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Optimisation analysis of large and small-scale abattoirs in relation to animal transport and meat distribution

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Abstract

This study reports the optimization analysis made to determine the benefits of establishing a small-scale local abattoir in comparison with the large scale-abattoir in relation to transport distance and time during animal transport and meat distribution, which have a direct impact on animal welfare, meat quality and the environment. Consumer attitudes towards locally produced meat and the self-sufficiency of the region, where the local abattoir was planned to be established, were also examined. It was found that consumers in the region strongly preferred locally produced meat and about 50% of the meat produced would be sufficient to meet demand in the region. Major benefits of having the local abattoir included: (1) Reductions in transport distance and transport time of collecting animals from farms and delivering them to the abattoir by 42% and 37% respectively. The corresponding greenhouse gas (GHG) emissions that were generated from vehicles reduced by 42%. (2) Reductions in transport distance, transport time and GHG emissions involved in distributing meat to the retailers, by 53%, 46% and 53%, respectively. (3) The significant reduction of transport distance and time improves animal welfare.

Keywords: animal welfare; environmental benefit; local food; route optimisation; transport distance; transport time.

Abbreviations: BSE_bovine spongiform encephalopathy; CH_4_methane; CO_carbon monoxide; CO_2_carbon dioxide; DPS_distribution planning software; E_emission; EF_ emission factor; FC_fuel consumption; GHG_ green house gas; GVW_ gross vehicle weight; IPCC_ intergovernmental panel on climate change; NMVOC_non-methane volatile organic compounds; N2O_nitrous oxide; NXx_nitrogen oxide; SEPA_Swedish environmental protection agency; SO_2_sulphur dioxide; TV_ thermal value; σ_standard deviation; μ_mean value.

Introduction

The recent tendency for reducing the number of abattoirs due to specialisation and centralisation is leading to an increase in animal transport from farms to abattoirs. Long distance transport and poor handling of animals impose stress on animals, compromising their welfare and health and ultimately reducing meat quality (Gebresenbet and Ericson, 1998). At the same time, societal concern is increasing to improve animal welfare, meat quality and safety, and environmental impact of transport activities in the production chain of meat.

Consumer confidence in meat production is an important issue for Swedish farmers and the meat industry in maintaining their economic competitiveness (Ljungberg et al., 2007). Since interest in the transparency of the food supply chain is increasing, a local food brand that offers assurances of food quality could attract the attention of consumers (Saltmarsh and Wakeman, 2004). In Sweden, consumers have reduced confidence in imported meat, particularly since the incidence of bovine spongiform encephalopathy (BSE) or mad cow disease, as information on the origins of such meat and how it is produced is very limited . The knowledge and perceptions of society regarding food quality, its origins and how it is handled and produced, combined with environmental and animal welfare issues, give rise to the actual demands made by society.

Transport has a negative impact not only on animal welfare and subsequent meat quality, but also on the environment in the form of emissions (Table 1) emanating from haulage vehicles (Gebresenbet and Oostra, 1997; IPCC, 2008). Empty return journeys are very common in the agricultural sector and the load rate is generally low, although it varies from 10% to 95% (Gebresenbet and Ljungberg, 2001). Vehicle scheduling and route optimisation could enhance the efficiency of logistics systems in goods distribution and collection. A previous study on transport routes (Gebresenbet and Ljungberg, 2001) measured transport distance and time of 15 routes for slaughter animals and 17 for meat distribution, optimised these routes with the software Route LogiX (DPS, 1996) and then compared the optimisation results with the measured values . It was found that optimising the routes for animal transport and meat distribution could reduce the transport distance by 18% and 17%, respectively. The respective time saving was about 22% and 21%.

There are two possible strategic alternatives for improving animal welfare during transport (Gebresenbet, 2003): Alternative I: Minimising stress-inducing factors through improving animal transport logistics and handling methods (improving handling, loading and unloading facilities and driving performance; optimising activities at the abattoir). Alternative II**:** Minimising or avoiding transport by promoting small-scale local abattoirs or developing mobile or semi-mobile abattoirs. Both these alternatives are feasible regarding the current tendency of the marketing system and structural adjustments. In both cases, effective logistics is an important aspect to be considered in the meat production chain. The logistics chain of the farm-abattoir system encompasses all activities from loading the animals on the farm, transport from farm to abattoir, unloading of animals at the abattoir, and operations in the slaughter chain from lairage box to chill room for carcasses. Collecting animals from many farms requires a dynamic planning process that takes into consideration road conditions, climate, traffic conditions, transport time and distance, queuing at the gate of the abattoir for unloading, etc. All these aspects are potentially stressful for animals.

