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# Transportation cost reduction for the native beef trade using the network analysis technique in Sisaket Province

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## Article Info

## Abstract

This study aims to propose a method of transportation cost reduction by using network analysis in a GIS platform with Sisaket, a province in the North-Eastern region of Thailand, as the study area. This study aims to achieve the following objectives: to study the transportation processes of farmers in delivering beef cattle to cattle markets, examine the cost and constraints transporters encountered in delivering beef cattle to the markets, generate the shortest routes with conditional factors for delivering beef cattle in sub-districts (Tambon) to the closest cattle market and to propose an optimum method of reducing the transportation costs for the farmers in the entire study area. Results found that the farmers (55%) mostly preferred selling beef cattle to the merchants at their farms, whereas some of them (45%) attempted delivering their beef cattle to the markets themselves. The transporters preferred delivering within 30–50 km through smooth road surfaces with available road shoulders. The areas within 30–50 km were delineated on the map showing all potentially accessible areas around the beef cattle markets. Then, the districts (e.g. Khukhan and Kanthararom districts) require consideration to establish temporary beef cattle markets and subsequently reduce beef transportation cost.

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## Introduction

The North-East of Thailand is the largest beef cattle feeding region (2.6 million) (Information Communication Technology [ICT], 2018). Approximately more than 300 thousand households are raising native beef cattle (ICT, 2018). More than 1.4-million native beef cattle have been raised in this region (ICT, 2018) because of low-cost feeding, high fertility, disease resistance, and high profit. Only two beef cattle markets are found in Sisaket Province (Som Poi and Kantharalak markets) (Sisaket Provincial Livestock Office, 2013). These beef cattle markets have served farmers from all over the province. Given that the remote districts are far from these markets, beef cattle delivery to these markets is excessively costly to the farmers. Thus, analysing cost and time consumption is an initial part in transportation cost reduction.

Geographic information system (GIS) and network analysis have been employed to evaluate spatial centralities and classify several phenomena regarding livestock in terms of monitoring (Altaweel, 2017), monitoring cattle behaviour and pasture use with GPS and GIS (Turner, 2019) with the pros and cons of the GIS applications and case studies in Italy (Enrico Sturaro, 2012). Mobility and accessibility are major determinants of lifestyle and prosperity affecting the region's growth or decline (Bell & Lida, 2014). Similar to a study by Fischer and Fröhlich (2006), they criticised that the knowledge spill overs have become a major focus of research on networks and clusters in recent years.

Therefore, the current study employed network analysis to define the areas around the beef cattle markets, with the information accessed conveniently by the transporters. The maximum distance used in this study originates from the interviews concerning the tolerance of the beef cattle with the least stress along with delivery processes. Several constraints from beef cattle transportation were considered regarding stress in the beef cattle, which include possible bleeding and undesirable meat quality as well as difficulties in transportation and management (Ruangchoengchum, 2016). Based on the information gathered from interviewees, the shortest routes can be concluded to be important in determining the transportation costs by considering reduced transportation costs and the stress to beef cattle during transportation.

The current study aims to study the farmers' typically used methods in delivering their cattle from their farms to beef markets, examine the cost and constraints the farmers and middlemen encountered in delivering beef cattle to beef markets, generate the possible accessible areas in sub-districts of the study area in response to the information taken from the farmers and the stakeholders and propose an optimum method to reduce the transportation costs for the farmers in Sisaket Province.

## Literature Review

### Network Analysis for Beef Cattle Studies and Beef Cattle Transportation

Network analysis was used to generate the movement of dairy cattle as a major risk factor for the spread of bovine tuberculosis (BTB) in emerging dairy belts of Ethiopia (Mekonnen et al., 2019). Similar to a study by Pozo et al. (2019), the network analysis was found very useful in generating the cattle movement and its association with the risk of BTB at the farm level in Castilla y Leon, Spain (Pozo et al., 2019). Furthermore, network analysis is a tool used to form the relationship between link flow and link cost. Several factors considered in cost function are travel time, distance, direct cost (fare, toll, fuel consumption, parking charge, etc.), reliability and comfort (Bell & Lida, 2014). Innovation facilitates the interim networks that are not only for the national and regional economic development scales but also the community and local economic scales (Fischer & Fröhlich, 2006). Cukrowski (2006) suggested that the application of network analysis directly provides other beneficial trades between producers and consumers.

