Independent Project in Technology

Cluster Building and Logistics Network Integration of Local Food Supply Chain

Techane G. Bosona

Institution för energi och teknik
Swedish University of Agricultural Sciences
Department of Energy and Technology

Examensarbete 2010:08
ISSN:1654-9392
Uppsala 2010

SLU, Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Energy and Technology

Techane G. Bosona

Cluster building and logistics network integration of local food supply chain

Supervisor: Girma Gebresenbet, SLU, Dep. Of Energy and Technology
Examiner: Alfredo de Toro, SLU, Dep. Of Energy and Technology
EX0417, Independent research project, 30 Credits, Technology, Advanced E
Course title: Independent project in technology
Independent project report (Institution för energi och teknik, SLU)
ISSN: 1654-9392
2010:08

Uppsala 2010

Keywords: Logistics; Network Integration; Local Food; Location Analysis; Route Optimisation; Collection Centre

Independent Project in Technology

Cluster Building and Logistics Network Integration of Local Food Supply Chain

[*Klusterbildning och logistik Network Integration av lokal mat Supply Chain*]

Techane G. Bosona

SAMMARY

In the agriculture sector, globalization of food production has considerably influenced the food supply system by increasing distance the food has to be transported to reach consumers. This situation not only has increased emissions of greenhouse gases but also has reduced the relationship between local food producers and consumers, affecting local food producers, their environment and culture.

In this study, local food supply chain characteristics were investigated using data from some local food producers and existing large-scale food distribution centers from entire Sweden. A coordinated distribution system of locally produced food was developed to improve logistics efficiency; reduce environmental impact; increase potential market for local food producers and to improve traceability of food origin for consumers. For this**,** integrated logistics networks were developed by forming clusters of producers and determining the optimum collection centers of food products for each cluster. These food collection centers could be linked to food producers, food distributors and consumers/retailers enabling coordinated distribution of local food products and facilitated the integration of food distribution from the collection centers into large scale food distribution channels.

The analysis carried out using tools such as Geographic Information System and Route LogiX software indicated that integrating the logistics activities in the delivery system of local food has advantages. It reduced the transport distance and time and the number routes of food collection and distribution. The possibility of integration of local food distributions into large scale food distribution channels increased the potential market for local food producers. These indicate its positive impact on environmental issue and traceability of food quality and origin. However, in this study, the locations of the customers of each producer and the existing delivery routes from producers to customers could not be mapped due to the shortage of data. Therefore, site specific and more detailed further studies have been recommended.

ACKNOWLEDGEMENTS

I would like to thank my supervisor Prof. Girma Gebresenbet, my examiner Dr. Alfredo De Toro and Dr. David Ljungberg for their valuable support throughout this project.

ABSTRACT

Food supply chain is the current focus in terms of food safety and environment. The objective of this study was to investigate the local food supply chain characteristics and develop a coordinated distribution system to improve logistics efficiency, reduce environmental impact, increase potential market for local food producers and improve traceability of food origin for consumers. The study was based on data from 90 local food producers and 19 existing large scale food distribution centers (LSFDC) from all over Sweden.

Location analysis was done using geographic information system (GIS), to map locations of producers and LSFDCs; to build cluster (C) of producers; and to determine optimal product collection centers (CC). The route analysis was carried out using Route Logix software, firstly for the case of produce collection from farms to CCs based on two scenarios: (1) producers transport their products (no coordination); (2) CCs manage coordinated collection of products; and secondly for product distribution from CCs to potential markets.

The comparison of scenario-1 and scenario-2 showed improvement by of 68%, 50% and 47% for number of routes, driving distance and total delivery time respectively. Totally, 14 clusters of producers were formed and 86% of these clusters could be integrated into the LSFDCs. This network integration could have positive improvements towards potential market, logistics efficiency, environmental issue and traceability of food quality.

Keywords: Logistics; Network integration; Local food; Location analysis; Route optimisation; Collection centre

CONTENTS

1 INTRODUCTION 7
1.1 Location Analysis 7
1.2 Logistic network integration 7
1.3 Local food supply 9
1.4 Objective 10
2 MATERIAL AND METHODS 11
2.1 Data Collection 11
2.2 Types of data 12
2.3 Mapping producers 14
2.4 Clustering the producers 16
2.5 Determination of optimum locations of collection centres 17
2.6 Analysis of product delivery routes 18
2.6.1 Scenario 1: Producers transport their products to CCs 18
2.6.2 Scenario 2: Coordinated collection of products to CCs 18
2.7 Integration with large scale food distribution centres 19
3 RESULTS 21
3.1 Description of data characteristics 21
3.2 Mapping and clustering 22
3.3 Route optimisation 22
3.3.1 Product collection routes- Scenario1 and Scenario 2 22
3.3.2 Product delivery routes to the potential markets 27
4 DISCUSSION 29
4.1 Main characteristics of producers 29
4.2 Implication of network integration 29
4.2.1 Implication on logistics efficiency 29
4.2.2 Implication on environmental issue 30
4.2.3 Implication on traceability of food quality 30
5 CONCLUSIONS 31
REFERENCES 33
APPENDIX A: ADDITIONAL TABLES 35
APPENDIX B: ADDITIONAL FIGURES 48
APPENDIX C: QUESTIONNAIRES 52

1 INTRODUCTION

Food supply chain is the current focus in terms of food safety and environment. Consumers' demand to have good knowledge and information of the food origin and how it is handled and transported is increasing (Banthham and Oldham, 2003). Therefore, research related to logistics in food and agriculture sectors is required and essential for the application of modern logistics practices to evaluate their effects on delivery performance and environment (Aronsson and Brodin, 2006). The efficiency of logistics management has a positive impact on the success of food producers (Brimer, 1995), because, logistics greatly affect the profit of producers, the price of food produces, and the satisfaction of consumers. Effective logistic management requires delivering the right product, in the right quantity, in the right condition, to the right place, at the right time, for the right cost (Aghazadeh, 2004). During the last 30 years, different firms have changed their strategies and logistics organization to suit to the centralization of production and distribution of goods, reduction of inventory and time based competition, and a positive change for environmental performance (Groothedde et al, 2005; Aronsson and Brodin, 2006; Töyli et al, 2008). Centralisation includes changes in transport modes as well as increased consolidation of goods, standardization and centralised governance of the logistics system, in different proportions (Aronsson and Brodin, 2006). In global context, firms have begun to consolidate their distribution activities to a few centers due to the fact that transportation activities become liberalised globally and transportation services become fast, flexible, and efficient (Oum and Park, 2003).

Since logistics role in firm's survival and prosperity is significant, such a management issue as "what degree of consolidated distribution centres (DCs) should be located in which places" is a tremendous challenge (Oum & Park, 2003). Therefore, in the process of developing improved logistics systems in the food supply chain, detail study of location analysis and route optimizations through network integration are very essential.

1.1 Location Analysis

The location decision of a facility should be requirements-driven. Thus an optimum location should be selected to satisfy those who are concerned where the facility's location site is (Chung, 2002). For choosing consolidated DCs the most important factors are market size, accessibility, and growth potential of the region; geographical location; transport facilities and modern logistics services (Oum and Park, 2003).

Different techniques of location analysis include cluster analysis (Fuente & Lozano, 1998), GIS based location analysis (Hernåndez and Bennison, 2000; Li and Yu, 2005), center of Gravity technique and Load-distance technique (Russell and Taylor, 2006). The use of GIS and gravity models allows more precise and accurate decisions to be made which becomes more important as the number of available sites reduces (Wood and Brown, 2006). Based on an extensive questionnaire survey of UK retailers conducted in 1998, Hernandez and Bennison (2000) reported that GIS could be used to support a wide range of location research techniques and the use of GIS by retailers is increasing. Fuente and Lozano (1998) used cluster analysis to decide which towns should be grouped in a particular zone and assigned a particular warehouse to each group of towns using centre of gravity algorithm.

1.2 Logistic network integration

Some researchers (Christopher, 2005; Morgan, 2007) argued that the phrase 'supply chain management' should be termed 'demand chain management' and the word 'network' should replace 'chain'. The supply network is a relatively recent area of serious research and the term 'network' is preferred since the system includes multiple suppliers, suppliers to suppliers as well as multiple customers and customers' customers (see Figure 1). Christopher (2005) defined supply network as "a network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users".

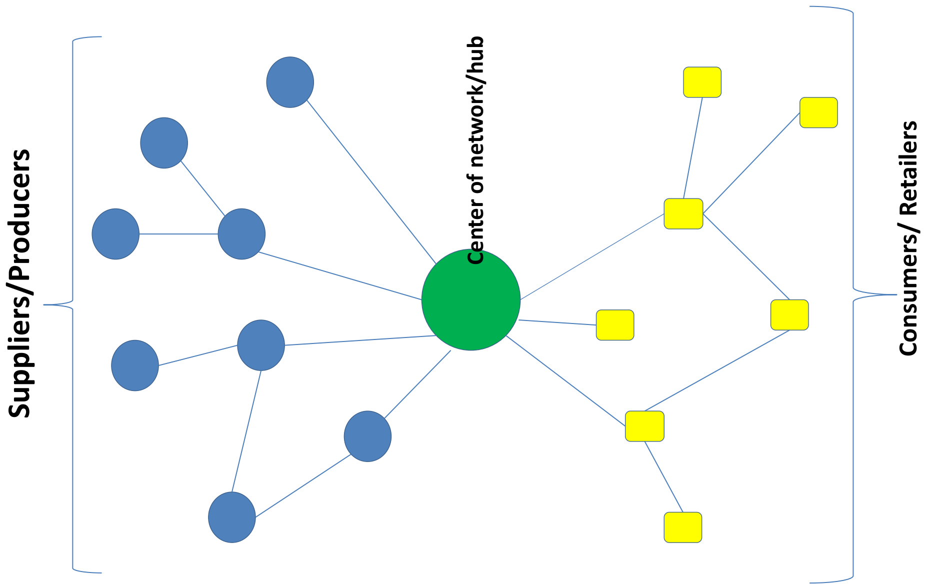


Figure 1. The concept of supply network

Clustering and network integration of firms are ways of collaborating to increase the competitiveness of a region at national level; or of a country at international level. Within the field of logistics, companies with best practice applied collaboration approaches and achieved good results (Sandberg, 2007), especially regarding the reduction of logistics cost about 40-50% was estimated at European level (Groothedde, 2005; Bourlakis M.A. and Bourlakis C.A., 2001).

In the network approach, inter-organizational relationship is important for exchanging resources. Forms of collaboration are based on economic motivations, power, trust, and information sharing (Trienekens, 2003; Gimenez, 2006). The network design problem (where, for example, more than one hub are integrated), in its general form, involves finding the optimum locations for the hub facilities, assigning non-hub origins and destinations to the hubs, determining linkages between the hubs, and routing flows through the network (Groothedde et al, 2005).

In food sector, where the shift of power is from producers to retailers, new approaches to marketing and new forms of product distribution are part of innovation (Beckeman and Skjöldebrand, 2006). In Sweden, clusters and networks existed especially in southern Sweden (Beckeman and Skjöldebrand, 2007) and the formation of cluster was a "bottom-up" initiative. A network of interested individuals and organizations was created where the Frozen

Food Institute served as a 'hub'. This was effective to produce information and boost the acceptance of new technology.

The technological dimension of innovation through the food supply chain such as advanced information and communication technology (e.g. e-commerce) systems are increasingly becoming the backbone of integrated supply chains (Trienekens et al., 2003). Communication between participants of the food supply chain and the consumer may most successfully be achieved through a coordinated effort (Forsman and Paananen , 2004; Saltmarsh and Wakeman , 2004).

Developing a link between companies ensures a long-term business relationship and enables the companies optimize their profit (Aghazadeh, 2004). The trends of relationships between the partners in the food industry are business-to-business and e-commerce systems. The efficient link between partners in food retailers, manufacturers and wholesalers is important for cost reduction (Aghazadeh, 2004). These facts indicate the importance of network integration for the local food producers to improve their overall efficiency.

In this project, network integration was introduced in order to link producers, service providers (example logistics service), food collection and/or distribution centers, and retailers and/or consumers so that they work together, based on trust, to share information and support each other to be competitive and improve their sustainable growth.

