

# Integrated Logistics Network for the Supply Chain of Locally Produced Food, Part I: Location and Route Optimization Analyses

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## ABSTRACT

*Due to a growing interest in locally produced food (LPF), there is a tendency of promoting local food systems. The objective of this study was to investigate the existing flow of LPF from producers to consumers and develop a coordinated and efficient distribution system for producers in Halland region, Sweden. An integrated logistics network (ILN) embracing producers, retailers, a collection centre (CC) and a distribution centre (DC) was proposed. Data collection, location analysis and route optimization analysis were conducted. Geographic information system (GIS) and Route LogiX software were utilized for the analyses. Four scenarios of food distribution were identified and analyzed. When compared to the existing system, the best scenario improved transport distance, time and number of routes up to 93%, 92% and 87% respectively. The distribution of LPF was integrated into large scale food distribution channel (LSFDC) and this could increase the sustainability of local food system.*

**Keywords:** *Locally Produced Food, Location Analysis, Route Optimization, Collection Centre, Distribution Centre*

## 1. Introduction

The globalizations of industries and low prices in transport sector have increased the distance between the place of production of goods and the consumer [1]. In the agriculture sector, globalization of food production has considerably affected the food supply system by increasing tonne-kilometers, increasing emissions of greenhouse gases and disconnecting local food producers and consumers [2]. Since this disconnection adversely affects smaller producers, their environment, societies and culture, there is a tendency of reconnecting local food producers and consumers.

The growing interest in LPF [1,3-5] has relation with increased environmental and food quality issues and attracted many consumers and researchers. The existing studies on the benefits and impacts of LPF are partial and few in number. Therefore, more studies are required in order to draw conclusions about economical, social and environmental benefits of the local food system and to assess the possible constraints [3].

Although there is no generally agreed definition [3],

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LPF can be characterized by the proximity of production place to the consumers [5]. In terms of distance, usually there is a limit, e.g. 160 km in UK [1,3] and 250 km in Sweden [1]. In addition to geographical distance, LPF is also considered as food which meets a number of criteria such as animal welfare, employment, fair trading relations, producer profitability, health, cultural and environmental issues [3]. In the current study, LPF refers to food produced and consumed mostly within particular geographical area and also distributed within the country.

There are many advantages associated with local food system. The main advantages [1,2,6] are:

- Economic advantages: it supplies products that have more values such as freshness, high quality and safety; it increases direct sale to consumers and strengthens the local economy.
- Social advantages: It increases employment opportunities in rural regions, enhances the local tourism, and promotes community integration.
- Environmental advantages: It reduces transport distance which in turn reduces emissions, and it minimizes the use of packaging materials.

However, there are also constraints associated with

local food production. The production can be more labour intensive which might increase the cost to the consumer, running and maintenance can be more expensive and transportation can be energy inefficient [1]. But, the producers can work together (through producers' network) and be cost effective by sharing resources and co-operating in marketing schemes [1].

Due to the increased demand for LPF, there is an interest to raise the profile of LPF and bring farmers and consumers closer together [7]. This is underway by encouraging the purchase of LPF and developing systems for marketing, distributing and selling LPF. In Sweden farm shops and farmers' markets have been ways to local food market promoting social interaction of local food producers with the consumers and their fellow producers while the consumers are willing to support the local producers by buying their products [1]. But there is also negative aspect of farmers' market. For example a case study in Sweden indicated that half of the people attending the farmers' markets drive their own cars leading to more congestion and greenhouse gas emission [1]. Inefficient logistics activities, fragmented communication messages and lack of resources to effectively provide information about food and farming to consumers are the main problems noticed in the case of local food systems [7]. This indicates the need of a coordinated distribution of LPF using an integrated approach.

Although collaboration improves logistics performance [8-11] effective logistics collaboration in the food delivery system can be possible through integrated logistics network (ILN). A network of food suppliers has a collective responsibility to supply food through managing flows of food products and providing information about the food products and relevant features of food supply such as food quality and origin [12]. Although, the need for food product traceability is becoming increasingly a global issue, developing food product traceability systems has been a major challenge both technically and economically [2,12]. Information connectivity is aspect of network integration that creates foundation for tracing products [12]. In such a network, optimally located and centralized warehousing and efficient management of logistics services as well as consolidation of goods are essential [8,13]. For this purpose location analysis and route optimization analysis are required.

