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GIS-Based Analysis of Integrated Food Distribution Network in Local Food Supply Chain

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Abstract

Local food producers need to integrate within networks of suppliers, distributor, customers and community representatives in order to increase their competitiveness. The main objective of this study was to evaluate the performance of an integrated food distribution network (IFDN) in Sweden. Location and route analyses were conducted using data of 11 producers, 149 customers and one distribution centre (DC). Geographic Information System (GIS) tools and location analysis techniques were utilized. Route analyses were done considering one non-integrated distribution system (scenario1) and three different integrated distributions systems (scenarios 2, 3 and 4). The results of location analysis indicated that the existing DC is located at best position. When compared to Scenario1, best improvements were gained in scenario3 i.e. up to 64% in number of routes, 53% in number of visits, 74% in transport distance and 63% in transport time. As a consequence, the emissions emanated from vehicles were reduced. The analyses gave insights into main implications of IFDN such as implication for logistics efficiency; implication for food and service quality; and implication for environmental sustainability of local food supply chain.

Keywords: Sweden, logistics network, GIS, vehicle routing problem, local food supply chain, location analysis, environmental impact

1. Introduction

The efficiency of logistics greatly affects the sustainability of success in business activities (Brimer, 1995; Tarantilis, Diakoulaki, & Kiranoudis, 2004). Especially, the importance of goods distribution has led to more scientific approach towards efficient logistics management (Rushton, Croucher, Bakaer, 2008). As networks and other organised ways of collaboration are means to increase the competitiveness of a region and a country (Beckeman & Skjöldebrand, 2007), in the food supply chains such networks at the community level contribute to the regional development. Innovation in the local food supply chains (LFSC) can be manifested mainly in process changes, new approaches to marketing, new forms of distribution and new conceptions of scope (Beckeman & Skjöldebrand, 2007). Therefore detailed researches are required to investigate the performances of LFSCs and their contributions for sustainable regional development.

The efficiency of logistics is related to environmental issues. Transport sector generates about 25% of the greenhouse gas (GHG) emissions related to the world energy consumption and about 75% of the emissions from the transport sector are from road transport (Intergovernmental Panel on Climate Change [IPCC], 2008; Määttä-Juntunen, 2010). From 1993 to 2003, the freight transport work on road (measured in tonne-kilometre (t-km)) increased by about 60% in EU countries. In Sweden, the CO_2 emission from all vehicle categories has been projected to increase from 18.5 million tonnes in 1998 to 25 million tonnes in 2020 (Ntziachristos, Tourlou, Geivanidis, & Andrias, 2002). However, the attentions given to the contribution of the freight transport sector to global warming is less when compared to the attentions given to the CO_2 emissions from car traffic and aviation (McKinnon, 2007). The transport in the agricultural sector is one of the areas where such reduction of emissions is expected as a contribution to the efforts to mitigate the risk of climate change (Jaradat, 2010). Within the agricultural sector, detailed investigations of logistics related activities are rare at the LFSC level.

1.1 Local Food Supply Chain

In Sweden, food produced, retailed and consumed mainly within the road distance of 250 km is usually considered as local food (Bosona, Gebresenbet, Nordmark, & Ljungberg, 2011). As the demand for locally produced food is increasing, recently, many actors made an effort to help producers of local and regional food to reach the market. However, logistics problem is the bottleneck in the local food system as uncoordinated and non-optimum food transport systems are not energy efficient (Bosona & Gebresenbet, 2011). There is considerable potential to increase the efficiency of energy use for food transport in LFSCs by organizing the food delivery system in new ways (Beckeman & Skjöldebrand, 2007), using more energy efficient vehicles and/or introducing the production of biofuel in the region (Wallgren, 2006), increasing the capacity utilization level of vehicles (Ljungberg & Gebresenbet, 2004) and planning optimum routes for food distribution (Gebresenbet & Ljungberg, 2001). In the present study, the current practices of distribution of locally produced food were investigated. First the location of the existing DC was examined using some location analysis techniques and ArcGIS. Then, distribution routes were suggested using different scenarios. Some of location analysis techniques and Geographical information system (GIS) have been applied. The ArcGIS Network Analyst tools such as vehicle routing problem (VRP) solver and Route solver have been extensively used (Environmental Systems Research Institute [ESRI], 2008).

1.2 Location of Food Distribution Centre

Location decision is one of critical elements in strategic planning for different firms (Sahin & SÜral, 2007; Farahani & Hekmatfar, 2009). Locating a single warehouse at best location that minimize the distance between the warehouse and delivery points (customers) was studied by Alfred Weber in 1909 and that study formally laid a base for the study of location theory (Farahani & Hekmatfar, 2009). In warehouse location decision, the main factors to be considered well are: nature of facility itself, environment in which it is to be located, customers to be serviced by the facility, and a metric that indicates distance or time between customers and facility. Therefore, in the case of finding best location for food collection/distribution centre, the aforementioned factors should be taken into consideration. Nowadays, location analysis is being supported by GIS (Bosona et al., 2011; Suárez-vega, Santos-Peňate, & Dorta-Gonzålez, 2012).

1.3 Vehicle Routing Problem

VRP is one of the most significant problems in the goods distribution management (Tarantilis et al., 2004; Giaglis, Minis, Tatarakis, & Zeimpekis, 2004; Bräysy, Nakari, Dullaert, & Neittaanmäki, 2009). VRP deals with finding the optimal routes in a distribution system where vehicles should be assigned to serve a set of customers. Figure 1 presents a typical VRP framework in which a set of customers are supplied from a single depot.

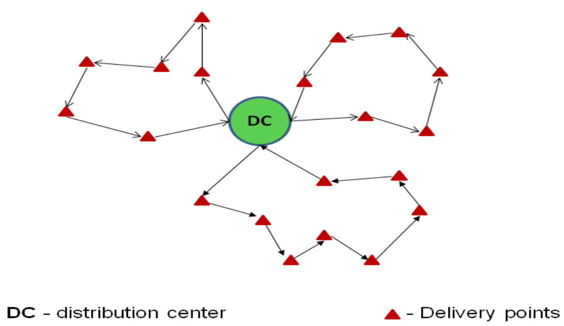


Figure 1. Schematic illustration of typical VRP framework with single-stage and multiple vehicles

Note: The solid arrows indicate that the vehicle routes are starting and ending at DC.

In modelling VRP, important issues such as number of stages (single-stage/delivery only or double-stage/both delivery and pickup), fleet size (single or multiple vehicles), vehicle capacity, delivery time window, and supply/demand nature (deterministic or stochastic) raise considerable challenges and need to be addressed well (Giaglis et al., 2004). With the efforts of finding optimal (e.g., shortest) routes, VRP has constraints that are related to data on location (e.g., depots and suppliers/customers locations), vehicles (e.g., speed, capacity of the vehicles) and paths between locations (e.g. main road, secondary road, steep gradients, weight limits on bridges, speed limit on roads) (Keenan, 2008).

GIS-based modelling of VRP enables to incorporate the important path constraints taking into considerations the distances of actual vehicle roads (Keenan, 2008). However, there are scientific gabs in applying GIS-based VRP models for food distribution due to factors such as lack of scientific data, road network, and technical knowledge on new GIS tools. Specifically, these GIS route optimization tools are not widely used for evaluating the efficiency of food distribution in LFSCs. It is also important to note that increasing competitiveness requires that food companies ceaselessly integrate within a network that includes the integration of a firm's logistics activities with those of their customers and suppliers (Gimenez, 2006; Hosseini, Azizi, & Sheikhi, 2012). However, such an integrated approach needs further investigation in the case of LFSCs as detailed studies are rare. Therefore, it is important to investigate the characteristics and implications of integrated food distribution network (IFDN) in LFSCs.

