Integration of Logistics Network in Local Food Supply Chains

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Abstract

The demand for locally produced food is increasing as global food supply system has considerably affected the confidence of consumers by increasing tonne-kilometres, food safety risk, environmental impact, and disconnecting local food producers and consumers. However, local food suppliers are not in the position to compete with large scale food supply systems due to high logistics costs. The overall objective of this study was to improve the logistics management of local food supply chains. In this thesis, food traceability issues and the local food supply chains were studied based on literature reviews and five case studies in Sweden.

The thesis comprises of six papers. Paper I considers food traceability issues. Paper II deals with comparison analysis of small scale abattoir and large scale abattoir in terms of animal supply and meat distribution. Paper III focuses on box-scheme based organic food delivery system, while Paper IV deals with coordination and regional integration in local food delivery system. Papers V and VI consider the case of clustering producers, determining collection centres, and forming coordination and integration within the network and further integration into large scale food delivery systems. The best locations of collection and distribution centres were determined using Centre-of-Gravity and Load-Distance techniques and Geographic Information Systems tools. Optimising food transport routes were done with Route LogiX and ArcGIS network analyst tools.

Effective food traceability system is an important tool to be considered as integral part of food logistics system as it facilitates the integrated management of food supply chain as a whole. Compared with large scale abattoirs, the local small scale abattoir could reduce travel distance, time, and emission and could improve animal welfare, meat quality and safety, and customer satisfaction. The integration of logistics managements along with clustering, coordination, and optimisation techniques, could reduce the transport distance, time, trips, and emission, and improve the vehicle capacity utilisation in the local food supply chains. As a consequence of reduced transport distance, number of vehicles and improved vehicle capacity utilisation, negative environmental impacts of local food supply systems could be reduced. The study revealed that the integrated logistics network has implications for improving food traceability, logistics efficiency, food quality and safety, the potential marketing channels, economic benefits, and competitiveness of suppliers; and for attenuating negative environmental impact and promoting sustainable local food systems.

Keywords: food traceability, local food supply chain, logistics network, clustering, coordination, integration, optimisation, location analysis, route analysis

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Dedication

I dedicate this thesis to Gari Bosona Dabala (father) and Birqo Abaginbar Biratu (mother).

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Bosona, T., Gebresenbet, G. (2013). Food traceability as an integral part of logistics management in food and agricultural supply chain. *Food Control* 33, 32-48.

II Gebresenbet, G., Bosona, T., Ljungberg, D., Aradom, S.(2011). Optimization analysis of large and small-scale abattoirs in relation to animal transport and meat distribution. *Australian Journal of Agricultural Engineering* 2(2), 31-39.

III Bosona, T, Gebresenbet, G., Nordmark, I., Aradom, S., Ljungberg, D. (2011). Box-scheme based delivery system of locally produced organic food: Evaluation of logistics performance. *Journal of Service Science and Management* 4(3), 357-367.

IV Bosona, T., Nordmark, I., Gebresenbet, G., Ljungberg, D. (2013). GIS-based analysis of integrated food distribution network in local food supply chain. *International Journal of Business and Management* 8(17), 13-34.

V Bosona, T., Gebresenbet, G., Nordmark, I., Ljungberg, D. (2011). Integrated logistics network for the supply chain of locally produced food, part I: Location and route optimization analysis. *Journal of Service Science and Management* 4(2), 174-183.

VI Bosona, T., Gebresenbet, G. (2011). Cluster building and logistics network integration of local food supply chain. *Biosystems Engineering* 108, 293-302.

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The contributions of Techane Bosona to the papers included in this thesis were as follows:

Paper I: Planned the study, carried out literature review and wrote the manuscript with revision by co-author.

Paper II: Analysed the data and participated in writing of the paper.

Paper III: Participated in data analysis and wrote the paper together with co-authors.

Paper IV: Participated in in data collection, analysed the data and wrote the paper with input from co-authors.

Paper V: Analysed the data and participated in writing of the paper with input from co-authors.

Paper VI: Analysed data and wrote the paper with input from co-author.

Other peer-reviewed publications

[1] Bekele, A., Bosona, T., Nordmark, I., Gebresenbet, G., Ljungberg, D. (2012). Assessing the Sustainability of Food Retail Business: The Case of Konsum Värmland, Sweden. *Journal of Service Science and Management* 5, 373-385.

[2] Bosona, T., Gebresenbet, G., (2010). Modelling Hydropower Plant System to Improve its Reservoir Operation: *International Journal of Water Resources and Environmental Engineering* 2(4), 87-94.

[3] Bosona, T., Gebresenbet, G., Bulitta, F.S. (2011). Modelling the dynamic response of camels' heart rate to physical activities. *Livestock Science* 142, 138-146.

[4] Bulitta, F.S., Bosona, T., Gebresenbet, G. (2011). Modelling the dynamic response of cattle heart rate during loading for transport: *Australian Journal of Agricultural Engineering 2*(3), 66-73.

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[6] Frimpong, S., Gebresenbet, G., Bosona, T., Bobobee, E., Aklaku, E., Hamdu, I. (2012). Animal Supply and Logistics Activities of Abattoir Chain in Developing Countries: The Case of Kumasi Abattoir, Ghana. *Journal of Service Science and Management* 5, 20-27.

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Abbreviations

AP	Acidification potential
BSE	Bovine spongiform encephalopathy
CC	Collection centre
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CSCMP	Council of supply chain management professionals
DC	Distribution centre
DNA	Deoxyribonucleic acid
DSP	Distribution planning system
EDI	Electronic data interchange
EP	Eutrophication potential
EU	European union
FAO	Food and agriculture organisation of the United Nations
FSC	Food supply chain
FTS	Food traceability system
GDP	Gross domestic product
GFL	General food law
GHG	Greenhouse gas
GIS	Geographic information system
GPS	Global positioning system
GWP	Global warming potential
HACCP	Hazard analysis and critical control points
HTP	Human toxicity potential
ICT	Information and communication technology
ILN	Integrated logistics network
IPCC	Intergovernmental panel on climate change

LDC	Local distribution centre
LFSC	Local food supply chain
LSA	Large scale abattoir
N_2O	Nitrous oxide
NMVOC	Non-methane volatile organic compound
NOx	Nitrogen oxide
PM	Particulate matter
RFID	Radio-frequency identification
SCM	Supply chain management
SEPA	Swedish environmental protection agency
SO_2	Sulphur dioxide
SSA	Small scale abattoir
UK	United Kingdome
USA	United State of America
VRP	Vehicle routing problem

1 Introduction

1.1 Background

During the recent decades, the flow and variety of goods have increased. Trade and transportation of goods have grown faster than gross domestic product (GDP) of nations (Curtis, 2003). In Sweden, goods transport by road increased from 304 million tons in 2003 to 353 million tons in 2007 indicating 16% increase over the 5 years period (EUROSTAT, 2009).

Worldwide, the distance and tonnage of food shipment have been increased during the past decades due to the increase in international trade in food from distant sources (Ljungberg et al., 2006). For example, the distance food travelled at the beginning of 21st century had increased than it was in 1980s, by 50% in UK and by 25% in USA (Halweil, 2002).

Even animal flow within Europe is significant. According to Ljungberg et al (2007), about 365 million farm animals were transported per year within the 15 member countries of the European Union (EU) up to year 2000 and about 67% of these were transported by trucks. For 27 member countries, the number of animals transported per year could have increased to about 475 million per year (Gebresenbet et al., 2010).

The increase in quantity and distance the food and food animals travelled has impact on environment. Transport sector generates about 25% of the greenhouse gas (GHG) emissions related to the world energy consumption while about 75% of the emissions from the transport sector are from road transport (IPCC, 2008; Määttä-Juntunen et al., 2010). In Sweden, the CO_2 emission from all vehicle categories has been projected to increase from 18.5 million tons in 1998 to 25 million tons in 2020 (Ntziachristos, et al., 2002) indicating that the contribution of the freight transport sector to global warming could increase. In the efforts to mitigate the risk of climate change (Jaradat, 2010), reducing emissions from the transport sector (including transport in the agriculture sector) should get more attention. For this, more investigations of logistics related activities are required in the agricultural sector including food logistics at local food supply chain (LFSC) level.

In addition to its negative impact on logistics cost and environment, the increase in food transport could affect the quality, safety, security, and traceability of the food. In a survey conducted by Ljungberg et al. (2006), more than 50% of the respondents indicated that there is problem of traceability in the food supply chain in the Swedish agriculture sector. In the agriculture sector, tracking slaughter animals from birth to finished products and tracking food shipments are becoming area of focus recently (Smith et al., 2005).

In general, the food supply chains have received more and more attention. The main factors for this are: the increasing food transport and the associated environmental impact, logistics cost and animal welfare concern; the increasing food safety and quality concern; the reduced consumers' interest in chemical based food production; and the increasing societal awareness concerning sustainable food production, processing and transport. As part of efforts to address these issues, LFSC is re-emerging as an alternative food supply system. Although the demand for local food is increasing, the major challenges of local food systems are related to logistics and this requires a comprehensive assessment to identify major bottlenecks and develop methods of tackling these problems. This necessitates the development of effective and efficient logistics systems for LFSCs. So far, research works focusing on improving logistics performance of local food systems are rare. However, the concept of local food logistics could emerge and this thesis can contribute a lot in this regard through improving the logistics performances of local food producers and distributors.

1.2 Logistics management

Logistics system is a wide, complex and important field (Aronsson and Brodin, 2006) and is part of supply chain management (SCM). Christopher (2005) defined SCM as:

> "the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole".

SCM focuses on the whole system of the chain while logistics management focuses on some specific activities in the supply chain. The council of Supply Chain Management Professionals (CSCMP). (CSCMP, 2011) defined logistics management as:

> “that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements”.

Logistics performance is determined by logistics efficiency (achieving the expected output with minimum resource), logistics effectiveness (achieving the highest percentage of expected output), and logistics competency (to be competent by gaining the best comparative net value) (Fugate et al., 2010). Logistics management is under continuous evolution due to the dynamics in global market, communication and transportation technologies, and customers need (Simchi-Levi et al., 2005).

Since effective logistics management is very important for survival of firms, such a management issue as “what degree of consolidated distribution centres (DCs) should be located in which places” is a challenge to be tackled (Oum and Park, 2003). Such important logistics questions should be raised and investigated in case of LFSC which is characterized by inefficient and fragmented logistics activities (Saltmarsh and Wakeman, 2004). Efficiency of food logistics could occur in quality control, packaging, labelling, traceability, ICT utilization, or acquiring and utilizing of storage and cold chain facilities. In the recent decade, EU food companies have given attention to logistics management as frontier of sustaining a competitive advantage in the global market where EU has been the world’s largest producer of food and beverages (Mangina and Vlachos, 2012).

1.2.1 Logistics in food supply chain

The concentration of farms, food industries, and wholesalers into smaller number with large sizes; the integration of supply chains management; the increasing consumers’ demand for food quality and safety; and the increasing societal awareness concerning environmental and animal welfare issues (Opara, 2003; Groom, 2011) are main characteristics describing the current trend in the food supply chains. For instance, in Sweden, the food sector constitutes about 15-20% of the total energy used which indicates that food production and delivery systems need to gain attention (Wallėn et al., 2004). Especially, reduction of the use of fossil fuels for producing and distributing food plays significant role in reduction of emission of greenhouse gases. Although transport’s contribution to the impact of total food supply chain on environment may be minor, it should be addressed as food transport is increasing in contemporary food supply chains (Nordmark, 2012). The increase in transport distance in turn increases losses in food quantity, quality and safety although the degree of losses could vary depending on the means of transport, type of produce, road network and environmental conditions. In general, as the food sector plays a significant role in a national economy, food logistics activities should be investigated and improved continuously (Gebresenbt and Oodally, 2000). Such investigation should address the cases of LFSCs. Efficient LFSC management could integrate the logistics activities of producers, distributors and consumers enabling local food producers to be competitive in the market (Gimenz, 2006), to meet the increasing demand for local food products, and to enhance the sustainability of local food systems (Zarei, et al., 2011).

