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Logistics and Supply Chains in Agriculture and Food

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1. Introduction

During the recent two decades, goods flow has been tremendously increased, even though the amount of goods remains at the steady state. Increased variety of goods, the just-in-time delivery system, low load rate, specialization and centralization of production systems, globalization of marketing and seasonal variations are among the main challenges of logistics system which may lead to the necessity of developing effective logistics in the sector. Effective logistics and technologies are a critical success factors for both manufacturers and retailers (Brimer, 1995; Tarantilis et al., 2004). Effective logistics requires delivering the right product, in the right quantity, in the right condition, to the right place, at the right time, for the right cost (Aghazadeh, 2004) and it has a positive impact on the success of the partners in the supply chain (Brimer, 1995).

Food chain logistics is a significant component within logistics system as a whole. The food sector plays a significant role in economy being one of the main contributors to the GNP of many countries, particularly in developing countries. According to the European Commission (2010), the food and drink industry is one of Europe's most important and dynamic industrial sectors consisting of more than 300,000 companies which provide jobs for more than 4 million people.

The current trend in food value chain is characterized by three overriding features:

- a. greater concentration of farms, food industries, and wholesalers into smaller number with large sizes;
- b. the evolution of integrated supply chains linking producers and other stakeholders; and
- c. ever increasing consumers demand for food quality and safety (food that is fresh, palatable, nutritious and safe) and animal welfare (Opara, 2003). However, to date, the linkage between logistics systems of the stakeholders in the agriculture and food supply chains is rather loose and fragmented. Even within individual firms, the vertical and internal integration as related to freight and logistics is loose, and therefore they are both economically and environmentally inefficient and not sustainable. In this regard, effective and efficient logistics will be a critical success factor for both producers and retailers.

In addition to the increase in transport of agricultural and related goods in the recent decades, empty haulage is common in agricultural sector and the load capacity utilization level of vehicles is very low (it varies between 10 and 95%) (Gebresenbet and Ljungberg, 2001). Therefore, efficient use of vehicles could be among the methods to reduce transport work and attenuate negative environmental impact (Gebresenbet and Ljungberg, 2001).

Within the agri-food chain, meat chain became societal interest and area of attention by researchers because of animal welfare, meat quality, and environmental issues as transport and handling of slaughter animals are associated with a series of stressful events for animals, compromising their welfare and meat quality. About 365 million farm animals (45 million cattle, 95 million sheep, 225 million pigs, and 300 000 horses) are transported per year within the 15 member countries of the European Union (EU)

The resulting transport intensification leads to environmental degradation by contributing to air pollution, global warming, ozone depletion, resource depletion, congestion and traffic accidents, particularly in the densely populated areas. The aforementioned constraints in the Agri-food chain necessitate the development of innovative logistics system taking into consideration, road and traffic conditions, climate, transport time and distance, and queuing at delivery points to:

- strength the economic competitiveness of stakeholders in the food supply chain
- maintain quality or adding value of food and improve animal welfare
- attenuate environmental impact

The objective of this chapter is to highlight the logistics system in the Agri-food chain and present case studies. In most of the case studies, mapping out the material flow; investigating the possibilities and constraints of coordinated and integrated collection of primary production and goods distribution; and investigating the food products and means of production that supported by information technology were carried out. Optimization of collection/distribution and the reduction in emissions from the vehicles as a result of optimization are presented. It is assumed that the information achieved through this investigation will assist to develop an effective transport-logistics system, which may enable an efficient utilization of vehicles to meet the current demand for attenuating environmental impacts.

The main methodologies employed in the case studies that will be included in this chapter include one or more of the following:

- a. Mapping out goods flow through comprehensive field data collection using questionnaires, interviews and measurements
- b. Optimization including location analysis and route optimization
- c. Coordination of distribution and demonstration
- d. Clustering and integration
- e. Modelling and simulation
- f. Estimation of economic and environmental impact

The studies were carried out through interviews and literature studies, field measurements, simulation and optimization. Data collection on daily distribution and collection including geographical location of collections/distribution points and routes was done using the

global positioning system (GPS) and geographical information system (GIS). Optimization of distribution/collection centers and route optimization were done using the gathered data and the software LogiX (DPS, 1996). Air emissions were calculated using the simulation model developed earlier by Gebresenbet and Oostra (1997), where the following parameters were considered: vehicle type, time (loading; unloading and idling), goods type, load capacity utilization level, transport distance; vehicle speed, geographical position of depot and delivery points, routes, and air emissions from vehicles.

In local food systems, the distribution infrastructure is partial, fragmented (Brewer et al., 2001; Saltmarsh and Wakeman, 2004) and often inefficient, as in non-centralized distribution, the share of the transportation cost per unit of the product is relatively high. This is an area that offers great potential for improvement with potential benefits both to suppliers and outlets. Case studies focused on local food systems, were carried and these studies confirmed that coordination and logistics network integration in food supply chain promote positive improvements in logistics efficiency, environmental impacts, traceability of food quality, and the potential market for local food producers. Such improvement is important as developing food product traceability systems has been a major challenge both technically and economically (Wallgreen, 2006; Engelseth, 2009).

In the case of animal transport and abattoir system, the operations considered involve loading, transporting and unloading animals and the slaughter chain from lairage box to cooling room for cattle carcasses. Data collection was carried out through truck-driver interviews; activity registration on routes and at delivery, and slaughter chain activity registration. Time and distance of transport could be reduced through route optimisation. The analysis of animal collection routes indicated potential for savings up to 20% in time, for individual routes (Gebresenbet and Ljungberg 2001).

In this chapter, the concept and case study on clustering and network integration is presented. In the case study, the locations of 90 producers and 20 delivery points were displayed on maps using ArcMap of GIS software and based on geographical proximity, 14 clusters were formed. The clustering and logistics network integration approach could provide an insight into the characteristics of fragmented supply chain and facilitate their integration. It indicated positive improvements in logistics efficiency, environmental impacts, traceability of food quality, and the potential market for local food producers.

2. Concept of logistics in agriculture and food supply chains

2.1 Logistics services in developed countries

The role of production and supply chain management is increasing worldwide due to the growing consumer concerns over food safety and quality together with retailer demands for large volumes of consistent and reliable product. In developed countries, product losses (post harvest losses) are generally small during processing, storage and handling because of the efficiency of the equipment, better storage facilities, and control of critical variables by a skilled and trained staff. Recently, the concept of Agricultural and Food Logistics has been under development as more effective and efficient management system is required for the food production planning, physical collection of primary produce from fields and homesteads, processing and storage at various levels, handling, packaging, and distribution

of final product. In the food supply chain many stakeholders such as farmers, vendors/agents, wholesalers, rural retailers and suppliers and transporters are involved. At all levels, information flow and management of produce is essential to maintain the food quality throughout the chain (see Figure 1). The flow of input resources from farms to consumers needs to be described in detail and the constraints in each sub-process needs to be identified to develop appropriate solutions for logistics related problems.

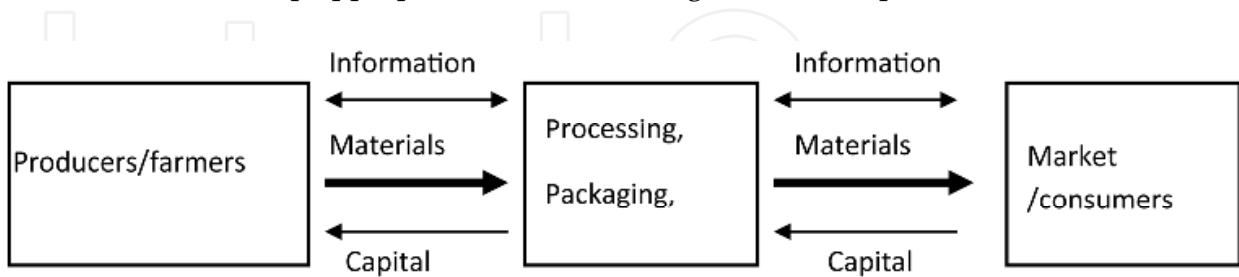


Fig. 1. Material, capital and information flow between producers (farmers) and consumers

It is important to note that lack of packaging facilities may be one of the constraints in the logistics system of small-scale farmers during the transition from subsistence to commercial farming. Significant post-harvest losses occur when especially vulnerable crops and fruits are subjected to mechanical damage (Ferris *et al*, 1993). Therefore management of packaging should be taken into consideration in the development of agricultural logistic systems.