The main objective of this study was to evaluate the performance of an integrated food distribution network in local food supply chain. The specific objectives were to:

(i) Collect relevant data and prepare GIS data base for further analysis of the distribution system;

(ii) Map the locations of local food producers and customers in relation to the distribution centre (DC);

(iii) Evaluate the optimality of the location of existing DC and carry out scenario-based route analyses;

(iv) Assess the environmental impact in terms of emissions generated from vehicles used for transporting food products.

The study was intended to analyse the current practices in the distribution of local food products in Borlänge municipality and surrounding area in Sweden. This enables to get insight into the nature of problems and identify the best scenarios that lead to improved distribution/logistics activities and can be used as basis for further detailed studies on LFSCs concerning economic, social and environmental issues.

2. Material and Methods

In this study ArcGIS network analyst tools were used widely. For this the raw data with relevant information on partners of the IFDN and road data of the study area were processed and used for location and route analysis (see Tables 1, 2, and Appendix). Figure 2 illustrates the methodology used in this study. The remaining sub-sections (of material and methodology section) describe briefly the approaches of location and route analyses.

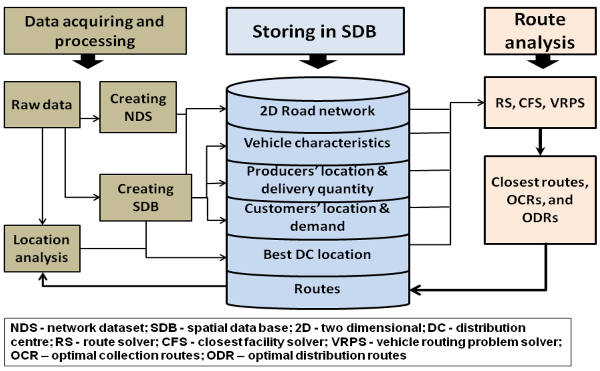


Figure 2. Illustration for the methodology used in data processing and analysis using ArcGIS (ESRI, 2008)

2.1 Study Area and Main Network Partners

The project area is found in the central Sweden (see Figures. 3(a) and 3(b)). The integrated food distribution network was initiated in 1999 and consists of producers, a distribution centre, customers (mainly schools, childcare centres, and elderly care centres) as partners. In 2010, there were about 11 food suppliers, 149 customers and a distributing company (see Table 1). Before 1999, all local farmers were distributing their produces from their store or farm to their customers and manage the logistics activities by themselves. However, after the initiative was started, the farmers in the network have integrated their logistics activities in distributing their produces and this logistics management has been managed by Borlänge municipality (see Figure. 3(b)).

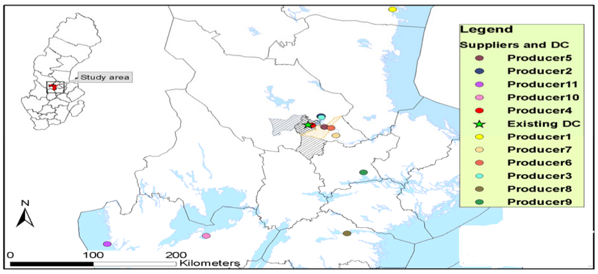


Figure 3(a). Location of producers in relation to DC

Note: Six producers are nearer to the DC (vary from 7-44 km); five producers are far away from DC (vary from 129 - 415 km).

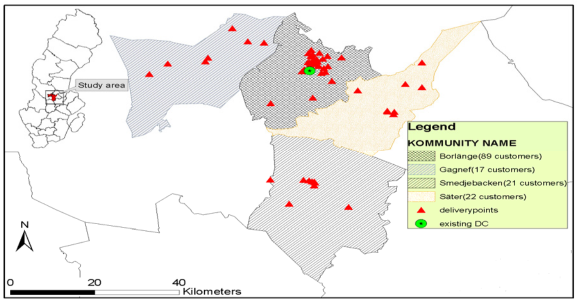


Figure 3(b). Location of the DC and delivery points (customers) within the four communities

Note: Customers with the same street addresses were represented by a single delivery point.

2.2 Data Collection

Important questionnaires were prepared and sent to respondents i.e. the transport company and responsible persons in Borlänge community who manages the food distribution initiative. The initial surveys included information useful to identify what types of data were available and how to obtain them. The replies were received via email, telephone call, and personal contact and discussions. In order to understand well the whole chain of this distribution system, meetings and group discussions were organised with key personnel running this food distribution system. Through repeated contact and discussions with the key personnel, the relevant available data were obtained. The gathered data include mainly the producers' addresses, quantity of delivery from each producer, type of vehicles used for transporting the food products (mainly dairy products, eggs, meat products, fruits and vegetables), the location of customers (delivery addresses), customers' demands and delivery time windows, frequency and weight of the deliveries to/from DC (see Tables 1 and 2).

Data on the digital road of Sweden was obtained from digital data base of Swedish university of agricultural sciences (SLU, 2009) and related information such as average speed on each category of road was obtained from Swedish road administration (http://www.trafikverket.se).

Table 1. Local food producers and related information

Supplier[a]	Quantity delivered to DC per year [t]	Distance from DC [km]	Vehicle capacity[c] [t]
Producer1	177	295	37.5
Producer2	400	26	4.75
Producer3	236	27	5.5
Producer4	89	7	12
Producer5	2.5	26	0.55
Producer6	31.2	34	1.2
Producer7	652	44	20
Producer8	842	129	24
Producer9	281	244	24
Producer10	34.6	293	4.75
Producer11	15.3	415	3.75
Total[b]	2761		

Note: [a]-Some of the producers also receive food products from other farmers in its vicinity and supply to DC;

[b]-The study was based on data of different years;

[c]-This vehicle capacity was considered during the analysis in the case of product collection to DC.

Table 2. Delivery frequency per week in cases of collection and distribution

Average frequency per week	No. of suppliers (collection)	No. of Customers (distribution)
0.2	0	1
0.25	0	1
0.5	0	6
1	1	56
1.5	0	20
2	1	62
3	0	3
4	4	0
5	5	0
Total	11	149

2.3 Evaluating the Location of Distribution Centre

In order to evaluate, the optimality of the location of DC, analyses were conducted using GIS-based spatial data and techniques of determining optimal location of facilities such as Centre-of-Gravity technique, Load-Distance technique and Location Factor Rating technique (Russell & Taylor, 2009).

2.3.1 Center-of-Gravity Technique

The Center-of-Gravity technique uses the distance goods moved and weight of goods to locate the DC at the centre of movement in a geographic area. It should be noted that this technique was based on Euclidean distances and it was used only to carry out a preliminary analysis and identify some potential locations of DCs. Then the identified candidate DCs were further checked using other techniques (Load-Distance and Factor Rating), considering real road distances that could be determined from GIS based road network dataset. Its mathematical formulation is given in equation (1).

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

Where:

x, y = coordinates of new DC;

x_i , y_i =coordinates of delivery point *i,* in decimal degrees;

w_i = annual weight transported to delivery point *i,* in t.

The analysis was done considering the following three cases:

(i) Considering Producers and Customers

In this case both the product collection from producers to DC and distribution from DC to customers were considered. The coordinates of the 11 producers (with their annual quantities delivered to DC) and coordinates of all customers (with their annual demands) were considered and the determined DC location is indicated as New DC1 in Figure 4.

(ii) Considering only Producers (the case of Collection)

In this case, the coordinates of all producers and their annual delivery quantities were used and the identified DC location is indicated as New DC2 in Figure 4.

(iii) Considering only Customers (the case of distribution)

In this case only, the coordinates of customers and their yearly demands were used and the new location is indicated as New DC3 in Figure 4.

2.3.2 Load-Distance Technique

In the Load-Distance technique, various candidate locations have to be chosen and evaluated using a product of load and distance as a measuring value. Its mathematical description is given in equation (2).

$$LD = \sum_{i=1}^{n} w_i d_i \tag{2}$$

Where:

LD = the measuring value of load and distance, in t-km;

w_i = the yearly demand at delivery point i, in t;

d_i = the distance between the proposed site of DC and delivery point i, in km;

n=number of collection and delivery points (sum of suppliers and customers).