The proposed network integration for the betterment of logistics activities in the local food product delivery system has the following palpable advantages: (1) to improve the transport of food product in terms of distance and time (2) to expand the market area for products (3) to strengthen the partnership between producers, distributors, retailers and consumers (4) to encourage exchange of knowledge and experience. This generally encourages the producers to improve their production both in quality and quantity. For example, according to Beckeman and Skjöldebrand, 2007, one apparent advantage of such a network is that each actor in the network concentrates on its specialty and improves its productivity.

This type of coordinated activity is also helpful for increasing the awareness of environmental issue and creating favorable situation for researchers. For example, well-established data management might come into existence which in turn helps to conduct more detail studies on the logistics activities to evaluate their impacts on cost, delivery performance, and environment.

1.3 Local food supply

In the present study, from a geographical perspective, local food refers to the food produced, retailed and consumed mainly in the specific area. There is an increased interest in the transparency of the food supply chain and therefore, traceability as aspects of food quality assurance have gained more and more importance lately. This in turn has aroused interest in local food production. A local food brand that offered further assurances of sustainability, would offer potential for meeting such demand (Saltmarsh and Wakeman, 2004). Local food has the following advantages associated with it: high quality and safety of food product; freshness and non-industrial; minimum use of packaging materials; customer satisfaction and friendliness to the environment (Forsman and Paananen, 2004). Even though various environmental factors are there, recycling of packaging is the most important factor affecting logistics (Denis 1997).

In many small and medium sized business logistics is highly fragmented and inefficient (Brewer et al 2001). In smaller parties, the tendency of frequent deliveries i.e., the concept of just in time, increases transport activities. The average load rate remains under 50% i.e. most of the time vehicles move only loaded partially (Gebresenbet, 2006). In most cases of food distribution systems of local food shops and localized farmers markets, where individual companies run their own vans or small trucks, logistics is relatively inefficient and fragmented. This is a key area that requires improvement (Brewer et al., 2001; Saltmarsh and Wakeman, 2004).

It has been difficult for small holder producers to become a supplier within the large retail market segment. This is due to the small production volumes, the inability to supply year-round, and the logistics cost (Trienekens et al., 2003). Therefore, in addition to improving the logistics efficiency, increasing the potential market for the local food producers is essential. For example, the use of consolidation centres whereby food products from several manufacturers are consolidated into full loads for delivery into regional delivery centers, offers small manufacturers the possibility of distributing product to a network of retail outlets that covers wider area (Collins et al, 1999).

1.4 Objective

The objective of this study was to investigate local food supply chain characteristics and develop a coordinated distribution system to improve logistics efficiency, reduce environmental impact, increase potential market for local food producers, and improve traceability of food origin for consumers. Specific objectives were to:

i) identify and map the local food producers and existing LSFDCs
ii) build cluster of the producers
iii) determine the optimum location of CC for each cluster and integrate with LSFDCs
iv) determine and map optimised routes for product collection and delivery system

2 MATERIAL AND METHODS

This study was conducted mainly based on the data collected from local food producers and their delivery systems all over Sweden. Location analysis and route optimization analysis were the main activities carried out. The technical tools such as GIS and RouteLogiX software were used. Figure 2 illustrates the general procedure followed in this study.

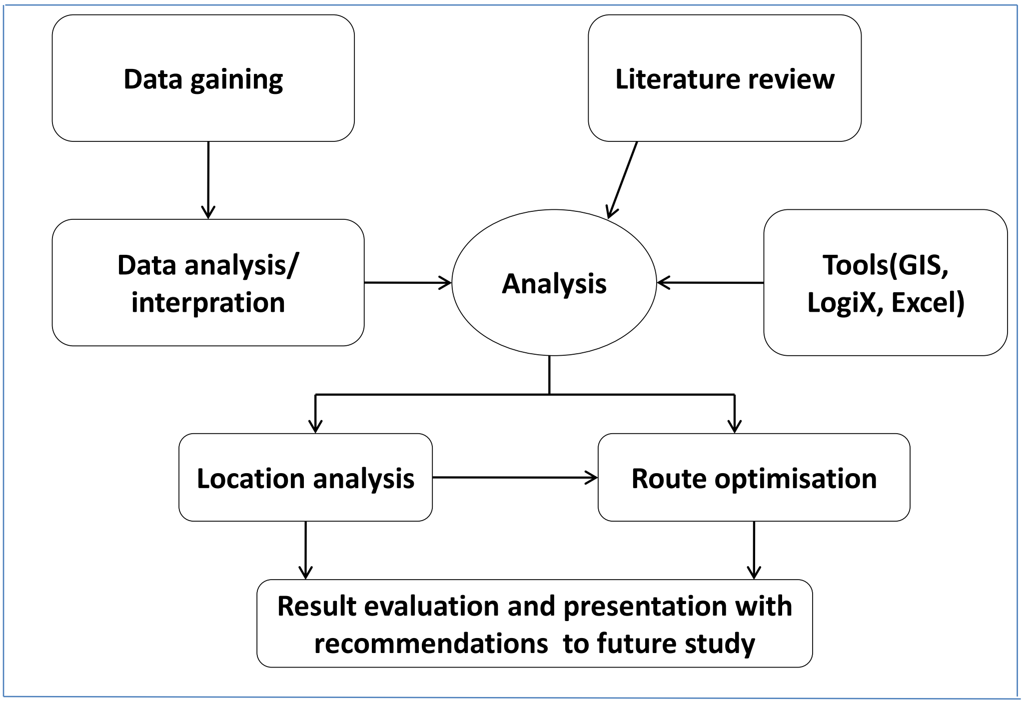


Figure 2. Schematic description of the study methodology

2.1 Data Collection

Surveys were conducted to collect data from local food producers. Structured questionnaires were developed and sent to each targeted respondents through email and airmail. The replies were received through email, telephone and/or on-line reply by filling out on-line questionnaires developed for this particular data collection. Out of 160 questionnaires, 90 responses, with the required information, were obtained representing 56% response rate, and uncompleted response were disregarded.

Regarding the LSFDCs, data was gathered via telephone and internet. Nineteen distribution centres were identified for three food distributing companies (Axfood, ICA and Coop) operating in Sweden.

2.2 Types of data

Data such as post code, annual production quantity, product delivery distance and load rate of vehicles were mainly used. Other information such as annual revenue, production type, delivery frequency, and product distribution cost as percentage of annual revenue was included.

The geographical distribution of the sample data of food producers covered almost entire Sweden. Table 1 presents the regional distribution, categorised into Southern, Central and Northern parts of Sweden. The main identified types of produces were meat, egg, dairy products and vegetables (see Table 2 and Figure 3). The producers were also categorized according to their annual production capacity (see Table 3).

Table 1. *Geographical distribution of farms*

Region	No of Producers	Percentage in the sample
Northern Region	20	22
Central Region	33	37
Southern Region	37	41
Total	90	100

Table 2. *Distribution of sample data in terms of production type*

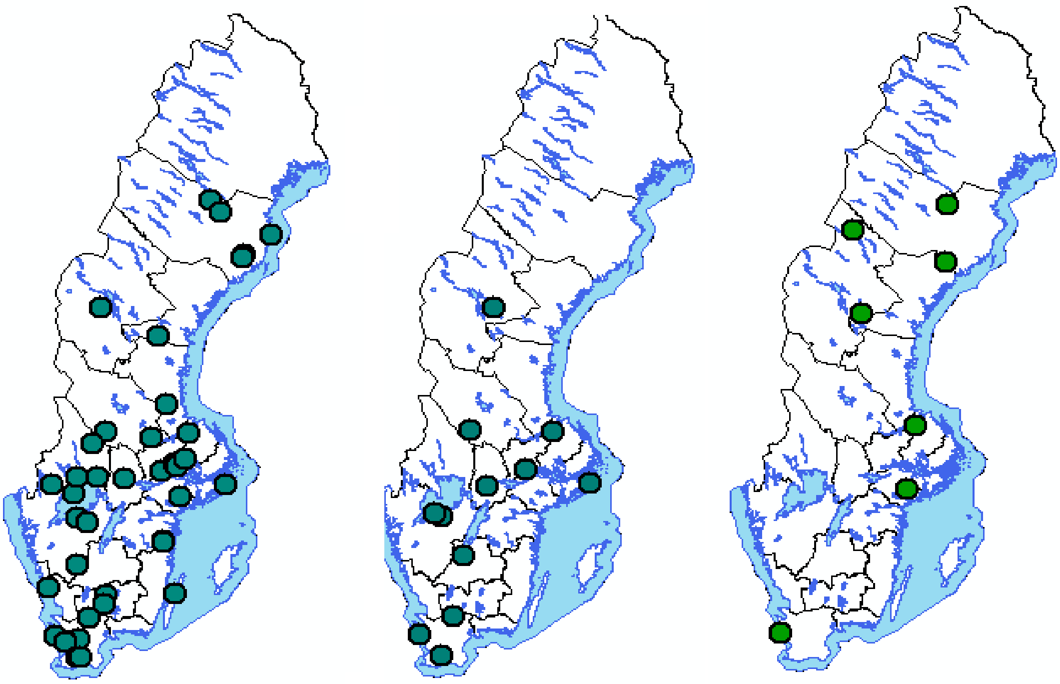
Production type	Number of Producers	Percentage in the sample
Meat	44	49
Egg	14	16
Dairy	8	9
Grain	14	16
Vegetable*	38	42
Not identified	15	17
Total	90**	100

*=includes fruit and potatoes **=total number of producers is 90 but some of them produces more than one type of products

Table 3. *Distribution of sample data in terms of annual production quantity*

Quantity range In tones	Number of producers	Percentage in the sample
0.8 up to <25	57	63
25 up to <50	9	10
50 up to <75	6	7
75 up to <100	5	6
100 up to <250	8	9
250 up to <500	4	4
500 up to 1000	1	1
Total	90	100

The other important factor that considered in this case was product delivery distance. The data comprises producers that sell their products on farm level and producers that transport their products to their customers and/or to market. In order to investigate the distribution of sample data in terms of delivery distances, the mean values of the minimum and maximum delivery distances were computed (see section 3.1).



(a) Meat product (b) Egg product (c) Dairy product

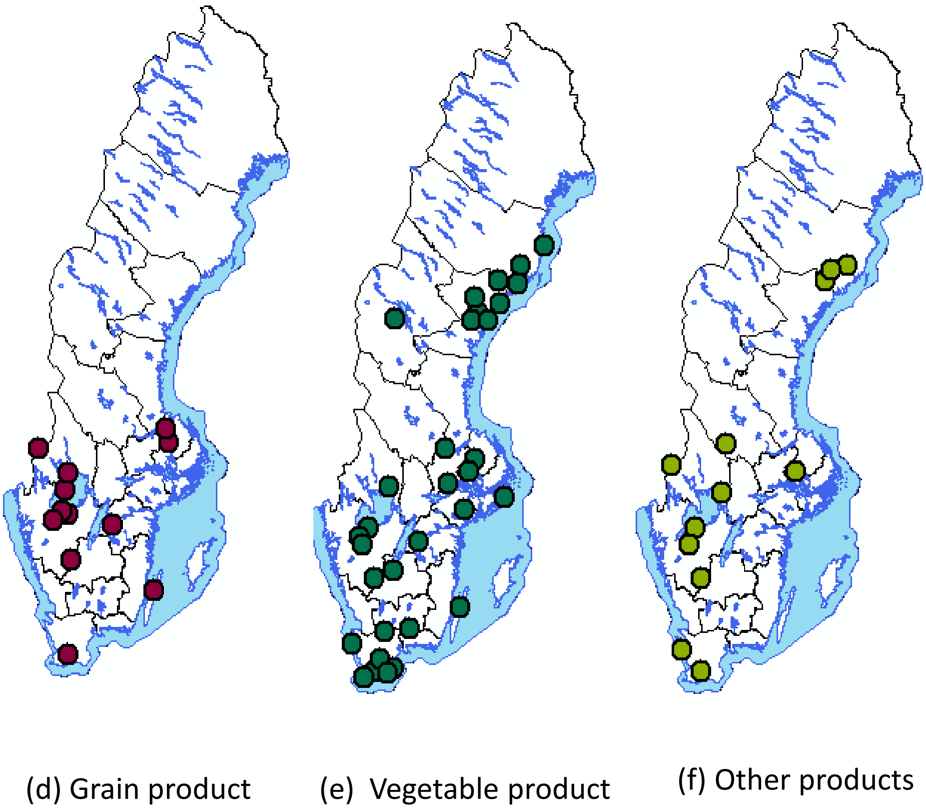
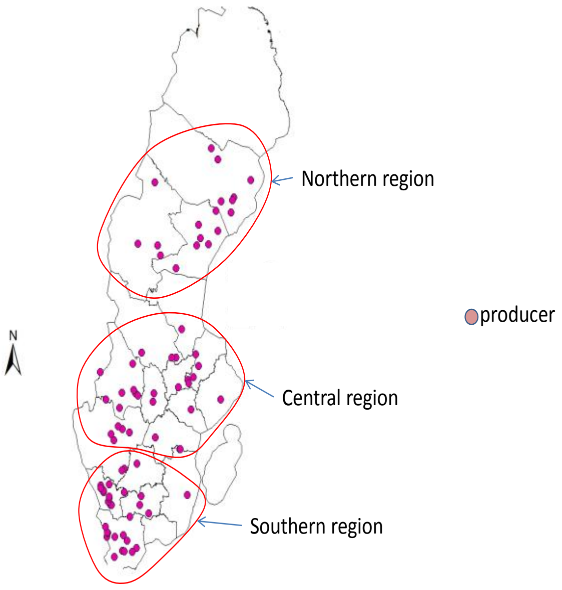