2.2 Logistics service in developing countries

The development of smallholder agriculture in developing countries is very sensitive to transport strategies. Many isolated farmers have little opportunity to escape poverty, as their potential marketing activities are hampered by inadequate or poor transport facilities. The rural transport planning must address the needs of people, as much as possible at the household level. Such well planned transport system enables smallholders make the transition from subsistence to small-scale commercial farming. This helps them to harvest and market crops more efficiently, reduces drudgery and, by facilitating communication, helps stimulate social integration and improve quality of life. Availability of road infrastructure (that includes feeder roads, tracks, and paths), storage facilities and transport services increases mobility and encourages production (Gebresenbet and Oodally, 2005).

Typical transport activities of a small-scale farmer could be represented as in Figure 2. The arrows show people mobility and goods flow to and from a homestead. Rural transport is usually classified into on-farm and off-farm transport.

On-farm transportation includes:

- a. transportation within fields
 - i. collecting harvested crops to one point for processing in the fields and temporary storage;
 - ii. distribution of fertilizers and seeds;
 - iii. transporting of firewood, timber and
 - iv. water,
- b. transport of agricultural products from fields to homesteads,

- c. transport of agricultural implements from homesteads to fields and vice-versa,
- d. transport of seeds and fertilizers to the fields;
- e. transport of implements between different plots etc.

Off-farm transportation includes:

- a. transport of agricultural products including animals to local markets,
- b. transportation to grinding mills
- c. transport of industrial products (commercial fertilizers, implements, seeds, etc) from markets to homesteads,
- d. transportation to health centres and schools, religion centres, and
- e. transportation to towns and bigger market

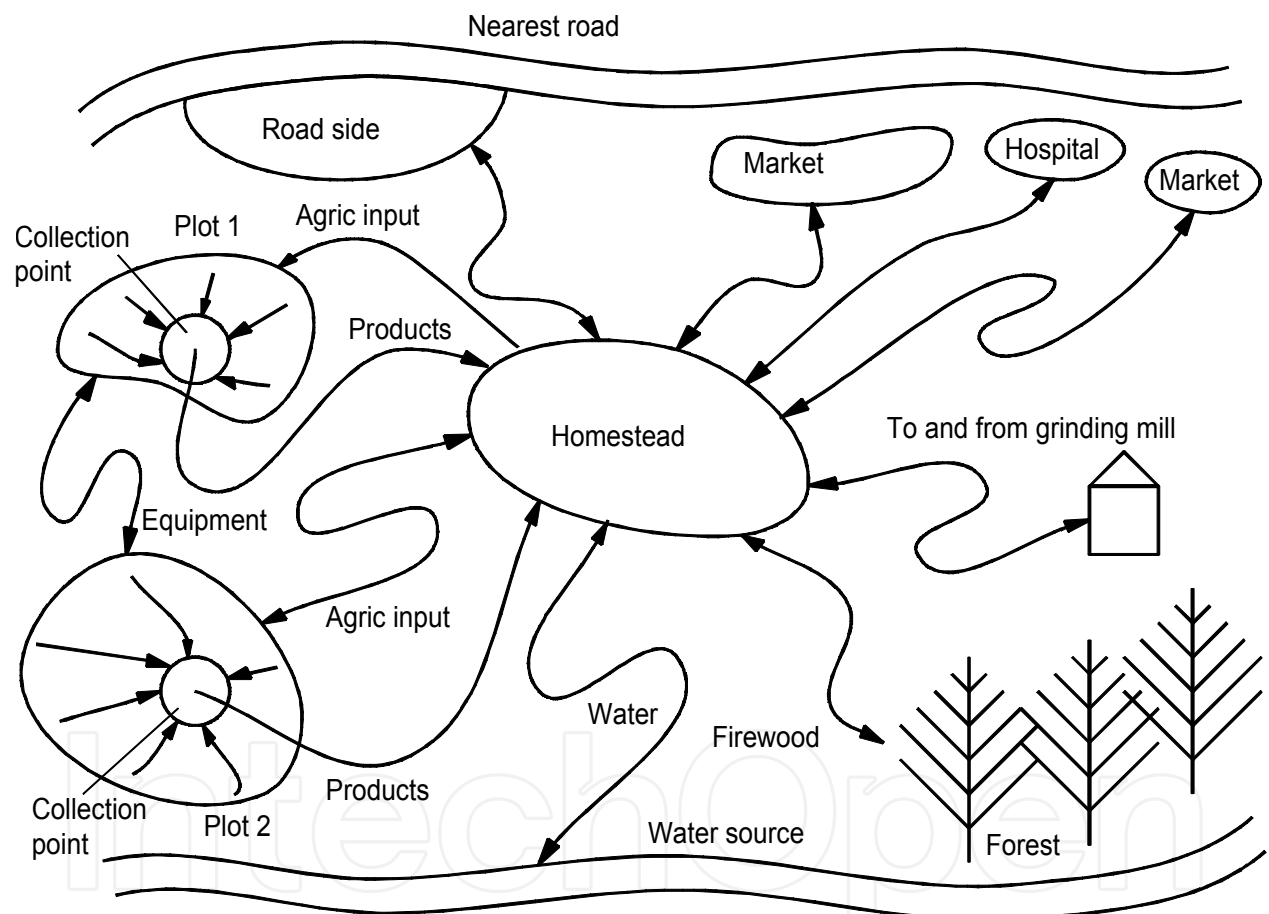


Fig. 2. Transport requirements for a typical small householder (Gebresenbet, 2001)

In agricultural systems of developing countries, animal power is used to replace human power and facilitate transport tasks. Animals are used to pull carts or sledges and as pack animals. At least ten species have been so domesticated, and their (absolute) capabilities depend primarily on body size. In relative terms, pack animals can carry 12 to 30 % of their body weight and can pull horizontally 40 to 60% of their body weight. These values depend on species, but field observations have returned higher values, probably at some cost of animals' well being.

In rural agricultural transport, in developing countries, special emphasis should be on collection, packaging, storage and distribution of agricultural primary products. Among the urgent tasks that formulated by the 8th plenary meeting of General Assembly of United Nation in June 1986, regarding transport and related infrastructure in developing countries, were improving and expanding the storage capacity, distribution and the marketing system; and development of transport and communications. Training of farmers (producers) may reduce loss due to harvest and temporarily storage, while other stake holders (for examples service providers) should take the responsibility to minimize loss. Loss in processing, storage and handling is high because of poor facilities and frequently inadequate knowledge of methods to care for the produce. Post-harvest losses run up to 40% varying from 15 to 25% on farm and 10 to 15% in trade. The high losses in developing countries represent not only a severe economic loss for the regions but also a major loss of nutrients to already malnourished populations (FAO, 1989).

The basic concept described in Figure 1 is also applicable for small-scale farmers in developing countries. However, the challenges of rural transport may be promoting the application of the concept of rural logistics (see Figure 1); developing rural infrastructure (storage and packaging facilities, collection points and centres); developing efficient and effective management of product and information flow; developing strategies to promote best transport services. Some of the main issues that require immediate attention are: encouragement of private entrepreneurs to take the responsibility of service provider in storage, packaging and transport services; development of collection centre systems to promote marketing possibilities by facilitating coordinated transport services. Constraints associated with the flow and storage of produce and services in food and agribusiness exist in developing countries include lack of adequate storage facilities and knowledge of handling; poor processing, management and transport services.