Plans are underway to establish a small-scale local abattoir in the town of Ockelbo (located at 150 km north of Uppsala city, Sweden), in response to consumer demands for locally produced meat. At present, animals are transported from the Ockelbo region to a large-scale abattoir in Uppsala and the meat is transported back from Uppsala to retailers in the Ockelbo area. However, the plans for establishing a local abattoir require optimisation regarding the location of the intended abattoir and an evaluation of transport distance and time, both for animal transport to the abattoir and for meat distribution to retailers.

The typical location analysis can be characterised as very complex and data-intensive (Bowersok and Closs, 1996), as detailed demands need to be considered to determine the most optimum location. According to Bowersok and Closs (1996), the main data required are definition of market, product, network, customer demand, transportation rate, and available and fixed costs. Different techniques for location analysis are available in the literature, such as cluster analysis (Fuente and Lozano, 1998), GIS-based location analysis (Hernandez and Bennison, 2000), centre of gravity and load-distance analysis (Russell and Taylor, 2009). The methods available for location analysis can be classified into three different groups (Jesuk, 2005): (a) Analytical, where transport parameters such as time, weight and distance are considered (time-ton-mile-centre solutions) to determine location of plant or distribution centre; (b) Linear programming or optimisation, where network optimisation treats the distribution channel as a network consisting of nodes (distribution centres) and arcs (transportation links); and (c) Simulation, where product flow is evaluated in a replication of the real system related to potential logistics channel networks.

The overall objective of this study was to investigate the benefits of establishing a small-scale local abattoir compared with the existing large scale-abattoir. The main parameters studied were transport distance and time, which have direct impacts on animal welfare, meat quality and the environment. Specific objectives were to:

- carry out location and transport application analyses, focusing on location and route optimisation to promote transport coordination
- investigate the benefits of establishing a small-scale abattoir in terms of animal welfare and meat quality
- estimate the environmental benefits of establishing a small-scale abattoir related to transport
- investigate consumer attitudes to local meat production
- investigate the self-sufficiency of the region in terms of meat production.

The study was performed on the case of the small-scale abattoir planned for Ockelbo (see Figure 1). It was assumed that establishment of a local abattoir at Ockelbo could substantially reduce transport distance and time, with positive consequences for animal welfare, meat quality and the environment.

Table 1. GHG emission factors for vehicles in road traffic

GHG	Emission factor [kg GJ^{-1}]
CO_2	72
CO	0.172
CH_4	0.0008
N_2O	0.001
NOx	0.84
NMVOC	0.041
SO_2	0.001

Source: Swedish Environmental Protection Agency

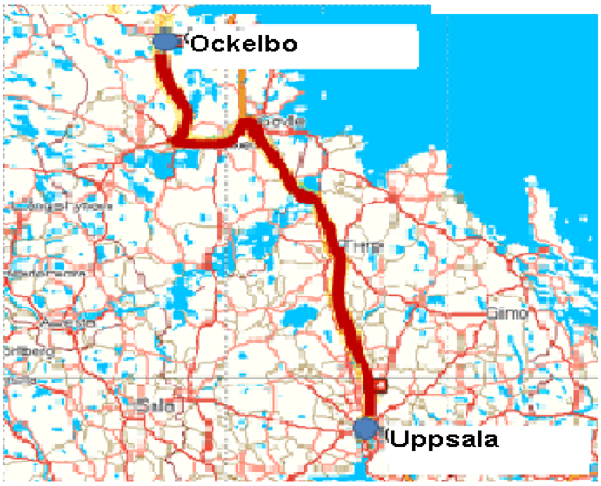


Fig 1. Location of Ockelbo (154 km from Uppsala)

Materials and methods

The feasibility of a local abattoir would depend on the availability of a regional supply of animals and a local market for the meat produced. Therefore the analysis consisted of two parts:

• A study on the effects of establishing the local abattoir on the transport systems for slaughter animals and meat distribution

• A study on consumer attitudes towards the locally produced meat.

The methods employed included collection of statistical data on population and farms in the region; interviews examining consumer perceptions; and optimisation analysis of abattoir location and transport routes.

