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Route and optimal location analysis of egg supplychain using geo-spatial technology

M. Krishnaveni, Sandeep Kumar Patakamuri and A. Rajeswari
Centre for Water Resources, Anna University, Chennai, India- 600 025
Email: mkveni@annauniv.edu, sandeep.patakamuri@gmail.com, raje_kesavan@yahoo.co.in

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Abstract: Supply chain of eggs is marred with inefficiencies starting from field level, till it reaches the customers. Present work concentrates on bringing down the cost of delivery of eggs from collection centres to the distribution centres by incorporating geospatial technologies in identifying optimal route rather than following vehicle driver's own discretion. Data pertaining to eggs handled per day, travel routes, travel time and fuel expenses etc., are collected by conducting on-field questionnaire survey. GPS survey was conducted to collect the spatial information of collection centres and distribution centres. The study results in identifying three optimal routes and also to identify four suitable sites for establishing new distribution centres. The optimal route identified in the study reduces the travelling distance by approximately 40km per day and thereby reducing fuel consumption.

Keywords: Location Based Services (LBS), Network analysis, Resource optimization, Routing, GIS

1. Introduction

Supply chain management is an integrated approach which synchronizes a series of processes involved in business management starting from raw material procurement to product delivery and customer feedback collection (Oliver and Webber, 1982; Hewitt, 1994; Brimer, 1995; Cooper, 1997; Pirim et al., 2014). In present world scenario, members of the supply chain compete as an integral part of supply chain links rather than as individual entities (Min and Zhou, 2002; Arshinder et al., 2011). Sustainability of any business depends on strategically well designed supply chain management by incorporating all the members of supply chain at different levels (Gardner and Cooper, 2003; Carter and Easton, 2011). Supply chain management has the potential to stimulate intra national and cross boundary marketing (Roekel et al., 2002).

Transportation and storage of goods are important components of supply chain management. Optimization of resources is possible by incorporating spatial information in resource management and planning (Koo et al., 1985; McKenzie et al., 1999; Wilson et al., 2004; Kumar and Agrawal, 2011).With the recent advancements in the field of Geographical Information Systems (GIS), it is possible to incorporate path constrains taking into consideration of the distances traversed by actual vehicle routes (Keenan, 2008).

Fresh eggs, irrespective of the farms where they are produced, would have almost same quality and taste. In a competitive market, profitability could be achieved by lowering the transportation costs, reducing breakages and timely transportation (Chakraborty, 2011). GIS has the ability to optimize the travel routes there by saving time and fuel resources. In agriculture sector, there are enormous challenges to incorporate spatial decision making in supply chain management (Opara, 2003; Ruteri and Xu, 2009; Gemesi, 2010). By suitable selection of spatial data along with some other ancillary data helps in identifying suitable locations for establishing new facilities (Melo et al., 2009; Zhang et al., 2011) or to find optimal routes for transportation of goods from one location to the other in a distribution network, till it reaches the end customer (Ljungberg and Gebresenbet, 2004; Sambrani and Subhas, 2009; Gebresenbet et al., 2011; Bosona and Gebresenbet, 2013).

Present study identified the reasons for inefficacy in the current practices and tried to bring down the cost incurred in delivery of eggs from collection centres to distribution centres and also to identify the suitable location for establishing new distribution centres. An estimated 25% of Green House Gas Emissions (GHGs) are attributed to transport sector. Out of this 75% of the emissions are resulting from road transport (Chapman, 2007; IPCC, 2007; Määttä-Juntunen et al., 2011).