In the absence of coordinated product delivery system, farmers themselves transport most of the produce, either as head loading or using pack animals, to both nearby and long distance markets. There are many constraints of such transport conditions: Amount of produce that can be transported by head loading or pack animals is limited; Transport time and distance is long; Drudgery on farmers; and Spoilage of produce during transport, etc. These constraints may result in reducing production and marketing opportunities for farmers, and consequently shortage of food for consumers. The reduction of spoilage and damages that could improve the marketing value of the produce may necessitate the availability of adequate processing, packaging and storage facilities and management for each varieties of produce (Gebresenbet and Oodally, 2005).

3. Logistics in abattoir chains: Animal supply and meat distribution

From effective logistics management point of view, an integrated approach from farm-to-table is required for effective control of food hazards which is a shared responsibility of producers, packers, processors, distributors, retailers, food service operators and consumers (Sofos, 2008). This is important issue, because the increase in world population and improvement of living standard increase the meat consumption and, especially in developed countries, consumers prefer food with no additives or chemical residues; food exposed to minimal processing; safe and economic food (Sofos, 2008; Nychas et al., 2008).

The increasing interest in transparency of food supply chain leads food industries to develop, implement and maintain traceability systems that improve food supply management with positive implications for food safety and quality (Gebresenbet et al., 2011; Smith et al., 2005). As animals stressing may damage meat quality, and lead to more contamination with pathogens, humane treatment of animals is getting more attention (Sofos, 2008). Tracking slaughter animals from birth to finished products and tracking food shipments are becoming area of focus recently (Smith et al., 2005). This helps to control the risk of animal disease, to reduce risk of tampering, to generate detail information on country of origin and animal welfare in the global food supply systems (Smith et al., 2005).

Animal identification and traceability as well as meat processing and distribution are some of the issues related to meat safety challenges (Sofos, 2008). In the process of establishment of animal identification and tracking systems, countries should take the following into consideration: Selection of appropriate technology and precision requirements, maintenance of confidentiality, payment of costs, premises number and animal identification number, livestock feed and meat safety (Sofos, 2008).

Underfeeding and stress of slaughter animals starts earlier than loading for transport to abattoir and continues at different steps until the time of slaughtering. Especially, the way non-ambulatory animals are managed at abattoirs has been reported as the ugliest aspects of pre-slaughter handling. Gregory (2008) indicated that, in US, about 1.15% of cattle waiting in pens at abattoirs in 1994 were downer animals and it was reduced to 0.8% in 1999. Recent study in a developing country, Ghana, indicated that about 7% of cattle waiting at abattoirs were downer animals (Frimpong et al., 2011).

For animal transport, besides the improvement of vehicles design and handling methods, continuous and accurate measurement and report of stress inducing factors and stress response parameters, and continuous observation of animals are necessary and essential to improve animals' welfare and the quality of meat, the final product. A complex instrumentation system, described in Figure 3 was developed at the Engineering department of Swedish University of Agricultural Sciences (Gebresenbet and Eriksson, 1998) to carry out the measurements of the parameters mentioned earlier simultaneously and continuously starting from the farms to the abattoir. The on-board instrumentation and the satellite steered position of the vehicles were controlled from the cabin of the vehicle. The instrumentation may be classified into four groups: Video cameras for monitoring animal behaviour, Heart rate sensor, GPS for measuring transport route, geographical location, vibration sensors, temperature and humidity sensors, emissions, and information transmission from vehicle to stationary database.

Although long distance transport and poor handling are stressful and compromise animals' welfare, there is tendency to reduce the number of abattoirs due to specialisation and centralisation. Since such long distant transport has a negative impact on animal welfare, meat quality and environment in the form of emissions emanating from vehicles, studies are undergoing to identify means of reducing the transport distance, transport time and animal stress in animal supply chain and meat distribution (Bulitta et al., 2011). Especially loading and unloading during transport for slaughter are identified as very stressful activities for animals.



Fig. 3. (a) Sketch of instrumented vehicle showing the positions of sensors , video camera and GPS; (b) vibration sensors mounted on animals

Gebresenbet and Ericsson (1998) made a continuous measurement of heart rate on cows from resting conditions at farm throughout the trip to abattoirs up to the point of stunning. The authors reported the performance of heart rate in relation to various activities from farm to stunning point (see Figure 3). The typical output result is presented in Figure 4, and as it can be observed the heart rate increased from about 45 bpm (beats per minute) to about 108 bpm during loading (separation of the animal from its group and forcing the animal to clamp the ramp into the truck). After loading, the heart rate falls and stabilized as soon as the animal was tied and maintained its position in the pen (Figure 4). The heart rate again raised as the vehicle started its motion. Another high heart rate peak occurred (Figure 4) when animals met unfamiliar animals from other farms, and the final rise in heart rate was during unloading. It is important to note that the heart rate profile reported in Figure 4, confirmed that loading and unloading activities are the most events that compromise the welfare of animal during transport. Bulitta et al. (2011) modelled (using exponential function) and analysed how cattle heart rate responds to the stressful loading process and indicated that heifers' heart rate rose exponentially from its mean resting value (80 ± 6 bpm) to a peak value (136 ± 35 beat per minute) confirming that loading is very stressful process for animals.

Two possible strategies for improving animal welfare during transport from farm to abattoirs are:

- i. Minimising stress-inducing factors through improving animal transport logistics and handling methods. These include improving animal handling throughout the logistics chain, improving the loading and unloading facilities, improving the driving performance and slaughtering activities at abattoirs.
- ii. Minimising or avoiding animal transport by promoting small-scale local abattoirs or developing mobile or semi-mobile abattoirs.

In both alternatives effective logistics is an important aspect to logistics chain of farm-abattoir system which encompasses all activities from loading animals, transport from farm

to abattoir, unloading at the abattoir, operations in the slaughter chain from lairage box to chill room for carcasses (see Figure 5). It is important to chill meat and meat products before transportation. The primary chilling is the process of cooling meat carcasses after slaughter from body to refrigeration temperatures. The European Union Legislation requires a maximum final meat temperature of 7 °C before transport or cutting. After primary chilling, any following handling such as cutting, mincing, etc., will increase the temperature of meat, thus the secondary chilling is required to reduce temperature below 7 °C. Such a secondary chilling is also of great importance in the case of pre-cooked meat products, because the temperature of meat after the cooking process should be rapidly reduced from about 60 to 5 °C, to prevent or reduce growth of pathogens that have been survived the heat process or re-contaminate the product (Nychas et al., 2008).

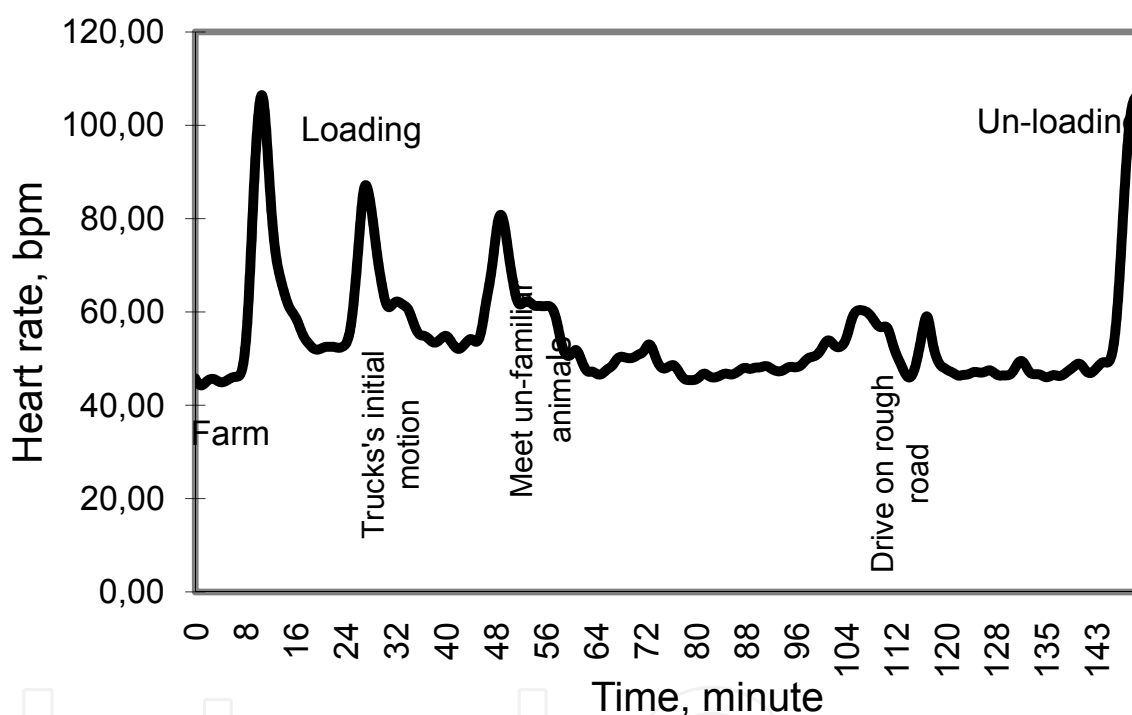


Fig. 4. Typical measured cow's heart rate profile during handling and transport. The peaks of the measured data indicate various events: loading of the animal on the truck; the vehicle starts moving; mixing with un-familiar animals i.e., when loading other animals from other farm; transport on the rough road; and un-loading at the abattoir (Gebresenbet and Eriksson, 1998)