1.2.2 Food traceability as part of logistics management in food supply chain

Historically, food scare have been with human beings for many years and it exists today. Food security refers to food safety (free from contamination) in developed countries while it refers to the availability of enough food in developing countries. Food quality is related not only to nutritional value but also to animal welfare as stress that compromises animal welfare is linked with meat quality. In relation to food safety and quality, societies need to know information such as country of origin and genetic engineering related issues. Only in Europe food borne illness affects about 1% of population (approximately seven million people) each year (Saltini and Akkerman, 2012). Food crises like bovine spongiform encephalopathy (BSE) and avian flu incidents (Hobbs et al., 2005; Bertolini et al., 2006) and the recent incidence of the horse meat scandal in Europe (BBC, 2013) in which horse meat has been processed and presented as beef (mislabeling) has damaged the confidence of (in the food supply chains) consumers and authorities. Other food related risks such as potential bioterrorism attacks and contamination with radioactive materials could highly disturb the food supply chain (FSC) (Greger, 2007; WHO, 2011).

Food traceability system (FTS) has emerged as a preventive management tool against the risk of food safety and quality. According to EU general food law (GFL) introduced under regulation 178(2002), a food/feed business operator must know the supplier and recipient of the product (see Figure 1). Traceability has been accepted as effective tool that enables to capture, integrate and manage information about the life history of food products within the whole FSC. Such improved information flow will in turn enhance the integration of logistics activities and improve the food supply chain management at whole. Therefore, it is important to address FTS as an important and integral part of logistics management in food and agricultural supply chains.

Figure 1. Conceptual illustration of one-step-backward and one-step-forward approach: who is the supplier of ingredients and/or raw material? Who is the receiver of food items?

1.2.3 Transport of food animals

Animal and meat supply chains became societal interest and area of attention by researchers as transport and handling of slaughter animals are associated with a series of stressful events. The transportation of animals to abattoirs is associated with challenging logistics problems. In relation to internationalization of marketing systems and structural adjustment in slaughter industries (Ljungberg et al., 2007), number of abattoirs have been reduced contributing to the increase in transport distance and time. These include: the reduction in number of abattoirs, specialization of abattoirs in terms of animal types, the need for a steady flow of animals at abattoir, and the need for cost effective transportation. Therefore, more efforts are needed to promote effective transportation and better animal handling (Ljungberg et al., 2007; Gribkovskaia et al., 2006). According to Gebresenbet (2003), the two possible strategic alternatives for improving animal welfare during transport are: (a) minimizing stress inducing factors through improving animal transport logistics and handling methods, and (b) minimizing or avoiding transport by promoting small-scale local abattoirs (less than 50 employees) or developing mobile or semi-mobile abattoirs. Improving logistics in animal and meat supply chain creates opportunities to improve both profitability and competitive performances of firms; adds value by creating time and place utility; and attenuates the environmental impact of transport (Gebresenbet and Ljungberg 2001; Gebresenbet and Oodally, 2005).

1.2.4 Logistics cost

Logistics is an important component that connects production and marketing and can affect a national economy as it requires extensive use of human and material resources (Anderson et al., 2005; Rushton et al., 2006; Waters, 2007). The increasing transport work of goods has direct impact on the logistics cost (cost of transport, inventory, warehousing, lot quantity, order and processing and information). Globally, the average logistics cost in 2002 was about 13.8% of GDP, although the figure was higher in developing countries (Elger et al., 2008). According to these authors, in 2002, the logistics cost was 9.9%, 13.3%, and above 14% in North America, Europe and rest of the World respectively.

In UK and USA the logistics costs as percentage of GDP are the least when compared to many countries, most probably due to good attention given to improve the logistics activities (Rushton et al., 2006; Mangina and Vlachos, 2005). In England, the logistics cost was 11.3% of GDP in 2002, which was the lowest in Europe (Solakivi et al., 2009; Elger et al., 2008). The logistics cost of USA was about 10.3% of GDP in 2000 and reduced to about 9.5% in 2005 (Elger et al., 2008). In Sweden the logistics cost was about 11.1% of GDP in 2000 and reduced to 8.5% in 2005 (Elger et al., 2008; Solakivi et al., 2009). In Sweden the total average yearly logistics cost for years 2003-2005 was about 217 billion SEK, out of which 36% was transport cost (Elger et al., 2008). In EU countries, about 41% of logistics cost is the share of transport (see Table 1).

Table 1. *Share of logistics cost for different elements of logistics management (Rusthon et al., 2006; Elger et al., 2008)*

Element of logistics management	% of logistics cost		
	USA	EU countries	Sweden[1]
Transport	45	41	36
Inventory	23	23	-
Warehousing[2]	22	21	45
Administration	10	15	19

1. Based on data for years 2003-2005 as provided by Elger et al.(2008);
2. Inventory cost was included in warehousing costs in the case of Sweden.

High logistics cost is one of major factors that hinder small scale local food producers to be competitive in market (Trienekens et al., 2003; Nordmark et al., 2012). This logistics cost includes costs for food packaging, warehousing, transport, marketing, and information handling. Two cases of data survey in Sweden (1st case considering 10 local food producers and 2nd case considering 78 local food producers) indicated that, the transport cost was on average 4.6% (range 1% - 8% in the 1st case) and 6.4% (range 1% - 17% in the 2nd case) of the total food supply cost (Nordmark et al., 2012). This indicates that when other costs such as inventory, warehousing, and administration costs are added, the logistics costs could significantly constrain the competitiveness of local food systems.

1.3 Environmental impact of logistics activities

Transport intensification leads to environmental degradation by contributing to pollution of air and water, global warming, resource depletion, congestion, waste disposal (hazardous, solid) and traffic accidents (Aronsson and Brodin, 2006). Chapman (2007) pointed out that about 26% of global CO_2 emission is the share of transport activity. Ljungberg (2006) mentioned that transport sector is responsible for about 21% of the total greenhouse gas emissions of the EU (15 member states). About 7% of the yearly GHG emission from Swedish agricultural sector was the share of carbon dioxide from fossil fuels. During 2007, the GHG emissions from this sector were estimated to be about 8.43 million tons of CO_2-equivalents which represented about 13% of GHG emissions of the country (Ahlgren, 2009).

Internationally, the total freight transport activity has increased significantly. For EU countries, the freight transport work on road, measured in ton-km, has increased by about 60% over the last two decades, from 1993-2003 (Lindblom and Stenqvist, 2007). The authors also discussed that over the same period, the transport activities in EU (including both freight and passenger transport) by all means i.e. air, maritime, rail and road, has increased by about 35%. 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). More attention has been given to global warming potential than acidification and eutrophication potentials due to the fact that global warming is global problem while acidification and eutrophication are more regional problems (Ahlgren, 2009).

There are efforts to reduce the environmental burden of transport sector. Some of the actions to be taken are improving the performance of vehicles, increasing the understanding on the environmental impacts of pollutant emissions, and exploring the role of new technologies (Royal Commission on Environmental Pollution, 1995). Aronsson and Brodin (2006) studied how firms may contribute to environmental improvement through structural changes of their logistics systems and identified four strategies that could reduce environmental impact and logistics cost: (i) introducing standardization in physical systems (e.g. load carriers and vehicles should be standardized in the way that the load carriers can fit to vehicles); (ii) introducing consolidation (e.g. increasing fill rate); (iii) improving supply chain management (e.g. introducing IT-supported information flow); and (iv) developing conceptual understanding of the relationship between warehousing and distribution systems.

1.4 Local food supply chain

Local food is associated with the proximity of farm (production place) to the consumers (Zajfen, 2010). In Sweden, food produced, retailed and consumed mainly within the road distance of less than 250 km is considered as local food (Nilsson, 2009). In this study, local food refers to food produced and consumed mostly within the particular geographic area and also distributed mostly within the radius of about 250 km. In case of LFSC, produces could be delivered by intermediate partners or directly from producers to consumers (see Figure 2).

Although many consumers in developed world don't enjoy foods sourced from long-distance (Halweil, 2002) and the demand for locally produced food is increasing, more than 60% of the food consumed in Sweden is imported (Wallgren, 2006).

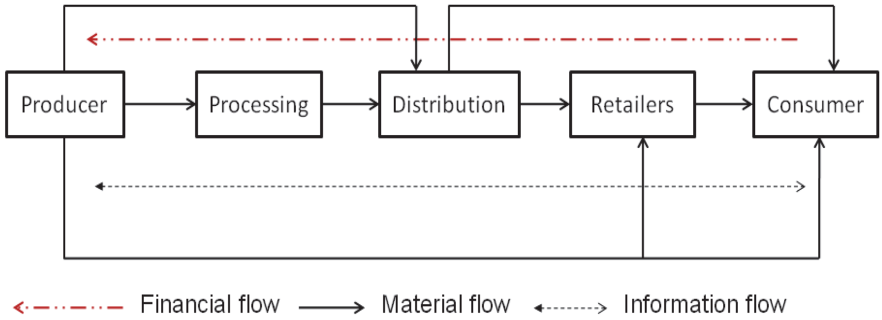


Figure 2. Example of supply chain that reflects the case of LFSC.

The global food uses large scale food distribution systems and might be advantageous in terms of high loading capacity during transportation and its better guarantee for continuous food supply. However, globalisation of food production and centralised marketing have been associated with some problems such as increased tonne-kilometre, traceability problem and disconnection between producers and consumers and related environmental problems. Marsden et al. (1999) pointed out that global industrial agriculture could have environmentally destructive activities hidden from consumers (produced by anonymous producers). Due to increasing awareness about the aforementioned problems in food supply chain and the globalisation issues concerning the environment and trade in wider context (LePoire, 2006), there is an increasing trend to provide technical and financial support to expand and improve the existing local food systems and facilitate the re-emergence of additional local food productions with the aim of realising more sustainable agriculture (Kassie and Zikhali, 2009).

1.4.1 Perceived benefits of local food systems

The long-distance food trade may be efficient as it can provide low-cost products to market (Halweil, 2002). However, it is associated with a range of unseen costs (to environment, to landscape, and to local farmers). Therefore, the coexistence of LFSC and global food supply chain is important. The local food systems have some perceived benefits over conventional food systems

(Jongen and Meulenberg, 2005). Promoting local food production could: encourage local farmers; promote local employment; promote quality and fresh food supply; increase consumer satisfaction; improve animal welfare and societal health; increase consumers' confidence in food they consume; increase social interaction; increase societal awareness on environmental issues; simplify food traceability and reduce food recall cost (Halweil, 2002; Jongen and Meulenberg, 2005; Wallgren, 2006). These perceived benefits could be categorized as economic, social and environmental advantages:

- *Economic advantages*: high value food (freshness), high consumers' confidence on food they consume, improved animal welfare, better food safety; contribution to local and regional economy.
- *Social advantages*: increase in local employment, local tourism, social interaction, food safety and national security
- *Environmental advantages*: reduction in transport distance, number of vehicles in traffic, emission, and packaging material, increase in reusable packaging material, increase in organic products.

1.4.2 Constraints compromising sustainability of local food supply chains

In the agriculture sector, unwise use of limited resources such as fossil fuels, phosphorus, water, and ecosystem services is not sustainable in the long run (Ahlgren, 2009). Sustainable agriculture refers to the agriculture with capacity to contribute to overall welfare by providing sufficient food and other agricultural products and services in a way that is economically efficient, socially responsible, and environmentally sound (Kassie and Zikhali, 2009).

The awareness on sustainability issue is relatively high nowadays. The driving forces for this are increased demand for energy, increased awareness on climate change, and increased organizational transparency concerning environmental and social issues (Carter and Easton, 2011). In sustainable supply chain management, strategic planning including environmental sustainability, organizational culture that takes into consideration social value and ethics, risk management and transparency issue, is very important (Carter and Easton, 2011).

The increased globalization of food systems is associated with homogeneity of food products, and increased transport distance and/or cost as well as food safety risks. This may endanger the sustainability of global food supply systems. As a result local food systems are getting attention and they are re-emerging as potential sustainable food production. However, there are constraints in local food systems. Some of the main problems are (Brewer et al., 2001; Trienekens et al., 2003; Saltmarsh and Wakeman, 2004; Ljungberg, 2006; Nilsson, 2009):

- *Logistics constraints*: inappropriate packaging and product handling, fragmented transport activities in LFSCs.

- *Inefficient resource utilization*: energy inefficient transportation, empty haulage, low load rate, food waste and wastage of recyclable materials.

- *Discontinuity of supply chain*: Small production volume, seasonal variation, and less marketing knowledge.