2. Study area and data description

Out of more than three crore eggs produced in Tamilnadu state of India, Chennai alone consumes approximately 50 lakh eggs per day (Hindu, 2012). South Chennai region is considered in the present study to understand the existing supply chain practices and to identify optimal transport routes to enable high profitability with minimal damages. The interesting fact in the supply chain of eggs in the study area is the ubiquitous presence of eggs. But the complex network of supply chain behind this presence is often overlooked. The geographical extent to the south of Adyar river is considered as South Chennai. It consists of four zones namely Alandur, Adayar, Perungudi and Sholiganallur which comprises of 45 wards with an area of 143 square kilometres. All the distribution centres in the study area receive eggs from two collection centres, one in Triplicane and the other in Perungulathur. Collection centre in Perungulathur covers only three distribution centres and hence it is not considered in this analysis. Location map of the study area is shown in the Figure 1.

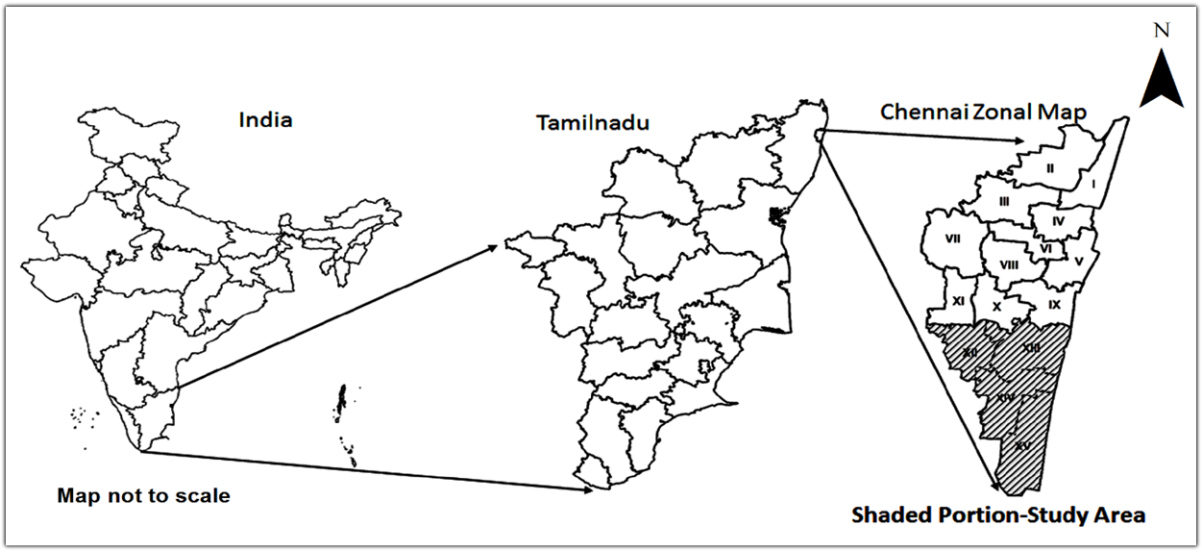

Figure 1: Location map of the study area

3. Materials and methods

Present study involves primary data collection from field visits using hand held GPS to obtain the spatial information of egg distribution centres. Data pertaining to current management practices like the volume of eggs handled per day, travel routes followed by the drivers, time of travel, fuel expenses etc., are collected by conducting user interviews. Secondary data on road network layer was obtained from Open Street Maps and refined as per the requirements of the study. Land use and ward maps were collected from various governmental sources. Incorporating these parameters assists in spatial decision making. Figure 2 shows the detailed flow chart of the methodology followed in the present research.

There are a large number of methods available in generating optimal routes. Network analysis has the ability to handle real world constraints in solving vehicle routing problems. The information collected from the drivers and the distribution centres indicated that the route followed by the drivers are clearly based on their own discretion which caused high fuel expenses (Goodchild, 2000; Bender et al., 2001; Martin et al., 2001; Papinski and Scott, 2011).

Road network layer is downloaded from open street maps data and clipped to the extent of South Chennai and used in network analysis. Road network data base is generated from ArcCatalog menu by modeling the turns, connectivity, elevation, cost metrics, network restriction and driving directions. Distribution centre layer is generated using the GPS points collected from field visit. South Chennai ward map is generated by digitizing Chennai wards map obtained from Corporation of Chennai. All the maps are generated at a uniform scale of 1:75,000 and added to ArcMap environment to proceed with route analysis.