Farms, slaughter animals and population in the Ockelbo region

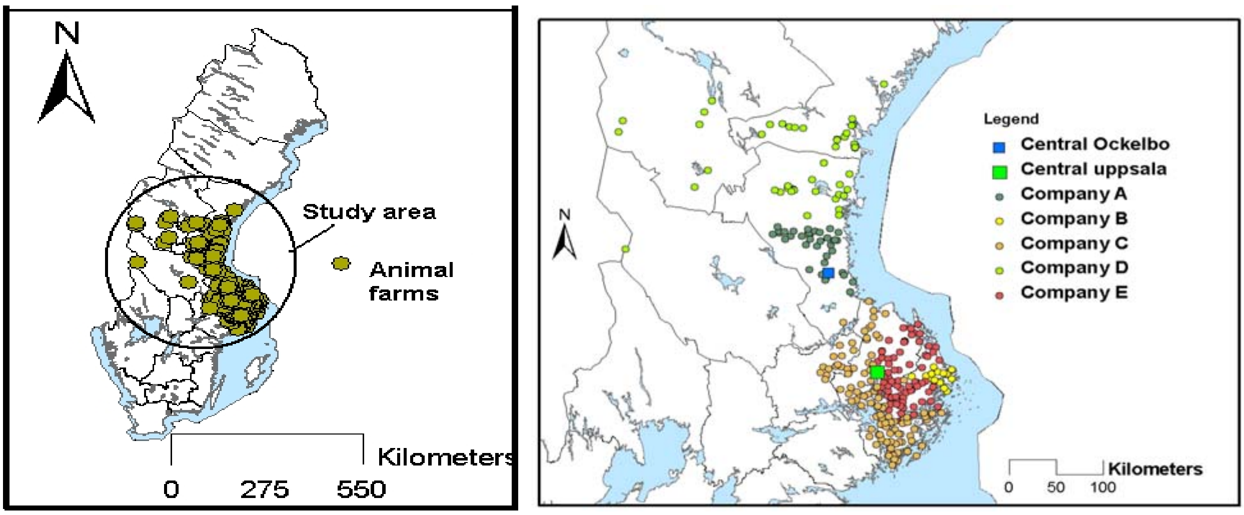
The information gathered included total number of farms supplying the Uppsala abattoir, number of farms that could be expected to supply animals to the Ockelbo abattoir and number of animals transported per year to the Uppsala abattoir from the Ockelbo region. The total number of farms (mainly cattle farms) supplying the Uppsala abattoir was 1635, of which about 500 were located in the Ockelbo region.

Consumer perceptions and attitudes

In order to determine consumer perceptions and attitudes in the region, a questionnaire concerning specific requirements for ethical and animal welfare, high quality meat, and information on the origin of meat and animals was developed and distributed to households and retailers. Care was taken to

Table 2. Summary of route analysis results for animal collection

Number of farms	Delivery to Uppsala		Delivery to Ockelbo		Distance and time saved if delivery made to Ockelbo			
	Distance [km]	Time [hr:min]	Distance [km]	Time [hr:min]	Distance [km]	Distance [%]	Time [hr:min	Time [%]
4	578	06:25	311	03:46	267	46.20	02:39	41.30
2	543	05:56	336	04:00	207	38.12	01:56	32.58
5	591	06:33	389	04:23	202	34.18	02:10	33.08
2	397	04:15	126	01:51	271	68.26	02:24	56.47
4	607	06:42	398	04:00	209	34.43	02:42	40.30
3	611	06:27	362	04:21	249	40.75	02:06	32.56
2	492	05:38	228	03:13	264	53.66	02:25	42.90
3	655	07:57	330	04:35	325	49.62	03:22	42.35
2	592	06:35	342	04:11	250	42.23	02:24	36.46
3	526	06:25	337	04:21	189	35.93	02:04	32.21
2	512	05:25	313	03:30	199	38.87	01:55	35.39
3	554	06:49	400	05:22	154	27.80	01:27	21.27
3	748	08:25	509	06:16	239	31.95	02:09	25.55
2	531	05:45	257	03:12	274	51.60	02:33	44.35
3	539	05:51	257	03:12	282	52.32	02:39	45.30
3	530	05:55	378	04:20	152	28.68	01:35	26.76
2	412	04:32	163	02:13	249	60.44	02:19	51.11
4	580	06:31	376	04:30	204	35.17	02:01	30.95
4	529	05:56	284	03:43	245	46.33	02:13	37.36
2	508	05:23	287	03:20	221	43.50	02:03	38.08
4	532	06:07	307	03:58	225	42.29	02:09	35.15
2	574	06:22	326	04:03	248	43.21	02:19	36.39
2	600	06:36	325	04:04	275	45.83	02:32	38.38
2	551	06:06	326	03:56	225	40.85	02:10	35.52
2	589	06:13	333	03:56	256	43.46	02:17	36.73
2	465	05:20	240	03:10	225	48.39	02:10	40.63
4	580	06:11	335	03:58	245	42.24	02:13	35.85
3	494	05:56	291	04:02	203	41.09	01:54	32.02
3	527	05:48	321	03:41	206	39.09	02:07	36.50
5	553	06:23	348	04:14	205	37.07	02:09	33.68
Total	16500	184:27	9535	126:21	6965	42.21	65:06	36.90



(a) Location of farms included in the study (b) Operating area of transport companies

Fig 2. Maps of Sweden and the study area: (a) Location of animal farms in the study area: (b) Operating areas of the five transport companies A-E are indicated by the colour of animal farm symbols.

ensure that the respondents represented a fair geographical distribution. The questionnaire consisted of seven questions, the first three of which sought general information, i.e. related to sex, age group and number of persons in a household. The last four questions directly concerned the interviewees' demand for locally produced meat.