- *Knowledge gap*: inadequate scientific data and research results concerning LFSCs and difficulties in utilizing new technologies (e.g. in fleet management and implementation of FTS)

1.5 Logistics related efforts to improve local food supply chain

In the food industry, efficient supply chain management is getting attention for its competitive advantages (Golan et al., 2004). Especially, the performance of food companies depends on their logistics performance (FAO, 2012). Some possible means of improving the performance of LFSCs are (Wallgren, 2006; Sohel-Uz-Zaman and Anjalin, 2011; Sundkvist et al., 2001):

- Coordinating, integrating and optimising the logistics activities,
- creating new organized selling ways (like box-scheme based delivery, direct delivery to schools, shops, restaurants etc) and new selling channels (market expansion),
- applying web-based ordering (facilitating connection between producer and consumers), and
- using efficient technologies (at each stage in the LFSC)

1.5.1 Logistics network integration concept

Logistics integration can be expressed as a joint management of logistics activities (i.e. having a joint planning and establishment of objectives and decision, and information sharing) (Gimenez, 2006). Restructuring management and providing training play a key role in facilitating the logistics integration. Logistics integration can be realized at two positively interrelated levels:

I) *Internal integration*: integration of logistics activities with activities in other functional units of a given firm such as production and marketing; and

II) *External integration*: integration of firm's logistics activities with other partners in the supply chain.

Logistics integration enables to reduce administrative work, increases the accuracy and continuity of information flow, and facilitates joint planning and implementation of FTSs. Integrated logistics network (ILN) is efficient tool to overcome high environmental and logistics costs (Mikkola, 2008). The network could also enable the farmers to contact with environmentalists, community leaders and break into a highly consolidated market such as supermarkets sourcing food from anywhere on the world, and capitalize on competitive advantages of local food such as freshness, variety, traceability and their bond with customers.

Cooperative relationships, resource saving and information sharing among partners of network are increasingly essential to develop effective logistics system within dynamic food supply chains (Bartlett, 2007; Liang, 2008). However, in order to achieve closer relationships that produce the promised benefits, the parties involved must develop high level of trust, commitment, and dependence. Trust; senior management support; ability to meet performance expectations; clear goals and partner compatibility are essential factors for realization of critical relationships (Daugherty, 2011).

1.5.2 Clustering, Coordination and optimisation in food delivery systems

Clustering: Based on geographic concentration, farmers could form a cluster. The clustering approach enables the farmers to facilitate formation of networks with related industries and institutions. It enables farmers to integrate their logistics activities, have common marketing strategies, improve their own business prospects and be more competent, and enables customers to support local agriculture more conveniently (Halweil, 2002; Beckeman and Skjöldebrand, 2006).

*Coordination***:** In logistics management of a firm, coordination can be expressed as having formal teamwork and sharing ideas (among different firms and/or functional units of a firm), information and other resources required for logistics activities (Gimenez, 2006). In the local food systems, producers can coordinate their delivery systems and share their workload and other resources such as transport and training services (Nordmark, 2012).

*Optimisation***:** In logistics systems, optimisation is one of the important tools that enable to find efficient solutions. For instance, optimisation technique is widely used for finding optimal facility locations, optimal goods distribution system, and product delivery routes.

Location analysis: Facility location analysis enables to determine the best location of facilities such as goods collection and distribution centres or hubs. Optimising the location of facilities improves the performance of firm's logistics systems. In facility location, decision is influenced mainly by cost, distance, accessibility, availability of manpower, availability of facilities and services, and availability of land. Therefore, location analysis is a complex and data-intensive process (Bowersok and Closs, 1996).

Route analysis: Rout optimisation is a powerful tool in the vehicle fleet management (Simchi-Levi, 2005) and it has been applied in many areas such as emergency routing of ambulances, routing bus services, municipal waste collection, animal and milk collection, and food distribution (Gebresenbet et al., 2011; Aronoff, 1995). In relation to route optimisation, although various algorithms are reported (Simchi-Levi, 2005) and some commercial software are available for vehicle scheduling and routing, their application to real-world problems is relatively scarce (Ljungberg, 2006).

Previous studies (see Table 2) pointed out that coordination and optimisation in food distribution is a potential strategy to promote economically effective and environmentally sustainable food distribution. Gebresenbet and Ljungberg (2001) studied some cases of possible coordination and optimisation in agricultural goods transport such as coordinating meat and dairy product distribution through combined loading, coordinating fodder transport and grain transport through back-haulage, and partial or total optimisation of vehicle fleet. Table 2 pointed out that coordinating and optimising food delivery systems could reduce number of routes, travel distance, and travel time.

Table 2. *Potential savings obtained in distance and time by optimising the delivery routes*

Case study	No. of routes	Distance before optimisation	Time before optimisation	Improvement due to optimisation %		Source
				Distance	Time	
Animal transport						
Study1	19	163	2:47	3.6	4.1	R1
Study2	15	2750	46	18	22	R2
Meat distribution						
Study2	17	1638	62	17	21	R2
Study3	10	1597	-	4.7	2.7	R3
Study3[1]	13	3054	62:45	37.7	32.4	R3
Grain transport						
Study2	45	4995	97	6.4	5.15	R2
Dairy distribution						
Study2	28	2234	92	22	24	R2

1. The case of coordination i.e. improvement is for route coordination (not necessarily for optimisation)
R1= Ljungberg et al. (2007); R2=Gebresenbet and Ljungberg (2001); R3=Gebresenbet et al. (2011)

In order to reduce the constraints and improve the local food systems, an integrated approach to logistics and supply chain management concepts should be developed. This provides an insight into characteristics of local food systems and facilitates the development of innovative methods of marketing and distributing local food products. The main driving factors for this are:

- *The increasing demand of consumers for local food*: This is due to increasing awareness about issues concerning food quality, food safety and security, animal welfare, environment, and traceability of food origin

- *The importance of reducing the logistics cost*: Logistics cost is the bottle neck hindering local food producers from being competitive in the market

- *The increasing recognition of sustainable food production*: This is due to population growth, scarce resources, and rapidly growing demand for quality food

- *The importance of filling scientific gap*: There is a scientific gap concerning how to create and manage (using the new technologies such as ICT-system) a well-organized way of marketing and delivering local food produces.

In Sweden, little attention has been paid to the logistics within the food supply chain (Ljungberg et al., 2006). Particularly, local food systems are old systems but less mature and underutilized and fewer efforts have been done, so far, to improve their efficiency (Wallgren, 2006). In general, there is a strong need for researches that can demonstrate how the suppliers of locally produced food can increase their competitiveness in the market and at the same time reduce the environmental impact. Therefore, conducting detailed research works and developing effective and efficient logistics systems in the local food systems are very important.

2 Objectives and structure of the thesis

2.1 Objectives

The overall objective of this thesis was to promote the competiveness of local food producers and attenuate environmental impact by implementing logistics network integration within local food supply systems. The specific objectives were to:

- conduct a comprehensive literature review on food traceability issues in relation to LFSC (Paper I);
- investigate the benefits of establishing small scale local abattoir (SSA) compared with large scale abattoir (LSA) (Paper II);
- evaluate the performance of coordinated and integrated food delivery systems (Papers III, IV, V); and
- develop a coordinated and integrated food distribution system for local producers and/or integrate into large scale food distribution systems (Papers V, VI).

In Paper I, it was intended to investigate the characteristics of contemporary food traceability system and to identify the role of food traceability in food logistics management and its applicability in local food supply systems. In Paper II, it was aimed (by establishing local small scale abattoir) to reduce the transport time, distance and emission from vehicles and to improve animal welfare and meat quality and safety. The aims of Papers V and VI were to form integrated logistics network by coordinating, integrating and optimising the collection and distribution of locally produced food and further integrating the local food system into large scale food distribution channels. In Papers III and IV, it was intended to evaluate the logistics performances of existing and better organized local food distribution systems.

2.2 Structure of the thesis

The thesis is based on six research works in which food traceability (Paper I) and different food delivery concepts (Papers II-VI) were dealt with.

- *Literature review (Paper I)*: Literatures concerning contemporary food traceability issues were reviewed focusing on identifying the definitions, major driving forces, benefits, technological advancement as well as challenges of implementing food traceability, and the way food traceability system could work in the case of LFSC.
- *Comparative analysis (Paper II)*: The collection of animals from farm and delivery to abattoirs and meat distribution from abattoir to consumers were analysed comparing the case of SSA and LSA. The comparison analysis was performed in order to identify the impact of establishing small scale abattoir.
- *Box-scheme based food delivery system (Paper III)*: The food delivery in which box-scheme based delivery of local and organic food produces were investigated. In this system, three food distributors (which also have their own farms) could coordinate the delivery activities.
- *Coordination and regional integration (Paper IV)*: The food delivery activities of local food producers were coordinated and integrated with institutional (communal) intervention.
- *Coordination and integration (Paper V)*: The food delivery activities of small scale local producers were coordinated and integrated (Papers IV-VI). Then, further integration into large scale food distribution channels was introduced (Papers V-VI).
- *Clustering, coordination and integration (Paper VI)*: The delivery in which the producers were clustered and their products were collected, in coordinated manner, to best collection centres (of each cluster) from where the food products were delivered to customers and the food delivery was further integrated into large scale distribution channels.

In Paper I, the investigation of food traceability issues considered food supply chain in general, even though, attention was given to specific issues related to local food systems and logistics integration. In the remaining five case studies (Papers II-VI), location and route optimisation analysis has been carried out. The importance of coordination and logistics network integration in the local food systems have been considered together with the implication for economic competitiveness of local food producers and attenuating environmental impact. Figure 3 presents the linkage between different studies included in this thesis. It explains how the methods (literature review, coordination, integration and optimisation) used in these case studies are interlinked. The main focus areas of each case study within the LFSCs, and the main findings in terms of food traceability and security, animal welfare, food quality, efficient resource utilisation, economic and environmental benefits as well as improvement in logistics management and sustainability of LFSCs have been illustrated in Figure 3.

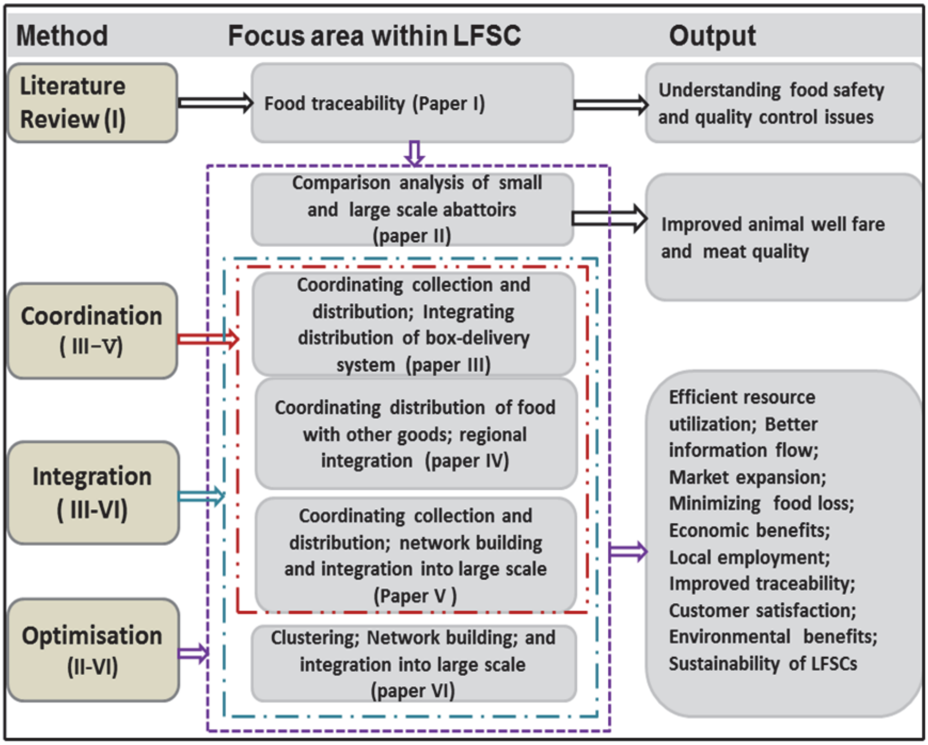


Figure 3. Relationship between the Papers (I-VI).

3 Methodology

3.1 Study area

The case studies (Papers II–VI) included in this thesis covered different parts of Sweden. Figure 4 presents the focus area of each case study. Papers II-IV focused on the central part while Paper V focused mainly on the southern part of the country. Paper VI covered almost the whole part of Sweden except a county in the northern part, namely Norrbotten County. In Papers III and V, the coverage of distribution area was larger than the coverage of food collection area. In Paper VI, both collection and distribution areas were almost the same.