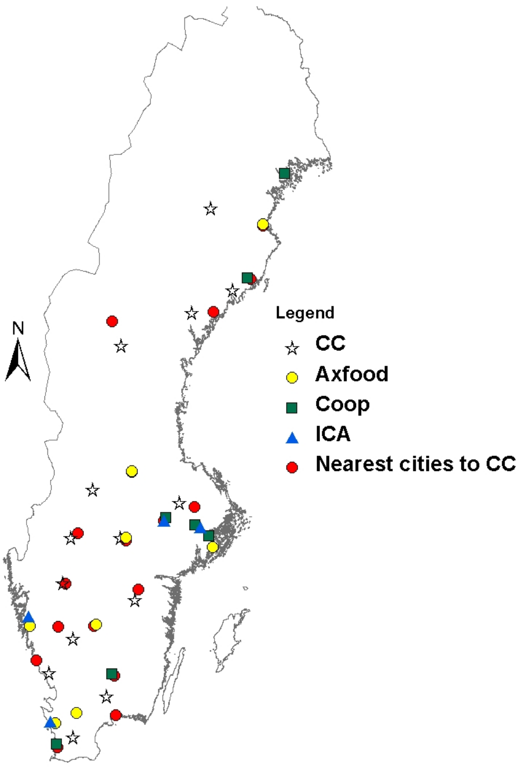
Figure 3. Map illustrating distribution of producers grouped according to production type

2.3 Mapping producers

First, the locations of producers were determined based on their postcode and additional information obtained from Geographical information database. Mapping and clustering the local food producing farms and existing food distribution centers were done using ArcGIS®9.3 (ESRI, 2008). A point shape files representing the precise geographic location of each of the 90 producers, potential markets and 19 existing LSFDCs were created and displayed on map (see Figures 4(a), 4(b) and Figure 5).



(a) Location of producers



(b) Location of potential markets (LSFDCs and nearby cities)

Figigure 4. Map illustrating the distribution of (a) producers (b) potential market

2.4 Clustering the producers

In this study, clustering was done in terms of geographical proximity of the producers. In the clustering procedure, all farms within 100 km were grouped into one cluster, because, for most of the producers (about 72%), the average product delivery distance from producers to customers (in the existing delivery system), was less than 100 km (see Table 4). Using GIS software, 14 clusters of farms were formed and an optimum location of CC was determined for each cluster. Figure 5 presents all the 14 clusters together with the optimum locations of CCs.

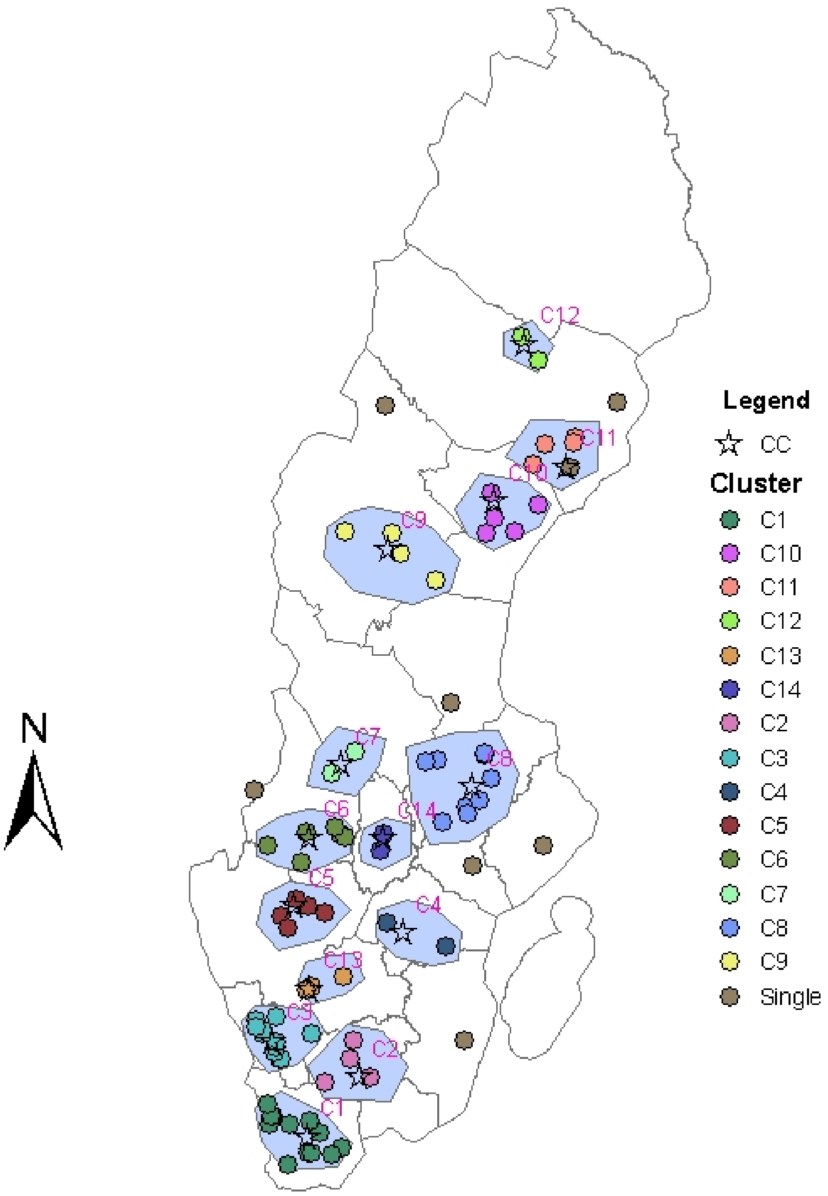


Figure 5. Clusters of producers: 14 clusters of 83 producers and 7 outliers indicated as single

2.5 Determination of optimum locations of collection centres

In the existing product delivery system, each farm distributes its own products to customers/market. In this study, coordinated transport of food produces was proposed such that produces from farms within the respective cluster will be delivered to CC and distributed to available/existing customers and/or to other potential market (see Figure 6). The proposed coordinated logistics operation requires the determination of optimum location of CC for each cluster. CC is to be used not only as temporary storage but also as a base for establishing coordinated distribution of food to the customers/retailers in its surrounding region and to the potential market, for example nearest possible towns/cities and existing large scale food distribution centers such as Axfood, ICA and Coop.

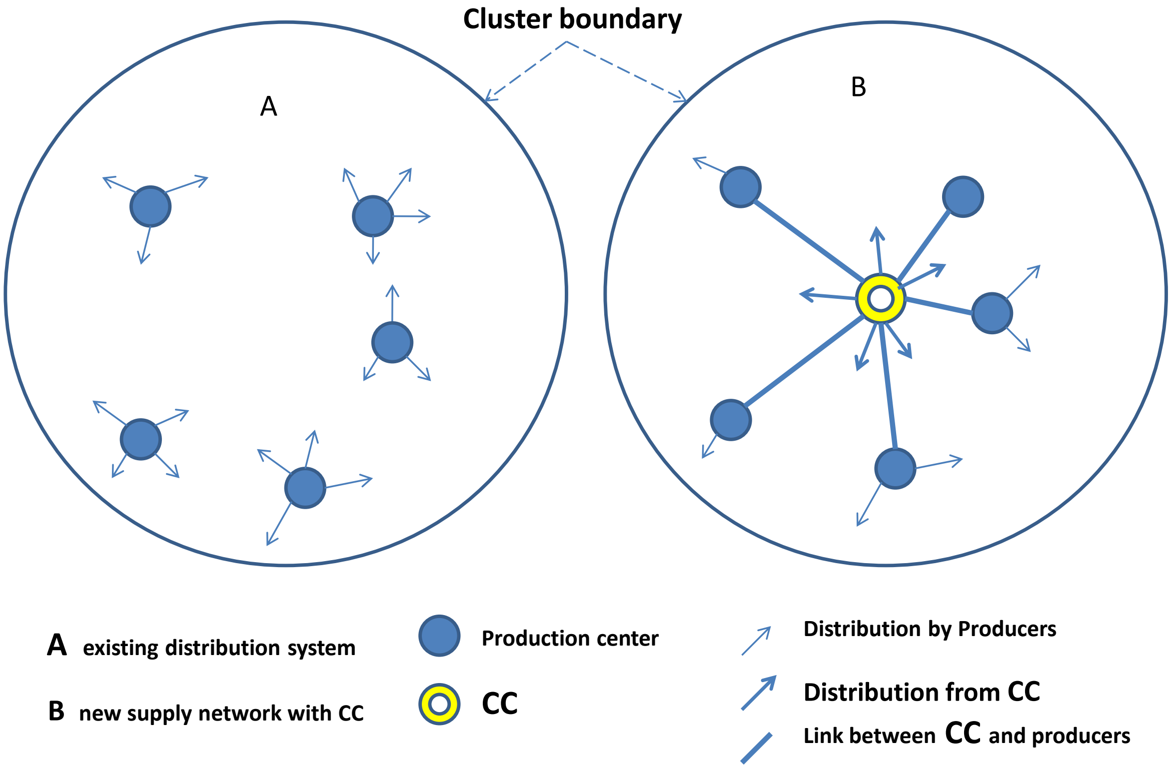


Figure 6. Existing distribution system (fragmented) and newly proposed coordinated distribution system via CC to different customers

The Centre-of-Gravity Technique (Russell and Taylor, 2009) was used to determine the optimum location of CCs. This method is a quantitative method for locating a facility such as a warehouse at the centre of movement in a geographic area based on weight and distance. The coordinates for optimum location could be computed using the following formulas (Russell and Taylor, 2006):

$$x = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i}, \qquad y = \frac{\sum_{i=1}^{n} y_i w_i}{\sum_{i=1}^{n} w_i}$$

Where:

x, y = coordinates of CC

x_i , y_i =coordinates of farm i

w_i = annual weight shipped from farm i

In this project, the yearly production quantity was taken as annual weight of products, assuming that all produced quantity would be delivered to CCs. The calculation of coordinates of the optimum CCs was done using both Microsoft excel 2007 and GIS.

2.6 Analysis of product delivery routes

The routes for collection of products from farms to CCs and product delivery routes from CCs to the potential markets were simulated for each cluster. The route analysis for collection of products was done based on the following two scenarios.

2.6.1 Scenario 1: Producers transport their products to CCs

In this case, all members of each cluster were assumed to deliver their products to their respective CC. This means there is no coordination in transporting products (see Figure 7(a)).