This technique was used to refine the preliminary analysis carried out using Center-of-Gravity technique. For this purpose, four candidate places, New DC1, New DC2 and New DC3 and the existing DC, were used. The yearly demand of customers (for the case of distribution) and quantities delivered by producers (for the case of collection) and the real road distance (see Figure 4) were used in the calculation. Finally, the candidate DC with the least measuring value was considered as best location (see section 3.3).

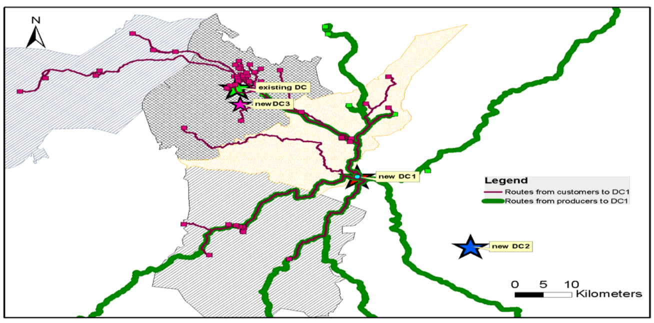


Figure 4. Locations of candidate DCs

Notes: Green lines are routes connecting New DC1 and producers and the red lines connect New DC1 and customers. The routes are examples of the shortest routes created using the road network dataset and used in the Load-Distance technique.

2.3.3 Location Factor Rating Method

Location factor rating evaluates location factors selected based on the conditions of the area under consideration. In this study, each factor was weighted from 0 to 1 according to its importance and then a score was assigned to each factor based on the attractiveness of the location compared to other candidate locations. Although such a score is subjective, it was done carefully by considering important factors such as availability of warehouse and other infrastructures, nearness to most of customers, and transportation cost. The assigned score values varied between 0 and 100 (see section 3.3). Then the weighted scores are computed for each candidate site by multiplying the factor weights by the score for that factor. Finally, the weighted scores are summed and the candidate site with the highest total weighted score is chosen as the best site.

2.4 Scenario-Based Evaluation of the Integrated Food Distribution Network

2.4.1 ArcGIS-Based Route Analysis

In this study, VRP was modelled using ArcGIS network analyst tools. For this purpose first road network datasets should be built. To create the ArcGIS-based 2-dimentional road network dataset covering the project area, the digital road data of Sweden, in Swedish National Grid Reference (SWEREF99_TM), was used. The digital road network comprised of motorway, national primary, national secondary and regional roads. The average speed limit was carefully assigned to each road type, based on information obtained from Swedish road administration (http://www.trafikverket.se) and included in the attribute table before creating the road network dataset. Road network dataset was created in geo database within ArcCatalog (ESRI, 2008). Travel distance and time were included as impedances to be used during determining shortest or quickest routes. During network dataset creation, it is important to ensure that edges and junctions are formed correctly for acquiring accurate results from network analysis.

The VRP solver in ArcGIS software solves problems using routing solvers which include the Route solver, Closest Facility solver, and Origin-Destination Cost Matrix solvers. These are built based on well known Dijkstra's algorithm for finding shortest paths (Dijkstra, 1959; ESRI, 2008). Each of these three solvers implements two types of path-finding algorithms i.e. the exact shortest path, and a hierarchical path solver, for faster performance (ESRI, 2008). In this project, Route solver and closest facility solver were used to map the routes and determine its real road distance (between each producer and DC) and the VRP solver was used to analyze (simulate un-optimized or optimized) collection and distribution routes. For this particular project, the VRP was built such that (see Appendix):

(i) a fleet of vehicles serves a set of delivery points;

(ii) the demand of each customer per visit must be satisfied by a vehicle assigned on the route;

(iii) each vehicle leaves and returns to the depot;

(iv) the vehicle capacity should not be exceeded;

(v) the delivery stages are single stages (i.e. product collection and distribution activities must be done separately);

(vi) the working time constraints for the driver and vehicle on each route should not be violated and;

(vii) delivery time window should be satisfied.

2.4.2 Analysis of Food Delivery Routes

After building the road network dataset and VRP model, evaluation of the recorded routes was performed. Out of the four communities, the recorded data of distribution routes were available only for Borlänge community (see Figure 3). In Borlänge community, information on order of visits, total time, and maximum drive distance was obtained for 12 existing distribution routes. This step of evaluating the recorded routes was also used to check how realistic the connectivity of road segments in the created road network and the output of the Network Analyst tools are. Although the optimal route determined by the network analyst can be the fastest route, in this study, the route optimisation analysis was based on the shortest route approach. Since the available data of recorded delivery routes were limited, the detailed route analysis of the entire food delivery system was carried out taking into consideration the following four different scenarios (see Figure 5).

Scenario1: Routes of delivery by producers

In this scenario, the analysis was done assuming that all producers involved in the project could distribute their own products to their customers (see Figure 5). This scenario is similar to the fragmented distribution system existed before the IFDN, under consideration, was initiated. The vehicle capacity varied and for each producer the respective vehicle capacity indicated in the Table 1, was considered in the analysis.

Scenario2: Routes of partially integrated collection and fully integrated distribution

In this case, producers deliver their products to DC and, the coordinated distribution from DC to customers is to be carried out by DC. Two options were considered for this scenario: Option-I is when each producer delivers only its own product to DC (see Figure 5). Option-II is when the products from some producers are transported in coordinated manner. Option-II is very similar to the existing food distribution initiative in Borlänge. For example, some producers use vehicles of a transport company to transport their products facilitating the possibility of coordinated food collection to DC.

Scenario3: Routes of integrated collection and distribution

In this case, both collection and distribution of products would be managed from DC in a coordinated manner. The appropriate vehicles would be assigned based on the quantity of products to be collected or distributed on each tour. In this study, the minimum capacity of vehicle (for coordinated collection) considered was 9.45 t (i.e. in volume about 30 food containers of equal volume) with the possibility of using a vehicle with more capacity based on the quantity to be collected. For the distribution case, only the vehicles with loading capacity of 9.45 t were used in the analysis. The detailed data concerning delivery quantity and delivery time window is provided in Appendix.

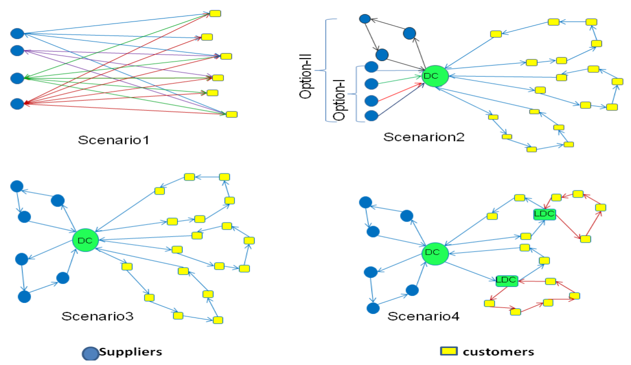


Figure 5. Schematic illustrations of the four scenarios

Scenario4: Distribution routes with local delivery centres

In the places where cluster of customers were found, one of these customers (customer with high food demand) was considered as local distribution centre (LDC) from where further deliveries could be done by light vehicles. In this case five LDCs were selected and the deliveries from these LDCs to customers within respective customer were analyzed. It should be noted that more than five LDCs could be selected, but it was assumed that these five LDCs were enough to demonstrate the influence of introducing LDCs.

In order to carry out the comparison analysis of the four different scenarios, the VRP model was run (in all scenarios), using flexible delivery time window within the limit given as 6:00-18:00 (only day time), although, sometimes it might be inconvenient to deliver food to customers between 10:00-12:00 a.m. The possible working time for each vehicle on each route was taken as 4:30-19:00. It should be also noticed that since data concerning the order of visits was not available, the analysis was based on the simulated optimal routes in all scenarios.