Optimizing the location of distribution centers or hubs improves the efficiencies of transportation system, and it has the dynamic implication over time [13]. Since a hub system reduces cost, distance and time by avoiding direct routing between all origin-destination pairs, in the facility (e.g. CC) location analysis, costs and distances are important quantitative attributes to be considered. Some other attributes that influence the location decision [13,

14] are: 1) access to production point, markets and/or distribution centers; 2) potential development of the region; 3) availability of labour and professional staff; 4) availability of transportation facilities; 5) availability, quality, and price of utilities and services; 6) governmental considerations; 7) environmental and ecological considerations; and 8) cost, size, zoning, and topography of available land.

Route optimization analysis is an important means to create improved goods distribution systems. It has been used in different areas, such as forest harvesting [15], solid waste collection [16] and agricultural goods transport [17], to reduce operational costs, and emissions.

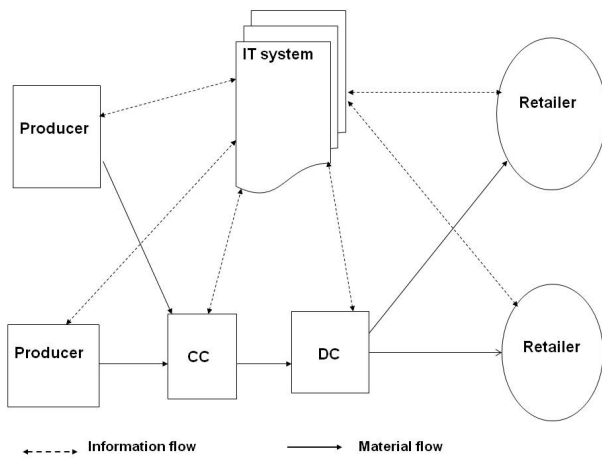
In the existing situation, the producers transport their products directly to their customers. Such uncoordinated distribution system is not efficient. In addition to this, there are other barriers that reduce the sales of producers, e.g. most consumers want to buy all the food in one place [18], the quantity and price of LPF fluctuates seasonally, the supply size and quality of products are limited in some cases [5,19]. This makes it difficult for a single farmer or smaller shop (especially in big cities) to compete with the big retail chains [5].

In order to solve these problems, new and better form of food distribution is required [10]. One of the possible new alternatives is integrating the logistics activities via hub network [20] enabling the formation of local food distribution lines that operate in conjunction with, or within, a larger conventional food business [5,21]. In this study, it was intended to study this innovative concept in depth with practical application in Halland region. For this purpose, ILN that connects producers, retailers, CC, and DC was formed to efficiently coordinate the logistics activities through integrated approach, where the distribution of products from producers is to be coordinated through CC and DC and supported with information technology (IT) system as shown in **Figure 1**.

The main objective of this study was to investigate the existing flow of food products from producers to consumers and to develop a coordinated and efficient food distribution system for local food producers participating in this pilot project in Halland region, Sweden. The specific objectives were to:

- 1) collect relevant data and organise in data analyzing tools such as GIS and Route LogiX software;
- 2) map the producers and delivery points (retailers/customers);
- 3) determine the optimum location of CC and DC;
- 4) carry out route optimization analysis;
- 5) integrate the distribution of locally produced food into the large scale food distribution centre.