In terms of transporting beef cattle from farms to cattle markets, the network analysis can generate the shortest routes regarding the constraints of travelling by showing the selected routes around the cattle markets. The shortest path analysis is based on a weighted graph of Dijkstra's algorithm (Dijkstra, 1959). The algorithm repeatedly finds a junction in the set of junctions with the minimum shortest-path estimation with travel cost or time. Based on the concept of the shortest path, the network analysis of GIS was developed (Environmental Systems Research Institute [ESRI], 2018). The shortest path algorithm has been developed to solve route problems. All encompassed routes are analysed and generated by the

service-area function in network analysis (ESRI, 2018). The service area is calculated from the connectivity of the road networks. Connectivity is not only a measure of relative isolation but also of centrality, where locations with high connectivity are centrally located (Bell & Lida, 2014). These networks are analysed physically with their determined impedance or constraint. The impedance measures the amount of resistance which may be measured by travel distance, time or speed (ESRI, 2018). The lowest impedance or the least cost path is preferred for an optimum path. Impedance must be determined from direct physical measurement as well as indirect measurements, such as people's experiences and satisfaction.

### Constraints in Beef Cattle Transportation

A long travelling time substantially increases the stress to the cattle and thus affects the cattle's health and meat quality (Chirase et al., 2004). Therefore, good animal welfare is required to maintain animal health during transport as stated by the World Organisation for Animal Health (Broom, 2005). Animal welfare concerns stress, injury, fatigue, mortality and morbidity that animals may experience during the transportation process as well as exposure to variable climatic conditions, noise, vibrations, toxins, poor handling and mixing with different animals (Schwartzkopf-Genswein et al., 2012). The standard of loading density is typically based on animal weight, which has slightly different applications per country (Whiting, 2000). Petherick and Phillips (2009) found that the space allowances affecting animal welfare during transportation are correlated well with the incapacity to accommodate standing animals as estimated from algometry. Furthermore, the transportation duration may be considered more than the transportation distance due to the accuracy of total time (Schwartzkopf-Genswein et al., 2012). Warren, Mandell, and Bateman (2010) confirmed that a study actually reported on the relationships between transportation distance and mortalities on arrival. Stress from transportation can affect cattle's body fluids and weight as well as cause energy depletion, ion depletion and protein catabolism (Schaefer, Dubeski, Aalhus, and Tong, 2001). Furthermore, the weather conditions require serious considerations as they affect cattle transportation. Undeniably, very warm weather and small trucks without systematic logistics can cause enormous problems, even if the cattle are to be delivered in a short time (Thomson, Loneragan, Henningson, Ensley, and Bawa, 2015; Warren, Mandell, & Bateman, 2010).

## Methodology

This study was conducted using a mixed research method between the Quantitative approach by using the questionnaire and Geographic Information System and Qualitative approach by using in-depth interviews. Information gathered from respondents was decoded and verified before placing it into the map. Consequently, those routes were traced to prove their validity and then digitised on the map in GIS. Eventually, network analysis was used to delineate the employed routes regarding constraint awareness. The preferable distances of

the beef cattle transportation were decoded, and the accessible ranges were displayed around the beef cattle markets in Sisaket Province.

*Study Site*

Sisaket Province is one of the top three provinces with a substantial number of farmers (38 thousand farmers) raising native beef cattle in the North-Eastern region of Thailand, after Surin (41 thousand farmers) and Ubolratchathani (44 thousand farmers) (ICT, 2019). The native beef cattle have been raised in many districts including Khukhan, Utumpornphisai, Meaung Sisaket, Wang hin, Prangkhu, Kantharalak, Rasi Salai and Kanthararom (Information and Communication Technology Center, 2016). Sisaket Province consists of 22 districts covering 8,840 km² and is connected to Cambodia in the south of the province (Figure 1).