2.6.2 Scenario 2: Coordinated collection of products to CCs

In this case, deliveries to the CCs were coordinated (see Figure 7(b)). The route analysis was carried out in two steps: In the first step, one or more routes were formed for each cluster and producers were assigned to each route, considering their proximity on map which was created using ArcGIS. In this case, it was assumed that for each route, appropriate trucks with different compartments can be assigned to deliver different types of food products that require different temperature. In the second step, route optimization analysis was conducted using RouteLogiX software (DPS, 2004).

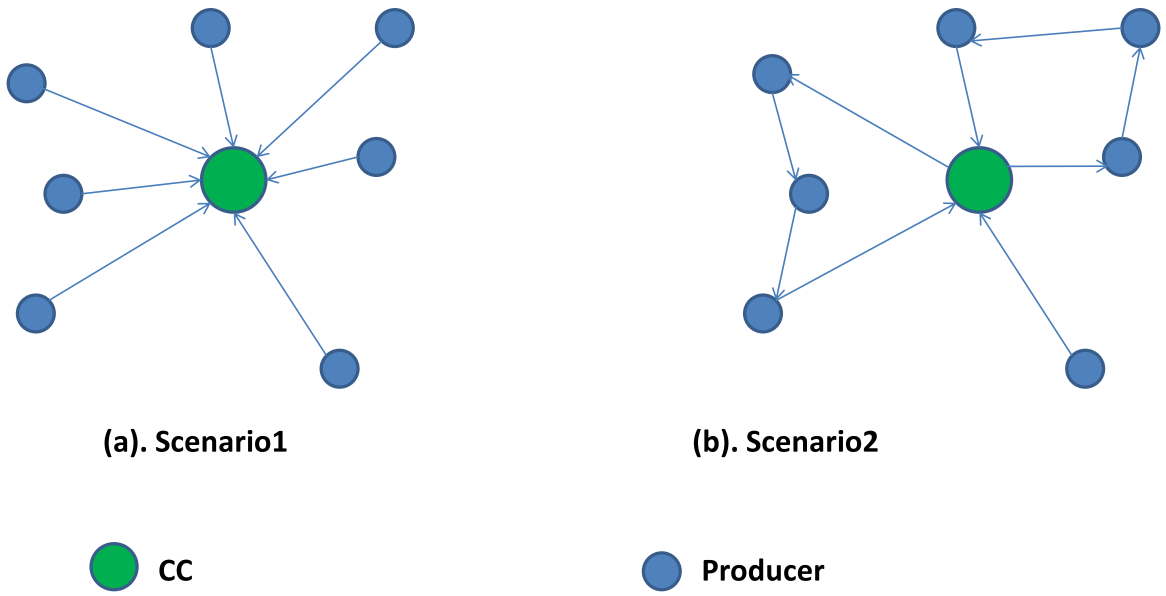


Figure 7. Uncoordinated and Coordinated collection of products

2.7 Integration with large scale food distribution centres

In order to increase the potential market for local food producers, the food delivery system was integrated with LSFDCs. For the purpose of integrating local food producers with large scale, first, LSFDCs in the vicinity of CCs were identified. Using RouteLogiX software, the optimum delivery distance and time were also determined for transporting products from CC to the identified potential market (nearby cities and LSFDCs) within the distance of 150km.

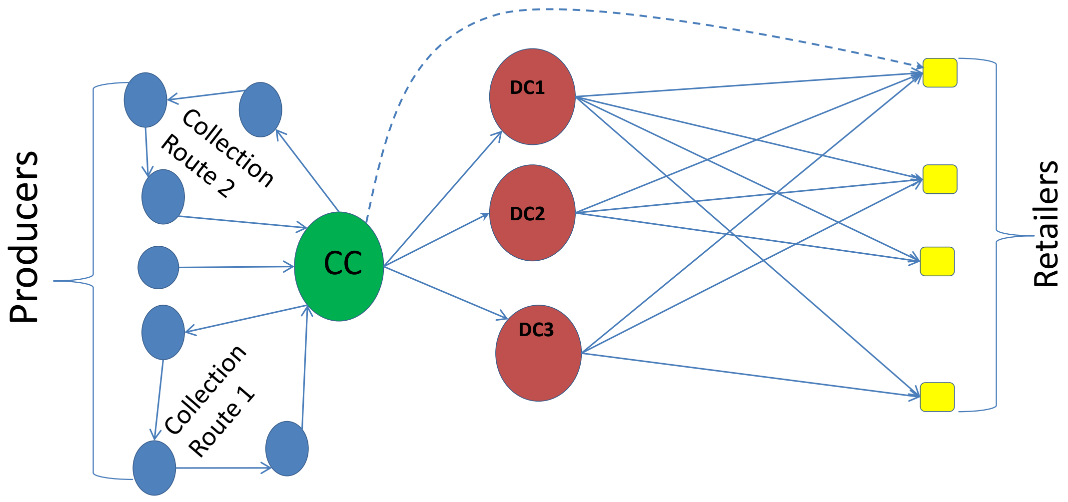


Figure 8. Network of product delivery system with coordinated collection: DC1, DC2, DC3 represents three of LSFDCs. The dash line indicates the case of direct delivery from CC to retailers or customers.

3 RESULTS

3.1 Description of data characteristics

The local food producers considered in this study were dispersed all over Sweden. When categorised into 3 regions, more than 41% of local food producers were in southern region (see Table 1 and Figure 4(a)).

The sample data comprise of producers with annual production capacity varying from the minimum value of 0.8 tones to the maximum value of 1040 tones. Table 3 shows that more than 63% of the sample farms produce, annually, less than 25 tons of food products per farm. The rest of the producers have production quantity less than 500 tones except one producer which has 1040 tons annually.

The annual revenue (in Swedish kroner) varies from 20 000 SEK to 115 MSEK and more than 72% of the producers in the sample data earn annually from 0.10 MSEK up to 5.00 MSEK while only 3 producers earns more than/or equal to 50 MSEK (see Table A.1. and A.2.).

Out of the 90 producers considered in this study, 5 producers sell their produces only on farm outlet while 85 producers deliver to their customers. The minimum delivery distance recorded was 12 km while the maximum delivery distance was 1300 km. About 72% of producers deliver to their customers within the area less than 100 km on average. More than 24% of producers transport their products to the customers within the distance of 100-500 km away from the farm location while only about 4% transport to a distance more than 500 km (see Table 4).

Table 4. *Distribution of sample data in terms of average delivery distance*

Distance range In km	Number of producers	Percentage in the sample of 53 producers
7 up to <50	19	36
50 up to <100	19	36
100 up to <500	13	25
500 up to 652	2	4
Total	53	100

Load rate of the trucks, as observed when they leave the farm to deliver the food products to customers was included in the data survey. Based on the information available for 70 of the sample farms, only trucks from 16% of farms have load rate of 100% and trucks from about 62% of farms have load rate of 50% or less while the mean load rate value was 58% of the truck loading capacity (see Table 5).

Table5. *Load rate as % of truck capacity*

Load Rate	Number of rodducers (Frequency)	Percentage in the sample
25	17	24
50	26	37
75	16	23
100	11	16
Total	70	100

As indicated in Table 2, many producers produce meat and vegetable products, 49% and 42% respectively while only about 9% have dairy products. Grain and egg producing farms are not common in northern region. Grain productions are concentrated in the southern region while egg production is common in both southern and central regions (see Figure 3). The two widely produced types of products, meat and vegetable are dispersed in all the 3 regions.

3.2 Mapping and clustering

The locations of all 90 farms and all 19 LSFDCs were displayed on map using ArcMap of GIS software (see Figure 4(a) and 4(b). Based on geographical proximity, 14 clusters were formed comprising 83 farms and the remaining 7 producers could not be annexed by the clusters because of their location. The two mostly populated clusters were cluster-3 and cluster-1 annexing 15 and 14 farms respectively (see Table 6, and Figure 5) and both are located in southern region. At the cluster level, the cluster with largest quantity of total annual production is cluster-6, which comprises 6 producers, with value of 1672tones. The second and third clusters are cluster-1 and cluster-3 with 1149.5 tones and 715tones respectively.

3.3 Route optimisation

3.3.1 Product collection routes- Scenario1 and Scenario 2

From the analysis of route optimization for the collection of products to CCs in the case of scenario1(no coordination), the driving distance at the cluster level (total driving distance to and from CC for all producers annexed by respective cluster) varied from about 78 km (for cluster-14) to 1610 km (for cluster-8) (see Figure10). Similarly the time required (including loading and unloading), in hr:min varied from 3:02 (for cluster-14) to 40:46 (cluster-8) respectively (see Figure 11). In the case of scenario2 (where delivery to the CC is coordinated), two routes have been created for each cluster except cluster-2 and cluster-11 which had only 1 collection route each. Cluster-14 has about 78km while cluster-8 has 584 km of driving distances, the shortest and longest routes observed in Scenario 2, and the respective total time required, in hr:min, was 3:02 (for cluster-14) and 15:08 (for cluster-8) as illustrated with Figures 10 -11.

Table 6. *Location of CCs and related important informations*

Collection Center	No of producers *	Latitude	Longitude	Total annual production[ton]	Total annual revenue [MSEK]	Average annual revenue [MSEK]
CC1	14	55.781	13.502	1149.5	50.00	3.57
CC2	4	56.509	14.551	122.4	2.90	0.73
CC3	15	56.902	12.683	715	373.15	24.88
CC4	4	58.223	15.492	288	12.50	3.13
CC5	5	58.509	13.048	112.8	10.95	2.19
CC6	6	59.319	13.277	1672	20.80	3.47
CC7	2	60.190	14.023	27	1.66	0.83
CC8	10	59.937	17.112	214.5	6.65	0.67
CC9	4	62.751	15.039	31	4.15	1.04
CC10	5	63.297	17.830	212.5	0.64	0.13
CC11	7	63.665	19.512	37	3.90	0.56
CC12	2	65.137	18.832	4	0.18	0.89
CC13	3	57.526	13.434	100	10.67	3.56
CC14	2	59.329	15.017	3.8	0.27	0.14
Scattered	7			95.5	7.65	1.09
Total	90			4785	506.07	

Table 7. *summary of comparison of scenario-1 and scenario-2*

Description	Scenario1	Scenario2	Improvement in %
Number of routes	81	26	68
Distance [km]	8935	4457	50
Time[hr:min]	227:16	119:15	47

Comparing the two scenarios of route analysis, the maximum potential improvements were observed for cluster-1 and cluster-3. The overall potential improvements by introducing scenario2 were about 68%, 50% and 47% for number of routes; distance and time respectively (see Table 7 and Figure 9-11). The routes of product collection, for clusters with high improvement, cluster-1 and cluster-3 are presented in Figures 12, and 13, for cases of both scenarios.

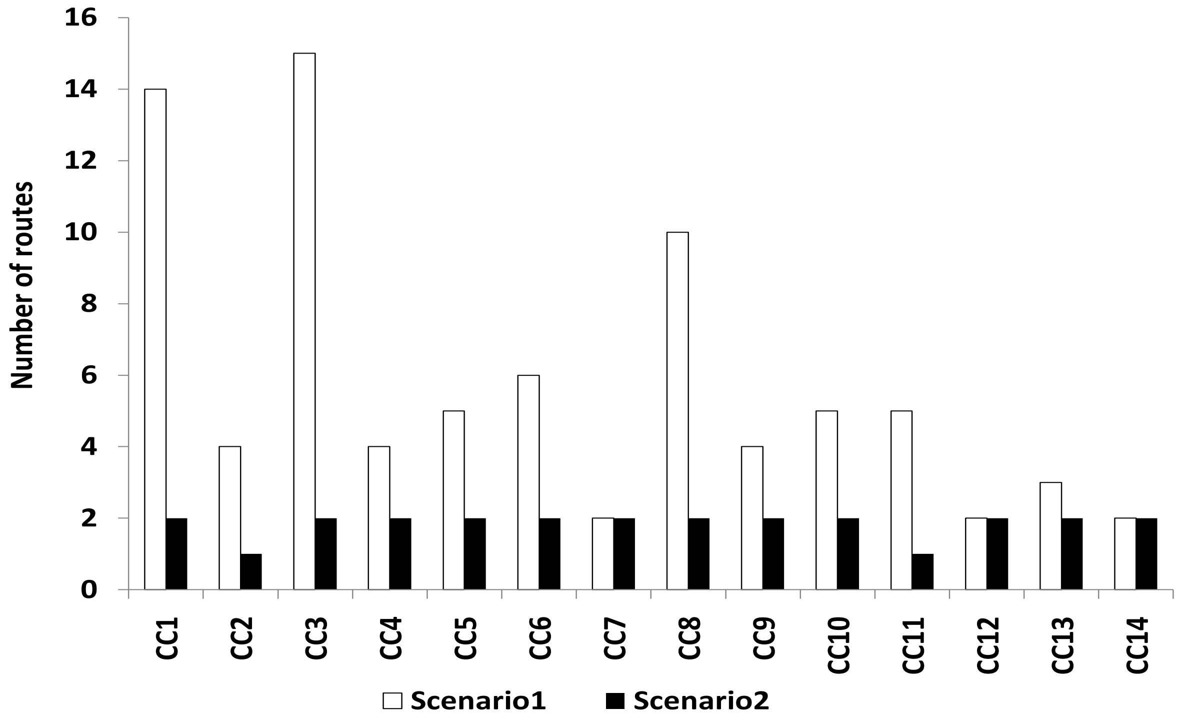


Figure 9. Number of routes for each cluster for Scenario1 and Scenario2.