Location analysis

One of the objectives of the study was to determine the optimum location of the local abattoir to be established in the Ockelbo area. The distance of farms from the abattoir and the number of animals to be transported from each farm were used in the determination of optimum location of the abattoir, using the centre of gravity method (Russell and Taylor, 2009), and about 500 farms were considered in this analysis. On average, each farm delivered 4 slaughter animals per visit. Other factors such as job opportunities, potential growth of the Ockelbo region, transport facilities, etc. were also taken into consideration.

Route planning and optimisation

The transportation application analyses focused on routing and scheduling transportation to optimise number of vehicles, transport distance and time. Regarding route planning for the animal transport to the abattoirs, an approach similar to that discussed by Gribkovskaia et al. (2006) was used. According to those authors, when integrating transportation planning and slaughter planning, it is important to avoid a shortage of slaughter animals at the abattoir and to avoid situations where animals wait too long before slaughter. Thus, in terms of route planning for collection of slaughter animals, farms that are close to each other should be visited on the same route and each vehicle can have its own district to cover (Gribkovskaia et al., 2006).

Transport companies

It was found that there were five transport companies (A-E) transporting slaughter animals from farms to the Uppsala abattoir (see Figures 2a and 2b). In total, they served about 1653 farms (represented by 309 postcodes). Each transport company had its own district (see Figure 2b). Of these five transport companies, only two (A and D) operated in the Ockelbo area. Each provided a service to about 50% of farms that could be expected to supply the Ockelbo abattoir. As Figure 2b indicates, company A operated in a more densely populated area than company D.

Simulation of animal collection from farms and delivery to the two alternative abattoirs

Simulation experiments were carried out using Route LogiX software (DPS, 2004) to analyse animal transport to the Uppsala and Ockelbo abattoirs. These simulations included about 500 farms that currently deliver animals to the Uppsala abattoir and that could be expected to deliver to the Ockelbo abattoir in the future. The following steps were followed to create randomised routes for collection of animals from the 500 farms and delivery to Ockelbo or Uppsala:
a) Create a list of all farm names
b) Generate a randomised value for each farm, from which farms may be chosen for each route c) Sort the list of farms using their randomised values d) Generate a randomised value for each farm, representing the number of animals to be collected from farms (the randomised value should follow a similar distribution to real animal transport routes in the region) e) Choose a number of farms, consecutively from the top of the list, until the number of animals is enough to fully load the lorry (maximum number of animals was 16 per trip) and create routes f) Using routes created at step (e), run route optimisation for the scenarios:
(1) delivery to Uppsala, and
(2) delivery to Ockelbo, and compute transport distance and time for the routes. The randomised values between 0 and 1 in (b) were generated using the random number function in Microsoft Excel. The randomised values in (d) were generated from a normal distribution (μ=4, σ=3), using Analysis ToolPak in Microsoft Excel (negative numbers were omitted). These parameters and procedures were chosen in order to resemble actual, documented animal transport routes (see Figures 3a and 3b). Figure 3b shows the normal distribution generated (mean value 4, standard deviation 3) for the 500 farms. In a very common vehicle type, a maximum of 16 cattle can be transported in each trip, and it is very unlikely that all animals are collected from the same farm. When selecting farms to create the routes (e), a route was considered complete if the number of animals did not exceed 16 but the number of animals on the farm next on the list was too large to be included in the same route.

Following the above procedure, 120 routes were created. Then, 30 of the routes (see Table 2) were used to carry out simulation experiment, where optimum transport time and distance were calculated using Route LogiX (DPS, 2004). Each route that started from the Uppsala abattoir ended there, while each route that started from the Ockelbo abattoir ended there.