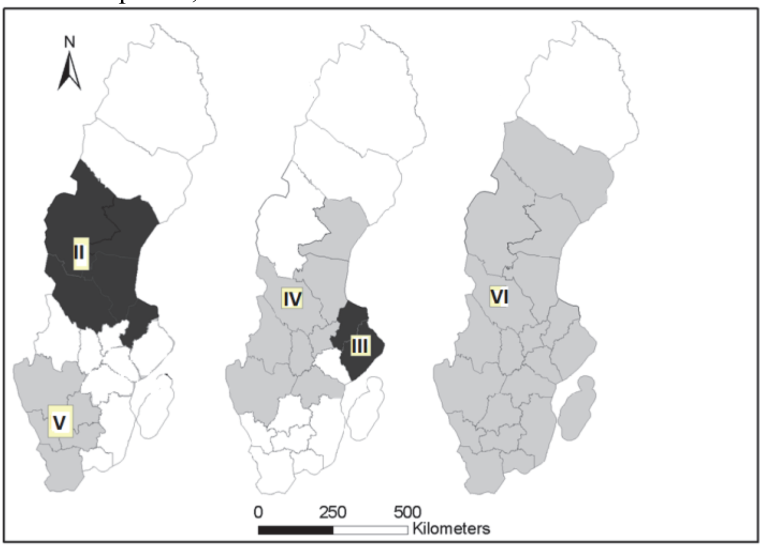


Figure 4. Geographical area of each case study (Papers II-VI). The shaded area covers the area where most of the producers and customers within each case study are found. The delineation is based on the boundary of counties.

3.2 Data collection

Interviews (Papers II-V), questionnaire based survey (Papers II, IV, VI), telephone and email conversation with key informants (Papers II-VI), physical observation (Papers II-V), field measurement (Papers II-III), meeting and round table discussions (Papers II-V), and internet based survey (Papers I-VI) were utilized to gather the required data and related information. Physical observation was made to investigate the activities at some of the collection and/or distribution centres and customer location. Field measurements were performed to record the delivery routes and/or geographical coordinates of required locations. Coordinates of locations of farms and delivery points were obtained from either recorded data or from internet sources such as Google map (Google, 2009; Hitta, 2009).

Information on the load rate was collected especially at the starting point (depot). In Papers IV and V, the information on load rate of distribution trucks (at the time of departure from DC for distribution) was considered. In Paper VI, load rate was recorded (uncoordinated case) when the vehicles left the farms to deliver food produce to customers. In some cases (Papers IV and VI), mostly raw data were received and processed and used for analysis. These data include mainly product type, production quantity, customer demand, delivery frequency, delivery time window, as well as information related to road network and emission from vehicles. The methods of data acquisition in each case study are presented in Table 3.

Table 3. *Means of data acquisition*

Description	Papers					
	I	II	III	IV	V	VI
Interview		✓	✓	✓	✓	
Questionnaire		✓		✓		✓
Physical observation		✓	✓	✓	✓	
Field measurement		✓	✓			
Telephone and email conversation		✓	✓	✓	✓	✓
Meeting and round table discussion		✓	✓	✓	✓	
Internet	✓	✓	✓	✓	✓	✓

3.3 Data analysis tools

In developing effective transport systems, the role of advanced information technologies such as global positioning systems (GPS) and geographic information systems (GIS) is very high. GPS was utilized to record the latitude and longitude of important location such as depot or retailer, place where a vehicle starts and stops for loading and unloading, and to record food collection/distribution routes (Paper III). Route LogiX, ArcGIS, and

Spreadsheet were the main tools used for analysis (see Table 4). Route LogiX software has powerful vehicle routing and route optimisation capability (DPS, 2004). It is used by different companies including food retail companies in Sweden (Nordmark, 2012). It has the capability to form best routes by minimizing travel distance and time. However, this version of Route LogiX has limitation as it handles planning of only one route at a time.

ArcGIS tools were used widely in this study. ArcMAP was used to map the locations of farms, delivery points, CCs and DCs. Application of ArcGIS network analyst tools such as vehicle routing problem (VRP) solver, route solver and closest facility solver were used to create and map the best routes (ESRI, 2008). These ArcGIS tools require the creation of road network dataset and preparation of spatial database in GIS environment (see Figure 5).

Table 4. *Main tools used for data analysis in this study*

Tool description	**Purpose**	**Paper**
GPS	• Record routs and coordinates of locations	II- III
Route LogiX	• locate CC, DC, farm location, and customer location • Simulate transport distance and time • map simulated routes	II-III, V, VI
ArcGIS (ArcMAP, ArcGIS Network Analyst Tools)	• locate CC, DC, farm and consumer locations • build cluster of producers (Paper VI) • simulate (Paper IV) transport distance and time • map simulated routes (Paper IV)	II-VI
Spreadsheet (Microsoft excel 2010)	• program and solve location analysis equations such as gravity method, load-distance, and location factor rating (see section 3.8) • program and solve emission estimating equations	II, IV-VI

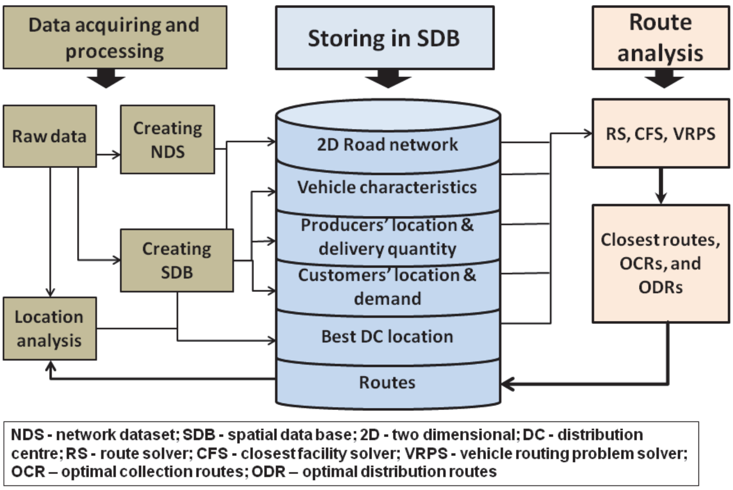


Figure 5. Illustration for the methodology used in data processing and analysis using ArcGIS Network Analyst Tools.

3.4 Food traceability

In Paper I, selected scientific papers and related documents published during 2000-2013 and focused on food traceability issues were reviewed bearing the following questions in mind: What does food traceability really mean? What are the driving forces and challenges food companies face during the implementation of food traceability systems? What are the technological advancement enhancing food traceability issues? What are the benefits of food traceability systems? How does food traceability system work in the case of LFSC? Figure 6 illustrates the scope of the literature review (paper I) and the investigated major issues related to the development and implementation of food traceability systems i.e. driving forces, barriers, definitions, technological advancement, expected benefits, performance, and improvement. Each of these issues was investigated, analysed and discussed.

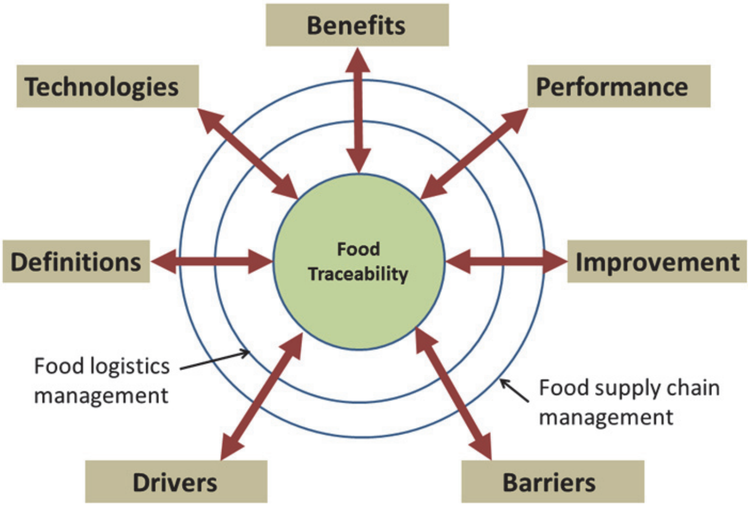


Figure 6. Analytic framework illustrating the scope of the literature review on food traceability (Paper I).

3.5 Animal collection and meat distribution (Paper II)

In Paper II, the animal supply from local farms to large scale and small scale abattoirs and meat distribution from both abattoirs were investigated based on sample data gathered for this purpose. Figure 7 illustrates the conceptual representation of animal flow from farms to local abattoir and from the same farms to the larger abattoir. The SSA is located at Okelbo about 154 km away from LSA located in Uppsala (see Figure 7). Only four farms (out of 500) and four retailers (out of the 25 retailers considered in this study) are indicated on the map for illustration purpose (Paper II). The Figure also shows the meat distribution from both abattoirs to customers in the vicinity of local abattoir.

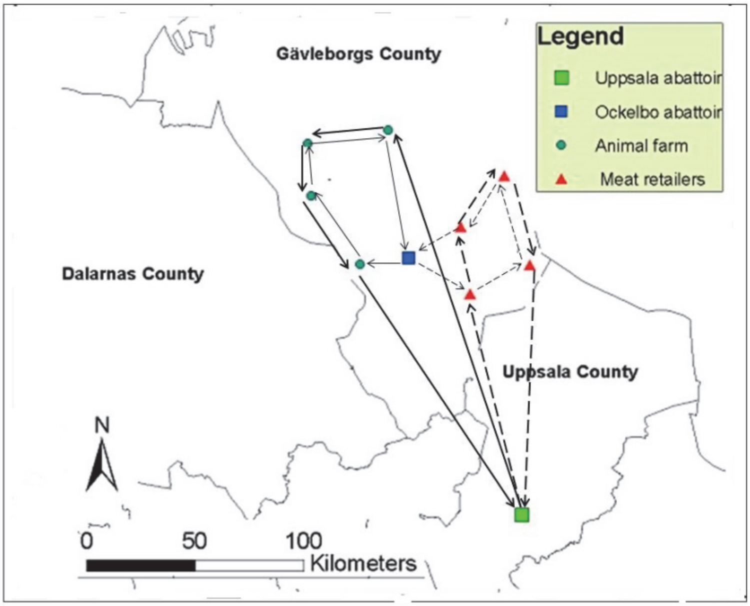


Figure 7. Animal supply and meat distribution: Solid arrows indicate animal supply to abattoirs and dashed arrows indicate meat distribution from the abattoirs. Thick arrows are used for the case of LSA.

The meat distribution was studied together with consumers' perception and attitudes towards meat products from local farms. In both animal supply and meat distribution cases, the comparison was done mainly in terms of transport distance and time, customers' satisfaction, and the impact on environment.

3.6 Clustering local food distribution system

In Papers II (meat distribution), V, and VI the location based Cluster-First and Route-Second approach was used (Simchi-Levi et al., 2005). In order to facilitate the coordination and integration of logistics activities, local food producers were clustered based on their geographical proximity (see Figure 8). The optimal transport routes serving the producers within the cluster were simulated using Route LogiX and ArcGIS network analyst tools. In Paper V, all producers were considered as a cluster and a CC was set for the cluster. Similar approach was used in Paper IV. However, in Paper VI, there were large number of producers dispersed all over Sweden, and about 92% of them were grouped into 14 clusters with a CC for each cluster. Within each cluster there might be one or more optimal collection and/or distribution routes. Figure 8 illustrates the clusters of local food producers comparing the cases of uncoordinated and coordinated delivery systems.

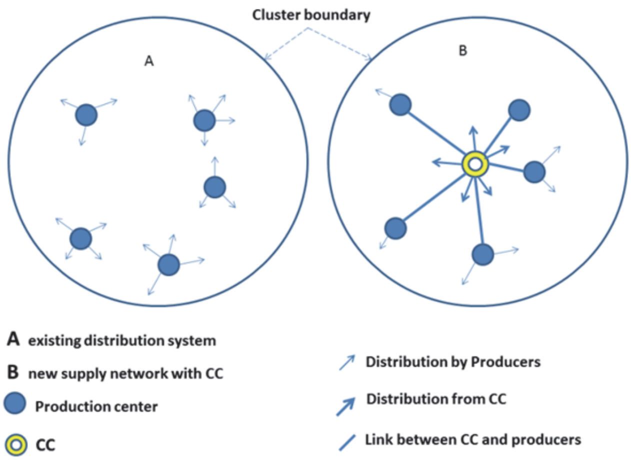


Figure 8. Uncoordinated and coordinated distribution systems: (A) Inefficient and fragmented distribution system and (B) newly proposed coordinated distribution system via CC to different customers in the context of local food systems (Paper VI).