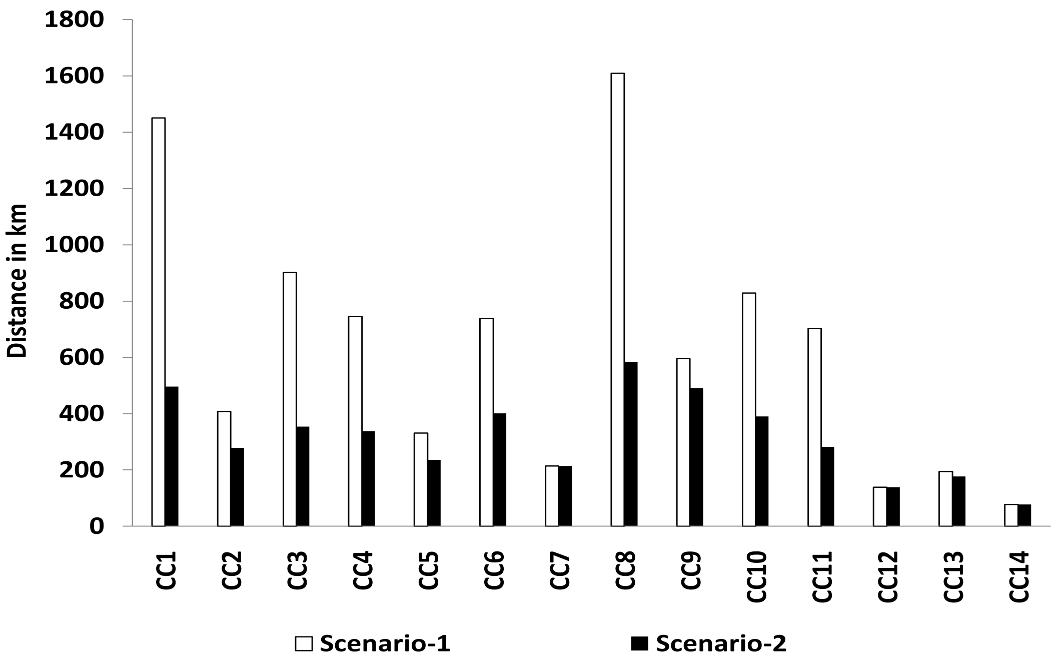


Figure 10. Driving distances for each cluster for Scenario1 and Scenario2.

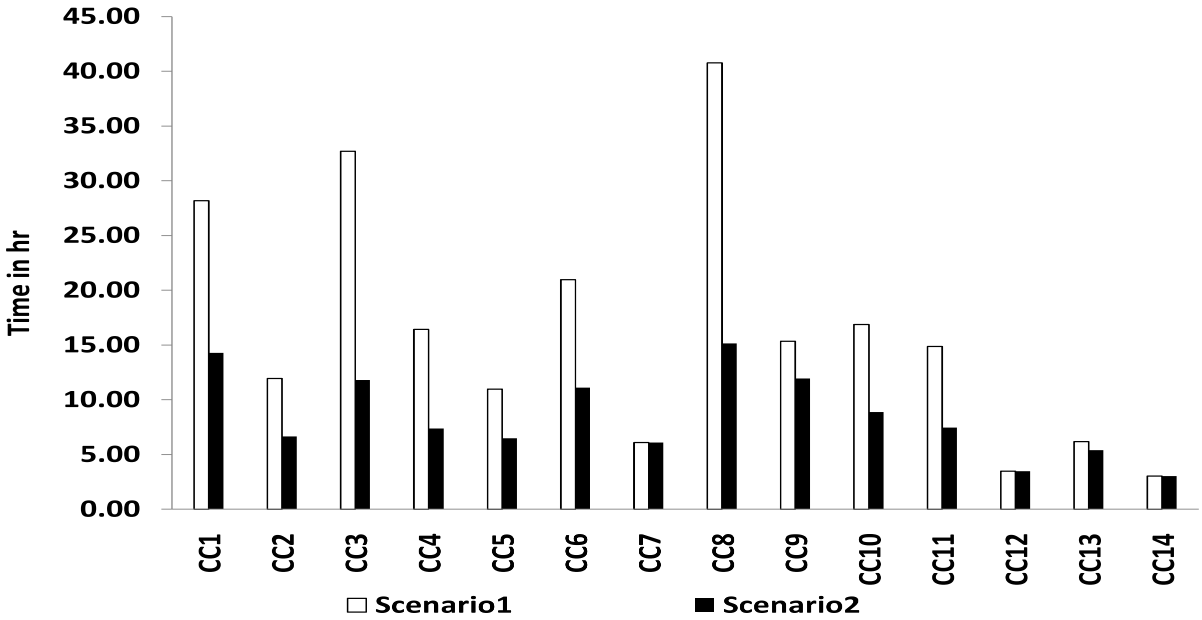
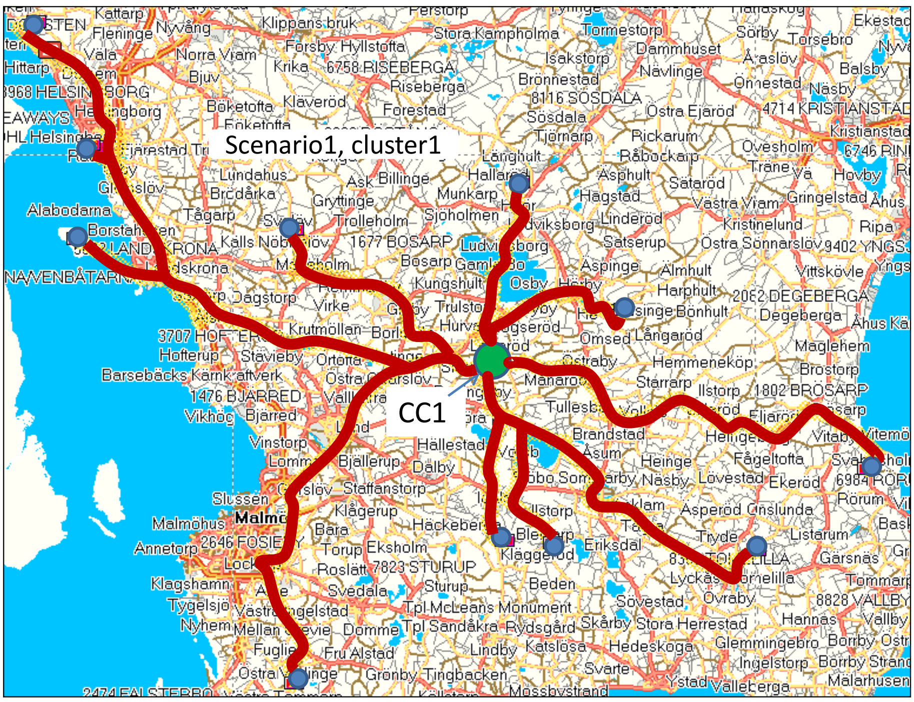
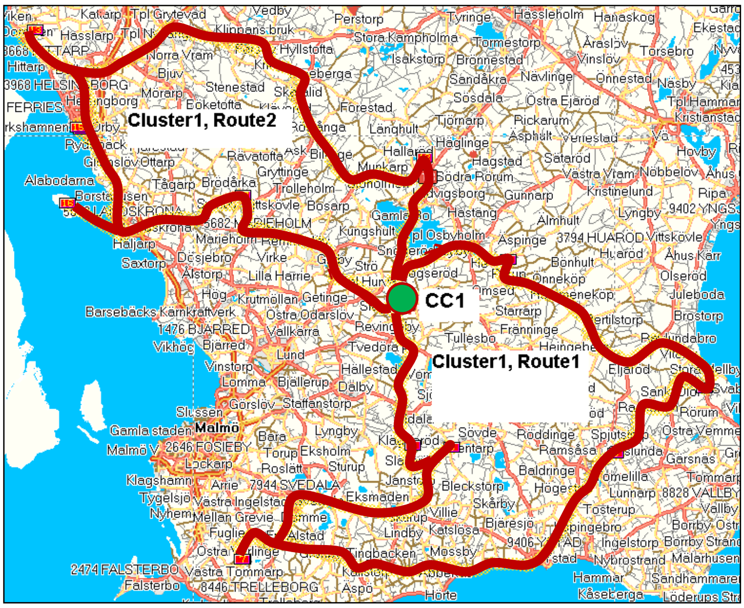


Figure 11. Total time estimated for Scenario1 and Scenario2.



(a). Routes in Scenario1, Cluster1



(b). Routes for scenario2, cluster1

Figure 12. Map illustrating a) routes for uncoordinated collection of products to CC1; (b) routes designed for coordinated collection of products to CC1.

(a). Routes for scenario1, cluster3

(b).Rroutes for scenario2, cluster3

Figure 13. Map illustrating: (a) Routes for uncoordinated collection of products

(b) Routes designed for coordinated collection of products to CC3.

3.3.2 Product delivery routes to the potential markets

As a potential market 17 cities and 19 food distribution centers which are found in the vicinity of CCs were identified. The two collection centers to which the large quantities of products are expected to be delivered, CC6 and CC1, are 32 km and 43km away from Karlstad and Malmö cities respectively (see Table A.5. and Figure B.2).

Regarding the network integration for further distribution of food products, out of the 14 CCs, 12 CCs were integrated into the existing LSFDCs with 29 routes (see Table A.6). Two collection centers (CC9 and CC10) could not be integrated with LSFDCs as they have no LSFDCs within 150 km length. Three collection centers (CC1, CC3, and CC8) have good potential market since each of them has four existing large scale food distribution centers surrounding it. For CC1 and CC8 the LSFDCs are within 100 km while for CC3, they are located within a distance greater than 100 km. Figure 14 shows the product delivery route from CC1 to potential markets.