2.5 Estimation of Emissions

The emissions from vehicles were estimated for each scenario based on the total length of routes in each scenario by considering, first single tour of delivery on each route and then the distribution throughout a year. The calculation was based on emission factors (per each km of transport distance) as given in Table 3(a) and the transport distances determined for each scenario (see section 3.4.2.). Table 3(a) was extracted from the emission factor values prepared for year 2010 by Swedish road authority (Trafikverket, 2009). The emission factors used in the calculation were the weighted average of the values for transport activities in the countryside and in the cities. Both light trucks (less than 3.5 t total weight) and heavy trucks (more than 3.5 t) were considered. The light vehicle option was considered for the case of scenario4 where LDCs were included in the analysis. The emission values were analyzed in terms of four environmental impacts i.e. global warming potential (GWP), human toxicity potential (HTP), acidification potential (AP), and eutrophication potential (EP) (see Table 3(b)). The data source for impact factors of each emission gas was ecoinvent (Centre for life cycle inventories) database (Ecoinvent, 2007).

Table 3(a). Emissions factors as presented for year 2010

Vehicles	Emission factors					
	CO_2 [kg km^{-1}]	CO [g km^{-1}]	HC [g km^{-1}]	NOx [g km^{-1}]	PMm [g km^{-1}]	SO_2 [g km^{-1}]
Heavy trucks						
In Country side	0.92	1.2	0.19	6.93	0.12	0.0013
In cities	1.26	1.6	0.32	10	0.17	0.0018
Weighted average	1	1.3	0.22	7.57	0.13	0.0015
Light trucks						
In Country side	0.26	0.17	0.026	0.64	0.048	0.0004
In cities	0.3	0.49	0.08	0.7	0.048	0.0004
Weighted average	0.27	0.3	0.05	0.05	0.048	0.0004

Note: Data source (Trafikverket, 2009).

Table 3(b). Impact categories and emission gases considered in this study

Potential Impact	Emissions	Unit
Global warming potential (GWP_{100})*	CO2, CO, HC, NOx	kg CO2 eq
Human toxicity potential (HTP)	NOx, PM, SOx	Kg 1,4-DCB eq**
Acidification potential (AP)	NOx, SOx	Kg SO2 eq
Eutrophication potential (EP)	NOx	Kg NOx eq

Note: *-potential impact over the time horizon of 100 years; **-1, 4-DCB is 1, 4-dichlorobenzen ($C_6H_4Cl_2$).

3. Results

3.1 Description of the Main Partners in the Network

Out of the 11 suppliers within the network, it was noticed that only 9 suppliers were active when this data was gathered, because Producer6 and Producer11 were not regular suppliers to DC (see Table 1). Although, the number of customers might vary from season to season and from year to year, based on the available data, their distribution in the four communities is as presented in Figure 3(b), i.e. 89 in Borlänge, 21 in Smedjebacken, 22 in Säter and 17 in Gagnef. The annual total quantity supplied to DC by the 9 regular suppliers was estimated to be about 2714 t. Considering 11 suppliers the estimated annual quantity was about 2761 t. In the absence of annual quantity, it was estimated mainly based on the weekly and monthly available data and the actual yearly quantity is expected to vary from the indicated values due to seasonal variation of production and demand. About 61% of the products were distributed in Borlänge community while Säter and Smedjebacken communities received about 14% each and Gagnef received about 11% of total quantity distributed via DC. In terms of transport distance, all suppliers (except producer11) were within 300 km from DC (see Table 1). Some of the suppliers not only produce the food, but also collect from the smaller producers in their vicinity.

In the Borlänge community, where 60% of the customers were found, the transport company involved in this network, run from 2 to 4 trips daily from Monday to Friday. However, in the delivery to other communities, namely Säter, Smedjebacken and Gagnef, the transport company coordinated the transport of food products with other goods. This could increase the efficiency of vehicle utilization. Concerning the collection of products from producers to DC, the transport company also picked up products of some producers namely producer1, producer7, producer8 and producer9. Other producers transported their products to DC using mostly their own vehicles.

3.2 Frequency and Time Window of Food Delivery

It was observed that the delivery frequency of food products from producers to DC varied from 1 to 5 visits per week (see Table 2) while the average delivery frequency from DC to customers varied from 0.2 to 3 trips per week. For most of the customers (42%) the delivery frequency was found to be twice a week while for about 38% of the customers, it was once a week (see Table 2). The overall average delivery frequency during distribution was found to be about 1.5 trips per week. The collected information concerning the quantity of products delivered from each producer to DC and from DC to each delivery point was provided in different time bases i.e. on weekly, monthly or yearly bases. But in the analysis the quantity of delivery per tour was required, and estimated based on the delivery frequency (which was provided on weekly base) and delivered quantity.

The delivery time window set by the customers varied from 6:00 (starting time) to 18:00 (end time). The starting time indicated in the data varied from 6:00 up to 16:00. For about 73% of the customers, the convenient delivery time was found to be between 6:00 to 8:00 (considering the starting time) while for 20% it was between 8:00-12:00 and for about 7%, it was set to be only after 12:00. For some customers with missing data the delivery time was assumed to be between 6:00-18:00.

The constraints concerning delivery day varied from one day per week to five days per week. In Borlänge community, there was delivery every day from Monday to Friday and in Gagnef community, there was delivery on four days except Tuesday. In Säter and Smedjebacken communities, the deliveries were carried out only on Tuesday and Thursday.

3.3 Evaluation of Distribution Centre

From the analysis made using centre of gravity technique, three locations were identified as potential location of DC and indicated as New DC1, New DC2 and New DC3 (see Figure 4). New DC1 was about 50 km away from the existing DC in the South-east direction. New DC2, was found to be at a place about 87 km from the existing DC in the South-east direction. Similarly, the third location, New DC3 was found to be at a place 10 km to the south of the existing DC.

The result of further analysis using load-distance technique (see Table 4) and location factor rating method (see Table 5) were used to identify the best location from the four candidate DCs considered in the analysis. From Table 4, the smallest value of load-distance summation is 358 069 t-km and from Table 5 the highest total weighted score is 87.5 revealing that the existing DC was the best site of collection/distribution centre.

Table 4. Summary of GIS based location analysis using load-distance technique

Summary	Latitude	Longitude	Summation of Load-Distance [t-km]	Comment
New DC1	60.260	15.779	404 074	50 km from existing DC
New DC2	60.096	16.132	473 803	87 km from existing DC
New DC3	60.431	15.411	389 156	10 km from existing DC
Existing DC	60.469	15.401	358 069	Best location

Table 5. Summary of the analysis using location factor rating method

Location factor	Weight	Score (0-100)				Weighted Score			
		Existing DC	New DC1	New DC2	New DC3	Existing DC	New DC1	New DC2	New DC3
Labour	0.15	90	60	60	90	13.5	9	9	13.5
Proximity and number of customers	0.15	80	60	50	80	12	9	7.5	12
Construction/leasing cost	0.05	80	50	50	60	4	2.5	2.5	3
Transportation cost	0.25	90	60	60	90	22.5	15	15	22.5
Community government/service	0.05	100	80	80	100	5	4	4	5
Infrastructure	0.2	100	60	60	90	20	12	12	18
Proximity of suppliers	0.15	70	80	90	70	10.5	12	13.5	10.5
Total Weighted Score						**87.5**	**63.5**	**63.5**	**84.5**

3.4 Route Analysis

3.4.1 Evaluation of Recorded Delivery Routes

Table 6 shows the basic existing delivery routes in the Borlänge community, where data of 12 recorded routes were available and evaluated. The travel distance of the routes varied from 16 km to 58 km with mean value of 41 km for non-optimized case. This agreed with the fact that the travel distance per route, estimated by driver/distribution centre, was about 60 km. The travel distance, simulated for optimised case, varied from 15 km to 39 km. In this case the route optimisation analysis was done without compromising the delivery time window set by each customer.