3.7 Scenarios of food delivery systems

In order to facilitate the coordination and integration of food delivery processes, different scenarios were set. Especially in Papers IV, V, and VI scenario-based analyses were carried out in which different scenarios were compared to the existing food delivery activities. In Paper III, food delivery routes of 3 companies were analysed mainly based on the recorded information of each route. For one of the companies three scenarios were considered although these scenarios described the real routes to some extent (Paper III).

3.7.1 Scenarios in Paper IV

In Paper IV, four scenarios were set (see Figure 9). Scenario1 represents the case of fragmented food delivery activities. In this scenario, it was assumed that all producers could distribute their own products to customers. In Scenario 2, collection of food products to DC was to be done by producers and the distribution from DC was to be managed by DC. In Scenario 3 both food collection and distribution activities were to be managed by DC. In Scenario 4 local distribution centres (LDC) were introduced and from these LDCs further deliveries should be done by light vehicles (see Figure 9).

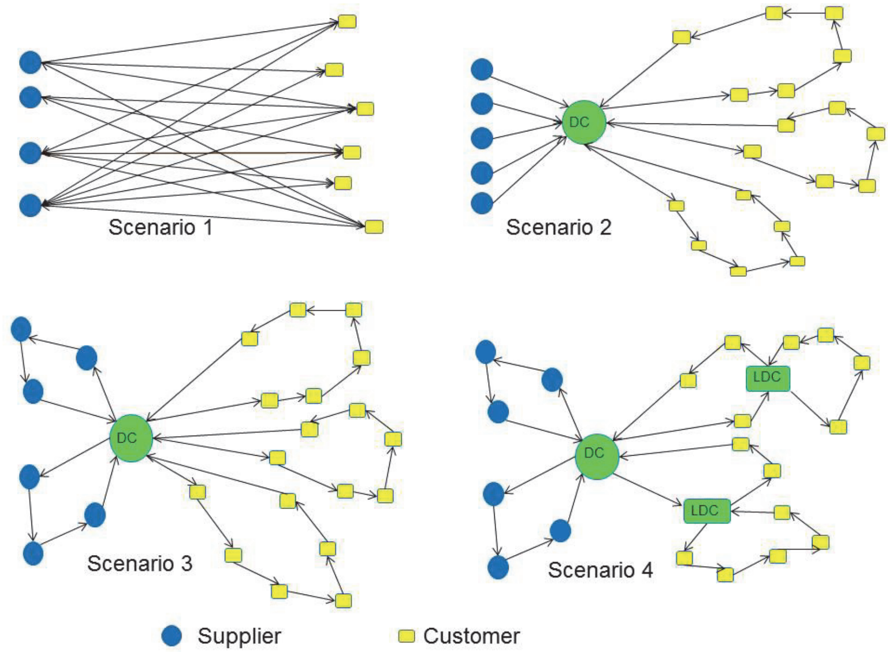


Figure 9. Scenarios in Paper IV.

3.7.2 Scenarios in Paper V

Four different scenarios were set as indicated in Figure 10. Scenario 1 represents the case of fragmented food delivery activities where each producer transports its own products to customers. Scenario 2 represents the case of uncoordinated food collection where producers deliver their produces to CC. The delivery from CC to DC was to be managed by CC while further distribution from DC to customers was to be managed by DC. In scenario 3, unlike scenario 2, the collection was carried out in coordinated manner. However, the distribution from DC was to be carried out in a similar way as described for scenario 2. In scenario 4, in every route, food collection and distribution were integrated. Scenario 4 was set with the assumption that the trucks could be furnished with different compartments for different products being collected and delivered.

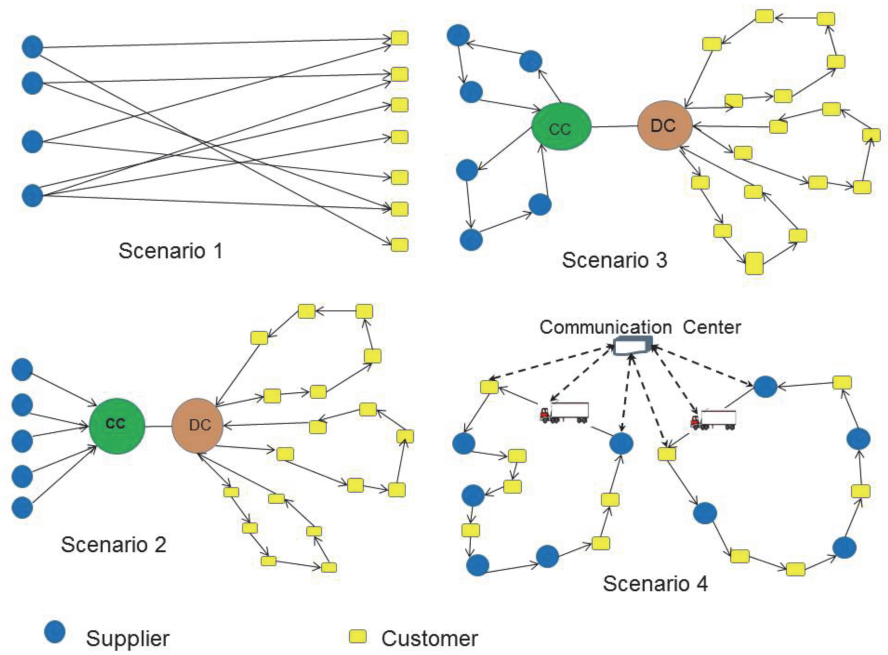


Figure 10. Scenarios in Paper V.

3.7.3 Scenarios in Paper VI

In this case study, two scenarios were set for the collection of food produces from producers to CC. In scenario 1, producers transport their produces to CCs. In scenario 2, the collection of food produces was to be coordinated and managed by CC.

3.8 Coordination and integration

In scenario based analyses (Papers III-VI) coordination and integration were widely considered (see Figure 3). The distribution of food to the customers was managed in integrated way by gathering data on demand of customers and preparing dynamic planning of distribution in the best way. In Papers V-VI, the distribution of local food was further integrated into large scale food distribution channels (see Figure 6 in Paper VI). In Figure 10, scenarios 2 and 3 indicate ways of collection to CC from where food produces could be transported to either to customers or to nearby food distribution centres of large scale food distribution channels.

3.9 Location analysis

In the location analysis, the initial tasks were acquisition of location related data and register the coordinates of all locations of producers, DCs, and delivery points (customers) and then mapping them. Analysis was conducted to determine the best locations of CCs and DCs. In Papers II, V, and VI, the best location of new CCs were determined for clusters of producers. In Papers II, abattoirs were used as CCs (for animal collection) and as DCs (for meat distribution). In Papers III, IV and V, the existing DCs were considered in the analyses.

Location analysis was conducted using Centre-of-Gravity, Load-Distance, and Location Factor Rating techniques as well as GIS network analyst tools (ESRI, 2008; Russell and Taylor, 2009). Centre-of-Gravity technique was used in Papers II, IV-VI while Load-Distance technique was applied in Papers IV-V. The Location Factor Rating technique was applied in Paper IV. Location Factor Rating technique enables to determine best facility location by evaluating location factors such as availability of infrastructures, nearness to most of customers, transportation services, nearness to suppliers, etc.

3.10 Route recording simulating and optimisation (Papers III-IV)

In Paper III, the GPS receiver was used to collect information about points along the routes following the deriver during food collection and distribution. The route recording process was performed along with registration of visiting order, arrival and departure times, loading and unloading times, and customers addresses as well as delivered quantity to each customer.

In Papers III and IV recorded routes (where order of visiting and coordinates of stopping places were recorded) were also analysed. In cases where routes were not recorded, routes of existing and new scenarios (set for the purpose of this study) were simulated and analysed.

Route LogiX software (DPS, 2004) was used in Papers II-III and V-VI, while ArcGIS network analyst tool (ESRI, 2008) was used in Paper IV to optimise the food collection and distribution routes. Although the optimal route determined by the network analysis can be the fastest route, in this study, the route optimisation analysis was based on the shortest route approach. In cases where registered real routes were available (Papers III-IV), the optimised routes were compared to the recorded routes (or routes simulated following the order of visiting). In the absence of such recorded routes, the optimised routes of proposed new scenarios were compared to the scenarios which approximately represent the existing routes (Papers II-VI) in order to investigate the potential savings due to optimisation.

The savings were presented and discussed mainly in terms of transport distance and time (Papers II-VI). In Papers IV-VI, savings in number of routes was also considered while in Paper IV, savings in number of visits (stops) was included. In Paper II, the route optimisation analysis was conducted along with comparison analysis to investigate the benefits of establishing small scale abattoir. The route optimisation analyses were performed based on different scenarios (varying from 2 to 4 scenarios) of food delivery systems (Papers III-VI).

3.11 Emission estimation

In Papers II and IV the emissions from vehicles were estimated. Emissions estimated in Paper II were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxide (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO_2). In Paper IV, carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_X), particulate matter (PM) and sulphur dioxide (SO_2) were estimated. In Paper II, emission value was estimated as:

$$E = FC * TV * EF$$

Where, E is emission in kg, FC is fuel consumption in m^3, TV is thermal value in GJ m^{-3} and EF is an emissions factor in kg GJ^{-1} (SEPA, 2010). Emission is related, to a lesser extent, to the load (ton-km), and mainly depends on distance driven by vehicles (vehicle-km) (Aronsson and Brodin, 2006). Based on this, the emission estimation in this study was based on vehicle-km.

In Paper IV, the emissions estimation was based on emission factors, in g km^{-1}, prepared for year 2010 (Trafikverket, 2009), taking into consideration the transport activities in the countryside and urban areas. It was estimated as:

$$E = D * EF$$

Where, E is emission weight in g, D is travel distance in km, and EF is the emission factor in g km^{-1}. The emission values were expressed (Paper IV) in terms of global warming potential (GWP), human toxicity potential (HTP), acidification potential (AP), and eutrophication potential (EP) on annual bases (Paper IV).

4 Results

4.1 Different aspects of food traceability systems (Paper I)

Table 5 depicts the major aspects of food traceability: definition, driving forces, benefits, barriers, and technological advancements in implementing food traceability systems.

Table 5. *Aspects of food traceability addressed in the literature review*

Aspect of FTS	Description
Definition	● Three key components were identified: backward follow-up of products (tracing), forward follow-up of product (tracking), and the product history information associated with the product movement in the supply chain. There exist limitations in existing definitions and new definition has been proposed (in this study) considering FTS as integral part of logistics management.
Driving forces	● The identified driving forces have been categorized as: regulatory, food safety and quality, social, economic, and technological concerns.
Benefits	● The identified benefits have been summarized as: increase in customer satisfaction, improvement in food crises management, improvement in FSCM, competence development (for companies), contribution to technological and scientific development and agricultural sustainability
Barriers	● The identified barriers have been summarized as: resource limitation, information limitation, standard limitation, capacity limitation and awareness limitation.
Technological advancements	● There are advancements in technologies for product identification (e.g. bar codes, RFID tags), quality and safety measurement (e.g. smart packaging devices), genetic analysis (e.g. DNA tests), environmental monitoring (e.g. temperature-indicators), geospatial data capturing (e.g. GIS, GPS), data exchanging (e.g. EDI), and data processing/analysis (e.g. QualTrace).

To address the linkage between FTS and logistics activities and reduce the limitations in defining FTS, a new comprehensive definition has been proposed (Paper I) as:

> *Food traceability is part of logistics management which capture, store, and transmit adequate information about a food, feed, food- producing animal or substance at all stages in the food supply chain so that the product can be checked for safety and quality control, traced upward, and tracked downward at any time required.*

The linkage between qualitative information and physical flow is key factor in developing effective and efficient traceability and this issue should be considered from logistics management point of view. Therefore, designing intelligent food packaging technologies which could be integrated with data capturing and transmitting devices is important logistics activity.

Traceability in agriculture and FSC is a field under development where more innovations are required. Further improvement of FTSs can be promoted by:

- encouraging the development and implementation of new, cheaper, user friendly and more effective traceability devices (e.g. nano-scale RFIDs) and data processing software;
- increasing the awareness and motivation of leadership and employee's technical skill to minimize capacity and awareness limitations;
- encouraging scientific researches that focus on improvement of FSCM and integration of traceability and logistics activities;
- organizing the high interests from society, government agencies, and researchers in the security of FSC and using it to attract financial funding for the development and implementation of better FTSs;
- preparing more clear traceability guidelines and regulations;
- Interlinking FTS and other quality and safety management programs such as Hazard Analysis and Critical Control Points (HACCP) systems;
- improving and controlling the standard and quality of the traceability information shared between actors of supply chain.