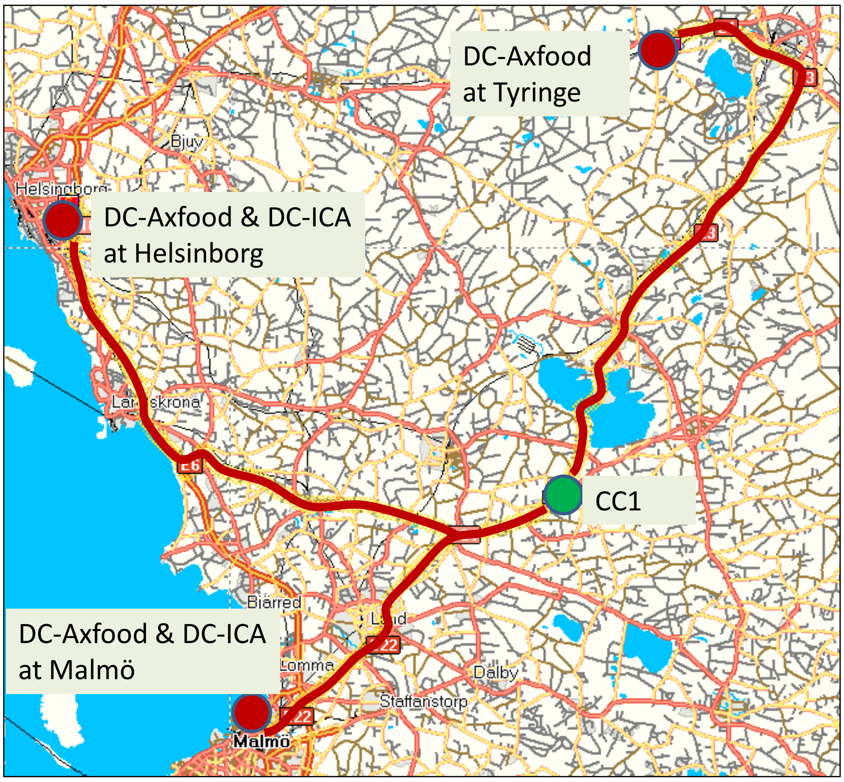


Figure 14. Example of distribution routes from CCs to potential market.

4 DISCUSSION

4.1 Main characteristics of producers

In this study, the analysis was conducted based on the 56% response rate obtained for questionnaires sent to 160 respondents. This response rate was satisfactory when compared to the response rates in the other studies. For example Gimenez (2006) indicated that studies had been conducted satisfactorily with response rates that vary from 15% to 30%.

The location analysis outputs gave clear understanding about the distribution of local food producers. Most of them are found in the southern and central regions, 41% and 37% respectively. The producers were grouped into 14 clusters and optimum collection centers were identified for each cluster. Regarding production type, meat, egg, dairy products and vegetables were the main identified products. The products provided by most of the producers were meat and vegetables, 49% and 42% of producers respectively. About 6% of the producers sold only on farm outlets while 72% delivered their products to customers within the area of less than 100 km around the farm location.

From the data survey, it was noted that producers want to expand their marketing channels and distribute their products to wider area but they have the logistic problem. Taking this into consideration network integration was considered to increase potential market for producers (see Figure 8). In addition to the customers in the vicinity of the producers, 17 towns/cities and 19 existing LSFDCs (see Figure 4(b)) were identified as potential markets in the surrounding region of each CC.

About 84% of existing LSFDCs are located in the southern and central regions i.e. 42% in each region (see Figure 4(b)). This makes the proposed network integration more feasible to be implemented in these regions. For example the CCs of mostly populated clusters of producers (CC1, CC3 and CC8) have been surrounded relatively by higher number (4 for each cluster) of LSFDCs (see Table A.6).

4.2 Implication of network integration

4.2.1 Implication on logistics efficiency

In the food and agricultural supply chain, reliable and effective transport systems for supplying food to consumers are essential. Because, in the food distribution system of local food producers, logistics is fragmented and inefficient compromising the sustainability of localized systems and this requires improvement.

Comparing the outputs of the route analysis for the two scenarios, uncoordinated and coordinated collection of products, coordination reduced number of routes, distance, and time. The maximum improvements were 87% for number of routes (for C3), 66% for driving distance (for C1) and 63 % for time (C8). All together, coordinating product transport from farms to CCs reduced the number of routes, driving distance and total time from 81routes, 8935.4 km, and 227.27 hr to 26 routes, 4456.6 km, and 119.25 hr implying total improvements of 68%, 50% and 48% respectively. Previous studies carried out on agricultural goods transport indicated that route optimization can reduce transport distance, time, number of deliveries, number of routes and Green Gas Emissions (Gebresenbet and Ljungberg 2001, Ljungberg, 2006).

About 86% of the clusters could be integrated into the existing LSFDCs with 29 routes connecting CCs and LSFDCs. The distance of the routes varied from 18 km to 135 km. About 48% of these routes are less than 100km.

4.2.2 Implication on environmental issue

In the present study it was noticed that producers of local food run mostly their own vehicles and about half of the vehicle capacity is unutilized. Taking into consideration these facts mentioned above, the proposed network integration indicates towards positive environmental impact by: (i) Reducing number of vehicles to be deployed for produce collection and distribution to customers; (ii) Increasing the utilization level of vehicle loading capacity; (iii) Reducing travel distance, time and fuel by following optimized routes; (iV) Reducing emissions (as the consequence of the facts mentioned above).

4.2.3 Implication on traceability of food quality

For the case of local food, the consumers know who the producers of each produce they purchase are. This increases the confidence of consumers because they mostly rely on those selling the food to keep it safe (Bantham and Oldham, 2003). The network integration also helps to increase the quality of local food produces through improving its traceability. For example, Engelseth (2009) indicated that a “bottom-up” and technically anchored approach could provide direction in developing food supply and product traceability in academia and business practice. An integrated traceability system provides an added layer of food security (Bantham and Oldham, 2003) and the efficiency of product traceability depends on information connectivity (Engelseth, 2009) which might be established more easily within proposed supply network integration.

5 CONCLUSIONS

This study was based on data of local food producers and large scale food distribution centers which were, geographically distributed all over the Sweden. Most of the producers (about 78%) and LSFDCs (about 84%) are located in the southern and central regions. The main production types were meat, egg, dairy products and vegetables. Most of the producers provide meat (by 49%) and vegetables (by 42%).

Regarding the route analysis for the case of delivery from producers to CCs, when compared to scenario-1 (no coordination), the coordinated collection of products in scenario-2 reduced the number of routes, driving distance and total time from 81routes, 8935.4 km, and 227.27 hr to 26 routes, 4456.6 km, and 119.25 hr implying total improvements of 68%, 50% and 47% respectively.

The integrated logistics network was developed by forming clusters of producers and determining their optimum CCs. These CCs could be linked to food producers, food distributors and consumers/retailers. Totally 14 clusters were formed and C1 and C3 were the two mostly populated clusters annexing 14 and 15 farms respectively.

About 86% of the clusters could be integrated into the existing LSFDCs. The logistics network integration approach indicated positive improvements towards logistics efficiency, environmental issue, traceability of food quality, and increasing potential market for local food producers.

In the current study, the locations of the customers of each producer and the existing delivery routes from producers to customers could not be mapped due to the lack of data. Therefore, site specific and more detailed further studies, especially in the southern region where the density of producers is high, have been recommended.

REFERENCES

Aghazadeh, S. 2004. Improving logistics operations across the food industry supply chain. *International Journal of contemporary Hospitality Management, 16(4), 263-268.*

Aronsson, H. and Brodin, M. H. 2006. The environmental impact of changing logistics structures. *The international Journal of Logistics Structures. The international Journal of Logistics Management,* 17 (3), 394-415.

Bantham, A. and Oldham, C. 2003. *Creating value through traceability solutions*. FoodOrigins, Illinois, USA. https://ifama.org/events/conferences/2003/cmsdocs/bantham.PDF. Accessed on 2010-10-03.

Beckeman, M. and Skjöldebrand, C. 2006. Clusters/networks promote food innovations. *Journal of Food engineering,* 79,1418-1425.

Bourlakis, M. A. and Bourlakis, C. A. 2001. Deliberate and emergent logistics strategies in food retailing: A case study of the Greek multiple food retail sector. *Supply Chain Management: An International Journal,*6(4), 189-200.

Brewer, A. M., Button, K. J. and Hensher, D. A. 2001. *Handbook of Logistics and Supply-Chain Management: Handbook in Transport Volume 2*. Pergamon Press, London.

Brimer, R. C. 1995. Logistics networking: A consideration of the components essential to an integrated logistics support network. *Logistics Information Management, 8(4), 1995.*

Christopher, M. 2005. *Logistics and Supply Chain Management: Creating value-Adding Networks, third edition*. Prentice Hall, Great Britain.

Chuang, P. 2002. A QFD approach for distribution's location model. *International Journal of Quality and Reliability Management,*19(8), 1037-1054.

Collins, A., Henchion, M. and O'Reilly, P. 1999. The impact of coupled-consolidation: experiences from the Irish food industry. *Supply chain management,* 4(2), 102-111.

Denis, O. 1997. Logistics in Europe - the vision and the reality. *Logistics Information Management,* 10(1), 14-19.

DPS 2004. *Route LogiX Professional V5.0.4.39.* Distribution Planning Software Ltd. Halesowen, UK.

Engelseth, P. 2009. Food product traceability and supply network integration. *Journal of Business & Industrial Marketing,* 24(5), 421-430.

ESRI 2008. ArcGIS Desktop Help. Environmental Systems Research Institute, 380 New York Street, Redlands, CA 92373-8100, USA.

Fuente, D. and Lozano, J. 1998. Determining warehouse number and location in Spain by cluster analysis. *International Journal of Physical Distribution and Logistics Management,* 28(1), 68-79.

Gebresenbet, G. and Ljungberg, D. 2001. Coordination and route optimization of agricultural goods transport to attenuate environmental impact. *Journal of Agricultural Engineering Research* 80(4), 329-342.

Gebresenbet, G. 2006. *Promoting effective goods distribution through route optimization and coordination to attenuate environmental impact*: *the case of Uppsala*. (Unpublished project report, Swedish University of Agricultural Sciences).

Gimenez, C. 2006. Logistics Integration processes in the food industry. *International Journal of Physical Distribution and Logistics Management,* 36(3), 231-249.

Groothedde, B., Ruijgrok, C. and Tavasszy, L. 2005. Towards collaborative, intermodal hub networks: A case study in the fast moving consumer goods market. *Transportation Research Part E*, 41, 567-583.

Hernåndez, T. and Bennison, D. 2000. The art and science of retail location decisions. *International Journal of Retail and Distribution Management,* 28 (8), 357-367.

Li, H. and Yu, L. 2005. A GIS-based site selection system for real estate projects. *Construction Innovations,* 5, 231-241.

Ljungberg, D. 2006. *Effective Transport systems in Food and Agricultural Supply Chains for Improved Economy, Environment and Quality*. Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala, ISSN 1652-6880.

Morgan, C. 2007. Supply network performance measurement: future challenges. *The International Journal of Logistics Management*, 18(2), 255- 273.

Oum, T. H. and Park, J. 2003. Multinational firms' location preference for regional distribution centers: Focus on the Northeast Asian region. *Transportation Research part E,* 40, 101-121.

Russell, R. S. and Taylor, B. W. 2009. *Operations Management Along the Supply Chain: Sixth edition*. John wiley and Sons (Asia) pte Ltd.

Saltmarsh, N. and Wakeman, T. 2004. *Mapping Food Supply Chains and Identifying Local Links in the Broads and Rivers Area of Norfolk*. East Anglia Food Link's Broads and Rivers Food Supply Chain, Research Project report. http://www.eafl.org.uk, accessed on 2010-05-16

Sandberg, E. 2007. Logistics Collaboration in Supply Chains: Practice vs. theory. *The International Journal of Logistics Management,*18 (2), 274-293.

Trienekens, J. H. Hagen, J. M., Beulensc, A. J. M. and Omta, S. W. F. 2003. Innovation through (International) Food Supply Chain Development: A Research Agenda. *International Food and Agribusiness Management Review*, 6(1).

Töyli, J., Häkkinen, L., Ojala, L. and Naula, T. 2008. Logistics and financial Performance: An analysis of 424 Finnish Small and Medium-Sized enterprises. *International Journal of physical distribution and logistics management*, 38(1), 57-80

Wood, S. and Brown, S. 2006. Convenience store location planning and forecasting–a practical research agenda. *International Journal of Retail & Distribution Management*, 35(4) 233-255.