In summary, there is a tendency of reconnecting local food producers and consumers due to the growing inter-



**Figure 1.** The concept of integrated logistics network in Halland project.

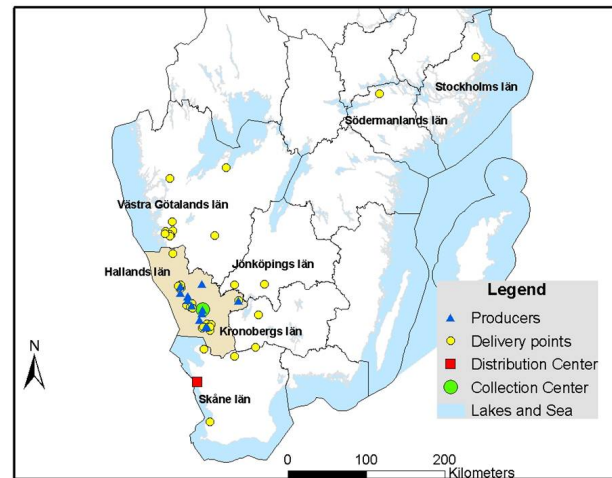
est in LPF. In the existing situation, the distribution of LPF is uncoordinated and not efficient. Therefore, forming ILN and planning optimized delivery routes for LPF are essential to promote efficient and effective logistics services for small scale food producers and improve the sustainability of local food supply system in the Halland region. The ILN is useful to solve the problems related to logistics, access to larger market, and access to information on the origin and quality of the food products. The results of this study confirmed this. The findings indicated that the implementation of ILN, in the delivery system of LPF, could reduce the transport distance, time and number of routes (number of vehicles) very significantly.

This paper is structured as follows. In Section 2, the materials and methods are described. In Section 3, the results are presented. In Section 4, the findings have been discussed. And in Section 5, the major conclusions and recommendations for future research have been given.

## 2. Materials and Methods

### 2.1. Project Area, Producers and Delivery Points

The project area is located in Halland County which is situated between 56°19'07"N and 57°35'56"N latitude and 11°27'37"E and 13°42'08"E longitude (see **Figure 2**). There were 14 producers considered in this study and all of them are located in Halland County. For four of them, only their addresses and annual production quantities were available. The remaining ten producers had information including the addresses of their respective delivery points. There were 44 (see **Table 1**) delivery points (addresses of existing customers) and most of them are located in Västra Götaland, Halland and Skåne counties (see **Figure 2**).



**Figure 2.** Map of south Sweden, illustrating locations of producers, delivery points, CC and DC.

### 2.2. Data Collection

Data was collected through questionnaires and interviews. The questionnaire was structured and sent to all producers. The collected data consisted of producer and customer addresses, frequency of delivery, annual production quantity, type of products, annual revenue, distribution cost as percentage of revenues and additional information on product distribution. Some of these data (e.g. annual revenue and distribution cost) are to be analyzed and reported in the part II of this paper.

### 2.3. Location Analysis

#### 2.3.1. Optimum Location of Food Collection Center

Two methods were employed to determine the best location of the CC. The first method was Centre-of-Gravity technique and the second method was Load-Distance technique. The mathematical equations of these techniques have been described by [22]. The techniques optimize the location of a facility such as CC by minimizing the transport distance and transport time, leading to economical and environmental benefits.

In the first method, the optimum location of CC was determined using the distance goods transported and weight of the delivered products [22]. The method uses straight line distances (between producer and CC) based on the coordinates of each producer and CC, on the digital map. The coordinates of the 14 producers, in relation to that of CC, and their annual production quantities were used in this analysis.

The second method is used when different options of locations are suggested, and the product of load and distance is used as measuring value. In the current case, three locations were suggested, and load-distance measuring value was determined for each. Finally, the loca-

**Table 1. Producers, their production quantity and number of delivery points.**

Description	Producers													
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
Quantity[t year <sup>-1</sup> ]	20	55	25	150	15	16	89	65	30	30	65	30	60	50
No. of delivery points	7	6	3	5	2	2	5	5	4	5	no info*	no info	no info	no info

\*-no information on number of delivery points was obtained

tion with lowest value of the summation of the load- distance value was selected. The actual road distances were calculated with Route LogiX software [23] and the annual production quantity was considered as load value.

One of large scale food distribution centers found in the region of these producers was chosen to serve as DC for the LPF. This DC is located in Helsingborg city and owned by one of the LSFDCs in Sweden. From the CC, the LPF are to be transported to distribution centre (DC).