The performance of food traceability system can be evaluated against its overall goal considering the performance indicators such as effectiveness, efficiency and competency of the implemented traceability system. This overall goal should incorporate important specific goals such as: compliance with rules and legislation; food safety and quality; social and stakeholders' satisfactions; economic benefits; and technological and scientific benefits. It was learnt that in cases where partners in the FSC have conflicting goals, the performance evaluation is more complex. This study also indicated that a better performance of a FTS can be explained in terms of its breadth, depth, precision, and access to data and information (Paper I). Food traceability could be simple (in case of short supply chains) and very complex in case of long supply chains that involve many partners. It should be noticed that implementing traceability system that fully cover the entire supply chain could lead to highest benefit than improving traceability partially (on a single production system) (Saltini and akkerman, 2012).

4.2 Characteristics of the investigated local food supply chains

4.2.1 Product types

The main identified locally produced foods were meat, egg, vegetables and fruits, dairy products, and fish. Most of the local food producers supplied meat and vegetables (Papers III-VI). For example in Paper VI, about 49% of the 90 producers had meat products while about 42% of them delivered vegetables. In paper V, about 33% of producers provided fruits and vegetables while about 25% of them had supplied meat. In Paper III, organic products such as vegetables, fruits, and meat were mainly supplied food items.

4.2.2 Means of transportation

The major means of transportation used in these local food supply systems include using own vehicle (Papers III-VI), and third party transport service (Papers II-VI). For example, in Paper V about 75% of producers (N=14) used mostly their own vehicles in the existing (uncoordinated) scenario. Utilizing third party service providers was realized in different ways i.e. via collaboration with other food producer or processing firm (Papers IV-VI), buying service from Transport Company specialised in transporting animal or food (Papers II-III). From food safety point of view, using means of transport which are not specialised in food transport could lead to risk of contamination (Ackerley et al., 2010). Especially transporting food items as backhauling or vice versa increases cross contamination of food produce. For example in Paper III third party transport vehicles were used on the way from transporting other goods. Such type of transport management requires more quality control management and more awareness creation regarding food safety issues.

4.2.3 Utilization of vehicle capacity

In the existing uncoordinated distribution, the load rate at the time of departure for distribution, varied from 25% to 100% with average value of 58% of vehicle capacity (Paper VI). Figure 11 illustrates that out of 70 producers about 43 producers started distribution with ≤ 50% loaded vehicles. In Paper VI, only

16% of sample farms (N=70) had load rates of 100%. However, in Paper IV, where the integrated food distribution has been practiced, the load rate was 100% in most cases at the time of departure time from DC. In the large scale food distribution channel, about 30-40% of loading capacity of trucks is often unutilized (Paper V). By integrating the distribution of local produces into large scale distribution channels (Papers V-VI), this free space of large trucks could be used for transporting these local food produces.

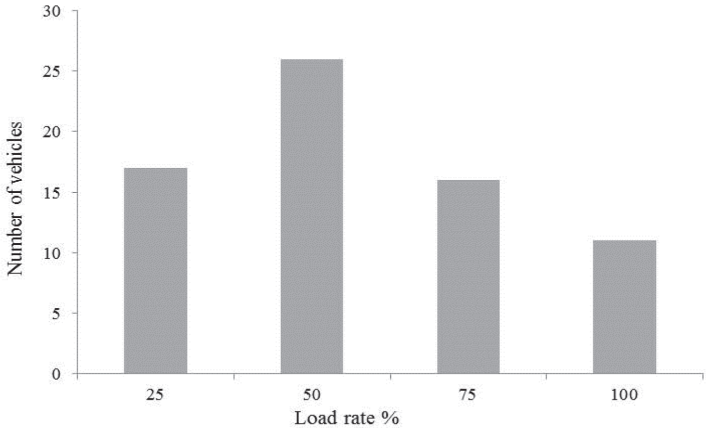


Figure 11. Vehicle load rate based on data from food producers (N= 70) recorded at departure time to deliver food products (Paper VI).

4.2.4 Delivery distance, frequency and time window

The distances of producers and customers from the CC/DC are presented in Table 6. Considering their maximum radius from CC/DC in km, the producers were found within the radius varying from 30 km (Paper V) up to 330 km (Paper IV). Similarly the customers were found within the area with the maximum radius varying from 50 km (Paper IV) to 480 km (Paper V). However, in Paper V, most of the customers were within the radius of 180 km (see Table 6).

The delivery frequency was not the same in different case studies and even it varied for different producers and customers within the same case study. In Paper IV, it was up to 5 times per week in the case of collection to DC and up to 3 times per week in case of food distribution to customers. In paper III, the delivery frequency during distribution was mostly once in 2 weeks. However, it should be noted that this delivery frequency applies only when the local food supply is possible i.e. there is seasonal variations. Data on the delivery time window was available in detail only for Paper IV where, the delivery time window set by customers varied from 6:00 to 18:00 (6:00 am to 6:00 pm) and the convenient delivery time for most of the customers was between 6:00-8:00.

In Paper III, it was observed that the delivery time mostly varied from 13:00 to 20:00 (see Table 6).

Table 6. *The delivery distances*

Paper	Maximum radius from CC for producers [km]	Maximum radius from DC for consumers [km]	Delivery[1] frequency	Delivery time window
II	50	53	-	-
III	30	115	0.25-0.5 per week	13:00- 20:00
IV	330	50	0.2-3 per week	6:00 - 18:00
V [2]	50	480	0.5-10 per week	-
VI	50	150	-	-

1. Delivery to customers;

2. Most (96%) of customers are within 180 km radius in the initial scenario.

4.3 Animal collection and meat distribution (Paper II)

In Paper II, about 1635 potential suppliers of LSA were identified. Out of these about 500 farms were considered in both determining best location for SSA and for creating 120 routes of animal collection. Out of these 120 routes, 30 routes were used during detail route optimisation analysis. These 30 routes involved only about 17% of these 500 farms. The comparison analysis of animal supply from local farmers to SSA and LSA (Paper II) indicated that the establishment of local abattoir could reduce transport distance (by 42%), transport time (by 37%) and emission due to transport (by 42%) when compared with the LSA in the region. The total travel distance to collect and supply to abattoir (considering single trip, in all 30 routes) was reduced from 16500 km (in large scale case) to 6965 km (in small scale case) i.e. 9535 km was saved. Consequently, the corresponding transport time was reduced from 8 h and 25 min to 4 h and 13 min. If all 120 routes were considered the distance and time saved could be increased by 75%, i.e. about 16686 km in animal supply could be saved. In the case of meat distribution, considering only the 7 routes, the total travel distance was 2256 km in large scale case and reduced to 1060 km in small scale case (see section 4.6.2).

4.4 Box-scheme based food delivery

In Paper V, the field measurement and analysis results indicated that on average about 134 boxes (on each delivery day) of fresh organic produce were delivered to 116 customers. The boxes were produced locally from wood with size of 25x30x40 cm. When there was additional order, paper bags (35x25x17 cm) were used as complement packaging material.

All producers investigated in Paper III are KRAV certified organic food producers. This certification is the Swedish labelling certification that the product has been organically produced, but it does not guarantee the quality of the organic food (Krav, 2013). However, this network of local food producers is determined to promote “local food with identity and quality”.

4.5 Best location of collection centres and distribution centres

In Papers II, IV, and V the producers were clustered into one cluster in each paper. In Paper III and VI there were 3 and 14 clusters respectively. In Paper II and V-VI, for each cluster of producers the best locations of new CCs were determined (see Table 7). In Papers III-IV, the existing DCs were used as CCs. In Paper IV, the optimality of the existing DC was checked and found to be the best location. In Papers II-IV, and VI the CCs were also used as DCs. In total about 21 CCs were considered in the five case studies (Papers II-VI) serving about 635 local food producers (see Table 7).

Table 7. *Number of CCs and related information*

Paper	No. of CCs	No. of producers	No. of customers	Quantity [t $year^{-1}$]
II[1]	2	500	-	-
III	3	20	150	-
IV	1	11	149	2761
V	1	14	44	700
VI[2]	14	90	-	4785
Total	21	635	-	-

1. The total identified farms were 1635 but 500 farms in vicinity of SSA were considered to determine best location of abattoir (considered also as CC);

2. The total number of producers were 90 but 7 producers were not included in the 14 clusters;

4.6 Route optimisation

4.6.1 Demonstration of recorded routes (Papers III-IV)

In some case studies, the existing real distribution routes were mapped using the recorded data on the actual order of visiting the delivery points (customers). Twelve routes in Paper IV and five routes in Paper III were studied in this manner (see Table 8). Based on the simulated values, the estimated length of recorded routes (Paper III-IV) was about 1666 km (see Table 8). Without considering other possible scenarios of creating new routes, optimising the routes by changing the visiting order, the average savings were 23% (Paper III) and 28% (Paper IV) for distance and 16% and 4% for time respectively. One of the 12 routes recorded in Paper IV is given in Figure 12.

Table 8. *Summary of recorded routes; the distance and time were summation of simulated values for all routes indicated under column 2*

Paper	No. of routes	Un-optimised routes		Optimised routes		Saving %	
		Distance [km]	Time [h:min]	Distance [km]	Time [h:min]	Distance	Time
III	5	1180	32:20	904	27:15	23	16
IV	12	486	65:04	349	62:35	28	4

Figure 12. Example of registered and optimised routes: (a) One of recorded distribution routes from DC (large dot) to delivery points (small dots), un-optimised (Paper IV); (b) the same, but optimised route.

4.6.2 Scenario based optimisation analysis (Papers III-IV)

The results of route optimisation analysis are presented in Tables 9(a) (for comparison analysis) and 9(b) (scenario based analysis). Considering the large scale abattoir, the analysis included 16500 km transport distance and about 184 h transport time for animal collection and 2256 km transport distance and 27 h transport time for meat distribution. Table 9(a) indicates that (when small SSA was considered) the distance and time were reduced by 42% and 37% respectively in the case of animal collection and by 53% and 46% for distance and time respectively in the case of meat distribution.

In Papers III-VI, food delivery routes were analysed by considering different scenarios and comparing with the initial scenario in each case. Table 9(b) presents the summary of potential savings gained due to route optimisation when compared to the initial scenario. The scenario based optimisation analysis indicated that the best scenarios could save the number of routs up to 68% (Paper VI), transport distance up to 74% (Paper IV, scenario 3), and time up to 63% (Paper IV).

In paper IV, scenario 4 reduced the distance, time and number of visits done by large trucks up to 31%, 27%, and 38% respectively when compared to scenario 3 of Paper IV. This is very important aspect to reduce large vehicles in traffic and improve city logistics. However, more small vehicles are needed to carry out the last delivery from LDCs.

Table 9(a). *Potential savings in distance and time by using SSA instead of LSA (Paper II)*[1]

Route type	No. of routes	Distance (LSA) [km]	Time (LSA) [h:min]	Average improvement by using SSA %		
				Routes	Distance	Time
Animal collection						
LSA	30	16500	184:27			
SSA	30	6535	126:21	0	42	37
Meat distribution						
LSA	7	2256	27:03			
SSA	7	1065	14:33	0	53	46

1. The distance and time were simulated values (not measured) and improvement is when small scale is compared with large scale abattoir.

Table 9(b). *Potential savings in distance and time by optimising food delivery routes*

Papers	Initial no. of routes	Distance before optimisation [km]	Time before optimisation [h:min]	Average improvement due to optimisation %		
				Routes	Distance	Time
III[1]	5	1180	32:20	0	23	16
IV[2]	9	2022	85:12	64	74	63
V[2]	23	6159	69	65	43	42
V[3]	23	6159	69	87	93	91
VI	81	8935	226	68	50	48

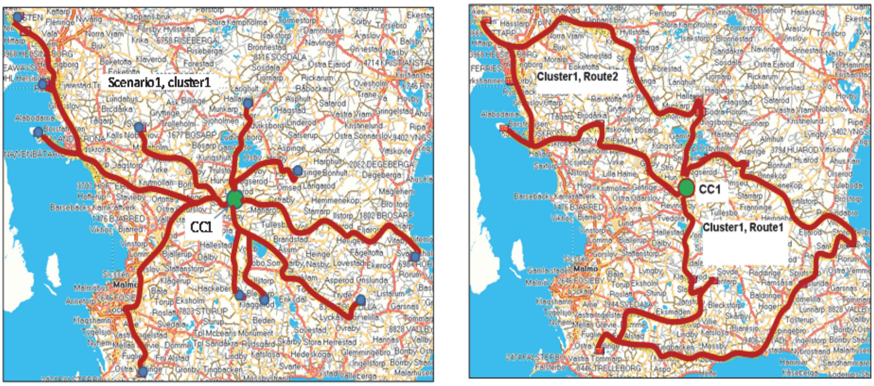
1. For Company-1 in Paper III, collection route and distribution route were considered as single route; scenario-1 and scenario-2 of Company-1 were considered neglecting customers in Stockholm; scenario-3 of Company-1 was also not considered (see Table 3 in Paper III);
2. The case of best scenario was considered (Papers IV- V);
3. When integration into large scale food distribution channels was considered which changed the values after optimisation and increased the savinings.