Meat distribution

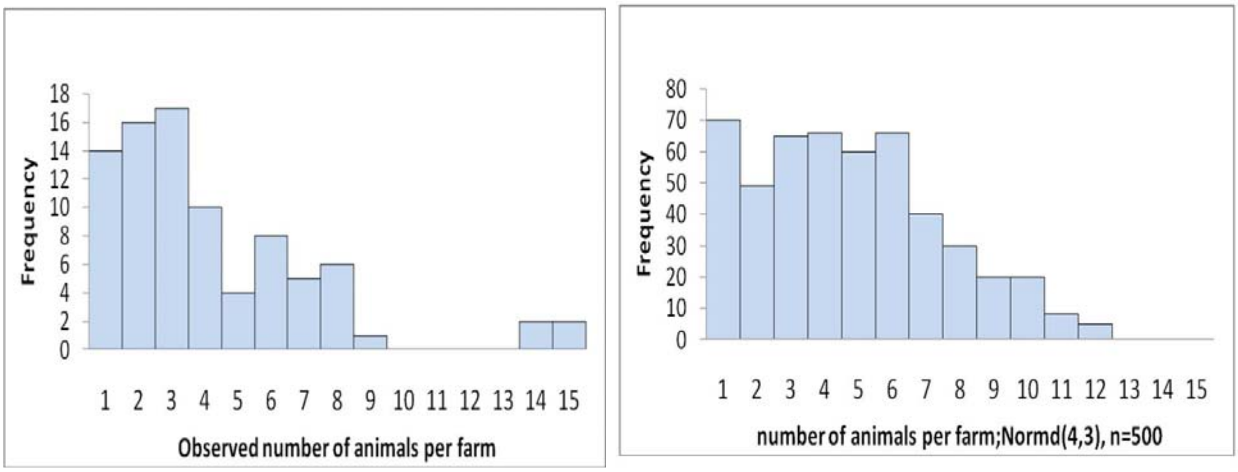
The main meat retailers in the Ockelbo region are those owned by two food distribution companies, ICA and Coop. In addition, about 50% of the meat from the Ockelbo abattoir was assumed to be delivered to Axfood in Stockholm. Route optimisation experiments were performed using 25 retailers (see Figure 4) in the case of meat distributed from both Uppsala and Ockelbo (see Table 3). The locations of these retailers were determined during data collection (13 retailers), while an internet survey was used to identify the remaining 12 retailers. Seven routes were created for meat distribution from each abattoir and compared (Table 3).

Estimating Greenhouse gas (GHG) emissions

The GHG emissions were estimated for animal collection and delivery to the abattoir and meat distribution in order to evaluate the environmental impact of the Ockelbo and Uppsala abattoirs. The GHG estimated 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). The calculation was based on a fuel consumption of the trucks and emissions factors, as used by other researchers (Apaydin and Gonullu, 2007). The truck model was Volvo FH12 and relevant data for Volvo FH12, Euro 3, MK1 were taken from

Table 3. Summary of route analysis results for meat distribution

Route	Delivery from Uppsala		Delivery from Ockelbo		Saving by using Ockelbo abattoir	
	Distance [Km]	Time [hr:min]	Distance [km]	Time [hr:min]	Distance [%]	Time [%]
1	281	3:05	133	1:45	53	43
2	211	2:20	120	1:27	43	38
3	270	3:00	117	1:28	57	51
4	335	6:00	130	2:40	61	56
5	432	4:38	188	2:28	57	47
6	446	4:55	199	2:41	55	45
7	281	3:05	178	2:04	37	34
Total	2256	27:03	1065	14:33	53	46



(A) Observed numbers of animals (B) Generated number of animals

Fig 3. Distribution of number of animals collected from each farm. (a) Observed numbers of animals collected from single farms for transport to abattoir; (b) Generated and normally distributed number of animals collected from each farm.

Volvo truck corporation (Volvo, 2001). An equation used by the Swedish Environmental Protection Agency (SEPA, 2010) was adopted to estimate emissions:

E = FC * TV * EF where: E is emissions 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}.

This Volvo truck model was used to transport animals from farm to abattoirs. The fuel consumption of a Volvo truck with up to 40 metric tons gross vehicle weight (GVW) in long distance driving is about 0.03 m^3 per 100km (Volvo, 2001). The thermal value for diesel (MK1) is about 35.28GJ m^{-3} of fuel consumed (SEPA, 2009). Data on EF (see Table 1) were taken from information presented by Swedish Environmental Protection Agency (SEPA, 2007). For meat distribution light truck was considered and its fuel consumption was taken as $0.011m^3$ per 100km (Trafikverket, 2009).

Results

Consumer responses

The study placed emphasis on consumer perceptions, environmental benefits and the potential resources of the area for self-sufficiency. Regarding local production and animal welfare, there were 91 responses to the questionnaire. Out of these responses:

- 70% were women and 30% were men
- Almost all stated that they preferred locally produced meat
- Over 90% were prepared to pay 5-20% more for local meat
- 70% were prepared to pay about 20% more than the ordinary price for local meat.

Fourteen randomly selected retailers situated around Ockelbo were interviewed in a complementary survey. According to these retailers, more than 50% of their consumers buy meat labelled as Swedish origin.

Optimum location of abattoir

The coordinates of the optimum location for the proposed small-scale local abattoir were 61°31'34"N; 16°27'58"E. This is about 90 km north-west of Ockelbo (60°54'14"N; 16°43'19"E) and the determination of the coordinates was based solely on the distribution of farms. However considering other factors such as job opportunities, potential growth of the Ockelbo region, transport facilities, etc., the most feasible location for the abattoir was decided to be Ockelbo itself (see Figure 1).