Table 6. Analysis result for the routes recorded in Borlänge community*

Day***	Route	Number of customers	Simulated					Saving in due to optimization[%]**	
				Non-optimized case		Optimized case			
			Recorded Time	Driving distance	Total time	Driving distance	Total time	Distance	Total time
Monday	1	5	02:24	16	02:49	15	02:48	6	1
	2	14	04:51	57	05:48	41	05:34	28	4
	3	11	02:30	21	04:26	16	04:18	24	3
	4	14	04:15	56	05:58	36	05:33	36	7
Tuesday	5	13	06:45	44	06:10	30	05:54	32	4
	6	12	07:15	58	06:01	30	05:39	48	6
Wensday	7	14	06:45	47	06:26	33	06:11	30	4
	8	15	06:15	50	06:52	36	06:33	28	5
Thirsday	9	7	06:45	24	04:09	24	04:09	0	0
	10	10	07:15	31	05:09	29	05:07	6	1
Friday	11	12	06:45	24	05:30	20	05:25	17	2
	12	11	07:15	58	05:46	39	05:24	33	6
	Total	138	69:00	486	65:04	349	62:35		
	Average	12	5:45	41	5:25	29	5:12	28	4

Note: *-Distance is in km and time is in h:min; **- Considering 30 min for loading time for each route, 15 min for unloading and handing over the product and 1 h and 30 min for resting and extra time; ***-Monday (routes 1-4), Tuesday (routes 5-6), Wensday (routes 7-8), Thirsday (routes 9-10), and Friday (routes 11-12).

The result of optimisation analysis indicated that the existing distribution route could be improved although some of the routes were already optimal, for example Routes 1, 9 and 10 were found to be the best routes (see Table 6). Some routes, for example routes 4, 6 and 12, were found to be non-optimal and could be improved by implementing the simulated new optimal routes (see Table 6 and Figure 6). In general, for the analysed 12 routes, the improvement for travel distance varied from 0 % to 48% and the improvement for total time (including loading/unloading) varied from 0% to 7%. On average, the improvement due to optimization was 28% for both travel distance and travel time, but it was only 4% for total time. This indicated that, using optimized routes could reduce the travel distance and travel time while the service time (loading/unloading) was unchanged.

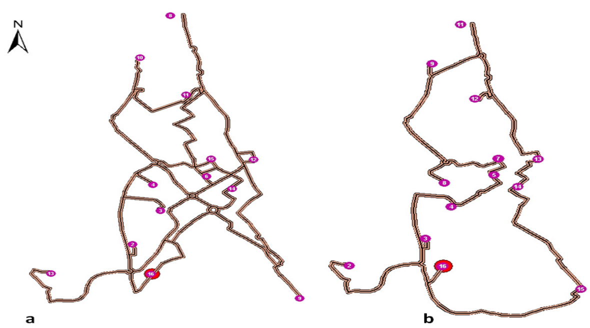


Figure 6. Example of registered routes for food distribution in Borlänge community

Note: (a) Route4 (56 km), simulated for non-optimised case for delivery on Monday; (b) Route4 simulated for optimized case (36 km). The red circle indicates DC and numbers in small circles indicate the order of visiting delivery points.

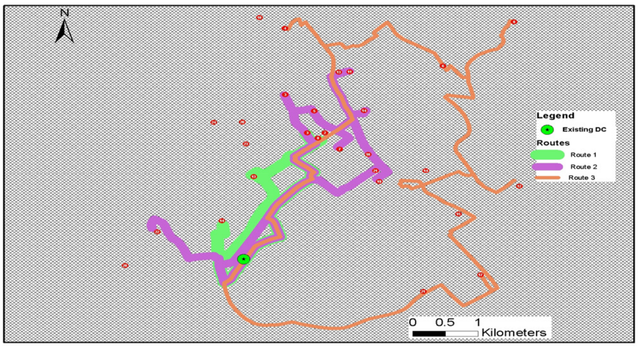
3.4.2 Scenario-Based Route Analysis

The results of scenario based route analyses have been summarized in Table 7. For Scenario1, the total number of routes was 25, while the total distance and time were about 7627 km and 228 h respectively. In Scenario1, the travel distance for each producer varied from 294 km to 2844 km while total time varied from 17 h to 54 h. In Scenario2, the number of routes was reduced to 16, while the total distance and total time were reduced to about 2734 km and 105 h. The number of visits (stops at delivery points) was also reduced from 334 to 158, because, in the case of integrated distribution, products from different producers (that were delivered separately in Scenario1) could be delivered together. When compared to scenario1, the improvements obtained in Scenario2 were 36%, 53%, 64% and 54% for number of routes, number of visits, transport distance and total time respectively. Further improvements were obtained in Scenario3 (when compared to Scenario 1), where the number of routes, number of visits, transport distance and total time were reduced from 25, 334, 7627 km and 228 h to 9, 158, 2022 km and 85 h respectively. This indicated improvements by 64 %, 53%, 74% and 63% respectively. The improvement gained in Scenario4 was slightly less than that of Scenario3 i.e. in Scenario4, the figures for improvement became 40%, 53%, 74% and 58% respectively. Figure 7 presents the distribution routes from DC to customers (see Table 7).

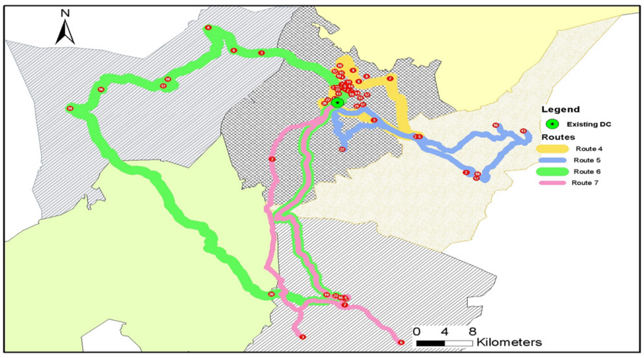
Table 7. Summary of route optimisation analysis based on 4 scenarios*

Scenario	Description	Number of routes	Number of visits	Distance	Total time	Improvement comparing with Scenario1 (%) Routes	Vist	Distance	Time
Scenario1	Distribution	25	334	7627	227:45				
Scenario2 (Option1)	Uncoordinated Collection	9	9	2182	44:46				
	Distribution	7	149	552	59:43				
	Sum	16	158	2734	104:29	36.00	52.69	64.15	54.12
Scenario2 (Option2)	Partialy coordinated collection	7	9	1865	31:34				
	Distribution	7	149	552	59:43				
	Sum	14	158	2417	91:17	44.00	52.69	68.31	59.92
Scenario 3	Coordinated Collection	2	9	1470	25:29				
	Distribution	7	149	552	59:43				
	Sum	9	158	2022	85:12	64.00	52.69	73.49	62.59
Scenario 4	Coordinated Collection	2	9	1470	25:29				
	Distribution	13	149	545	70:40				
	Sum	15	158	2015	96:09	40.00	52.69	73.58	57.78

Note: *Distance is in km and time is in h: min.



(a) 3 of the 7 distribution routes



(b) 4 of the 7 distribution routes

Figure 7. Simulated distribution routes

Note: (a) the 3 routes with in Borlänge community (route-1=10 km, route-2=20 km and route-3= 30 km). Pointes shown as outliers in (a) are some of the delivery points served by other routes in (b); (b) the 4 routes within the four communities (route-4= 63 km, route-5= 102 km, route-6= 182 km; route-7= 145 km).

In order to investigate the potential savings by amending the delivery time window, further analysis was done (see Table 8). Without changing the delivery time window set by each customer, the length of each route varied from 20 km to 266 km. When the delivery time window was made flexible between 6:00-18:00, the route length varied from 10 km to 182 km and the total transport distance and time were reduced from 1457 km and 78 h to 552 km and 60 h respectively. This indicated that the flexibility in time window could improve the transport distance, time and number of routes by 62%, 23% and 22% respectively (see Table 8).