Three optimal routes were requested to be generated from collection centre to the distribution centres as identified from the field interview conducted at collection centre. The Network Analyst window present in the Network Analyst toolbarenables input of network parameters like origin, destination, point barriers, line barriers and polygon barriers and the network restrictions like speed limits, one-way roads etc. The distance travelled, time consumed, serviceable area, closest facility, origin-destination cost matrices, Vehicle Routing Problems etc., were provided to the network analysis which were used in generating optimal path. The optimum routes are generated in a way to cover all the distribution centre while travelling lesser distances in a short span of time. This will ensure fuel savings and improved profitability.

In the second stage, suitable sites for establishing new distribution centres are identified by using the data on egg demand in an area and the handling capability of the existing distribution centres. GIS has the capability to identify the optimal site identification, making use of a well-defined criteria passed during spatial decision making (Ma et al., 2005; Kar and Hodgson, 2008; Irizarry et al., 2013; Hiremath et al., 2013).

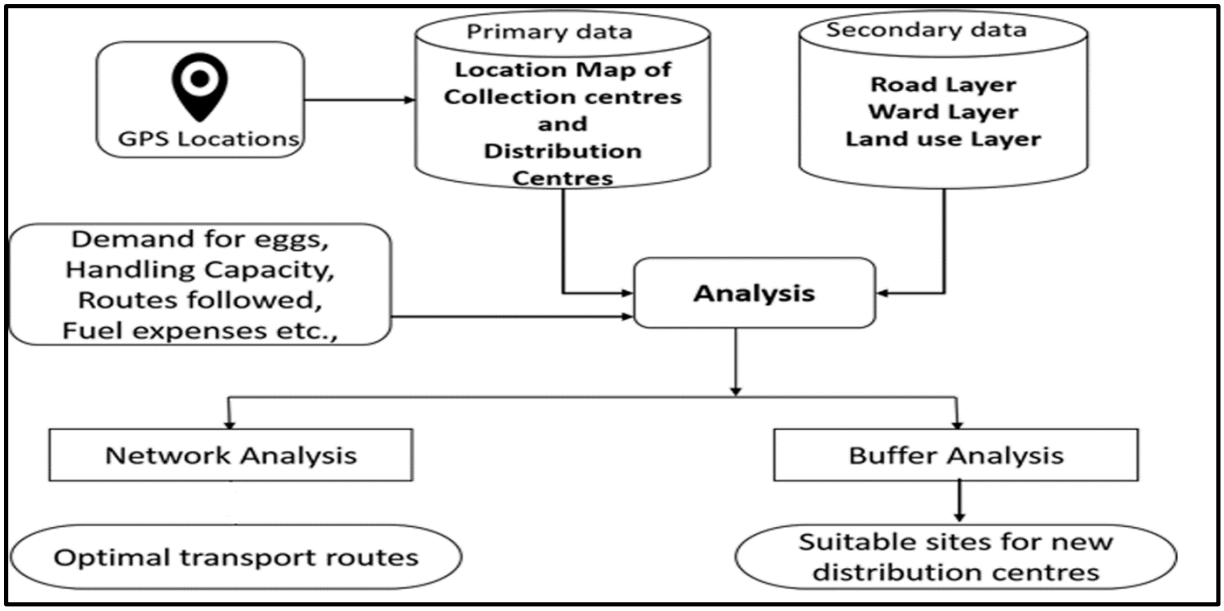

Figure 2: Methodology flow-chart for route and optimal location analysis of egg supply chain

4. Results and discussions

Route optimization for egg distribution aims at minimizing the cost of travel involved in transporting from one location to another either in terms of the number of trips required or total distance travelled or through a combination of these two factors. Identifying the existing path taken and the distance travelled by the drivers was a difficult task as thedrivers were allowed to take different routes at different times of the day. This made the comparison of the data a challenging task. Nevertheless, enormous efforts were taken to obtain the information from the drivers pertainingtotheroutestheyfollow and distance and time estimations were made.