**2.3.2. Mapping the Production and Delivery Points, CC and DC**

First, the longitude and latitude coordinates were determined for each producer, delivery point, and DC based on their postcode and additional geographical information obtained from digital database. The coordinates of CC were determined as described above. Then all the identified locations were mapped using ArcMAP of GIS software [24]. A point shape files representing the geographic location of these places were created and displayed on the map (see Figure 2).

**2.4. Scenarios for Collection and Distribution of Locally Produced Food**

Coordination within food supply chains is essential for the effectiveness and efficiency of chains in the competitive environment and coordinative structures can be organised in different ways [25]. In the current study, different scenarios were considered to realize such coordination. In the coordination process different routes were created using the digital maps which enable the visualization of the production and delivery points in relation to CC and DC. The route optimization analysis was carried out using RoutelogiX software which has most powerful vehicle routing including optimization [23]. It finds optimized routes by minimizing driving distance and time, which in turn reduces transport cost and emission of green house gases. Since this software handles planning of one vehicle at a time, each of the routes formed in this study was optimized separately [23].

For detailed analysis, four scenarios were set carefully taking into consideration the relations between the producers, the delivery points, CC and DC. The delivery frequency and quantity per tour were also taken into consideration based on the available information.

**2.4.1. Scenario 1: When Producers Distribute Their Products**

In this case, all producers deliver their produces to their

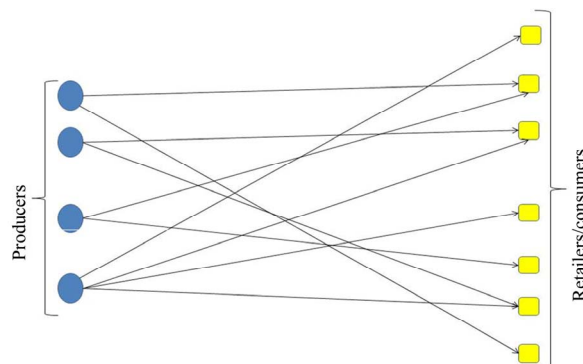
respective customers (retailers) in a single or more routes depending on the location and number of their customers/delivery points (see Figure 3). This scenario is similar to current distribution practice. Since there is no detail information concerning the distribution route for each producer (only the locations of customers were available) product delivery route was created for each producer with the assumption that deliveries to customers which are very close to each other can be done by the same route. Totally 23 possible routes were formed and analyzed under this scenario.

**2.4.2. Scenario 2: Collection by Producers and Distribution by DC**

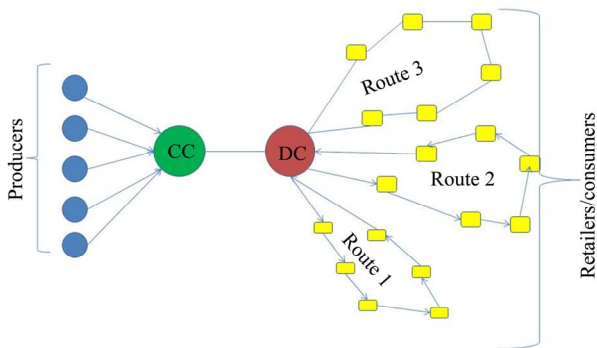
Scenario 2 includes three parts of transporting products from producers to retailers. These are transporting from producers to CC, from CC to DC and from DC to delivery points (see Figure 4). Under this Scenario two options, Option I and Option II, were considered.

Option I: When distribution of food products from DC to retailers is to be treated separately at DC *i.e.* assigning vehicles that distribute only LPF of the producers under consideration. For this purpose, 5 distribution routes were designed where the number of delivery points served by a single route varied from 2 to 12.