**Figure 1** Sisaket districts and two beef cattle markets, namely, Som Poi and Kantharalak markets

*Data Collection*

Computers have been used to augment the human experience in the presence of ground truth in the 21st century. A set of applicable interview transcripts is examined in the network analysis (Pokorny et al., 2018). The data used in this study were collected from the interviews and observations conducted in the beef cattle market. A total of 397 farmers at the beef cattle markets were asked to complete the questionnaires. Moreover, 25 participants, who transported the beef cattle to the beef cattle markets in Sisaket Province, were rigorously interviewed regarding the constraints associated with transportation. These participants were selected systematically by considering the farm locations over the province without duplicating the farm locations. After obtaining the information from the interviews, the delineated routes on the map were validated to prove the physical conditions by interpreting the constraints gathered from the interviewees.
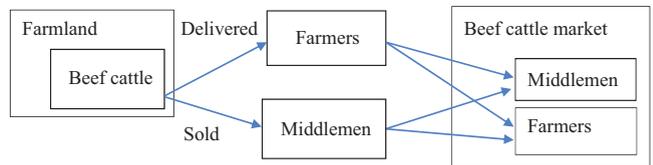
*Transportation Process and Means*

According to the literature and documentary review, a total of 46,451 beef cattle farmers were reported in Sisaket Province (Sisaket Provincial Livestock Office, 2017). Based on the results of 397 questionnaires received from farmers, 55 percent of the beef cattle were transported to the beef markets for trade by either farmers or middlemen (Ruangchoengchum, 2016). The rest of the beef cattle were sold at farmlands as shown in Figure 2.

*Transportation Costs*

From the semi-structured interviews and questionnaires carried out by Ruangchoengchum (2016), the farmers typically hired truck services from local people to deliver their beef to the cattle markets (Pakeechay, Wattanachant & Angkulasearanee, 2014). The transportation costs varied depending on the distance of transportation and the number of cattle. Normally, most vehicles can carry four to six cattle (Table 1).



**Figure 2** Transportation processes for delivering beef cattle to beef cattle markets

**Table 1** Transportation costs from a truck service to beef markets in Sisaket Province (for *the rental of a six-wheeler truck*)

| Distance | Cost (Baht: 1 beef cattle) | Cost (Baht: 5 beef cattle) |
| --- | --- | --- |
| 10–50 km | 100–200 baht | 500–1,000 baht |
| 50–90 km | 200–300 baht | 1,000–1,500 baht |
| More than 90 km | 300–400 baht | 1,500–2,000 baht |

*Data Analysis*

The study created a road network dataset and prepared a spatial database for network analysis, particularly the locations of beef markets as well as the locations of villages in the study site. This information was further analysed in the ArcGIS 10.2 (ESRI, 2018) with functions of network analysis to present the shortest routes from the sub-districts of farm locations to the closest beef markets in the province. In general, the network analysis follows six steps in the GIS platform as follows: 1) Configuring the Network Analyst environment, 2) Adding a network dataset to ArcMap, 3) Creating the network analysis layer, 4) Adding network analysis objects, 5) Setting network analysis layer properties and 6) Performing the analysis and displaying the results. Following the data from the questionnaires and semi-structured interviews, this information was transcribed corresponding to the spatial dimensions over the study area. Finally, the non-service areas located far away from the beef markets were identified for transportation cost reduction consideration.

**Results and Discussion**

*Transportation Methods of Beef Cattle Transportation*

The result shows that the farmers (55%) mostly preferred selling beef cattle to the merchants at their farms, whereas some of them (45%) attempted delivering their beef cattle to the markets themselves. The transportation cost was excessively high for the districts located far from the beef cattle markets in the province (as shown in Table 1). It can reduce the income of the farmers gained from selling the cattle at the cattle markets.

*Constraints of Beef Cattle Transportation*

According to the interviews, the transporters frequently stop along the roadside to give some water to the cattle due to the hot weather and load density in the truck. The rough roads cause added stress to the beef cattle. Therefore, the constraints in this study must concern some remarkable factors, such as the availability of road shoulders, load density, distance and road surfaces.

*Shortest Routes for Transportation from the Sub-Districts of the Farmlands to the Beef Cattle Markets*

Shortest routes showing the preferable ranges with constraints around the beef markets in Sisaket were identified using the network analysis in GIS platform (Figure 3). The travelling distance from 30 to 50 km was determined regarding the minimum and maximum travelling time to avoid fatigue and stress affecting the beef cattle. This received information is consistent with transportation stress as defined by Chirase et al. (2004), Warren, Mandell and Bateman (2010), Petherick and Phillips (2009), Schwartzkopf-Genswein et al. (2012), Thomson et al. (2015), Warren et al. (2010) and Whiting (2000) who stated that transportation stress affects cattle health and meat quality.