All the spatial layers and relevant network constrain parameters required to run the network analysis were provided to the network analyst and three routes were generated that cover all the distribution centres at a reduced travel distance in a short time period. The paths optimized for transportation of eggs is depicted in Figure 3.

Without the optimal path selection, the drivers were estimated to be travelling approximately 150 km. This distance could be reduced to 110 km per day (about 27 %) by following optimal path. This leads to a phenomenal savings in terms of fuel expenses.

From the interviews with distributors, the operational convenience is found to be about 750 metres for any given distribution centre. Hence buffers zones are created around the distribution centre with a circular radius of 750metres as shown in Figure 4.

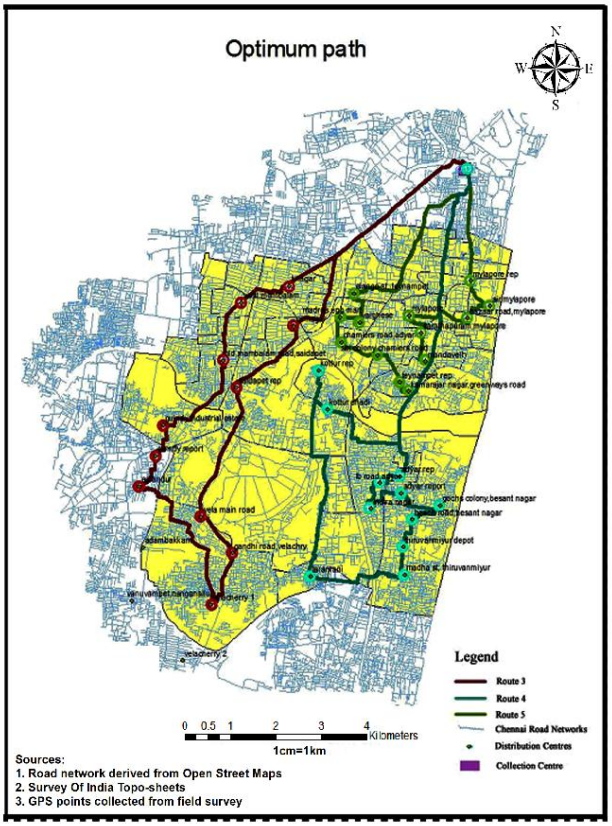

Figure 3: Map showing shortest path for transportation of eggs

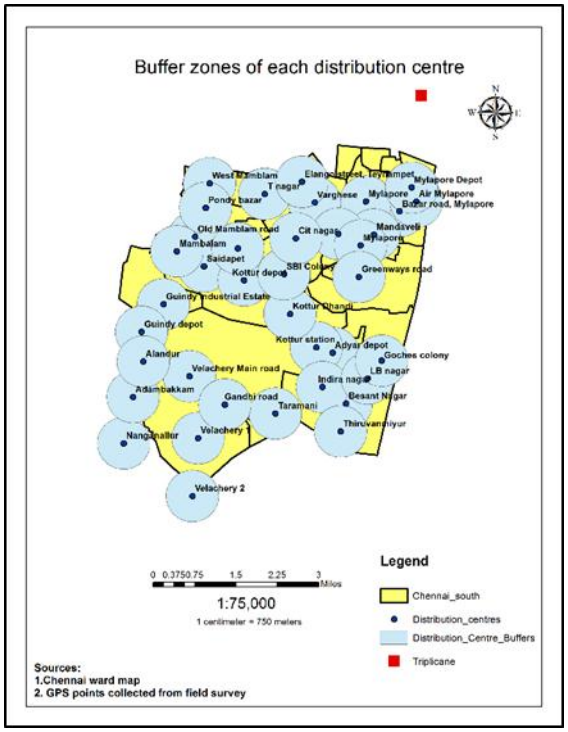

Figure 4: Map showing distribution centres and their operational convenience (750m buffer)