4.7 Coordination and integration

4.7.1 Coordinating food collection and distribution (Papers III-VI)

In some cases food collection and distribution could be coordinated. In Paper V, scenario 4 (see Figure 10) was set for this type of coordination and the analysis result indicated that such coordination could save transport distance and time up to 62% and 57% respectively. However, its practical application was found to be uneasy. In Paper III, the distributors coordinate the food collection with distribution by picking products of some producers on the way to main distribution fleet.

In Papers IV-VI, the concept of coordinated collection of products from producers to the optimal location of CC was introduced. For this the optimised routes of coordinated collection were designed for each cluster of producers with the assumption that the food producers could fully cooperate to use common CC (for each cluster) and coordinate their transport activities during food collection from farms to CC (see Figure 13).



(a) un-coordinated collection (b) coordinated collection

Figure 13. Map illustrating (a) routes simulated for uncoordinated collection (b) routes simulated for coordinated collection of products to one of collection (Paper VI).

For example, in Paper VI, the coordinated food collection resulted in potential saving in transport distance (by 50%), time (by 48%) and number of routes (by 68%) considering the average value of the 14 clusters. Figure 13 illustrates the routes of collection to one of the CCs in which potential savings of 66% (transport distance), 50% (time) and 86% (number of routes) were gained.

4.7.2 Coordinating food distribution with distribution of other goods (Papers III-IV)

In some cases, the food distributing companies involved in the local food supply network coordinated the distribution of food products with non-food items to utilise the vehicle capacity efficiently. In Paper IV, this method was applied during delivering food from DC to customers located relatively far away from DC, since it is costly to transport small quantity of items over long distance. In Paper III, transporting food products to long distances was performed using vehicles of other companies which could pick food items on the way from transporting other goods. Also, in some cases, food products were picked from collection centres by vehicles on the way from job. It was noticed that such a type of coordination could improve the utilisation of the vehicles; could save time; reduce number of fleets; and reduce logistics cost. However, it should be done carefully, because from food safety point of view, transporting food items with other products could cause food contamination.

4.7.3 Integration of food delivery activities

Forming network of producers, distributors and consumers could facilitate the integration of the logistics activities in collection, packing and distribution of local food products. In Paper III, the network comprised about 20 producers of organic food. In Paper IV about 11 producers were included in the network, while in Paper V about 14 producers were considered to be partners of a network. These networks also enabled the integration of local food delivery activities into large scale food distribution channels. In Paper V, where route optimisation and integration into large scale food distribution channels was considered, the best savings were obtained i.e. 87% in number of routes, and 93% in distance, 91% in time (see Figure 10 and Table 9(b)). In Paper VI, out of 14 clusters of local food producers, 12 clusters could potentially be integrated into the large scale food distribution channels (see Figure 14).

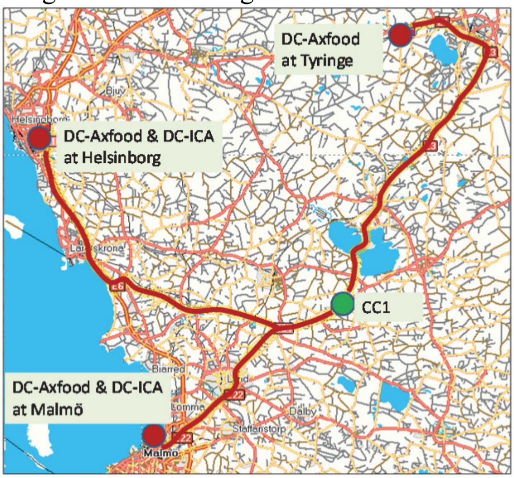


Figure 14. Example of integration into large scale food distribution channel, where the collection centre (CC1) was linked to nearby supermarkets (Paper VI).

4.8 Environmental impact assessment

This study revealed that savings in emissions were gained due to coordination and optimisation of local food delivery systems (see Table 10; Figure 15). For example, considering single trip of delivery (on all routes), the potential savings in CO_2 emission values in Papers II and IV are presented in Table 10. The savings in CO_2 emission varied from 42% to 75% for cases indicated in this Table.

Table 10. *Potential savings in CO_2 emission values*

Paper	Description	CO_2 emission in tonnes		Saving %
		Initial scenario[1]	Alternative scenario	
II	Animal collection	12.58	7.27	42
II	Meat distribution	0.63	0.30	53
IV	Scenario-3	4.35	1.15	73
IV	Scenario-4	4.35	1.10	75

1. Initial scenario is the case of LSA in Paper II and it is the case of scenario-1 in Paper IV.

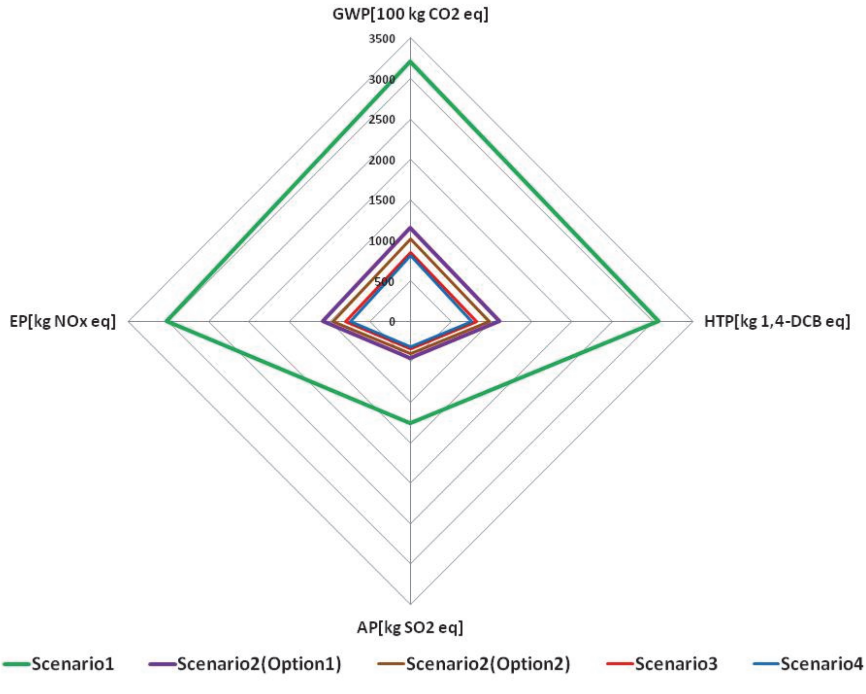


Figure 15. Environmental profiles of the four scenarios (Paper IV), considering the estimated (annual) emissions from vehicles. GWP is expressed in 100 kg CO_2 eq, while the remaining factors are expressed in kg of their reference measurements.

In Paper II, the estimated value of CO_2 for LSA (considering 30 routes of animal collection and 7 routes of meat distribution) was about 13205 kg considering only single trip of animal collection and meat distribution. The value was reduced to about 7564 kg when SSA was considered. Similarly CO was reduced from about 31.51 kg to 18 kg, while NOx was reduced from about 154 kg to 88.24 kg.

In Paper IV, the emission values were also expressed in terms of environmental impact potentials, on annual bases. The GWP (in t CO_2 eq per year) was reduced from about 321 (in scenario of maximum emission) to about 81 (in scenario of minimum emission). Similarly, HTP (in kg 1,4-DCB eq per year), AP (in kg SO_2 eq per year), and EP (in kg NOx eq per year) were reduced from 3068 to 754; 1261 to 310; and 3025 to 743 respectively. Figure 15 shows the comparison of different scenarios in terms of environmental impact. It illustrates that scenarios 3 and 4 are the best delivery scenarios in terms of environmental impact.

5 Discussion

5.1 Perception towards local food

The literature review indicated that there exist societal needs to know the origin of the food they consume and to get more access to locally produced food. These issues are related to food safety and quality as well as animal welfare issues. The local food systems simplify the issue of tracing the origin of food products. However, the high cost of locally produced food has impact on the customers' preference in the market. In Paper II, the local people involved in the survey confirmed that they preferred locally produced meat, favouring the local small scale abattoir, and about 90% of them were ready to pay about 20% more for the local food. This supports the suggestions which indicated that people will often pay more prices for local food (Haweil, 2002).

The society has also more trust on local food producers as food fraud is common in globalized and complicated food supply systems. For example a high level of cooperation and trust was noticed among partners of the network studied in this study. In Papers III and IV it was also learnt that the consumers enjoyed the good food distribution service and fresh local products. The increasing demand for local food encourages the producers to increase their production in both quality and quantity. Producers considered in these case studies (Papers II – VI) had interest to expand their marketing channels if they could reduce their production and delivery costs and become competent. The current study also depicted that the small scale producers want to reduce their logistics cost and increase their production and reach out to the more consumers. The intervention by municipalities (Paper IV) in building network of local food producers has encouraged the local food producers in the region. Since the initiative (Paper IV) has been successful, the municipalities have been encouraging more producers to join the network and the number of communities served by the network (Paper IV) is expected to be increased in the future.

The improvement gained in the local food systems could increase the satisfaction of consumers, and increase the competiveness of local food producers. For example in Paper III, prior to the formation of logistics network, the producers experienced constraints associated with the logistics service. The improved system also contributed to reduction in environmental impacts especially when the efficient logistics systems are introduced by sharing resources and minimizing the use of packaging materials. In general, the improved local food systems have vital economic, social and environmental advantages, and such studies could increase the positive societal attitudes towards local food systems.

5.2 Animal supply and meat distribution chains

The local abattoir was more attractive in relation to animal transport and subsequent animal welfare and meat quality. It decreased the transport distance and time, improving the welfare of slaughter animals. In Paper II, about 42% and 37% savings in travel distance and travel time respectively were gained for the case of animal supply from farms to local SSA when compared with LSA. Local meat supply could also increase the customer satisfaction.

In addition to transport distance and time, there are other conditions that should be taken into consideration during planning animal supply to abattoirs. In planning animal collection and meat production, maintaining steady supply of slaughter animals to abattoir and avoiding breaks in meat production are important criteria (Gribkovskaia et al., 2006). Although, underfeeding and pre-slaughter stress start earlier than loading for transport to abattoir and continue at different steps until the time of slaughtering (Gregory, 2008), loading and unloading during transport are identified as very stressful activities for animals (Kenny and Tarrant, 1987; Gebresenbet and Ericsson, 1998; Scientific Committee, 2002). For example studies in Sweden indicated that heart rate of cows doubled during loading (from about 50 to 105 beats per minutes) on trucks (Gebresenbet and Ericsson, 1998).

5.3 Box-scheme based organic food supply chain

Box-scheme based food delivery systems have been applied for supplying organic and fresh local products mainly fruits and vegetables. This system used locally prepared packaging material (wooden boxes) which could be re-used. Customers are usually motivated towards box schemes by its positive contribution to environment, and food quality (Brown et al, 2009). Such scheme can be efficient when run by a network of producers, distributers and consumers. In Paper III, such a network enabled the partners to collaborate chiefly for mutual benefits e.g. to reduce logistics cost, food prices and product waste while improving food safety and quality and customer satisfaction.

5.4 Location and route optimisation

In Papers II, IV, V, and VI, location and route optimisation analyses enabled to get insights in the local food delivery systems and identify the best scenarios. For designing effective and efficient logistics systems in local food supply chains, CC/DC should be located at best places. This is important because location is an important aspect in a company's strategic plan and a wrong facility location decision can result in excessive costs, especially for transportation and distribution of goods (Russell and Taylor, 2009). In Paper IV, the optimality of location of existing DC was checked and has been found to be best palace. This is one of the reasons why the integrated food distribution network (Paper IV) in Borlänge area has become a successful existing project.

