PROMOTING EFFECTIVE GOODS DISTRIBUTION THROUGH ROUTE OPTIMIZATION AND COORDINATION TO ATTENUATE ENVIRONMENTAL IMPACT, THE CASE OF UPPSALA

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ABSTRACT

Goods transport has steadily intensified in the last decades and its impact on environment increases analogously. Particularly, goods distribution in towns contributed not only to the negative environmental impact, but also creates congestion. The tendency of frequent deliveries in small parties of goods is growing in the contemporary distribution system following the principle of just in time, JIT. And thus vehicles are partially loaded and the number of vehicles per kilometre increases.

The current paper presents the study made on the food distribution in and around Uppsala town of Sweden, to map out the system and to investigate the possibilities and hindrances of co-ordinated distribution to promote an economically effective and environmentally sustainable distribution system.

The project was conducted with close collaboration between universities, municipality and thirteen producing and distributing companies. The methods employed include conducting series of seminars, field measurements on distribution performance, conduct overall distribution simulation and optimisation, route optimisation in terms of sequences of delivery and distance, and computation of emissions. It was a participatory form of project where the main actors, i.e., producers and distributors actively participated particularly in the seminars where co-distribution constraints, field measurement results and possible solutions were discussed.

The measured parameters were time (driving, loading, unloading, motor-idling, resting, exact time of delivery for each customer, start and end of distribution), load rate of vehicles in terms of weight and volume, transport distance, routes of distributions, vehicle's speed, and geographical locations of producers and delivery points. The latest three parameters were measured by the Global Positioning System, GPS.

The measured vehicle data were thereafter used to optimise distribution and to compute emissions with the distribution planning software, DPS, and the dynamic simulation model, MODTRANS, respectively. All together, 38 routes and 513 deliveries were made with 19 vehicles and the total transport distance was 4322 km. Route optimisation experiments were made for every route. The maximum time saved after optimisation for some companies was about 40% and the maximum distance reduced was about 34%. However, about 16% of the routes were well planned by the drivers.

Simulation experiments were also made to observe various possible combinations. It was found that almost all the producers lie very near to each other, and many of them (especially those distributing in the suburbs of Uppsala) follow similar routes and acquire many common customers. Combination of two or more routes reduced haulage by about 45%. Those companies distributing bread products meet very often at the delivery points, and follow one another to the next delivery points.

Total optimisations of distribution were made for the whole routes and by group, for instance, bread or meat distributions. Total optimisation reduced the number of vehicles by 42%, routes by 58% and the total distance by 39%.

The vehicles' load carrying capacity utilisation at the initial point of loading varied between 5% to 90%. Motor-idling at the delivery points was observed. Out of the 38 routes, the drivers allow the motor idling during unloading for 25 routes. The time distribution for driving, stop, and stop with motor idling were 71%, 21%, and 8% respectively.

The environmental impact of the contemporary distribution routine was estimated by computing emissions emanated from the vehicles for each route and presented in the report. Parameters such as vehicle's weight, load, road conditions (slopes of the roads), vehicle's speed and motor-idling, were considered for emission estimation.

It may be concluded that, there is a potential to implement co-ordination in two stages. Companies distributing similar food products in the same route could develop a common delivery route without any technical development of vehicles. Those distributing in the same route, but their commodities require different temperature in the vehicle, may require vehicles with different compartments with different temperature.

Keywords: food distribution, route optimization, coordination

1. INTRODUCTION

1.1. Background

Transport plays a controversial role and highly related to almost all human activities. It stimulates economy, improves the well being of human life, and at the same time contributes to the environmental constraints in the form of pollution, depletion of ozone layers, global warming, depletion of resources, waste, noise, vibration, barriers and congestion in densely populated areas.

There is a sustained trend in the intensification of goods transport activities to reach the demands from steadily growth of integrated and globalization of economy in the recent decades. Traditionally, goods transport increases at a similar rate with GNP (references). However, the recent distribution system where the principle of just in time (JIT), is successively applied and causing to increase the rate of transport growth, in terms of vehicles per kilometre faster than GNP.

Transport of food and agricultural produce is a significant component of goods transport as a whole in Sweden. It comprises about 17% of the total amount of transported goods (SIKA Statistik, 2006) and 15 % of transport work in ton-km performed by lorries respectively (SCB, 2000) .Transport of daily products continuously increases in the sector mainly due to rationalisation and centralisation of production and processing systems (references).