APPENDIX A: Additional Tables

Table A.1. *Coordinates and other important information of producers*

Producer	Latitude [decimal degree]	Longitude [decimal degree]	Route number (Scenario2)	Cluster	County/city	Annual Production [tones]	Annual Revenues [1000SEK]	Average Annual Revenue [1000SEK]
1	55.574	14.003	1	C1	Skåne län	3	99.8	
2	55.662	14.213	1	C1	Skåne län	350	2700	
3	55.585	13.521	1	C1	Skåne län	6	12000	
4	55.582	13.613	1	C1	Skåne län	200	3000	
5	55.833	13.748	1	C1	Skåne län	5	1000	
6	55.574	14.003	1	C1	Skåne län	9	300	
7	55.432	13.118	1	C1	Skåne län	14	950	
8	55.432	13.116	1	C1	Skåne län	2.5	300	
9	55.909	12.701	2	C1	Skåne län	3	600	
10	55.970	13.549	2	C1	Skåne län	5	600	
11	55.919	13.118	2	C1	Skåne län	400	12000	
12	56.008	12.735	2	C1	Skåne län	3	150	
13	56.010	12.728	2	C1	Skåne län	140	16000	
14	56.141	12.624	2	C1	Skåne län	9	300	
	55.781	13.502		CC1		1149.5	49999.8	3571

Producer	Latitude [decimal degree]	Longitude [decimal degree]	Route number (Scenario2)	Cluster	County/city	Annual Production [tones]	Annual Revenues [1000SEK]	Average Annual Revenue [1000SEK]
	55.593	13.024		NT	**Malmö**			
1	56.506	14.813	1	C2	Kronobergs län	85	1500	
2	56.924	14.425	1	C2	Kronobergs län	5	200	
3	56.411	13.844	1	C2	Skåne län	27	1000	
4	56.694	14.349	1	C2	Kronobergs län	5.4	200	
	56.509	14.551		CC2		122.4	2900	725
	56.881	14.803		NT	**Växjö**			
	56.174	14.864		NT	**Karlshamn**			
1	57.014	12.451	2	C3	Hallands län	15	5000	
2	56.675	12.847	1	C3	Hallands län	30	2850	
3	56.673	12.882	1	C3	Hallands län	60	61900	
4	56.752	12.715	1	C3	Hallands län	15	1900	
5	56.824	12.757	1	C3	Hallands län	30	100	
6	56.824	12.757	1	C3	Hallands län	65	10000	
7	56.870	12.766	1	C3	Hallands län	150	115000	
8	56.870	12.766	1	C3	Hallands län	89	12000	
9	57.165	12.729	2	C3	Hallands län	20	1300	
10	56.985	13.518	1	C3	Hallands län	30	100	

Producer	Latitude [decimal degree]	Longitude [decimal degree]	Route number (Scenario2)	Cluster	County/city	Annual Production [tones]	Annual Revenues [1000SEK]	Average Annual Revenue [1000SEK]
11	56.969	12.450	2	C3	Hallands län	25	40000	
12	56.972	12.449	2	C3	Hallands län	16	10000	
13	57.013	12.453	2	C3	Hallands län	65	1000	
14	57.122	12.289	2	C3	Hallands län	50	110000	
15	57.053	12.290	2	C3	Hallands län	55	2000	
	56.902	12.683		CC3		715	373150	24877
	57.117	12.267		NT	**Varberg**			
1	58.044	16.433	2	C4	Kalmar län	75	5000	
2	58.318	16.044	1	C4	Östergötlands län	200	1500	
3	58.038	16.448	2	C4	Kalmar län	1	1000	
4	58.039	16.447	2	C4	Kalmar län	12	5000	
	58.223	15.492		CC4		288	12500	3125
	58.406	15.627		NT	**Linköping**			
1	58.506	13.337	2	C5	Västra Götalands län	2	500	
2	58.564	13.085	2	C5	Västra Götalands län	90	9000	
3	58.365	12.726	1	C5	Västra Götalands län	5	500	
4	58.224	12.883	1	C5	Västra Götalands län	15	150	
5	58.420	13.725	2	C5	Västra Götalands län	0.8	800	

Producer	Latitude [decimal degree]	Longitude [decimal degree]	Route number (Scenario2)	Cluster	County/city	Annual Production [tones]	Annual Revenues [1000SEK]	Average Annual Revenue [1000SEK]
	58.509	13.048		CC5		112.8	10950	2190
	58.504	13.155		NT	**Lidköping**			
1	59.008	13.136	1	C6	Värmlands län	270	9000	
2	59.364	13.230	1	C6	Värmlands län	1040	5000	
3	59.187	12.369	1	C6	Värmlands län	30	1000	
4	59.366	13.999	2	C6	Värmlands län	30	1600	
5	59.316	14.121	2	C6	Värmlands län	2	200	
6	59.444	13.881	2	C6	Värmlands län	300	4000	
	59.319	13.277		CC6		1672	20800	3467
	59.399	13.529		NT	**Karlstad**			
1	60.348	14.306	2	C7	Dalarnas län	12	660	
2	60.068	13.793	1	C7	Värmlands län	15	1000	
	60.190	14.023		CC7		27	1660	830
	60.500	15.436		NT	**Borlänge**			
1	59.521	16.382	1	C8	Västmanlands län	8	300	
2	59.687	16.918	1	C8	Uppsala län	3.5	250	
3	59.610	16.958	1	C8	Uppsala län	42	2500	
4	59.753	17.246	1	C8	Uppsala län	20	1100	

Producer	Latitude [decimal degree]	Longitude [decimal degree]	Route number (Scenario2)	Cluster	County/city	Annual Production [tones]	Annual Revenues [1000SEK]	Average Annual Revenue [1000SEK]
5	60.029	17.530	2	C8	Uppsala län	100	500	
6	60.297	17.395	2	C8	Uppsala län	5	600	
7	60.307	17.395	2	C8	Uppsala län	1.5	500	
8	60.237	16.251	2	C8	Dalarnas län	20	300	
9	60.230	16.011	2	C8	Dalarnas län	7	300	
10	60.231	16.016	2	C8	Dalarnas län	7.5	300	
	59.937	17.112		CC8		214.5	6650	665
	59.627	16.550		NT	**Väströs**			
	59.856	17.634		NT	**Uppsala**			
1	62.917	15.158	2	C9	Jämtlands län	3	45	
2	62.680	15.353	1	C9	Jämtlands län	20	3000	
3	62.941	13.930	2	C9	Jämtlands län	7	1000	
4	62.365	16.284	1	C9	Jämtlands län	1	100	
	62.751	15.039		CC9		31	4145	1036
	63.170	14.685		NT	**Östersund**			
1	63.079	17.828	2	C10	Västernorrlands län	20	150	
2	62.905	17.593	2	C10	Västernorrlands län	2.5	50	
3	63.390	17.728	1	C10	Västernorrlands län	160	250	

Producer	Latitude [decimal degree]	Longitude [decimal degree]	Route number (Scenario2)	Cluster	County/city	Annual Production [tones]	Annual Revenues [1000SEK]	Average Annual Revenue [1000SEK]
4	62.917	18.332	2	C10	Västernorrlands län	25	150	
5	63.232	18.942	2	C10	Västernorrlands län	5	35	
	63.297	17.830		CC10		212.5	635	127
	63.298	18.711		NT	**Örnsköldsvik**			
1	63.997	20.058	1	C11	Västerbottens län	3	100	
2	63.712	18.875	1	C11	Västernorrlands län	6	800	
3	63.665	19.512	1	C11	Västernorrlands län	150	800	
4	63.943	19.970	1	C11	Västerbottens län	14	600	
5	63.712	18.874	1	C11	Västernorrlands län	10	400	
6	63.934	19.229	1	C11	Västerbottens län	4	400	
7	63.665	19.512	1	C11	Västerbottens län	125	800	
	63.665	19.512		CC11		37	3900	557
	63.831	20.275		NT	**Umeå**			
1	65.207	18.724	2	C12	Västerbottens län	3	125	
2	64.934	19.143	1	C12	Västerbottens län	1	50	
	65.137	18.832		CC12		4	175	88
	64.763	20.988		NT	**Skellefteå**			
1	57.550	13.485	2	C13	Västra Götalands län	5	90	

Producer	Latitude [decimal degree]	Longitude [decimal degree]	Route number (Scenario2)	Cluster	County/city	Annual Production [tones]	Annual Revenues [1000SEK]	Average Annual Revenue [1000SEK]
2	57.680	14.155	2	C13	Jönköpings län	8	144	
3	57.511	13.367	1	C13	Västra Götalands län	87	10440	
	57.526	13.434		CC13		100	10674	3558
	57.730	12.945		NT	**Börås**			
	57.754	14.131		NT	**Jönköping**			
1	59.170	14.965	1	C14	Örebro län	0.8	20	
2	59.373	15.033	2	C14	Örebro län	3	250	
	59.329	15.017		CC14		3.8	270	135
	59.282	15.209		NT	**Örebro**			
1				Single	Stockholms län	8	500	
2				Single	Södermanlands län	1	45	
3				Single	Jämtlands län	5	900	
4				Single	Västerbottens län	70	1500	
5				Single	Värmlands län	5.1	700	
6				Single	Kalmar län	5	3500	
7				Single	Gävleborgs län	1.5	500	
						95.5	7645	1092

NT= Nearby Town

Table A.2. *Distribution of sample data in terms of annual revenue*

Revenue range In 1000SEK	Number of producers	Percentage in the sample
20 up to <100	8	9
100 up to <500	25	28
500 up to <1000	18	20
1000 up to <5000	22	24
5000 up to <10000	6	7
10000 up to <50000	8	9
50000 up to <100000	1	1
≥100000	2	2
Total	90	100

Table A.3. *Distance and time estimated for Scenario1*

Cluster	No of producers	Driving Distance [km]	Driving Time[hr:min]	Loding &Unloading [hr:min]	Total Time[hr:min]
CC1	14	1450	18:50	9:20	28:10
CC2	4	407	8:16	3:40	11:56
CC3	15	902	20:42	12:00	32:42
CC4	4	746	12:46	3:40	16:26
CC5	5	331	6:38	4:20	10:58
CC6	6	738	15:28	5:00	20:28
CC7	2	214	4:46	1:20	6:06
CC8	10	1610	34:06	6:40	40:46
CC9	4	596	12:40	2:40	15:20
CC10	5	828	13:32	3:20	16:52
CC11	7	703	12:12	2:40	14:52
CC12	2	138	2:08	1:20	3:28
CC13	3	194	4:10	2:00	6:10
CC14	2	78	1:42	1:20	3:02
Total	83	8935	167:56	59:20	227:16

Table A.4. *Distance and time estimated for Scenario2*

Cluster	Route	Number of producers	Driving Distance[km]	Driving Time[hr:min]	Loading & Unloading Time[hr:min]	Total Time [hr:min]
C1	1	8	270	04:08	03:10	07:18
C1	2	6	226	04:28	02:30	06:58
C2	1	4	279	04:49	01:50	06:39
C3	1	8	197	03:14	03:10	06:24
C3	2	7	157	02:34	02:50	05:24
C4	1	1	131	02:15	00:40	02:55
C4	2	3	206	02:58	01:30	04:28
C5	1	2	112	01:37	01:10	02:47
C5	2	3	124	02:11	01:30	03:41
C6	1	3	242	05:00	01:30	06:30
C6	2	3	159	03:07	01:30	04:37
C7	1	1	107	02:17	00:40	02:57
C7	2	1	107	02:41	00:40	03:21
C8	1	4	237	04:50	01:50	06:40
C8	2	6	347	05:58	02:30	08:28
C9	1	2	222	04:15	01:10	05:25
C9	2	2	269	05:21	01:10	06:31
C10	1	1	37	00:52	00:40	01:32
C10	2	4	354	05:31	01:50	07:21
C11	1	7	282	04:38	02:50	07:28
C12	1	1	107	01:35	00:40	02:15
C12	2	1	32	00:30	00:40	01:10
C13	1	1	21	00:59	00:40	01:39
C13	2	2	155	02:34	01:10	03:44
C14	1	1	59	01:16	00:40	01:56
C14	2	1	18	00:39	00:40	01:19
Total	38	83	4457	80:17	39:10	119:15