Meat spoilage may occur during processing, transportation and storage in market. An important aspect of fresh meat distribution and consumption is effective monitoring of time/temperature conditions that affect both safety and overall meat quality. Appropriate packaging, transporting and storage of meat products are important, since meat products spoil in a relatively short time. Scientific attention on meat spoilage increased when shipment of large amounts of meat products started (Nychas et al., 2008). The EU

legislation requires a maximum final meat temperature of 7°C before transport and the vehicle for meat transport must be provided with a good refrigerated system. The meat transport from cold storage to retail outlet and then to the consumer refrigerator are critical points for meat quality and safety (Nychas et al., 2008). Animal collection from many farms and transporting to abattoirs requires a dynamic planning process taking into consideration stress inducing factors such as road conditions, climate and traffic conditions transport distance and time, queuing at the gate of abattoir for unloading (Gebresenbet et al., 2011).

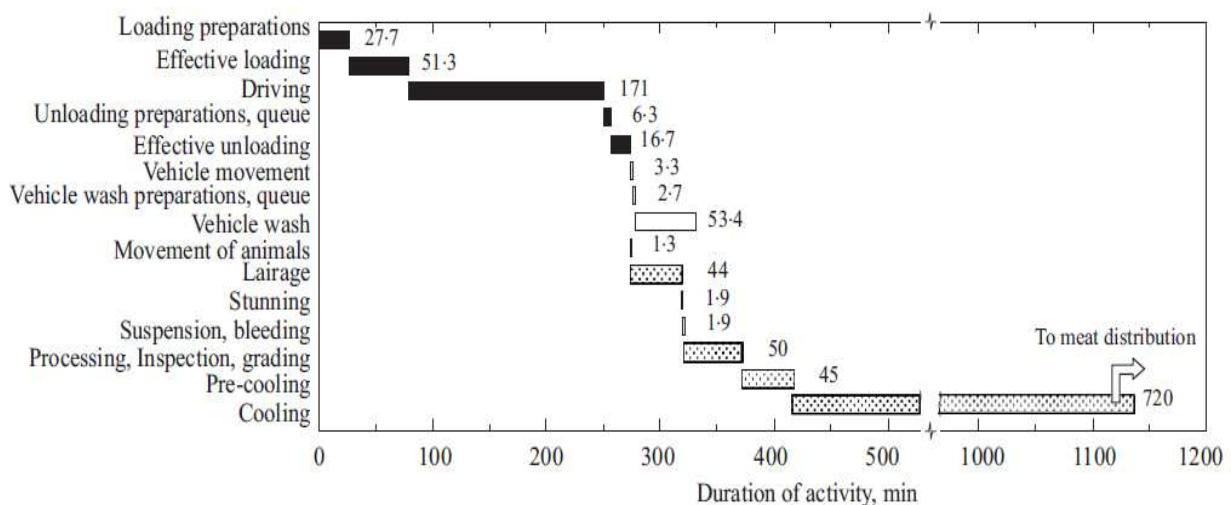


Fig. 5. Duration of activities in the cattle transport chain, from loading to slaughter; observed mean values; for the activities following after suspension and bleeding, the values were obtained from interviews; for loading and driving, average accumulated durations for transport routes involving loading of cattle only (at on average 4 farms), are represented; ■, full vehicle; □, empty vehicle; ▨, animal/carcass (Ljungberg et al., 2007)

A study conducted in Sweden (Gebresenbet et al., 2011a), comparing a small-scale local abattoir (situated at the best location in the vicinity of targeted consumers outside big city) to a large scale abattoir located in the centre of nearby big city indicated that establishment of the small abattoir could play a significant role in increasing consumer confidence in local meat products. In both cases (small scale abattoir and large scale abattoir) route analyses were conducted to explore the potential savings in transport distance, time and emissions related to animal collection from farm to abattoirs and meat distribution from abattoirs to meat shops or consumers. Considering the animal collection from farms to small scale abattoir, transport distance, time and emissions were reduced by 42% and 37% respectively when compared to large scale abattoir (see Table 1). Similarly, considering meat distribution from abattoir to consumers/retailers, the transport distance and time were reduced by 53% and 46% respectively when small scale abattoir was used (Gebresenbet et al., 2011a). In other case studies route optimisation experiments were conducted (i.e. measuring the real world distribution route and re-planning the route by conducting route optimisation experiments using RoutLogiX) on 34 routes of animal transport and 27 routes of meat distribution and the potential improvements were obtained in terms of transport distance and time (see Table 1).

Case study	No. of routes	Distance before optimisation [km]	Time before optimisation [h]	Improvement due to optimization %		Source
				Distance	Time	
Animal transport						
I	19	163	2:47	3.6	4.1	Ljungberg et al., 2007
II	15	2750	46	18	22	Gebresenbet and Ljungberg, 2001
III ⁿ	30	16500	126:21	42	37	Gebresenbet et al., 2011a
Meat distribution						
II	17	1638	62	17	21	Gebresenbet and Ljungberg, 2001
IV	10	1597	-	4.7	2.7	Gebresenbet et al., 2011b
IV ^m	13	3054	62:45	37.7	32.4	Gebresenbet et al., 2011b
III ⁿ	7	2256	27	53	46	Gebresenbet et al., 2011a

ⁿ The case of comparison of small scale and large scale abattoir and improvement is when small scale is compared to large scale abattoir

^mThe case of coordination i.e. improvement is for route coordination (not necessarily for optimisation)

Table 1. Potential savings in distance and time by optimizing the routes of animal supply and meat distribution

Coordination and optimisation in food distribution is a potential strategy to promote economically effective and environmentally sustainable food distribution. A case study conducted in Sweden pointed out that possible coordination of meat distribution in rural area around a city could reduce transport distance and time up to 38% and 32% respectively (see Table 1). The coordination could be formed between different companies distributing different food items and companies distributing only meat; and between companies distributing only meat. In a similar study, first coordinating and then optimising the food deliveries in and around the city could reduce the number of routes by 58%, number of vehicles by 42% and transport distance by 39% (Gebresenbet et al., 2011b). Such coordination in food distribution system could also improve the vehicle load rate, motor idling, emission from vehicles and congestion. Some of the major possibilities for improved coordination and transport planning of agricultural goods transport are: possible coordination of meat and dairy product distribution through combined loading; possible coordination of fodder transport and grain transport through back-haulage; and partial or total optimisation of vehicle fleet (Gebresenbet and Ljungberg, 2001).

Uncoordinated and non optimum food transport systems are not energy efficient in local food systems, although there is considerable potential to increase the efficiency of energy

use by organizing the food delivery system in new ways (Beckeman and Skjöldebrand, 2007), using more energy efficient vehicles and/or introducing the production of biofuel in the region (Wallgreen, 2006), increasing the utilization level of vehicles' capacity (Ljungberg and Gebresenbet, 2004) and planning optimum routes for food collection and distribution systems (Gebresenbet and Ljungberg, 2001).