Route optimisation of animal transport

A summary of route simulation results of 30 routes created for collecting animals from farms and delivering to the Uppsala and Ockelbo abattoirs is given in Table 2. The route distance for delivery to the Uppsala abattoir varied from 397 to 748 km (with the mean value of 550 km) and the transport time (excluding loading and unloading time) varied from 4 hours and 15 minutes to 8 hours and 25 minutes (with the mean value of 6 hours). The route distance for the Ockelbo

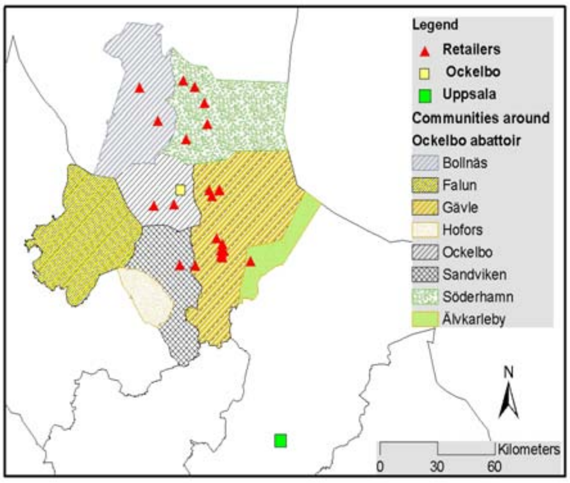


Fig 4. Location of 25 retailers for meat distribution around Ockelbo abattoir. These retailers were considered in sample route optimisation for the case of meat distribution from the Ockelbo and Uppsala abattoirs.

(A) Delivery route to Uppsala

(B) Delivery route to Ockelbo

Fig 5. Examples of routes for collection of animals from farms and delivery to: (a) Uppsala abattoir (distance: 580 km; time: 6 hours 11 minutes) and (b) Ockelbo abattoir (distance: 335 km; time: 3 hours 58 minutes).

abattoir varied from 126 to 509 km (mean value 318 km), while the transport time varied from 1 hour and 51 minutes to 6 hours and 16 minutes (mean value of 4 hours and 13 minutes as reported in Table 2). The results of the simulation experiments showed that the transport distance could be reduced by an average of about 42% and the travel time by 37%. Figures 5a and 5b show typical examples of routes created during the simulation experiment.

Route optimisation of meat distribution

Table 3 presents the route optimisation results for meat distribution. In the case of the Uppsala abattoir, the route distance varied from 211 to 446 km, while for the Ockelbo abattoir it varied from 117 to 199 km. The total distance and transport time for the 7 routes (only driving time, excluding loading and unloading) when meat was distributed from the Uppsala abattoir were 2256 km and 27 hours, respectively, while the corresponding figures for meat distribution from Ockelbo were 1065 km and 14 hours and 33 minutes. This implies that distribution distance could be reduced by about 53% and distribution time by 46% by using the Ockelbo abattoir. Figure 6 shows examples of routes created in simulation experiments of meat distribution from abattoirs to retailers.