Option II: An Integrated distribution: In this case, transporting LPF from producers to CC and from CC to DC is similar to that of Option I. However, the delivery from DC to delivery points was considered to be integrated into the existing distribution routes of LSFDC. It was also assumed that the products could be delivered only by utilizing the empty space of the trucks in the LSFDC as about 30 - 40% of loading capacity of these



**Figure 3. Fragmented distribution in Scenario 1.**



**Figure 4. Uncoordinated collection and coordinated distribution for Scenario 2 (Option I).**

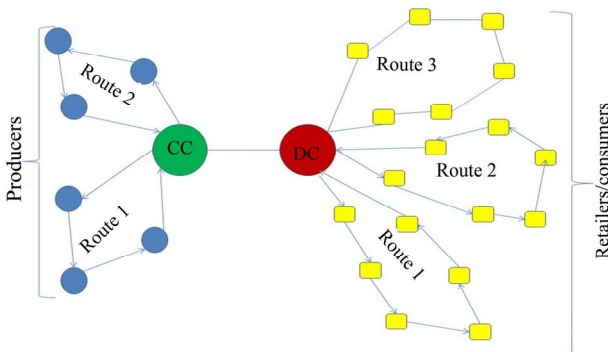
trucks is usually unutilized.

**2.4.3. Scenario 3: Collection by CC and Distribution by DC**

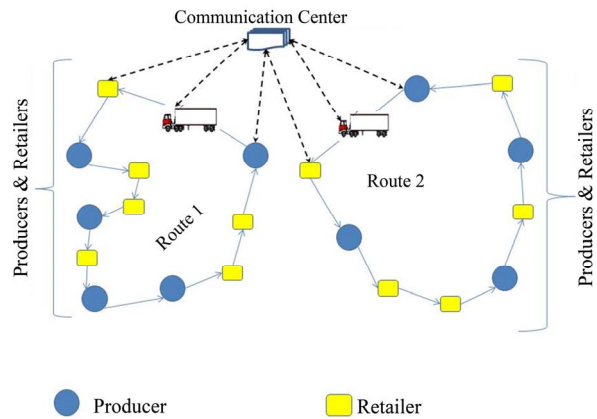
In Scenario 3, the collection of products to CC and delivery to DC were considered to be coordinated and managed by the CC and for this two routes were created (see **Figure 5**). Similar to scenario 2, in scenario 3, two options were considered for distribution from DC to consumers/retailers.

**2.4.4. Scenario 4: Integrated Collection and Distribution**

In Scenario 4, both collection and distribution of products were to be coordinated in every route. This coordination is to be performed by centralised management with support of IT system, where the drivers receive information from the communication centre and collect the products from the producers while delivering to the retailers at the same time (see **Figure 6**). This can be practical by furnishing the trucks with different compartments for different products being collected and delivered. In this case, the task is to pick the products from producers in a route and deliver to the retailer in the same route. Four routes were created based on the geographical



**Figure 5. Coordinated collection and coordinated distribution for Scenario 3 (Option I).**



**Figure 6. The concept of coordinated collection and distribution (scenario 4).**

location of producers and delivery points *i.e.* assigning producers and consumers close to each other, on the same route.

Concerning the vehicles, in scenario 1 (existing system) and in the collection part of scenario 2, the producers could use light transport cars and passenger cars. In the option I (of scenario 2 and scenario 3) and in scenario 4 it was assumed that light trucks with loading capacity up to 3.5 t would be assigned. In option II (of scenario 2 and scenario 3) it was assumed that light trucks (for collection and transporting to DC) and heavy trucks (about 30 - 40% of the capacity of trucks owned by LSFDC) would be used for further distribution from DC.

**3. Results**

**3.1. Investigation of Producers and Product Delivery Points**

All the producers of LPF considered in this study were located within the radius of 50km from CC, within Halland County (see **Figure 2**) while most of their existing customers were found within the radius of 180km from CC. Out of 44 delivery points, 22 were found in Halland (50%) and 20 delivery points were located in the adjoining counties (46%). Only 2 delivery points were in non adjoining counties.

Two of these delivery points, Norrtälje (within Stockholm County) and Eskilstuna (within Södermanland County) are far from both CC and DC (see **Figure 2**). Norrtälje is the furthest away, 625 km from DC and 554 km from CC while Eskilstuna is the second furthest away, 520 km from DC and 443 km from CC. Delivery to Norrtälje was only once per week, while delivery to Eskilstuna was 5 times per week.

**Table 1** reports the number of delivery points for 10 of the producers and the number varied from 2 to 7. Totally,



the 14 producers produce 700 tons per year. For each producer the quantity varied from 15 tons to 150 tons per year with mean value of 50 tons per year.