4. Logistics in milk supply and dairy product distribution

Milk is an important agricultural produce that livestock keepers use for both consumption and market. The marketing of milk, surplus to family and farm needs, improves farm income, creates employment in processing, marketing and distribution and contributes to food security in rural and urban communities (Gebresenbet and Oodally, 2005).

In developing countries, demand for milk is expected to increase by 25% by 2025. In such developing countries smallholders are the main producers of milk. Dairy imports to developing countries have increased in value by 43% between 1998 and 2001, and over 80% of milk consumed in developing countries, (200 billion litres annually), is handled by informal market traders, with inadequate regulation (Gebresenbet and Oodally, 2005). From transport services point of view, marketing of milk is difficult for producers who are living in scattered and isolated areas. These farmers can only sell butter to the urban areas and the remaining milk products are for home consumption. Delivery of fresh milk from long distance to urban by small-scale farmers is difficult for two main reasons. Firstly, the daily milk produce is relatively small to deliver to urban area and transporting perishable commodity over long distance is difficult. Secondly, milk quality deteriorates as it is transported over longer time without processing. The only available traditional processing is fermentation. To promote marketing of milk for small-scale farmers, it is necessary to develop strategies for on-farming chilling and collection of milk.

In developed nations, transport companies collect the milk from farms to collection points and thereafter transport to dairy plants (Gebresenbet and Ljungberg, 1998). The dairy industry provides a special milk container in which the farmers store the milk before the transporters collect the milk. Usually tank Lorries and tank trailers are used for collecting milk from farms and deliver to the nearest dairy. The milk supplied to dairy companies is processed and distributed to consumers. The dairy products such as milk, powder, edible fat and cheese are distributed by dairy product distributors. In such a process, the tank Lorries collect milk upto their full capacity and pump to the tank trailer which is usually placed in the best place as illustrated in Figure 6.

Optimizing the routes of milk collection enables to improve the transport distance and time. Gebresenbet and Ljungberg (2001) measured 60 routes of milk collection which totalled to be about 6357 km. By conducting optimization experiments on these routes, using LogiX (DPS, 1996), the authors found that the distance could be reduced by 16%. Similar optimization experiment on the routes of dairy product distribution reduced the distance by 22% and time by 24%.

In developed countries, it is noticed that due to structural changes in the milk production system, the number of farms reduces while the level of production remains relatively constant. This is shown by Figure 7 which illustrates the case of Sweden.

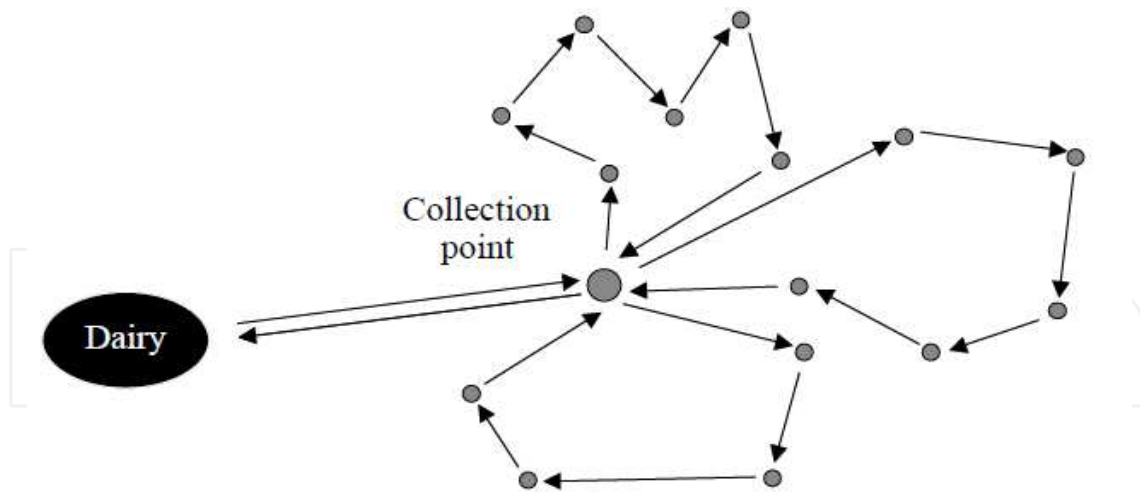


Fig. 6. Schematic presentation of possible way of milk collection from farms and delivery to the dairy industry (Gebresenbet and Ljungberg, 2001)

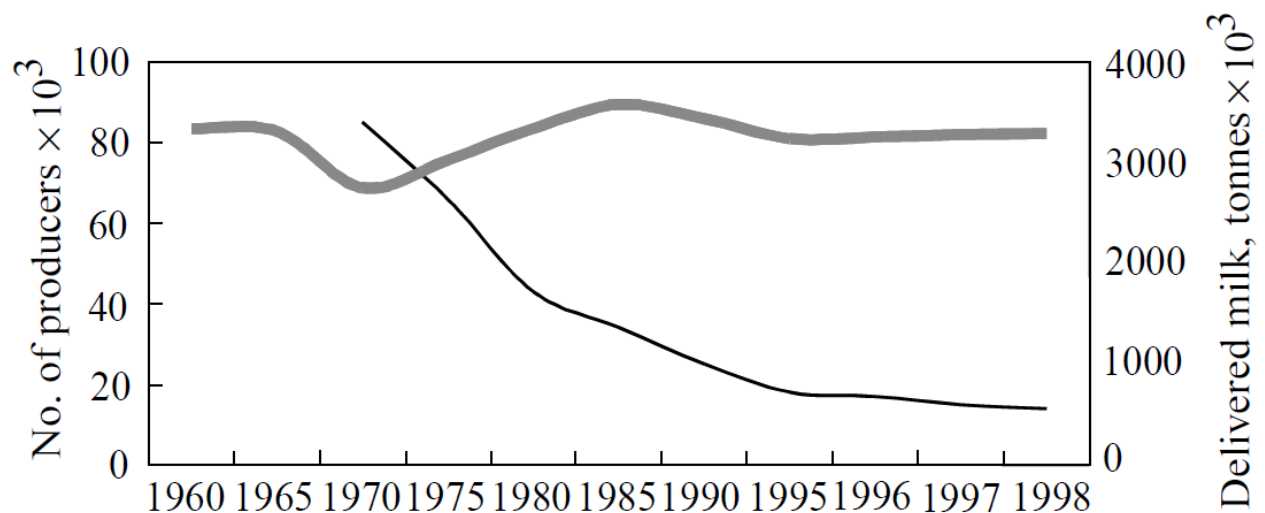


Fig. 7. Total milk production and number of milk producers in Sweden from 1960 to 1998; —, number of producers; —, delivered milk (source: Gebresenbet and Ljungberg, 2001).

The European Union (EU) limits the maximum level of milk production of member countries, for example in Sweden to 3.3 million tonnes per years (Gebresenbet and Ljungberg, 2001; Bouamra-Mechemache et al., 2008). The domestic consumption of dairy products in EU is as high as 90% of its milk production. And still, EU is a major player on the world dairy market and the EU dairy sector is expected to be market oriented in the future (Bouamra-Mechemache et al., 2008). The milk quotas enabled the EU market gain stability for the last 25 years and the international market have also benefited due to strategic product management on the world market. The expected challenge to future dairy industry is world dairy market fluctuations and price volatility due to the increase in EU milk quota by 1% annually until 2015, the year when the quota will be removed ultimately (Geary et al., 2010). This in turn will have impact on logistics of milk and dairy products in the future.

In developing countries individual traders or small scale agencies collect milk from producers and supply to collection centres. Milk may be carried to the collection points as head loads, shoulder slings, on bicycles, on pack animals, animal carts or small boats (Gebresenbet and Oodally, 2005). Advanced milk collection process found in developing countries begins with the producer delivering milk to a collection point where the volume is measured, or the milk weighed, recorded, and sometimes it is sampled and checked for quality. The milk is later transported, to a larger collection centre where, if possible, it is chilled. The collected milk is subsequently sent in bulk to a processing plant by truck. The time-delay from milking to delivery at the processing plant often exceeds five hours and is negatively affecting the quality of non-refrigerated milk, which is often rejected by dairy processing plants and is also not acceptable by consumers (Gebresenbet and Oodally, 2005).

