party hauler collecting raw milk instead of self-delivering due to the lower of transportation cost.

For further study, the assumption of limited capacity of a truck of third party hauler can be relaxed by including more types of vehicles. Moreover, because of the error of human-decision process of grouping dairy farms for each route of milk collecting may occur. Instead, operations research models can be developed and integrated with GIS to support human-decision process of milk collecting route network problems.

Acknowledgements

The author would like to thank Mr. Channarong srianuchat and Ms. Chanita Chanto for collecting data.

References