The potential impact of emissions generated from road transports up on the atmosphere is leading to an increase of environmental concern, both at regional and global levels. It is therefore a common national, regional and global responsibility to attenuate the negative environmental impact and design strategies for the development of environmentally sustainable transport system within the context of sustainable economic and social development formulated by the UN commission on Environment and Development (1987). Thereafter, emission control polices have been adopted and being implemented by many nations to limit the adverse of environmental impact of economic activities. The United Nation conferences on environment held in Rio de Janeiro in 1992, Kyoto in 1997 and Buenos Aires in 1998, and the European Union adopted various environment and development related resolutions to reach the vision of sustainable development within the coming two to three decades. Emphasis was given on substantial reduction of emissions emanated from transport activities. Following the UN directives and the awareness and pressure from the society, the Swedish parliament and government developed ranges of proposals to successively reduce emissions from vehicles.

To date, transport of trucks are more and more specialised for specific goods and this discourages loading various goods on the same vehicle. Many vehicles are designed to transport specific commodities, for instance, milk, meat, bread, etc. Some commodities require specific packaging and atmospheric conditions. The other factor for specialisation is hygienic regulation of food products during transport, and thus the nature of the producers plays also an important role.

The other main factor for an increase of transport activities in the contemporary distribution system, as mentioned earlier, is the tendency of frequent deliveries in smaller parties, i.e., the concept of just in time. Most of the vehicles are moving with partially loaded and the average load rate remains under 50%. Though an increase of transport work in terms of tonkm may gently increases every year, an increase of number of vehicles per kilometre is significant due the tendency of using JIT approach, specialisation of trucks and lack of co-ordination.

1.2. Some strategies to reduce environmental impact

To reach the goal of developing environmentally sustainable transport system, research institutions and other organisations put their efforts to promote the following strategies (Gebresenbet, 1998).

a) effective utilization of vehicles
b) improve vehicle's technology
c) improve fuel efficiency
d) searching for alternative fuel system
e) promote IT supported logistics system,
f) improve driving performances,
g) integrated supply and distribution system

In the recent years, development of effective models of distribution channels between various organisations in the supply, production and distribution has received significant attention (Dornier et al, 1998). Material flow between various links within the food production and distribution branches (Figure 1) used to be evaluated in terms of cost. However, the current conditions require evaluation and optimisation of, material flow in terms of not only economy but also environmental consequences.

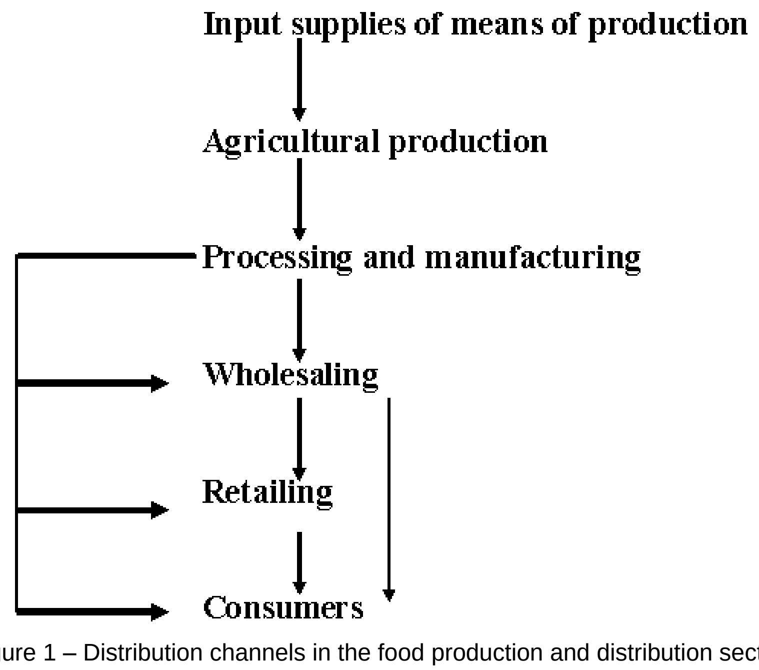

Figure 1 – Distribution channels in the food production and distribution sector

The tendency of including third party system, which uses a centralised terminal system to break the distribution system depicted in Figure 2 by minimising the number of transactions required to deliver product assortments (Bowersok and Closs, 1996) is in progress.

However, as illustrated in Figure 3, the third party may not be necessary to acquire depots if the producers and retailers are in the same area. The necessary organizations are (see Figure 3):

(a) the web-based marketing, order and billing system, and
(b) Transport organization.

These two organizations could accomplish the role of service provider by co-ordinating orders and deliveries. After receiving orders from retailers and consumers, groupage of commodities will be made and appropriate vehicles will then be assigned to deliver for each route in accordance with the required time of delivery of each customer. Such a system may require special packaging system for the products and the vehicle may have different compartments to ensure the quality of the products during transport.