In countries like Mauritius, the marketing of the milk is traditionally undertaken by milk retailers who visit several cow keepers, holding special containers with capacity of 300 litres for transporting fresh milk. The retailer fills the container after visiting 10 to 15 producers and then proceeds to the urban areas to deliver to the consumers. The link between the retailer and the cow keepers is very important as it enables the producers to concentrate on production while the retailer provides a reliable market for the produce. A milk collection system that under-estimated the role of retailers was initiated in Mauritius but failed, because instead of developing policies and effective credit system for the producers and converting retailers into private contractors to supply the factory with milk, the system tried to by-pass them creating a system which was not sustainable (Gebresenbet and Oodally, 2005).

A milk collection initiative in Brazil where a milk collection programme was developed for farmers, most of whom were producing 100 litres per day per farm on average, was found to be successful (Urraburu, 2001). The important element in the programme was the common cooling tank. Within a year, bulk milk collection production grew from 28% to 70% and included 55 private cooling tanks representing some 55,000 litres per day. The impacts of the programme on dairy farmers was the dramatic reduction of transport costs, which in some regions fell by 80%, improvement of product quality as the time between milking and conveying milk to the dairy was significantly reduced (Gebresenbet and Oodally, 2005)

5. Logistics in grain supply chain

During the recent 20 years, goods flow has been tremendously increased, mainly not due to the increase in the amount of goods, but due to other factors such as specialization and centralization of production systems and globalization of marketing (Gebresenbet and Ljungberg, 2001). Agricultural goods transport is a significant component within such increasing goods transport. For example about 13% of the international sea-borne trade is grain transport (Gebresenbet and Ljungberg, 2001). Grain transport is the main component in agricultural transport in general and it includes grain transports from farm to depot/terminals, between farms, between terminals, from farms and terminals to fodder industries and mills and from terminals to ports for export. Figure 8 illustrates the

material flows to, within and from agriculture and food sector (Gebresenbet and Ljungberg, 2001).

Due to the legal limit of total weight of a lorry, the drivers have to estimate the load weight and it is not unusual that the actual loads exceed the legal maximum loads due to overloading (see Figure 9). The case study in Sweden (Gebresenbet and Ljungberg, 2001) indicated that the load rate for grain transport routes is as high as 95% at the delivery point during the harvesting season.

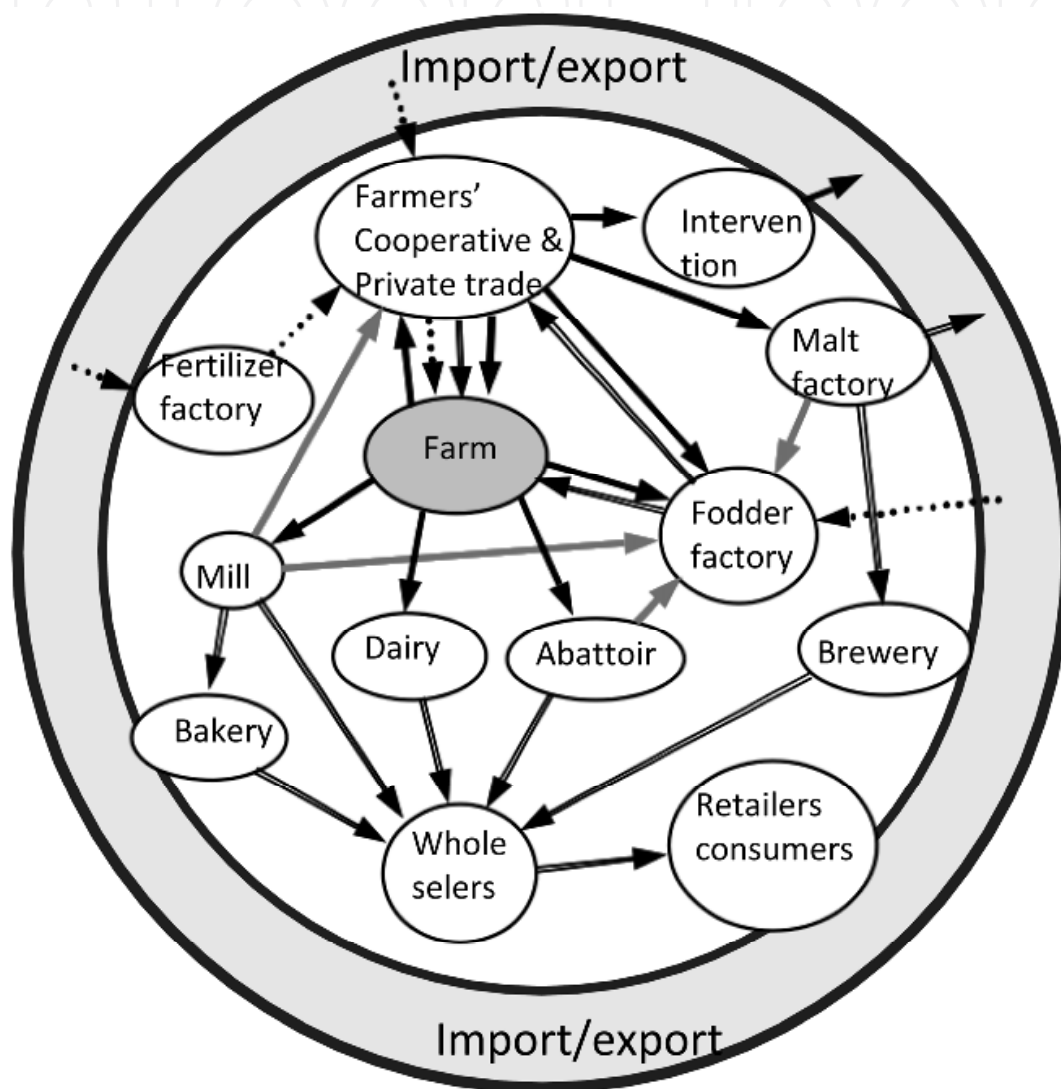


Fig. 8. Material flows from and to farms and other sectors in Uppsala region; *intervention is export subsidized by the European Union (EU); the national department of agriculture buys grain and stores it from season to season before it is exported, to reduce price fluctuations and support the lowest price level:

•••► Means of production~seed, ► fertilizer ize (commercial), plant protection, supplies to fodder factory, etc.; Agricultural produce~grain, milk, live and slaughtered animals; ==►, Processed products~flour, malt, fodder, dairy products, meat; —► By-products~bran, whey, natural fertilizer, by-products from malt production (Gebresenbet and Ljungberg, 2001).

These authors also mentioned that during grain-related transport routes, unnecessary/unjustified motor idling was found to be more than 30% of stoppage time. They also estimated the emission from vehicles during grain transport before and after optimisation of grain transport routes. Table 2 presents the motor idling and emission reduction by optimising the transport routes of grain in relation to other agricultural products such as milk and meat. Air emissions were calculated using the simulation model developed earlier by Gebresenbet and Oostr (1997), where the following parameters were considered: vehicle type, time (loading; unloading and idling); goods type; load capacity utilization level; transport distance; vehicle speed; geographical position of depot and delivery points; routes air emissions from vehicles.