The districts with the largest number of farmers raising native beef include Khukhan, Uthumphon Phisai, Mueang Sisaket, Wang hin, Prang Ku, Kantharalak, Rasi Salai and Kanthararom (Table 2).

*Cost Reduction for Beef Cattle Transportation for Sisaket Province*

To determine distance, the transportation cost can be estimated by setting the considering factor corresponding to time travel data to finalise the transportation costs within 30 and 50 km (Table 3). Farmers may pay 93.75 baht for a distance of 30 km to the beef market. The farmers may pay a maximum of 156.25 baht for the maximum distance (50 km) to the beef market.

Considering the smooth road surface and the available road shoulders shown on the map in Figures 3 and 4, the farmers may consider using those routes for beef cattle transportation themselves. Regarding the results in Table 3, the maximum transportation cost of five beef cattle to the market was around 156.25 baht for a distance of 50 km, whilst the maximum cost of hiring a truck was 1,500 baht (Table 1). Thus, the transportation cost for five beef cattle using the network analysis can be concluded as cheaper than hiring a truck service at 1,343.75 baht. This result confirms the studies of Dijkstra (1959), Cukrowski (2006) and Bell and Lida (2014) that the application of network analysis can generate the shortest routes that consider safer travelling cost function.
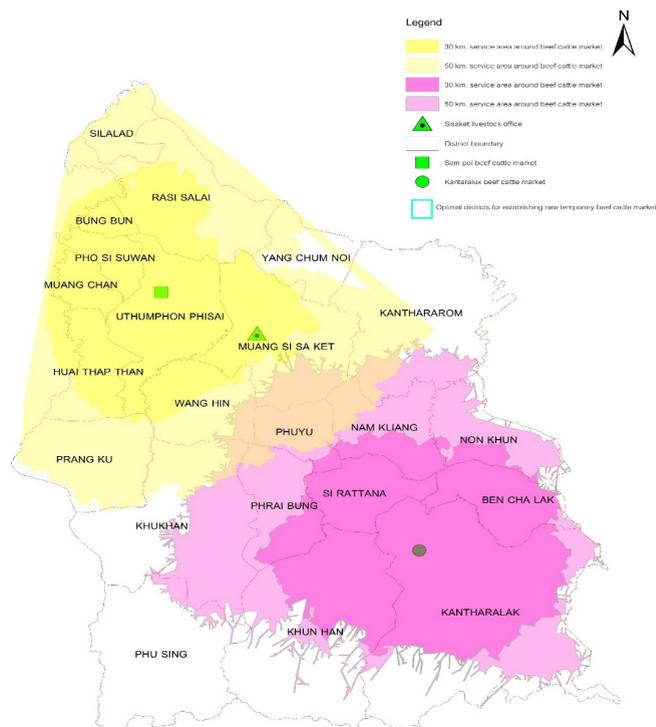


**Figure 3**   Shortest routes around the beef market, Kantharalak and Som Poi cattle markets within 30 and 50 km, respectively