Table 8. Potential savings by amending the delivery time window

Delivery time window for the distribution from DC	No. of routes	No. of visits	Distance [km]	Total time [h]
Fixed delivery time window*	9	149	1457	78
Flexible delivery time window**	7	149	552	60
Saving (%)	22	0	62	23

Note: *-The delivery time window varied between 6:00-18:00 but exactly as set by each customer;

**-The delivery time window was assumed to be any time between 6:00-18:00 leading to more savings.

Table 9 reveals that the difference in the two scenarios (Scenario3 and Scenario4) is in the distribution part. In Scenario4, when compared to Scenario3, the number of routes and total delivery time were increased from 7 to 13 and from 60 to 70 h respectively. Number of visits remained the same since the customers remained the same in both scenarios. However the transport distance reduced slightly from 552 km in Scenario3 to 545 km in Scenario 4. Scenario 4 reduced the distance, time and number of visits for large trucks by 31%, 27% and 38% respectively when compared to scenario 3. However the introduction of LDC increased number of routes by 46% and total time by 16%.

Table 9. Comparison of scenario 3 and scenario 4 considering only the case of distribution from DC

Description	Distribution without LDCs (scenario 3)	Distribution with LDCs (scenario 4)		Saving	
		Light and heavy trucks	Heavy truck*	Light and heavy trucks	Heavy truck
No. of Routes	7	13	7	Increased by 46%	0%
Total distance[km]	552	545	381	Decreased by1.3%	31%
Total time[h]	60	70	44	Increased by 16%	27%
No. of visit	149	149	92	0%	38%

Note: *considering only heavy trucks and comparing with scenario3. LDC – Local Distribution Centre.

3.5 Emission Values

The emissions considered were carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_X), particulate matter (PM) and sulphur dioxide (SO_2). The emission values were estimated for transport activities of a year and expressed in terms of GWP, HTP, AP and EP (see Table 3(b)).

The annual estimated value of GWP for scenario 1 was 321 t CO_2 eq which was reduced to 102 t CO_2 eq (for scenario 2, option-II), 85 t CO_2 eq (for scenario3) and 81 t CO_2 eq for scenario4. HTP (in kg 1,4-DCB eq) was reduced from 3068 to 972, 813 and 754, while AP (in kg SO_2 eq) was reduced from 1261 to 400, 334, and 310 in scenarios 2, 3, and 4 respectively. Similarly, EP (in kg NOx eq) was reduced from 3025 to 959, 802 and 743 respectively (see Figure 8).

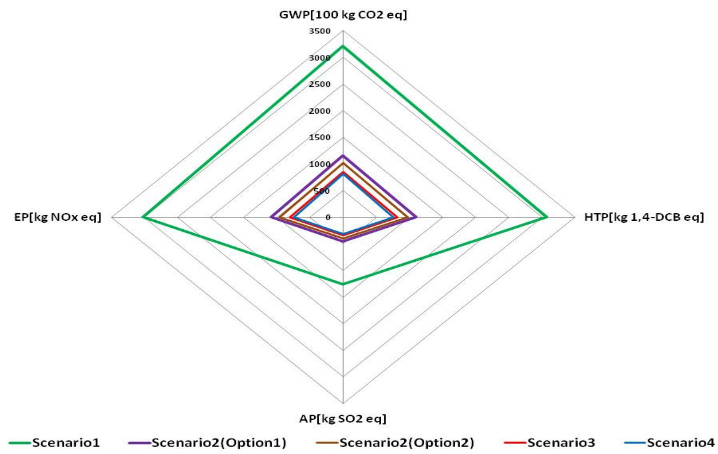


Figure 8. Environmental profiles of the four scenarios

Note: considering the estimated (annual) emissions from vehicles: GWP is expressed in 100 kg CO_2 eq, while the remaining factors are expressed in kg of their reference measurements.

4. Discussion

An efficient management of goods distribution requires the determination of optimal location and optimal delivery routes. This study confirmed that existing DC was located at best location and this was one of the reasons behind the success of integrated food distribution network, initiated in Borlänge. The study enabled to prepare the dynamic maps that could illustrate source of food and delivery points in relation to DC which can be important resources for future expansion of the distribution network. This strengthened the observations by other researchers (Keenan, 2008; Määttä-Juntunen, 2010) that location problems are complex and they are an existing area where GIS can be used to enhance location analysis techniques. The GIS based maps make it possible to compare the feasibility of different candidate DC locations suggested by location analysis techniques. The maps also provide powerful assistance to decision makers especially to annex more food producers and expand the food distribution service to more new potential customers. The current investigation gave insights into the characteristics of IFDN and its main implications within the scope of local food supply system.

4.1 Implication for Logistics Efficiency

The effectiveness of GIS in handling, display, and manipulation of geographic and spatial information (Beni, Villeneuve, LeBlanc, & Delaquis, 2011), increases the application of ArcGIS based location analysis and modelling of VRPs which could enable to design best routes (Tavares, Zsigraova, Semiao, & Carvalho, 2009; Oxendine, Sonwalkar, & Waters, 2012). In this study, the scenario based route optimisation analyses indicated the potential for improving food delivery systems. When compared to Scenario1, more improvements were obtained in Scenario3 than in Scenario2, as a result of better coordination in the product collection to DC. For example, in Option-I of Scenario2, the improvements were 36%, 64% and 54% and these figures were increased to 64%, 74% and 63% respectively in Scenario3. In Option-II of Scenario2 the better improvements (than option-I) were obtained due to the partial coordination in the product collection (see Figure 5). Option-II was similar to the existing local food distribution practice in Borlänge indicating that so far the new initiative has improved the local food distribution by 44% (number of routes), 68% (distances) and 60% (total time). Although the existing practices in food supply network (option-II of scenario2) has improved the logistics service, detailed evaluation of the recorded routes revealed that there is potential savings of 28% (on average ranging from 0% to 48%) for both travel time and distance. Gebresenbet et al. (2011) reported possible saving up to 40% for travel time and distance by optimising individual route of food distribution in city area. Due to more coordination in collection, further improvement is possible if scenario3 and Scenario4 are implemented. The analysis result of Scenario4 indicated that introducing LDCs had negative consequence by increasing number of routes and delivery time. This may lead to more congestion, and more labours (e.g. drivers) and more time (loading and unloading time). However, using light trucks might be advantageous by reducing driving time and distance of heavy trucks (see Table 9). This issue should be studied further considering the trade-offs between the negative and positive consequences of using LDCs.

In some cases the distribution company operating in this project uses its vehicles by coordinating the transport of food products and other goods increasing the efficiency of vehicle utilisation. When the vehicles start the distribution tour, they are fully loaded at DC increasing the resource utilisation, especially when compared to the old system in which vehicles of each supplier were running partially empty. The results of some previous studies also indicated that coordinated and integrated food delivery systems could improve the logistics activities in the LFSCs (Ljungberg, Gebresenbet, & Aradom, 2007; Osvald & Stirn, 2008; Bosona & Gebresenbet, 2011; Gebresenbet, Nordmark, Bosona, & Ljungberg, 2011).

4.2 Implication for Food and Service Quality

In solving VRP, meeting delivery time windows depends on the preference of users (analysers), based on the customers need (ESRI, 2008). In the IFDN of the current study, there is high level of cooperation and trust, and truck drivers are allowed to deliver in the absence of customers in most cases. Therefore, the potential savings by amending the delivery time window (see Table 8) can be utilised enabling the partners to gain economic benefits (e.g. reduced logistics cost and low food price) and to increase the service quality. In such cooperation, some critical relationships factors are trust (Fischer, 2012); senior management support; ability to meet performance expectations; clear goals and partner compatibility (Daugherty, 2011). These factors increase the interaction between supply chain partners which in turn will increase the ability to achieve desired goals in the supply chain management under consideration (Deshpande, 2012; Bosona & Gebresenbet, 2013).