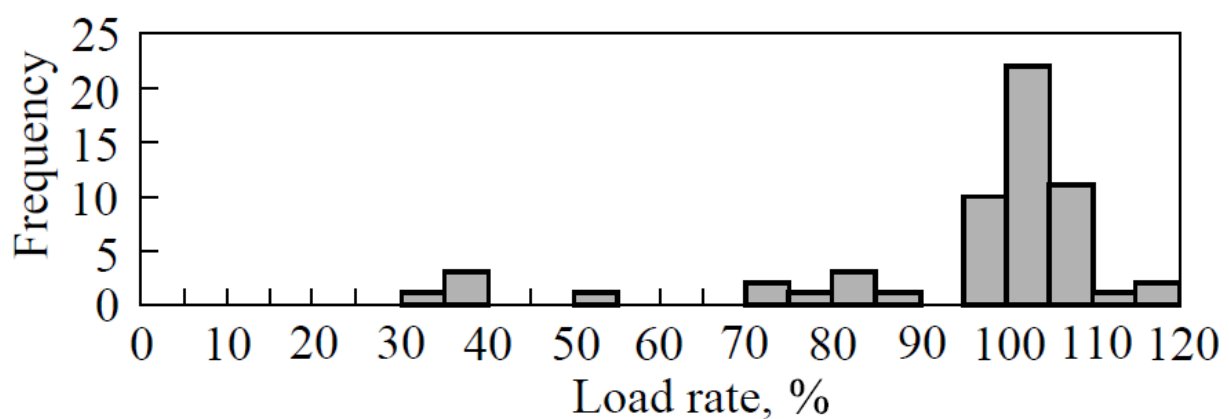


Fig. 9. Load rate distribution at unloading point of grain: The figure illustrates that load rates exceed 100% in many cases (source: Gebresenbet and Ljungberg, 2001).

Description	No. of routes	Distance before optimisation [km]	Time before optimisation [h]	Motor idling** [%]	Reduction of CO2 emissions [%]
Grain transport	45	4995	97	36	6.3
Milk transport	60	6357	185	65	6
Dairy transport	28	2234	92	3.5	22
Animal transport	15	2750	46	1.6	18
Meat transport	17	1638	62	4.6	17

*-source: Gebresenbet and Ljungberg, 2001 with some modification.

**Motor idling time in relation to total time.

Table 2. Motor idling and possible reduction of emission during transport of grain and other agricultural products*

In grain transport systems, back-hauling can be used for the delivery of fodder to farms (Gebresenbet and Ljungberg, 2001). Although the grain transport from farms is concentrated during the harvesting season, there is a possibility to coordinate the delivery of fertilizers

and other means of production with grain transport i.e. the farmers can dry their grain and keep it at the farm till the time of delivery of means of production. The intensity of grain delivery at the harvest season causes capacity problems for vehicle resources and transport planning. Planning of production and orders at farm level, to minimize the seasonal effects, would improve the conditions for transport planning and coordination (Gebresenbet and Ljungberg, 2001). In developing countries, grain collectors are responsible for commercialising the grain within the country and exporting surplus. Even though, these grain collectors are considered as informal by the government body in some countries, they served an important role in the grain supply chain. For commercialising grain, it can be collected from individual farmers to a critical size that can be transported cheaply for retail locally, and the surpluses can be exported at premium prices elsewhere (Gebresenbet and Oodally, 2005).

6. Logistics in local food supply chain

In the agriculture sector, globalization of food production has considerably influenced the food supply system by increasing distance the food has to be transported to reach consumers. This situation not only has increased emissions of greenhouse gases but also has reduced the relationship between local food producers and consumers, affecting local food producers, their environment and culture. In terms of distance, locally produced food can be characterized by the proximity of production place to the consumers and usually there is a limit, e.g. 160 km in UK, and 250 km in Sweden. In addition to geographical distance, locally produced food is also considered as food which meets a number of criteria such as animal welfare, employment, fair trading relations, producer profitability, health, cultural and environmental issues (Bosona et al., 2011). Currently it is observed that customers have been motivated (to purchase the local food) by contributing positively to the ecosystem (a more altruistic reason) and by food quality and pleasure (a more hedonistic reason) (Brown et al. 2009; Bosona and Gebresenbet, 2011).

In this section we presents the main results of two case studies in Sweden, concerning the investigation of local food supply chain characteristics and developing a coordinated distribution system to improve logistics efficiency, reduce environmental impact, increase potential market for local food producers and improve traceability of food origin for consumers. In these studies, integrated logistics networks were developed by forming clusters of producers and determining the optimum collection centers (CC) linking food producers, food distributors and consumers/retailers enabling coordinated distribution of local food produces and facilitating the integration of food distribution in the local food supply systems into large scale food distribution channels (see Figures 10 and 11). In these case studies, after mapping the location of producers and delivery points as well as potential collection and distribution centers using geographic information system (GIS), the best collection points were determined using center-of-gravity and load-distance techniques (Russell and Taylor, 2009). Then detailed collection and distribution routes were analysed using RoutelogiX software (DPS, 2004). As summarized in Table 3, the result of the analysis indicated that coordinating and integrating the logistics activities of local food delivery system reduced the number of routes, the transport distance and transport time for the delivery system of local food. Such logistics network integration could have positive

improvements towards potential market, logistics efficiency, environmental issue and traceability of food quality and food origin.

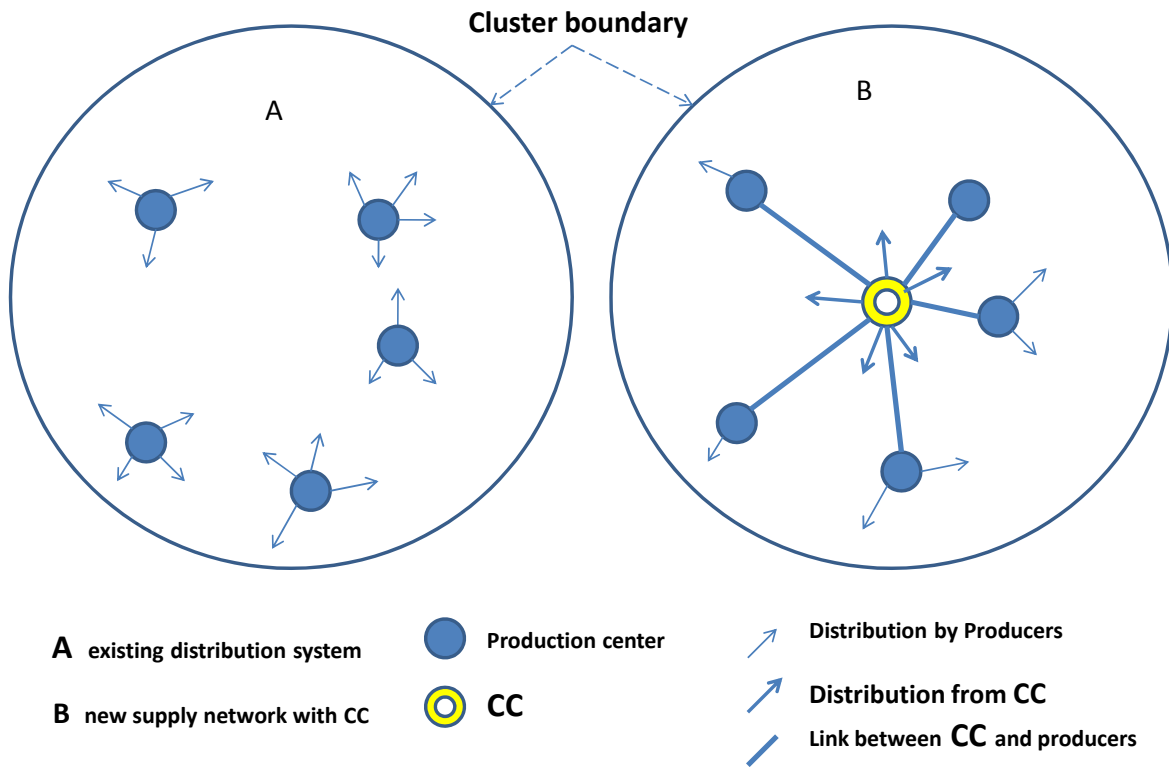


Fig. 10. Fragmented distribution system (existing) and newly proposed coordinated distribution system via CC (collection center) to different customers (Source: Bosona and Gebresenbet, 2011)