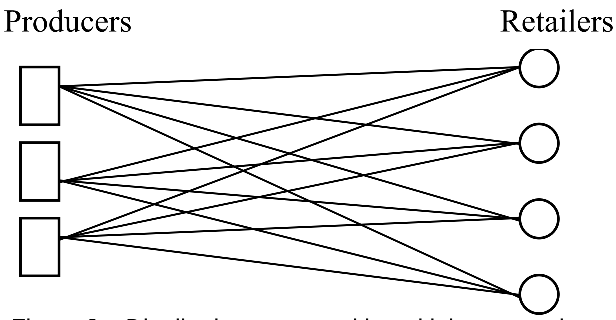

Figure 2 – Distribution system with multiple transaction

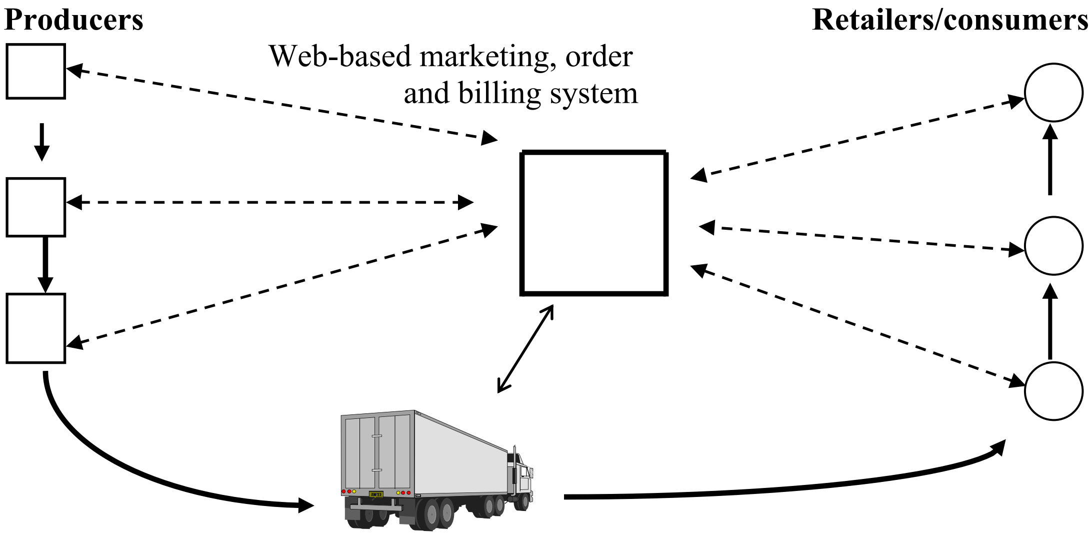

Figure 3 – Co-ordinated distribution system using the third party, i.e., order and service provider. The thick and thin arrows depict material and information flows respectively

1.3. Earlier works

Important researches on a co-ordinated agricultural produces and food transport system were conducted at the beginning of 1980s. Westin (Westin, 1982) assessed the food supply and distribution system to a sparsely populated area of Vilhelmina in relation to economy. Westin concluded that a co-ordinated transport system is economically viable and a guarantee for the continued food supply in such areas.

Ottosson and Svensson (1982) investigated the possibility of combined and co-ordinated on-farm and off-farm transport including both collection and distribution. A model was developed to determine the effect of co-ordinated transport in terms of transport distance, transport work and vehicle utilisation. The main principle of the model was that a truck leaves terminals with full load, and unloads successively and loads also at the delivery points successively in such a way that when it arrives to the terminals, it will be fully loaded. According to their reports, the total haulage can be reduced by 20% if all companies involved integrate their transport system.

A simulation model, MODTRANS, (Gebresenbet and Oostra, 1996) has been developed at the Department of Agricultural Engineering of SLU to study the goods transport in relation to environment. Especial emphasis was given to the material flow (both collection and distribution of agricultural and related products). The model calculates also the emissions generated from trucks.

Kristiansson and Pettersson (1996) made an important study on goods distribution in the densely populated area of the city of Gothenburg. An inventory assessment was made using the response obtained from the concerned actors through questionnaires to determine the constraints and potentials for co-ordinated distribution. The authors reported that with the exception of retailers, all the involved organisations, such as producers, transport companies and the commune have shown a great of enhancing co-distribution. However, the problem associated with implementation remains un-answered. The transport research institute, TFK, (1997) conducted similar appraisal on urban goods distribution with special emphasis on the role of information technology, IT, to develop better structure for urban distribution.

However, further comprehensive works are required to describe the material flow within local and regional perspective, continuous measurements of vehicle's and driver's performance, distribution route trucking, geographical locations of producers and delivery points, and simultaneous computation of emission, to develop an information technology supported distribution system and to determine the environmental benefits. This may necessitates to conduct the present study to provide better information on the contemporary distributions on local and regional levels.