Environmental impact

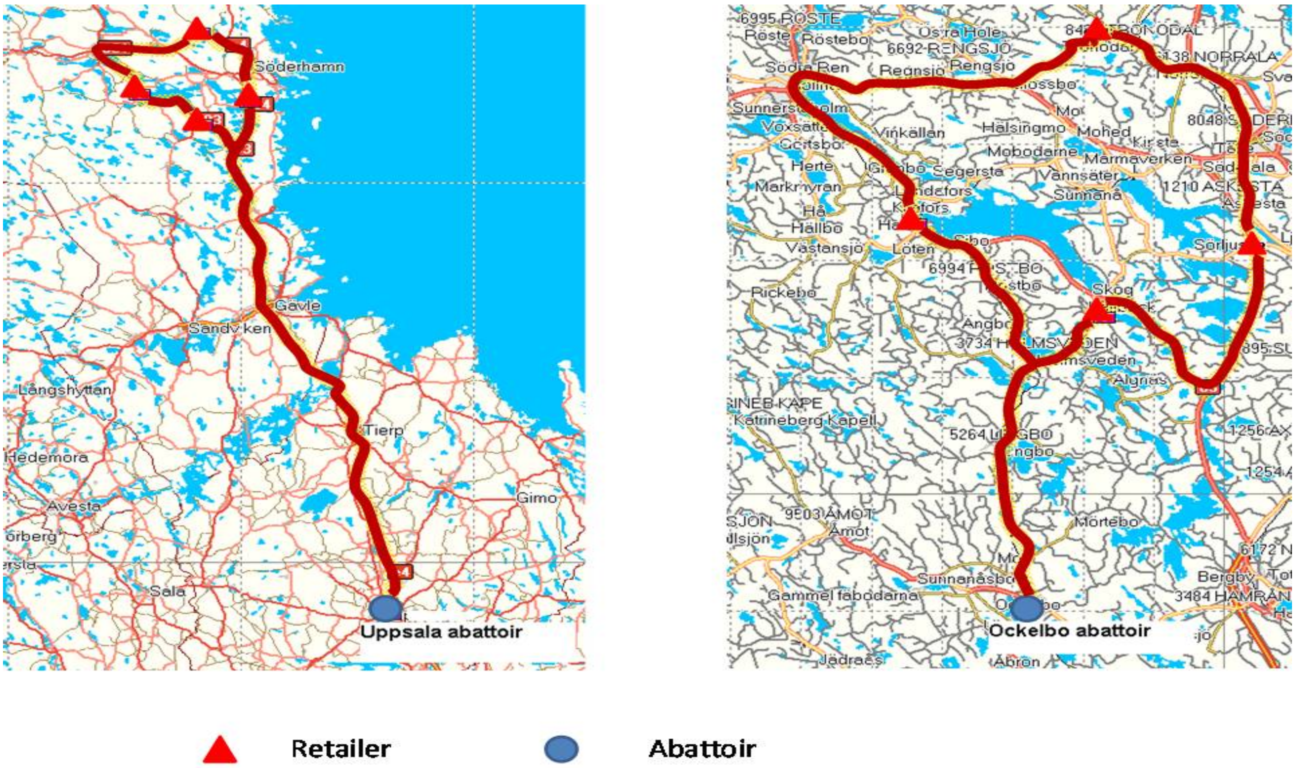
The calculations indicated that using the Ockelbo abattoir reduced GHG emissions. In the case of collecting slaughter animals, by considering the total distance of 30 routes, as presented in Table 2, CO_2 emissions were reduced from 12574.79 to 7266.13 kg. Similarly, CO emissions were reduced from 30 to 17.36 kg and NO_x emissions from 146.69 to 84.77 kg (see Figure 7a).

In the case of meat distribution, considering the total distance of 7 routes (see Table 3), CO_2 emission was reduced from 630.37 to 297.58 kg, CO emission from 1.51 to 0.71 kg and NO_x emission from 7.35 to 3.47 kg (see Figure 7b).

Discussion

Beef consumption in Sweden is around 18.2 kg per person per year (Gerbens-Leenes and Nonhebel, 2002). The population in the Ockelbo region is about 198 595, and the estimated total meat consumption is 4 369 ton per year, which means local meat production is more than sufficient for the consumers in the Ockelbo region. The survey of the consumers in the Ockelbo area indicated that they preferred locally produced meat and that they were prepared to pay more for such meat. The survey also showed that consumers expected high quality food, from healthy animals raised in a natural environment. Ethical factor, i.e. improved animal welfare was the main concern of the consumers. The survey clearly showed that consumers have confidence in local meat and are willing to consume it. This supports the necessity of establishing a small-scale local abattoir at Ockelbo.

The decision on location of a facility should be needs-driven and the location should be selected to satisfy as many concerns as possible (Chuang, 2002). Market size, accessibility and growth potential of the region; geographical location; transport facilities and modern logistics services are important factors in choosing facility location (Oum and Park, 2003). Even though the optimum location of the abattoir was estimated to be at about 90km from Ockelbo (see Section 3.3), it was decided to locate it at Ockelbo once other factors such as job opportunities, potential market and



(A) Route 5- Meat distribution from Uppsala

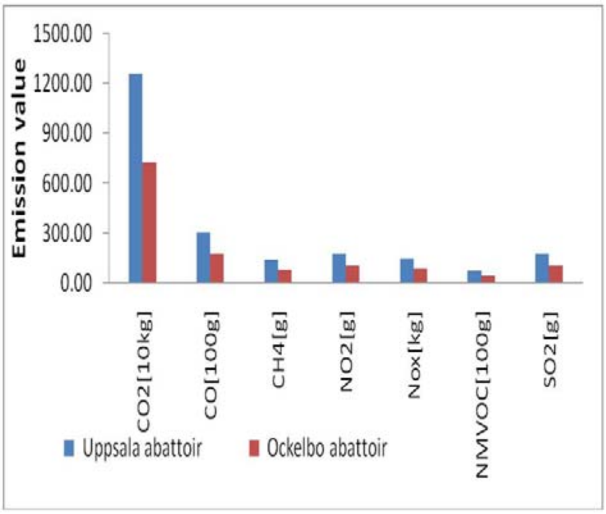
(B) Route 5-Meat ditribution from Ockelbo

Fig 6. Example of routes for meat distribution: (a) is route for distribution from Uppsala abattoir; and (b) is route for distribution from Ockelbo abattoir**.**