In addition to best location of CC/DC, creating best food delivery routes has great potential of improving the local food supply systems. The optimisation analysis in this study could reduce number of routes, transport distance and time up to 68%, 74%, and 63% respectively. This indicated that in logistics of local food systems, there is high potential of improvement which could lead to better competiveness of local producers and sustainability of local food systems. The utilization of new technologies such as ArcGIS and Route LogiX has facilitated the location and route optimisation analysis, and mapping locations of farms, CCs, DCs, delivery points and the food delivery routes. These in turn could facilitate the understanding about the food systems as well as communication and decision making activities.

5.5 Logistics network integration in local food supply system

The current thesis demonstrated that local farmers can create effective logistics networks and use a more commercial approach taking into consideration the timely needs of consumers. Such networks facilitate the in-depth cooperation and integration in the LFSC management. Such integrated management allows the local farmers to share marketing, transportation, and distribution capacity; and link up with other institutions such as restaurants, school cafeterias, independent grocers, and other potential customers (Walweil, 2002). In relation to improving FSCM, Gustafsson et al. (2006), pointed out that supply chains in fresh food can be simplified, reorganized, and become more efficient and effective.

In designing and implementing better logistics systems, logistics managers strive to: analyze the cost and service of existing logistics structures; search for alternative logistics structures (within the existing facilities or designing new facilities); and reduce the environmental impact of logistics systems (Aronsson and Brodin, 2006). The process of designing effective logistics networks depends upon the efficient transfer of information, finance and physical goods (Hesse, 2004). The network integration improves the understanding about customers' needs which in turn helps the producers to improve their production and the distributors to improve their logistics service (Sohel-Uz-Zaman and Anjalin, 2011). In forming integrated logistics network in food supply chain, insuring information connectivity is essential. In this regard, designing and implementing effective food traceability could facilitate the logistics network integration in the food supply chain (Paper I).

5.6 Implication of logistics network integration in local food supply systems

5.6.1 Implication for food logistics management

Implication for food traceability: The logistics networks help to facilitate the development of effective and efficient FTSs in the case of small scale FSC where there exist lack of information about the traceability systems and lack of knowledge to implement it (Paper I). In order to overcome these problems, a central database can be established for small scale food producers so that they can easily access and share information via a personal computer and internet connection. In the case of small scale enterprises with a simpler and shorter FSC, an efficient paper-based traceability system (simplest form of traceability) could enable to effectively trace the product

The network enables partners get access to the right information at the right time (Golan et al., 2004; Donnelly et al., 2012). The network also facilitates the availability of organized data for researches, planning and management purposes related to local food systems. For example in Papers III and IV, where the network has already been introduced practically, it is relatively easy to get more organized data on the food delivery system. Such network based information connectivity could serve to encourage the local food producers and provide the added layer of food security (Bantham and Oldham, 2003; Beckeman and Skjöldebrand, 2006 ; Liang, 2008). The network facilitates information exchange among the network partners as well as disseminates information to other concerned national and international organizations and governmental bodies. Bourlakis and Bourlakis (2006) strongly argued that IT operations should be formulated alongside logistics operation of food retailers. This facilitates the implementation of food traceability systems.

Implication for logistics performance: In the case where there is high level of cooperation and trust, (e.g. Papers III and IV), the logistics network enables to improve the service quality as well as economic benefits to meet performance expectations (Daugherty, 2011). Efficient logistics service requires delivering the right product, in the right quantity, in the right condition, to the right place, at the right time, for the right cost (Brimer, 1995; Aghazadeh, 2004; Tarantiles et al., 2004).

In Paper II, transport distance was reduced by 42% for animal transport and 53% for meat distribution via establishment of the local abattoir and optimisation of routes for animal supply and meat distribution (see Table 9(a)). This indicates that it is possible to reduce transport distance by promoting production near the market and increasing number of local suppliers (Kvarnbäck, 2000).

In Papers V and VI, integrating the delivery of local food products into large scale food distribution channels revealed high potential of improvement in the logistics services i.e. up to 93% in distance and 91% in time in Paper V and 50% in distance and 48% in time in Paper VI (see Table 9(b)). In Paper IV, the best scenario has improved the distance and time by 74% and 63% when compared to the old fragmented distribution system. Such coordinated distribution system also reduced the number of vehicles which in turn increased traffic safety and reduced noise and emissions (Doran, 2011). It also could improve packaging services (e.g. Paper III), load rate (e.g. Paper IV). Good packaging includes brand and marketing information; uses minimum resources; reduces the weight of packaging material; and increases reusable packaging materials and reduces environmental impacts (Gustafsson et al., 2006). In general, integrating logistics activities in food supply chain can improve logistics services (Mangina and Vlachos, 2005; Van Donk et al., 2008).

Logistics networks facilitate conditions for training farmers and employees in food companies such as drivers. The training should be given taking into consideration the welfare of food producing animals and food damage or contamination risks associated with food packaging, labelling, handling and transporting activities (Ackerley et al., 2010).

5.6.2 Implication for food quality

Consumers mostly prefer food with no additives, less processed, and safe food (Sofos, 2008; Nychas et al., 2008). Therefore, investments in food supply chain design should not only aim at improving logistics performance but also at preservation of food quality (Van der Vorst et al., 2009). The local food has advantages such as freshness, high quality and safety. The logistics networks increase these food quality attributes. In Paper III, it was noticed that the producers were dedicated to satisfy the consumers by providing fresh products and this increased the demand for local organic food products. The evaluation of coordinated food distribution (Paper IV) indicated that the project attracted more local food suppliers and there was an increase in use of organic food in the project area (Doran, 2011).

In Paper II, reducing the travel distance and time could have positive impact on meat quality and animal welfare. During meat transport, 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 EU the requirement is a maximum final meat temperature of 7°C before transport and the vehicle for meat transport must be provided with a good refrigerated system (Nychas et al., 2008).

5.6.3 Implication for potential marketing and economic benefits

This study indicated that, in the local food system the producers have problems to reach out to the consumers relatively far away from production places. The network integration facilitates the supply of local food to schools, restaurants, governmental institutions, and religious institutions (Halweil, 2002) and to integrate the marketing of local produce into superstore chains. In this thesis (e.g. Papers III and IV), web-based ordering and information exchange as well as well-organized advertising and selling products are proved to be successful in expanding potential marketing channels. In such projects local food producers benefit from shared transport which reduces the logistics cost and increases their competition in the market (Doran, 2011).

Coordinating goods transport and reducing empty vehicles movement are examples of profitable measures (Kvarnbäck, 2000; Gebresenbet and Ljungberg, 2001). Solakivi et al. (2009) indicated that implementation of modern information systems and more efficient data processing could significantly contribute to the reduction of logistics costs. For example, logistics costs of European Enterprises (as percentage of turnover) reduced, during the recent decades, from about 12% in 1987 to 6% in 2003, indicating a reduction of 50% (Solakivi et al., 2009).

5.6.4 Implication for attenuating environmental impact

Reducing the transport distance, transport time, and number of vehicles in the traffic leads to reduction of environmental impact. The main environmental problems associated with transport activities are: air pollution, impact on climate, noise, and impact on the landscape (Kvarnbäck, 2000). From emission reduction point of view, optimising transport activities is the best option for CO_2 reductions. Therefore, integrated logistics management in local food delivery systems enables to create better food delivery systems decreasing the negative environmental impacts. In Paper II, the emission values were reduced by 42% in animal collection and by 53% in meat distribution when local SSA was considered instead of the LSA in the region. In Paper IV, emission was reduced by 73% in case of scenario 3 and by 75% in case of scenario 4 when compared to uncoordinated scenario.

Introducing the LDCs for last delivery (scenario 4 of Paper V) could be important from environmental aspect as it could reduce number of large vehicles. This scenario could reduce energy consumption, emission, congestion, and noise and it can be implemented best by innovative ways such as introducing smaller and quieter electric cargo vehicles and electric (or non-electric) cargobikes for the last mile delivery from LDCs (Cyclelogistics, 2013). These facts indicate that coordination and integration are effective tools to attenuate environmental impacts of logistics activities. Implementing such coordination and integration strategies in many cases of food supply chains could have vital contribution to the global efforts to combat impacts of climate change.

At the local and regional levels, improving the local food delivery systems is part of efforts made to reduce the environmental impact. It creates chance to increase the awareness on the damages on the environment due to acidification and eutrophication problems. Andersson (2010) reported that due to increasing awareness about the environmental issue, large scale food retailing companies are trying to reduce their pollution by planning efficient delivery routes, utilizing right trucks with efficient capacity utilization, and training the drivers. According to Aronsson and Brodin (2006), in many cases, environmental measures taken at macro level (by government and legislative authorities) and micro level (by companies) could not keep pace with growing transport volume. At micro level, incorporating environmental sustainability principles into decision-making processes is also a challenging activity for logistics managers. As a result, integration of environmental issues into transport policies and decision-making processes has been given a high political priority in Europe (Aronsson and Brodin, 2006).

6 Conclusions and final remarks

Effective food traceability system is an important tool to be considered as integral part of food logistics system as it facilitates the integrated management of food supply chain as a whole. Local food producers have strong linkage with the customers. However, small scale food producers have traceability information and knowledge limitations when compared to large companies. Therefore, a central database is required where these small producers can easily access and share traceability information.

When compared with large scale (Paper II) the small scale abattoir could reduce transport distance and time by 42% and 37% respectively in the case of animal collection and by 53% and 46% respectively in the case of meat distribution and as a consequence emission from vehicles was reduced. It could also increase customer satisfaction as about 90% of customers involved in survey (Paper II) confirmed that they preferred local food and were willing to pay up to 20% more for locally produced meat.

Logistics related constraints in local food systems could be tackled through clustering, coordination, integration, and optimisation techniques. The integration of logistics network in local food supply chains could increase the performance of the entire chain by reducing overstock, delivery delay, final product price, and by increasing product value, quality and safety as well as customer satisfaction.

The logistics network integration and optimisation using tools such as Route LogiX and ArcGIS could result in vital improvements at two levels:

(i) Comparing to the existing conditions, alternate scenarios could improve the delivery activities from producers to their existing customers i.e. considering average values (average from each case studies, Papers III-VI), improvements gained were up to 63% for distance, 74% for time, and 68% for number of routes.

(ii) Integrating into the existing large scale food delivery channels could lead to more improvements, i.e. up to 93% in distance, 91% in time, 87% in number of routes.

As a consequence of reduction in transport distance and number of vehicles, the emission from vehicles could be reduced. This in turn could play important role in reducing environmental impacts, especially if the best scenarios are implemented on wider area.

This study has also revealed that the integrated logistics networks have implications for improving food traceability, logistics performance, food quality and quantity, the potential marketing channels (and economic benefits), competitiveness of suppliers and attenuating negative environmental impact.

It is important to remark that:

- Clustering local food producers can facilitate the logistics integration process and collaboration between suppliers of different food items.
- Scenario 3, in which food collection and distribution were coordinated (Papers IV-V) was found to be the best scenario recommendable for practical implementation.
- Scenario 4, in which local distribution centres were introduced (Paper IV) is also important model that can be effectively implemented if the last delivery from local depots can be conducted by innovative ways such as using smaller and quieter electric cargo vehicles and/or cargobikes.
- Local food producers need to expand their marketing channels, reduce logistics cost, increase their production, and become competent in food marketing and reach out to more consumers. Therefore, appropriate interventions by authorities and research institutions are recommendable to facilitate the implementation of integrated and sustainable local food supply systems.

7 Further Research

The global Food traceability is complex process and is a potential area of research in agri-food supply chain and many questions are still to be answered. Therefore, further researches on traceability are required with focus on issues such as: improving technological aspects; linking traceability system and food production units and logistics operation; standardizing the information exchange; forming awareness creation strategies; communicating traceability information to consumers and other stakeholders; developing effective frameworks for evaluation of traceability performance.

The current study focused mainly on improving the logistics management of local food systems focusing on transport part i.e. location and rout analyses. Further research on local food supply chain focusing on procurement, inventory management, storage and packaging activities are recommended to address the holistic view of food logistics systems and further promote the competitiveness of local food systems in the agriculture sector and attenuate the negative impact on the environment.

The economic aspect of integrated distribution system of local food should be investigated in detail. In connection to this, the trade-off between economic benefits of establishing small scale abattoirs and animal welfare/meat quality should be studied in detail.

New technology based, site specific detailed studies are important to have dynamic planning that enables to solve problems related to potential changes in the local food supply chains. The increase in the production of local food and its influence on the imported food on market can be investigated. It is also necessary to investigate the possible food losses along the local food supply chain and develop strategies to reduce such losses.

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