Such a high level of cooperative relationships among the partners of food supply network is also useful to: share expertise and resources; exchange information; reduce food price; reduce time spent by customers for purchasing food; improve product quality; use advanced technology; have better planning, joint control over the important logistics functions, joint problem solving and mutual competitive advantages in the market; and improve social and environmental sustainability. Efficient LFSC management, integrates the logistics activities of producers, distributors and consumers enabling local food producers to compete in the modern global market (Gimenz, 2006) and enables to meet the increasing demand for local food products and to enhance the sustainability of LFSCs (Zarei, Fakhrzad, & Paghaleh, 2011).

Van der Vorst, Tromp, and Van der Zee (2009) pointed out that proper food supply chain design should aim not only at improving logistics performance but also at preservation of food quality and environmental sustainability. Food quality is mostly determined by biological variations, time variations and environmental conditions. The environmental conditions such as temperature, humidity and presence of contaminants may be influenced by type of packaging, way of loading and the availability of temperature conditioned transportation means and warehouses. In the IFDN of the current study, all the partners have responsibility and successfully manage the food quality control confirming the fact that a network of food suppliers has a collective responsibility to manage the flow of food products and related information about food quality and origin (Bosona et al., 2011). In general, the Borlänge community manages the food distribution in integrated manner by ordering food products from local producers, buying the logistics service from a transport company and facilitating information exchange among the network partners as well as disseminating information to governmental bodies and other concerned national and international organisations.

4.3 Implication for Environmental Sustainability of Local Food Systems

Reducing the number of vehicles, transport distance and transport time leads to reduction in GHG emissions (Ljungberg et al., 2007) and in distribution cost for goods-distribution companies (Osvald & Stirn, 2008). When compared to Scenario1, Scenario2 (Option-II) reduced the emission by 68%. Scenario3 improved the emission reduction level up to 73% while in Scenario4 the emission reduction reached 75%. The reduction in number of vehicle stops was also reduced by 53% (see Table 7) indicating further reduction of emissions and reduction in number of vehicles which in turn cuts down the risk of car accident. It should be noted that although reducing long transport distance leads to reduction of fuel consumption, in the real world, minimizing the distance travelled need not necessarily minimize emissions as the shortest route may involve traversing minor and/or congested roads (McKinnon, 2007). The distributing company involved in the network under consideration also controls its vehicles to satisfy the important environmental requirements leading to reduction of emission, noise, congestion and harmful wastes, fulfilling the legal requirements and communities' need.

In terms of environmental impact, when compared to Scenario1, all the remaining three scenarios had diminished GWP, HTP, AP and EP (see Figure 8) as a result of integration of food distribution activities and optimisation of delivery routes. Lindblom and Stenqvist (2007) mentioned that, in Europe, optimizing transport activities is the best option for CO_2 reductions than short-sea transportation. Also intermodal transports (combining road and rail) may reduce emissions compared to using only road transports.

The damage on ecosystems due to eutrophication and acidification impact of some emissions; the impact on human health due to toxicity potential of some emissions contaminating air and water; and the disturbance on climate due to increasing global temperature caused by emitted GHGs, are important environmental aspects of supply chain management. These issues have been the leading focus of research over the past two decades, due to the increasing prices of energy and awareness on climate change and should be addressed well in order to promote sustainable development. The sustainability issue focuses also on the reduction of product waste, mostly due to unqualified quality such as food waste (Van der Vorst et al., 2009).

In the 21st century, sustainability is becoming main concern of society and supply chain management should meaningfully address this issue (Carter & Easton, 2011). The current initiative in Borlänge is a good example of such a sustainable supply chain management as it could address the three main performance factors: economic performance; environmental performance and social performance. This study revealed that more benefits can be obtained from this IFDN, by implementing Scenario 3 or Scenario 4 in the future. It is also recommendable that, the analysis should be updated using new data when the number of producers (or the quantity they supply) and number of customers (or their demand) in the network changes, for example if more communities join this network and when road network and/or vehicle fleets change.

The limitation of this study is that it considers a single network of local food supply system. Therefore, many such networks should be initiated in different geographical areas and studied well to generate more knowledge and promote sustainability of local food supply systems.

5. Conclusion

Efficient supply chain management could integrate food producers, distributors and consumers enabling these actors to compete in the modern global market and stiff competition. In this study location and route analyses were conducted to investigate the performances of IFDN in LFSC. The GIS-based analysis enabled to prepare the dynamic maps illustrating location of the producers (source of food) and customers and DC as well as delivery routes. The existing location of DC has been found to be the best location under the current situations.

The route optimisation analyses indicated significant improvements. When compared to Scenario1, in Scenario2 (Option2), number of routes, number of visits, transport distance and total time were reduced by 44%, 53%, 68% and 60% respectively while the reduction in Scenario 3 became 64%, 53%, 74% and 63% respectively. The improvements in scenario4 were 40% for routes, 53% for visits, 74% for distance and 58% for total time. This study also confirmed that a significant improvement could be gained by amending the delivery time window and this can be applied as there is high level of trust among the partners and there is cooperation of customers to accept amended delivery time windows.

The significant reduction in number of vehicles (routes) and stops, transport distance and transport time led to significant reduction in emissions. The emission reduction was up to 68% in Scenario 2 (Option2), 73% in Scenario3 and 75% in Scenario 4. In terms of environmental benefits, when compared to Scenario1, all the remaining three Scenarios had reduced the environmental impacts such as GWP, HTP, AP and EP. In summary, the current investigation, gave insights into main implications of the IFDN: implication for logistics efficiency; implication for service and food quality; and implication for environmental sustainability of LFSCs.

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Appendix. Detailed information at each delivery point

Table A1. Detailed data used for route analysis of distribution from DC

Delivery point	Latitude	Longitude	Freq_week	Start_Time	End_Time	Vol_ trip
1	60.152	15.228	0.5	12:00:00	13:00:00	1
2	60.081	15.308	0.5	06:00:00	18:00:00	2
3	60.081	15.308	0.5	11:00:00	12:00:00	1
4	60.134	15.416	2	12:00:00	15:00:00	1
5	60.143	15.418	2	10:00:00	11:00:00	1
6	60.143	15.418	2	12:00:00	13:00:00	1
7	60.143	15.418	0.2	06:00:00	18:00:00	1
8	60.146	15.415	2	11:00:00	12:00:00	3
9	60.146	15.415	2	06:00:00	18:00:00	1
10	60.146	15.415	1.5	06:00:00	18:00:00	1
11	60.146	15.415	0.25	06:00:00	18:00:00	5
12	60.146	15.406	0.5	11:00:00	11:30:00	2
13	60.146	15.406	2	11:00:00	11:30:00	3
14	60.146	15.406	1	08:00:00	09:00:00	1
15	60.146	15.406	2	10:00:00	11:00:00	1
16	60.149	15.393	1	10:00:00	11:00:00	3
17	60.149	15.393	2	06:00:00	18:00:00	1
18	60.149	15.393	1.5	06:00:00	18:00:00	1
19	60.151	15.37	1	09:00:00	11:00:00	1
20	60.071	15.56	1	12:00:00	13:00:00	1
21	60.071	15.56	1.5	06:00:00	18:00:00	1
22	60.485	15.452	1.5	06:00:00	18:00:00	1
23	60.482	15.478	1	16:00:00	18:00:00	1
24	60.482	15.478	1	06:00:00	08:00:00	1
25	60.53	15.408	2	06:00:00	08:00:00	1
26	60.53	15.408	1	10:00:00	18:00:00	1
27	60.392	15.413	2	06:00:00	08:00:00	1
28	60.392	15.413	1	06:00:00	08:00:00	3
29	60.392	15.413	1	06:00:00	08:00:00	3
30	60.488	15.436	1.5	06:00:00	18:00:00	1
31	60.376	15.232	1	06:00:00	08:00:00	1
32	60.349	15.761	2	07:00:00	09:00:00	3
33	60.349	15.761	1	07:00:00	09:00:00	1
34	60.349	15.761	1	07:00:00	09:00:00	1
35	60.349	15.761	1	07:00:00	09:00:00	1