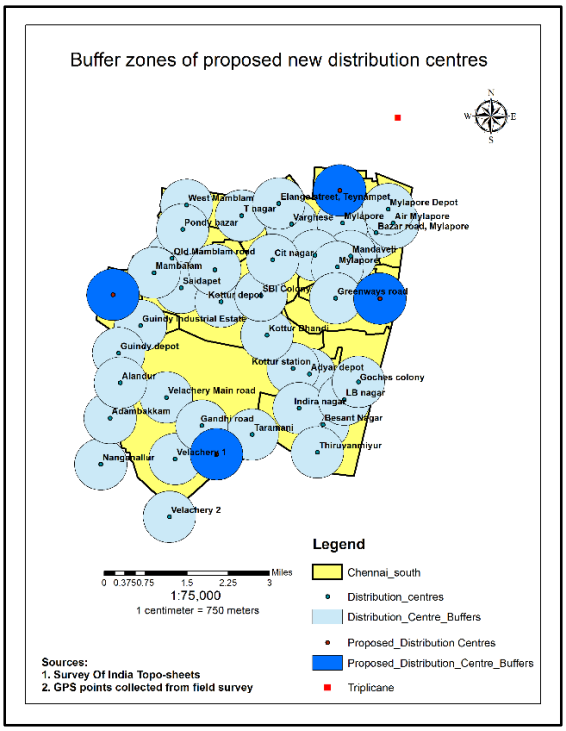

Figure 5: Map showing proposed distribution centres and their operational convenience (750m buffer)

From the buffer analysis, it is found that there were regions in the study area which are not covered by any of the existing distribution centres but eggs were supplied from surrounding distribution centres. And some regions are found to be served by more than one distribution centre.

The viability for setting up a new egg distribution centre has been decided based on the demand in the region and the minimum handling capacity of existing distribution centres. From the statistics collected from distribution centres (Appendix A), it has been decided that any region with a demand of 8000 eggs per day is ideal for setting up a new distribution center. The rationale behind this idea is based on the assumption that it is the minimum Return on Investment (ROI) that people in this business consider worthy.

The study identified four sites to establish new distribution centres as depicted in Figure 5. All these distribution centre, if operate with mutual collaboration, will improve the efficiency of egg distribution.

In South Chennai, six distribution centres are being served by the collection centre at Perangulathur location. Irregularities are observed during field observations ranging from lack of record keeping to lack of control over delivery routes. Most of the data required were either inaccurate or not available and in worst case scenario, distributors were not willing to part with the data. Due diligence was paid to rectify errors and to ensure the data quality. It is recommended to educate the distributors and retailers of the importance in keeping record of the sales and business transactions.

Egg shell breakages are directly proportional to transportation and handling activities. Transportation and handling activities start at the farm level and continue till it reaches the consumers. Since the study is concerned only with transportation from collection centres to distribution centres and limited to the southern parts of Chennai, amount of breakages in the earlier part were unknown. Hence, establishing relationship between breakages and transportation was not possible. However, the officials at the National Egg Coordination Committee pointed out that the breakages might get reduced to 6-8% from the 8-10%.

In some of the regions, density of distribution centres is very high and the operational area overlap in such regions. It is found that traders operate on their own discretion which culminates in inefficient practices. And some of the distribution centres found to be operating on larger geographical area. It is proposed to establish new distribution centre in the areas with high demand for eggs and lesser distribution density. It is suggested that all the distributors and traders operate with proper understanding and collaboration among them in order to improve profits and conserve resources. This study is easily reproducible at various geographical locations and will help in saving resources and will aid in sustainable business development.

5. Conclusion

The study identified three optimal routes for supplying eggs in south Chennai. It is suggested to add four new distribution centres. The optimal route identified in the study reduces the travelling distance by approximately 40km per day (about 27 %) and thereby reducing fuel consumption.

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