Table A.5. *Distance and Time estimated for nearest towns/cities*

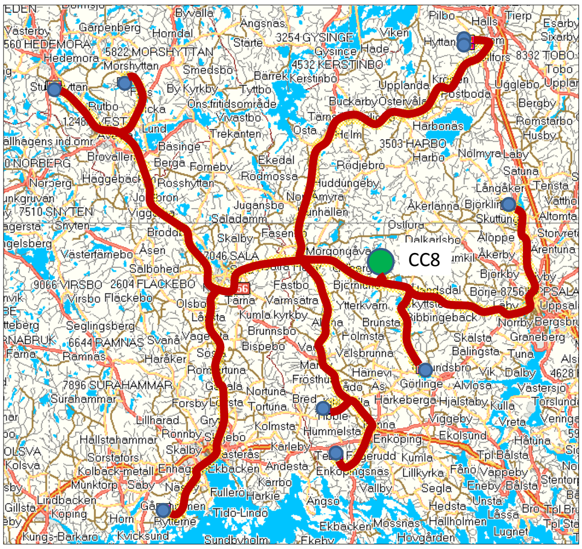
Cluster	Nearest Town	Driving Distance [km]	Driving Time [hr:min]	Loading & Unloading [hr:min]	Total Time [hr:min]
CC1	MALMÖ	86	00:54	01:00	01:54
CC2	VÄXJÖ	137	02:00	01:00	03:00
CC2	KARLSHAMN	120	02:00	01:00	03:00
CC3	VARBERG	93	01:22	01:00	02:22
CC4	LINKÖPING	58	01:02	01:00	02:02
CC5	LIDKÖPING	19	00:30	01:00	01:30
CC6	KARLSTAD	64	01:32	01:00	02:32
CC7	BORLÄNGE	254	03:46	01:00	04:46
CC8	VÄSTERÅS	147	02:22	01:00	03:22
CC8	UPPSALA	76	01:38	01:00	02:38
CC9	ÖSTERSUND	153	02:48	01:00	03:48
CC10	ÖRNSKÖLDSVIK	142	02:10	01:00	03:10
CC11	UMEÅ	139	01:50	01:00	02:50
CC12	SKELLEFTEÅ	244	02:54	01:00	03:54
CC13	BORÅS	99	01:36	01:00	02:36
CC13	JÖNKÖPING	131	02:00	01:00	03:00
CC14	ÖREBRO	32	00:30	01:00	01:30

Table A.6. *Distance and time from CC to LSFDCs*

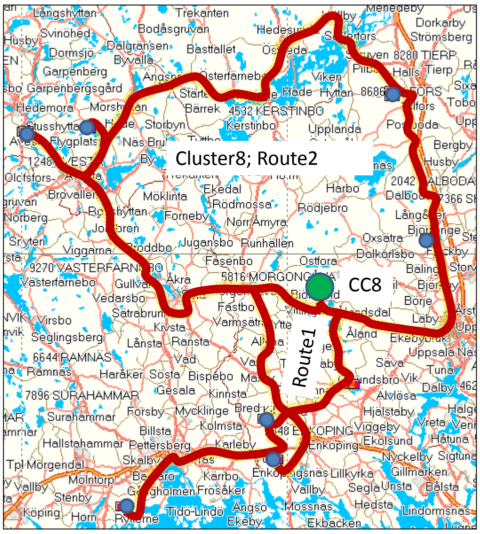
Cluster	Post nr	City	Driving Distance [km]	Driving Time[hr:min]
CC1	24194		-	-
DC-Axfood	25015	Helsinborg	51	00:32
DC-Axfood	28235	Tyringe	59	00:39
DC-Coop	21124	Malmö	36	00:23
DC-ICA	25669	Helsinborg	67	00:45
CC2	34392		-	-
DC-Coop	35250	Växjö	70	00:53
DC-Axfood	28235	Tyringe	86	00:59
CC3	31197		-	-
DC-ICA	25669	Helsinborg	116	01:14
DC-Axfood	25015	Helsinborg	128	01:21
DC-Axfood	28235	Tyringe	130	01:22
DC-Axfood	40126	Göteborg	112	01:08
CC4	59052		-	-
DC-Axfood	55111	Jönköping	121	01:20
DC-ICA	44240	Kungälv	120	01:19
CC5	53157		-	-
DC-ICA	44240	Kungälv	120	01:19
DC-Axfood	40126	Göteborg	129	01:23
DC-Axfood	55111	Jönköping	119	01:19
CC6	66050		-	-
DC-Axfood	70117	Örebro	135	01:29
CC7	78050		-	-
DC-Axfood	78128	Borlänge	81	00:59
CC8	74450		-	-
DC-Coop	72136	Västerås	56	00:39
DC-ICA	72184	Västerås	61	00:42
DC-Coop	19791	Bro	85	01:05
DC-ICA	17671	Järfälla	94	01:02
CC11	91691		-	-
DC-Coop	90137	Umeå	64	00:47

Cluster	Post nr	City	Driving Distance [km]	Driving Time[hr:min]
CC12	93071		-	-
DC-Axfood	93124	Skellefteå	113	01:16
CC13	51454		-	-
DC-Axfood	55111	Jönköping	61	00:46
DC-Axfood	40126	Göteborg	110	01:10
DC-ICA	44240	Kungälv	130	01:23
CC14	71940		-	-
DC-Axfood	70117	Örebro	18	00:13
DC-Coop	72136	Västrås	112	01:10
DC-ICA	72184	Västrås	112	01:11

APPENDIX B: Additional Figures

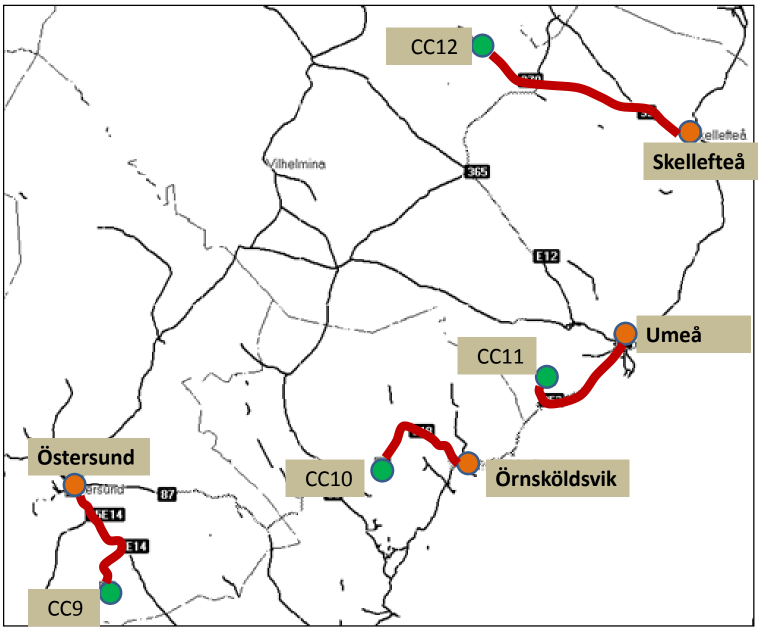


(a). Routes of Scenario1; C8

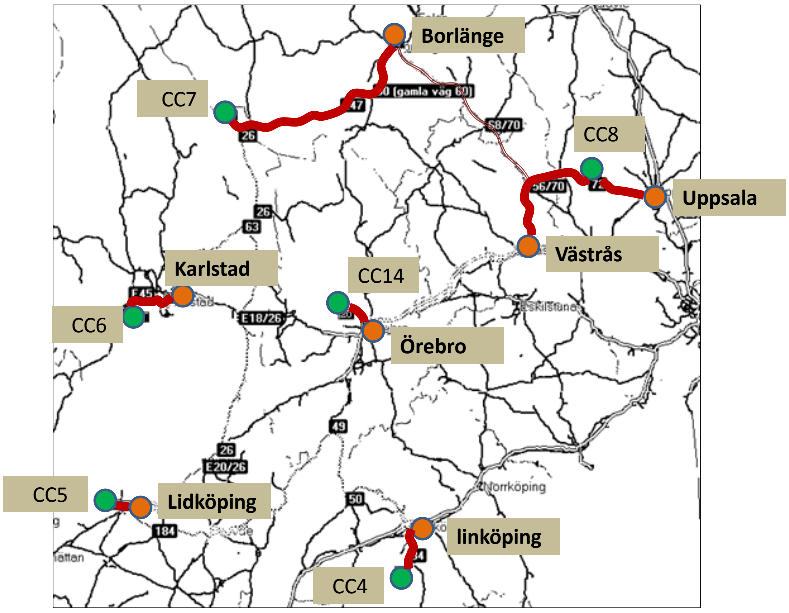


(b). Routes of Scenario2; C8

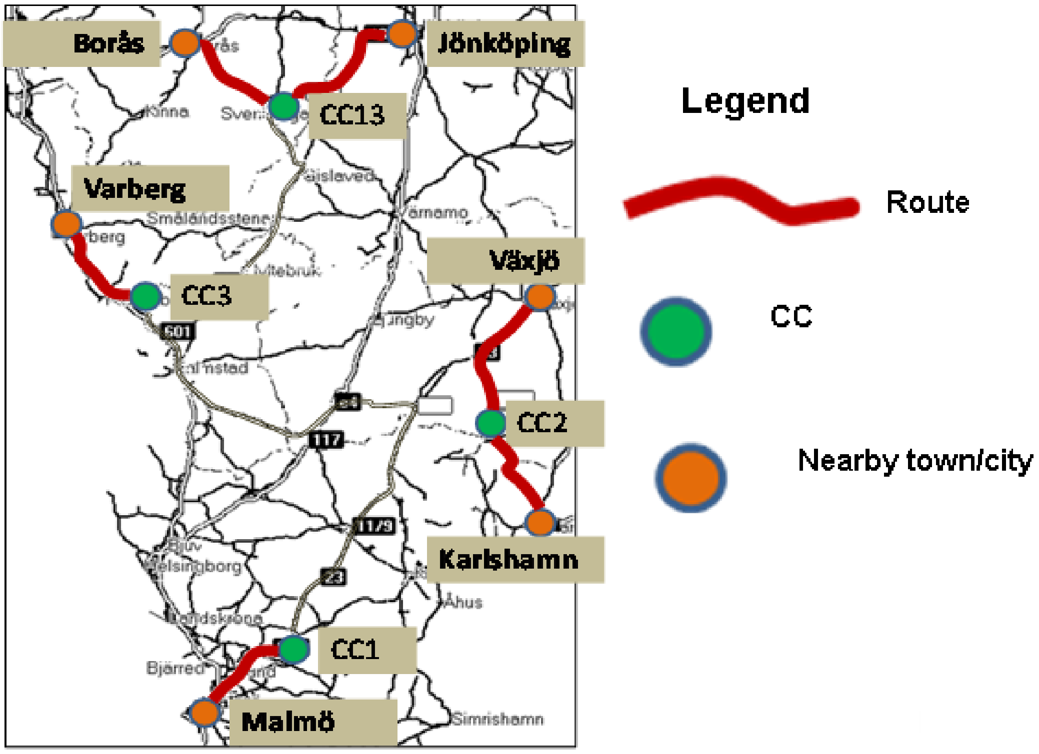
Figure B.1. Map illustrating: (a) Routes for uncoordinated collection of products to CC8. (b) Routes designed for coordinated collection of products to CC8



(a). Northern region



(b). Central region



(c). Southern region

Figure B.2. Towns/Cities close to CCs and considered as potential market.

APPENDIX C: Questionnaires

Questionnaires related to Food products:

1. What type of products do you produce?
2. To which branch of food products belong your products? (example egg product, dairy products, fruits and vegetables etc)
3. Where is location the production?
4. Where is the place for processing and packing?
5. In which months is delivery possible without storage?
6. In which months are products delivered after storage?
7. What is the total production quantity?
8. What is the revenue in Swedish kronor per year?
9. What is the distribution cost as percentage of revenue?

Questionnaires related to distribution of products:

10. Where do you sell the products?
11. Who are your costumers and which selling channels do you use?
12. How do you distribute the products?
13. What is the load rate when the vehicle leaves the production place for distribution?
14. What is the frequency of distribution?
15. What types of problems are there in relation to transport?

SLU
Institutionen för energi och teknik
Box 7032
750 07 UPPSALA
Tel. 018-67 10 00
Pdf.fil: www.et.slu.se

SLU
Department of Energy and Technology
Box 7032
SE-750 07 UPPSALA
SWEDEN
Phone +46 18 671000