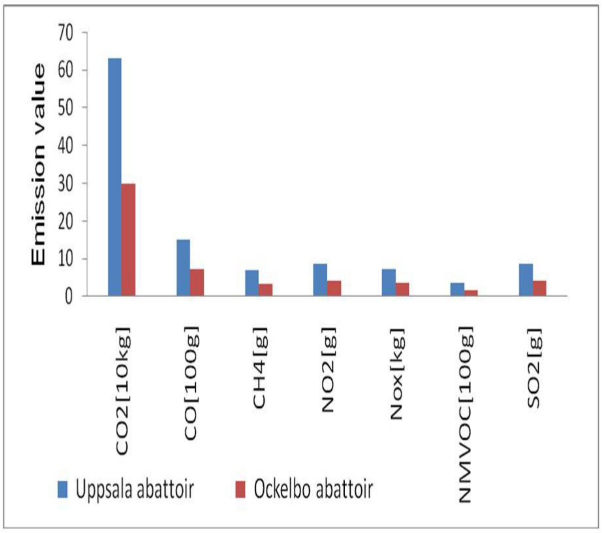
growth of the Ockelbo area had been taken into account. The numerous criteria involved in the facility location problem include: availability of transportation facilities, cost of transportation, availability of labour, cost of living, availability and nearness to raw materials, proximity to markets, size of markets, attainment of favourable competitive position, anticipated growth of markets, income and population trends, cost and availability of industrial sites, proximity to other industries, cost and availability of utilities, government attitudes, tax structure, community-related factors, environmental considerations, assessment of risk and return on assets (Jesuk, 2005).

The study showed that 50% of meat production would be sufficient to meet local demand in the region. Establishing an abattoir at Ockelbo would also make a vital contribution to job opportunities in the area and reducing transport distance and time which in turn has major implications for animal welfare and environmental issues, as well as meat quality. Since transportation is a stressful experience for animals, improvements in logistics are important. The simulation experiments showed a reduction in transport distance and time for both animal collection from farms to abattoir and meat distribution from abattoirs to retailers for the Ockelbo abattoir compared with that in Uppsala. This has positive implications for animal welfare and meat quality. For example, one of the regulations concerning animal welfare during transport of live animals imposed by the EU is that no animal should stay more than 8 hours on a vehicle (Gribkovskaia et al., 2006; Miranda-de la Lama et al., 2010). In the simulated routes for animal collection for the Uppsala abattoir, the driving time was up to 8 hours and 25 minutes, while the maximum time for the Ockelbo abattoir was 6 hours and 16 minutes. This indicates that the Ockelbo location is more acceptable from an animal welfare point of view. Decreasing handling and transport times, planning the arrival at the abattoir and speeding up unloading at the destination are other important measures for improving animal welfare (Miranda-de la Lama et al., 2010). The simulation experiments comparing the Ockelbo abattoir with that in Uppsala showed that the transport distance could be reduced by about 42% and the time by 37% for the case of animal collection and delivery. In the case of meat distribution from abattoirs to retailers, the driving distance could be reduced by about 53% and the time by 46% when the Ockelbo abattoir was used. These positive results confirm the importance of route planning and optimisation analysis in improving the efficiency of the farm-abattoir logistics chain (Ljungberg et al., 2007; Miranda-de la Lama et al., 2009; Miranda-de la Lama et al., 2010). These results also demonstrate the potential benefits of increasing the efficiency of logistics for local food production, where the system tends to be relatively inefficient and fragmented (Saltmarsh and Wakeman, 2004).

Establishing an abattoir at Ockelbo instead of Uppsala could reduce GHG emissions by about 42% in the case of animal collection and by about 53% in the case of meat distribution. This is positive improvement towards environmental issues in the agricultural sector. Mitigating the risk of global climate change requires more challenging efforts to reduce emission of GHGs from agricultural sector (Jaradat, 2010). According to IPCC (2008), a mitigation strategy is particularly needed for the transport sector, which generates about 25% of the GHG emissions related to world energy consumption. About 75% of the emissions from the transport sector are from road vehicles.



(A) Emissions values in the case of animal collection



(B) Emission values in the case of meat distribution

Fig 7. Graphs illustrating GHG emissions

Conclusions

Establishment of a small-scale abattoir at Ockelbo could play a significant role in increasing consumer confidence in local products. It could also considerably reduce transport distance and time required in collection of animals from farms and meat distribution from abattoirs. This in turn has strong implications for improving animal welfare and meat quality, and reducing emissions from vehicles.Taking into consideration about 500 farms in the region, the major consequences of establishing a local abattoir at Ockelbo compared with Uppsala were:

• Transport distance and time, and emissions in collection of animals from farms and delivery to abattoirs could be reduced by about 42%, 37% and 42%, respectively.

• Transport distance, time and emissions in distribution of meat from abattoirs to retailers could be reduced by about 53%, 46% and 53%, respectively.

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