The largest product type was fruits and vegetables as about 33% of the producers supplied fruits and vegetables. About 25% supplied meat while the grain products, egg and dairy products were supplied by 17%, 17% and 8% of producers respectively. The producers were selling about 63% of the products within their own county (see part II). The producers used three means to transport their product to customers in the existing distribution practice (see **Figure 7**), *i.e.* using their own vehicles (75%), working with transport companies (68%) and cooperating with other producers (16%) (see **Figure 7**).

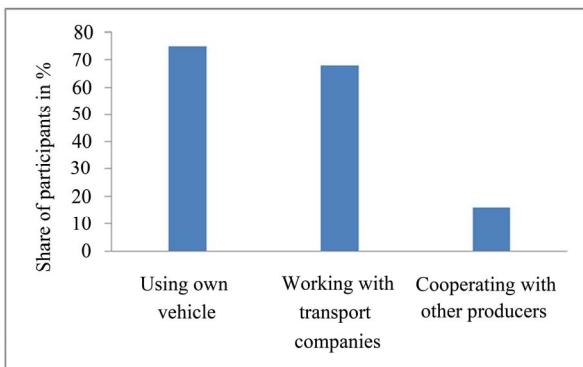
### 3.2. Location and Route Optimization Analyses

The location analyses conducted using Centre-of-Gravity and Load-Distance techniques showed that the optimum location of the CC was at place called Slöinge with coordinates of 56° 55'15"N latitude and 12° 34'15"E longitude. The geographical location of the DC was at 56° 02'56"N latitude and 12° 43'08"E longitude which is located in Helsingborg city, about 208 km away from CC.

Regarding the route optimization analysis, 23 routes were created and analyzed in scenario 1. The results indicated that the simulated driving distances and times varied from 56 km to 1554 km and from 57 min to 17 hr respectively. For the scenario 1, total driving distance was 6159 km while total driving time was about 69 hr.

In scenario 2, the driving distance and time were simulated for each producer in the case of food collection to CC. For two producers, the driving distance and time were considered to be zero, because they were located at the same place as CC. For the rest of producers, the simulated driving distance varied from 9 km to 123 km while the driving time varied from 6 min to 1 hr and 36 min. The total distance and time for the 10 producers were 519 km and 6 hr and 26 min.

For scenario 3, two optimized collection routes were



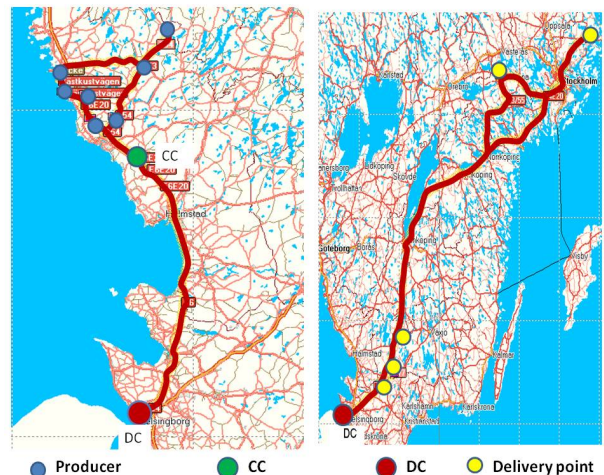
**Figure 7.** Means of transporting LPF in the current practice.

formed and analyzed. The simulated driving distances were 70 km and 169 km for route 1 and route 2 respectively while their driving times were 1hr and 2 hr and 33 min. For the case of food distribution from DC to customers/retailers, 5 routes were formed and optimized in both scenario 2 and scenario 3. The total driving distance and time for the 5 routes were about 3047 km and 34 hr. The distance of each route varied from 425 km to 1352 km while the time varied from 1 hr and 27 min to 14 hr.

Considering both collection and distribution routes together, for scenario 2 (option I), total simulated driving distance and driving time of all routes were about 3774 km and 42 hr respectively. For option II the figures were less *i.e.* about 727 km and 8 hr. Similarly, for scenario 3 the total driving distance and time were about 3493 km and 40 hr for Option I, and about 446 km and 6 hr for option II. **Figure 8** presents examples of simulated routes in scenario 3.