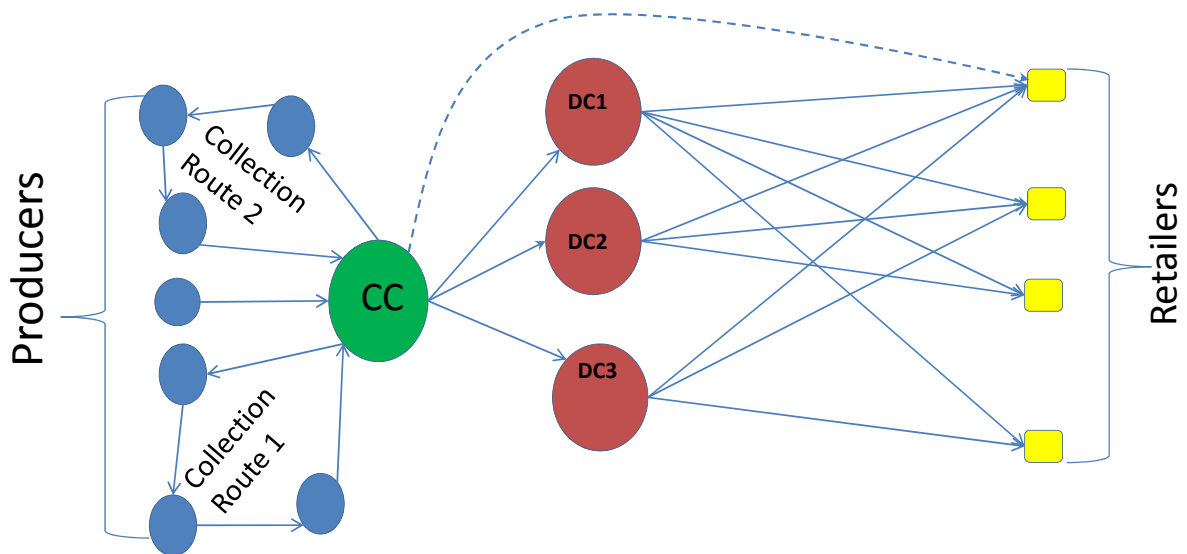


Fig. 11. Network of product delivery system with coordinated collection. DC1, DC2, DC3 represent three of large scale food distribution channels. The dashed line indicates the case of direct delivery from CC to retailers or customers.

Case study	No. of routes	Distance before coordination /integration [km]	Time before coordination /integration [h]	Improvement due to optimization %			Source
				Routes	Distance	Time	
I	81	8935	226	68	50	48	Bosona and Gebresenbet 2011
II*	23	6159	69	87	93	91	Bosona et al., 2011

*- Although there were more scenarios, the scenario with best improvement was chosen.

Table 3. Potential savings obtained by co-ordination and integration of routes for delivering locally produced food

Coordination and network integration in local food supply chain increases logistics efficiency, potential market, access to information and reduces environmental impact (Bosona and Gebresenbet, 2011; Gebresenbet and Ljungberg 2001, Ljungberg, 2006; Ljungberg et al, 2007). In the food distribution system of local food producers, logistics is fragmented and inefficient compromising the sustainability of localized systems and this requires improvement (see Figure 11 and Table 3). Therefore forming the best collection and distribution centres for locally produced food is very important. Such location decisions should be supported technically since the location decisions have the dynamic implication over time (Sabah and Thomas, 1995). Therefore, in the process of developing improved logistics systems in the local food supply chain, detailed location analysis (mapping and clustering producers and determining optimum location of collection and/or distribution centres) and route analysis (creating optimised routes for product collection and distribution, simulating route distance and delivery time) are very essential (Bosona and Gebresenbet, 2011) .

Potential producers of local food want to expand their sales area. However, increasing sales of locally produced food, on small scale bases, needs to overcome the main problems such as low size of production and more volatility of market price and high seasonality of food products on market, inadequate packing and storage facilities, limited or no means of transport and limited knowledge of potential market (Bosona et al., 2011). These problems can be overcome mainly if the local food systems can be embraced by dominant food supermarket and superstore chains and this can be facilitated by integrating the local food system into large scale food distribution channels.

Such integration in local food systems plays a key role in sharing information and scarce/expensive resources as it enables the stake holders get access to the right information at the right time. Well organized information concerning local food is important to satisfy the increasing demand of consumers to have good knowledge and information of the food origin and how it is handled and transported. The logistics network integration is also helpful in creating favourable situation for interested researchers. For example, well established data management might come into existence which in turn helps to conduct

more detail studies on the logistics activities enabling further improvements that increase the sustainability of local food systems (Bosona and Gebresenbet, 2011, Bosona et al., 2011). The integration also facilitates improved traceability system which depends on information connectivity and provides an added layer of food security which might be established more easily within integrated systems (Bantham and Oldham, 2003; Engelseth, 2009). One apparent advantage of such a co-ordination and logistics network integration is that each stakeholder in the network concentrates on its specialty and improves its productivity in both quality and quantity (Beckeman and Skjöldebrand, 2007).

Studies (Bosona et al, 2011; Bosona and Gebresenbet, 2011) indicate that in local food systems, producers of local food run mostly their own vehicles and about half of the vehicle capacity is unutilized. Therefore, the coordination and logistics network integration in local food system leads towards positive environmental impact by: (i) Reducing number of vehicles to be deployed for produce collection and distribution of local food products; (ii) Increasing the utilization level of vehicle loading capacity; (iii) Reducing travel distance, time and fuel by following optimized routes where possible; (iv) Reducing green house gas emissions (as the consequence of the facts mentioned above).

7. Conclusion

From effective logistics management point of view, an integrated approach from farm-to-table is required for effective control of food hazards which is a shared responsibility of producers, packers, processors, distributors, retailers, food service operators and consumers. Therefore, tracking slaughter animals from birth to finished products and tracking food shipments are becoming area of focus recently. Studies indicated that, in the food and agriculture supply chains, there are potential area of logistics related improvements in terms of reducing transport routes, distance and time; reducing emission from vehicles; improving the packaging of food products and improving transport services. This can be implemented in collecting, storing and transporting slaughter animals, meat products, milk and dairy products, grain and related products.

These logistics related improvements are possible in developed and developing countries. In case of local food systems, an integrated logistics network that embraced producers, customers (delivery points), collection centers and distribution centers in the local food supply chain is very important, because the logistics services in such local systems are fragmented and inefficient, compromising competence of local food producers. Introducing and implementing logistics related coordination and integration in the local food systems greatly improve the sustainability of local food systems. In general, studying and identifying the constraints and developing and implementing more effective and efficient concepts of logistics services in the agriculture and food supply chains is very essential for overall economic growth of a country and for environmental benefits.

General observations for practitioners

Agriculture and food supply chain is specific and complex area with important responsibilities. There are two main demands:

- a. Maintaining food quality and safety including animal welfare along the supply chain, and

b. Reducing logistics cost.

The concept of *Agricultural and Food Logistics* is slowly emerging as one of the important types of logistics to reach the requirements for maintaining quality of raw materials for food and food products or even to perform value adding activities in the food supply chain. The questions related to post harvest loss, which ranges up to 70% in developing countries, animal welfare during transport, and the concern of origin of food stuffs and how they are produced and processed are societal questions.

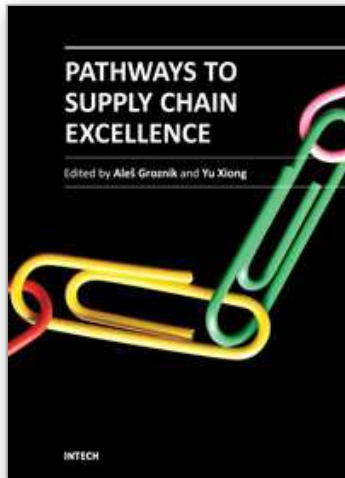
In relation to globalization of marketing system, it is a vital for all stakeholders to reduce logistics cost in order to increase their economic competitiveness. Therefore, development of effective and efficient *Agricultural and Food Logistics* is necessary and essential.

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Edited by Dr. Ales Groznik

ISBN 978-953-51-0367-7

Hard cover, 208 pages

Publisher InTech

Published online 16, March, 2012

Published in print edition March, 2012

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