**Table 2** List of districts in service and non-service areas around beef cattle markets in Sisaket Province

| Delivery distance | District names |
| --- | --- |
| Som Poi beef cattle market | |
| 30-km coverage | 1. Uthumpornphisai<br>2. Bungboon<br>3. King Amphoe Pho Srisuwan<br>4. Mueang Chan<br>5. Hauy Tubtan<br>6. Northern part of Wanghin<br>7. Western part of Mueang Sisaket<br>8. Southern part of Rasislide |
| 50-km coverage | 1. Central and southern of Wanghin<br>2. Prangkhu<br>3. Northern part of Khukan<br>4. Southern part of Mueang Sisaket<br>5. Western part of Kantararom<br>6. Eastern and southern part of Mueang Sisaket |
| Kantharalak beef cattle market | |
| 30-km coverage | 1. Srirattana<br>2. Benjalux<br>3. Kantharalak<br>4. Norther part of Khunharn<br>5. Eastern part of Phaibung<br>6. Southern part of Numkeang<br>7. Southern part of Nonkhoon<br>8. Southern part of Phayong |
| 50-km coverage | 1. South-eastern part of Kantharalak<br>2. Northern part of Nonkhoon<br>3. Northern part of Namkeang<br>4. Southern part of Kantararom<br>5. Western part of Phaibung<br>6. Eastern part of Khukan<br>7. North-western part of Khunharn |
| Integrated coverage of 50 km in between Som-poi and Kantharalak beef cattle markets | 1. Phayong<br>2. Southern part of Mueang Sisaket<br>3. Eastern part of Wanghin<br>4. Southern part of Kantararom<br>5. North-western part of Namkeang |
| Non-service coverage | 1. Phusing<br>2. Central and southern part of Khunharn<br>3. Southern part of Kantharalak<br>4. Western part of Khukan<br>5. Northern part of Kantararom<br>6. Yangchumnoi, except for the north-western part |

**Table 3** Transportation costs analysed via network analysis

| Distance (km) | Travel time (min) | Fuel consumption (L) | Transportation costs (THB per 5 beef cattle) |
| --- | --- | --- | --- |
| 30 | 20 | 3.75 | 93.75 |
| 50 | 40 | 6.25 | 156.25 |

*Note:* The average of diesel prices for Thailand was 25.00 Thai Baht as of 2018

## Conclusion and Recommendations

Regarding the analysis results on the reduction of transportation costs for beef cattle, six districts including Phu Sing, the central and southern parts of Khun Han, the southern part of Kantharalak, the western part of Khukhan, the northern part of Kanthararom, and Yang Chum Noi, except the north-western part, are excluded in the service areas for beef cattle markets. Moreover, the Kantharalak beef cattle market is slightly far away, whilst several more sub-districts are around Kantharalak beef cattle market than the ones around Som Poi beef cattle market in Uthumphon Phisai. Therefore, establishing some temporary beef cattle markets is possible, particularly in Khukhan and Kanthararom districts, which were recorded to have a large number of farmers feeding beef cattle (Figure 4).

As for the international trade of beef cattle to Cambodia, establishing a beef cattle market in Khukhan may offer several advantages to the farmers in terms of motivating the farmers to participate in international trading. Conversely, establishing a beef cattle market in Kanthararom may offer various benefits to farmers in terms of connecting the domestic trade between Sisaket and other proximate provinces. Moreover, Khukhan and Kanthararom districts comprise a large number of farmers who have traded beef cattle to the nearest neighbouring country. Considering the technique and procedures, it could reduce the cost of beef transportation over the studied site.
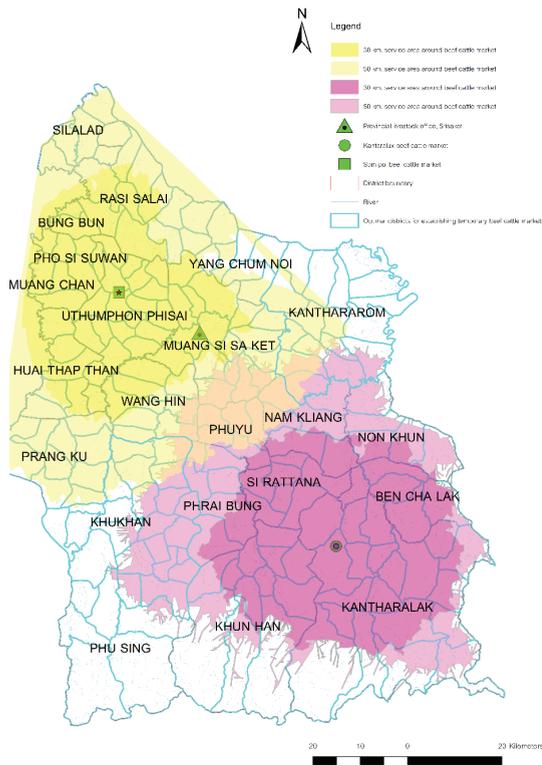
**Figure 4**    Proposed temporary beef cattle markets in Kanthararom and Khukhan

## Conflict of Interest

There is no conflict of interest.

## Acknowledgments

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