For the scenario 4, the simulated driving distance and time varied from 133 km to 1124 km and from 3 hr to 13 hr. The total driving distance and time and number of routes were 2343 km, 30 hr and 4 routes respectively indicating the improvements of 62%, 57% and 83% (see **Table 2**).

**Table 2** presents the summary of route optimisation analysis for all scenarios. When compared to scenario 1, a significant saving was gained in distance, time and no of routes in the remaining three scenarios. For example, in scenario 2 (option II) the driving distance, driving time and no of routes were reduced from 6159 km, 69 hr and 23 routes to 727 km, 8 hr and 11 routes respectively, indicating improvement of 88% in both distance and time and 48% in no of routes. Similarly, in option II of scenario 3, the total driving distance and time and no of routes were 446 km, 6 hr, and 3 routes with respective im-



**Figure 8.** Examples of simulated routes for Scenario 3. (a) Collection route, (b) Distribution route.

**Table 2. Summary of route optimization analysis.**

Scenario	Driving Distance	Driving Time	No. of routes	Improvement when compared to Scenario 1[%]		
	[km]	[h]		Distance	Time	no. of routes
Scenario 1	6159	69	23	-	-	-
Scenario 2 <i>Option I</i>	3774	42	16	39	39	30
<i>Option II</i>	727	8	11	88	88	48
Scenario 3 <i>Option I</i>	3493	40	8	43	42	65
<i>OptionII</i>	446	6	3	93	91	87
Scenario 4	2343	30	4	62	57	83

provement of 93%, 91% and 87%.

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## 4. Discussion

### 4.1. Main Characteristics of Existing Local Food Delivery System

More than one third of producers produce fruits and vegetables. The physical distribution of such products requires appropriate packaging in order to be transported to end users. This type of packaging can be facilitated by the proposed ILN.

Concerning the food distribution activities, collaboration in the food supply chain was relatively uncommon in the existing system. Only about 16% of the participants had collaboration with other producers so far. Although it was at low level, such an experience of collaboration can play important role in implementing the proposed coordinated distribution system in the Halland region. It was also known that about 68% of participants had experience of working with transport companies. Most of the participants (about 75%) transported their products mainly with their own vehicles indicating that the logistics activities in the existing local food system were uncoordinated and needs improvement.

In the existing system, the frequencies of product delivery to customers varied markedly. Some of the producers delivered ten times a week to its major customers,

while others only delivered during a limited period of the year and/or every other week. This has great impact on the logistics, because it makes the transport demand vary considerably throughout the year.

### 4.2. Location and Route Optimization Analyses

The location analysis enabled determines the best location of CC which facilitated the coordination of product collection and delivery to DC. This CC was determined considering only limited number of producers and their production quantity. If more producers join the system in the future or if the producers increase production quantity the location of optimum CC might change.

The result of rout optimization analysis indicated that the ILN could reduce the transport distance, time and number of routes when compared to the current distribution practices which is similar to scenario 1. Although the improvements were gained in both option I and option II (in scenario 2 and scenario 3), more saving was gained in option II, especially the saving in distance and time was increased by more than 50% when compared to the saving in option I. The saving in scenario 4 was better than that of option I.

Option II of scenario 3, in which the improvements of 93%, 92% and 87% were gained for distance, time and routes respectively, was found to be the best of all scenarios followed by option II of scenario 2. This significant saving in the option II was the result of integrating the distribution of LPF into the conventional LSFDC.

### 4.3. Implications of ILN

#### 4.3.1. Improving Logistics Service

In the existing product delivery system, about 75% of producers use their own vehicles to transport their products *i.e.* the logistics service is fragmented. The producers expressed their ambition to solve logistics problems through the application of the proposed ILN. Previous studies [26] and the significant improvements obtained in

the current study indicated that the integrated approach could increase the efficiency of logistics service in the supply chain of LPF. In the identified scenarios, especially, in the option II of scenario 2 and scenario 3, the LPF were considered to be loaded on empty spaces of the trucks being used in the conventional LSFDCs and this greatly improved the efficiency of utilizing the vehicles loading capacity. However, in option II, the delivery frequency and quantity to each existing customers might change leading to the dissatisfaction of these customers and this should be investigated further.