36	60.342	15.757	1	07:00:00	10:00:00	1
37	60.342	15.757	1	07:00:00	10:00:00	1
38	60.352	15.732	1	07:00:00	09:00:00	1
39	60.352	15.732	1.5	06:00:00	18:00:00	1
40	60.352	15.731	2	07:00:00	09:00:00	2
41	60.352	15.731	2	07:00:00	09:00:00	1
42	60.352	15.731	1.5	06:00:00	18:00:00	1
43	60.412	15.605	2	07:00:00	08:00:00	1
44	60.412	15.605	2	08:00:00	09:00:00	1
45	60.412	15.605	2	08:00:00	09:00:00	1
46	60.412	15.605	1	07:00:00	09:30:00	1
47	60.412	15.605	2	07:30:00	09:00:00	1
48	60.43	15.81	2	09:00:00	10:00:00	1
49	60.43	15.81	2	09:00:00	10:00:00	1
50	60.43	15.,81	2	07:00:00	10:00:00	1
51	60.42	15.881	2	07:00:00	10:00:00	1
52	60.412	15.612	1.5	06:00:00	18:00:00	1
53	60.412	15.612	1.5	06:00:00	18:00:00	1
54	60.491	15.422	2	06:00:00	08:00:00	3
55	60.491	15.422	1	06:00:00	08:00:00	1
56	60.491	15.422	2	07:00:00	11:00:00	1
57	60.492	15.424	1	06:00:00	11:00:00	1
58	60.489	15.428	2	06:00:00	08:00:00	1
59	60.489	15.428	2	06:00:00	08:00:00	1
60	60.489	15.428	1.5	06:00:00	08:00:00	1
61	60.489	15.428	1	08:00:00	12:00:00	2
62	60.485	15.438	1	06:00:00	18:00:00	1
63	60.483	15.439	1	16:00:00	18:00:00	1
64	60.483	15.439	2	06:00:00	08:00:00	1
65	60.477	15.461	1	06:00:00	08:00:00	1
66	60.477	15.461	2	07:00:00	11:00:00	1
67	60.492	15.419	2	06:00:00	08:00:00	3
68	60.492	15.419	2	06:00:00	08:00:00	2
69	60.492	15.419	1.5	06:00:00	18:00:00	1
70	60.492	15.419	1.5	06:00:00	18:00:00	1
71	60.492	15.419	2	06:00:00	08:00:00	3
72	60.499	15.413	1	06:00:00	08:00:00	1
73	60.499	15.413	2	06:00:00	08:00:00	1
74	60.496	15.421	1.5	06:00:00	08:00:00	1
75	60,496	15.435	1.5	06:00:00	08:00:00	1
76	60.496	15.435	2	06:00:00	07:30:00	1
77	60.496	15.435	1.5	06:00:00	18:00:00	1
78	60.496	15.435	1	06:00:00	07:30:00	1

79	60.503	15.431	1	06:00:00	11:30:00	1
80	60.503	15.428	1	16:00:00	18:00:00	3
81	60.503	15.431	2	06:00:00	08:00:00	2
82	60.503	15.431	1	06:00:00	08:00:00	1
83	60.494	15.393	1.5	06:00:00	08:00:00	1
84	60.494	15.401	1	06:00:00	11:00:00	1
85	60.494	15.401	1	16:00:00	18:00:00	3
86	60.494	15.401	2	06:00:00	08:00:00	1
87	60.494	15.401	1.5	06:00:00	18:00:00	1
88	60.49	15.402	1	06:00:00	08:00:00	1
89	60.49	15.402	1	06:00:00	08:00:00	1
90	60.484	15.404	2	06:00:00	08:00:00	2
91	60.484	15.404	1	06:00:00	18:00:00	2
92	60.484	15.404	1.5	06:00:00	08:00:00	1
93	60.484	15.404	1	06:00:00	18:00:00	1
94	60.484	15.404	1	06:00:00	18:00:00	1
95	60.476	15.395	2	06:00:00	08:00:00	1
96	60.476	15.395	2	06:00:00	08:00:00	2
97	60.476	15.395	1	06:00:00	08:00:00	1
98	60.474	15.377	2	06:00:00	08:00:00	2
99	60.474	15.377	1.5	06:00:00	08:00:00	1
100	60.474	15.377	1	06:00:00	18:00:00	1
101	60.474	15.377	1	06:00:00	18:00:00	1
102	60.468	15.368	1	06:00:00	11:00:00	1
103	60.468	15.368	1	06:00:00	08:00:00	1
104	60.468	15.368	1	06:00:00	08:00:00	1
105	60.468	15.368	1	06:00:00	08:00:00	1
106	60.466	15.467	2	06:00:00	08:00:00	1
107	60.466	15.467	2	06:00:00	08:00:00	1
108	60.463	15.451	1	06:00:00	11:00:00	1
109	60.463	15.451	2	06:00:00	08:00:00	3
110	60.463	15.451	2	06:00:00	08:00:00	1
111	60.44	15.496	1	06:00:00	16:00:00	2
112	60.44	15.496	2	06:00:00	08:00:00	1
113	60.44	15.496	2	06:00:00	08:00:00	1
114	60.511	15.413	1	06:00:00	11:00:00	1
115	60.511	15.413	2	06:00:00	08:00:00	2
116	60.518	15.412	1.5	06:00:00	08:00:00	1
117	60.518	15.412	2	06:00:00	18:00:00	1
118	60.518	15.412	2	06:00:00	18:00:00	1
119	60.513	15.406	1	06:00:00	11:00:00	1
120	60.521	15.395	1	06:00:00	12:00:00	3
121	60.521	15.395	1	06:00:00	08:00:00	1

122	60.521	15.395	1	06:00:00	18:00:00	1
123	60.512	15.477	2	06:00:00	10:00:00	7
124	60.512	15.477	1	06:00:00	10:00:00	1
125	60.512	15.477	2	06:00:00	08:00:00	1
126	60.512	15.477	2	06:00:00	08:00:00	1
127	60.512	15.477	2	07:00:00	11:00:00	1
128	60.504	15.457	2	06:00:00	08:00:00	2
129	60.504	15.457	2	06:00:00	08:00:00	1
130	60.522	15.442	2	06:00:00	08:00:00	1
131	60.508	15.538	2	06:00:00	08:00:00	1
132	60508	15.538	1	06:00:00	08:00:00	1
133	60.594	15.068	3	12:00:00	12:30:00	2
134	60.594	15.068	2	10:00:00	10:30:00	1
135	60.594	15.068	2	10:00:00	10:30:00	1
136	60.497	14.951	1	11:00:00	11:30:00	1
137	60.508	14.963	3	10:00:00	10:30:00	2
138	60.508	14.963	1	09:00:00	09:30:00	1
139	60.491	14.79	1	10:00:00	10:30:00	1
140	60.491	14.79	1	09:00:00	09:30:00	1
141	60.491	14.79	0.5	10:00:00	10:30:00	1
142	60.491	14.79	2	08:00:00	09:30:00	1
143	60.46	14.71	0.5	10:00:00	10:30:00	1
144	60.46	14.71	1	13:00:00	13:30:00	1
145	60.46	14.71	2	10:00:00	10:30:00	1
146	60.556	15.134	2	09:30:00	10:30:00	1
147	60.556	15.134	3	10:00:00	10:30:00	2
148	60.552	15.205	2	09:30:00	10:30:00	1
149	60.552	15.205	2	09:00:00	09:30:00	1

Note: **Longitudes** and **Latitude** values are in decimal degrees; **Freq_week** is number of deliveries per week; **Start_Time** and **End_Time** are the starting and ending time of delivery time window (in hour:minute:second and expressed as fraction of 24 hours in GIS attribute table during analysis); **Vol_trip** is the number of food containers to be delivered at each point such that full volume of a container weighs 300 kg on average.