#### 4.3.2. Expanding Potential Market Area

In this study, in addition to finding better solution for the logistics problems, the objective of the producers was to expand their sales area. Only 2 out of 44 existing customers were in non adjoining counties indicating that the producers have difficulties to expand their sales area and reach the consumers in the other counties.

However, increasing sales of LPF needs to overcome the main problems (related to local food systems) such as low size of production and more volatility of market price and high seasonality of food products on market [4], inadequate or no packing and storage facilities, limited or no means of transport and limited knowledge of potential market [5]. These problems can be overcome, if the LPF be embraced by dominant food supermarket and superstore chains [3] and this can be facilitated by the application of the proposed ILN which integrates the local food system into LSFDC and fulfils the ambition of the producers to expand their sales.

#### 4.3.3. Improving Access to Information

Efficient ways of sharing information and scarce/expensive resources play a key role in developing ILN [27, 28]. Well organized information concerning local food is also important to satisfy the increasing demand of consumers to have good knowledge and information of the food origin and how it is handled and transported [29]. Such consistent flow of information in local food system could be realized via the application of this ILN enabling producers and consumers get access to the right information at the right time.

#### 4.3.4. Improving the Sustainability of Local Food Systems

The developed ILN is important to secure the flow of LPF from producers to consumers and to improve the food quality through training opportunities and sharing/ learning professional skills [1]. This type of better food supply chain management that empowers the producers is required to achieve sustainable local food supply chain [25,30]. Especially in European countries where the

populations mostly use supermarkets, local food system can be sustainable if it can become financially and physically accessible to the mainstream market, maximizing distribution of LPF through supermarkets [21] and this accessibility to large market can be achieved through the application of the proposed ILN.

The positive implication of ILN towards achieving and maintaining more sustainable local food systems can be confirmed by expanded potential markets, access to better technologies and practices, improved logistics and minimized food miles and reduced green house gas emissions [17,31], traceability of food origin, availability of information on nutrition and value. This ILN also creates more opportunity for identifying problems in the supply chain of LPF and launching research projects to provide appropriate solutions and maintain the sustainability of local food systems in different regions/countries [4].

Part II of this paper reports the results of analyses done regarding the implications of the proposed integrated approach on environment, marketing arrangements/managements and economic tradeoffs in the supply chain of LPF.

## 5. Conclusions

This study initiated with the aim to investigate the existing flow of LPF from producers to consumers and to develop a coordinated and efficient food distribution system for local food producers in Halland region. For this purpose, an ILN that embraced fourteen producers, 44 delivery points, one CC and one DC was formed. All producers were located within the radius of 50km from CC. Most of their existing customers were found within Halland county (50%) and the adjoining county (46%) within the radius of 180 km from CC.

The optimized CC was located at 56°55'15"N latitude and 12°34'15"E longitudes. The DC, which was 208 km far from CC, was used as centre of the network to integrate the local food system into LSFDCs.

The formation of ILN and the location and route optimisation analyses, conducted based on four scenarios utilising tools such as GIS and professional Route LogiX software, made it possible to get more insight into the impact of integration of local food systems. When compared to the existing, uncoordinated delivery system which was most similar to scenario 1, the remaining scenarios (scenarios 2, 3 and 4) showed significant improvements. Option II of scenario 3 was found to be the best scenario with the improvements of 93% for transport distance, 92% for transport time and 87% for number of routes. Option II also improved the efficiency of utilizing the vehicles loading capacity in the LSFDC.



The application of this ILN will satisfy the needs of producers and consumers through solving the problems related to logistics, access to larger market, and access to information on the origin and quality of the food products. These advantages of ILN indicate that the application of this type of integration will greatly improve the sustainability of local food systems.

This study was site specific, and the analysis results mainly reflect the situation of the supply chain of LPF in the Halland region, which was selected for this study. Therefore, similar, site specific and detailed studies are required to establish well coordinated and sustainable supply chain systems for LPF.

## 6. Acknowledgements

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