2. OBJECTIVES

The main objective of the current work was to map out the current distribution system and determine the constraints and possibilities of developing a co-ordinated goods transport in and around Uppsala town, and to demonstrate the role of IT to promote economically effective and environmentally sustainable distribution system through co-ordination and route optimisation.

It was assumed that the IT-supported co-distribution benefits:

- distributors by attenuating transport cost,
- retailers to maintain minimum inventory, and
- society by reducing environmental degradation.

3. METHODS

The method applied was a participatory form of work, where the main actors, i.e., producers and distributors actively participated in the identification of core problem and possible solutions. Implementation of the project had the following components:

- carry out series of seminar with the involved companies,
- conduct measurements on the distribution performances
- perform optimisation experiments at various levels, i.e., for each route, for each company , for companies distributing similar commodities, and all the companies as a whole
- estimate the environmental benefit in terms reduced emissions generated from the vehicles before and after optimisation

3.1. Parameters

The parameters considered for this study were:

- time for various activities (loading, unloading, resting, driving, stop with and without motor idling at the delivery points)
- vehicle utilisation level, load rate, in terms of volume,
- goods' weight for every deliver,
- distance, vehicle's speed, road conditions,
- geographical position of producers or depots and delivery points,
- emissions.

The total goods loaded, the amount delivered at every delivery point, vehicle's utilisation in terms of volume prior to first delivery point were estimated. The maximum allowable load carrying capacity of each vehicle, the distance between each interval and the total distance of each route or trip were documented.

3.2. Participated companies

In total, fourteen companies from different branches participated in the project (3 transport companies, 5 bakeries, 3 meat distributors, 2 freezed food distributors, and 1 flower distributor). Field measurements were made for eight of them. Except one bakery, all the other seven companies are in Uppsala town and their geographical is shown in Figure 4. The companies are situated within the radius of approximately one kilometre.

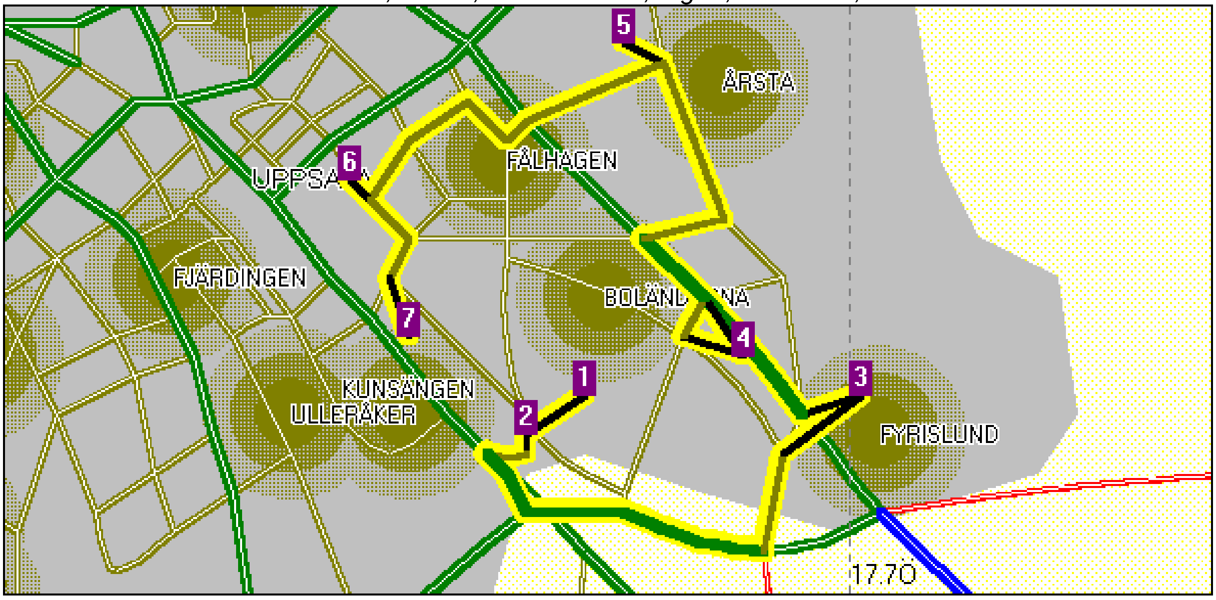

Figure 4 – The numbers in the map denote the location of companies involved

3.3. Series of seminar

The main objectives of the seminar were: to discuss the economic and environmental advantages of co-ordinated distribution system, exchange experiences among the participants, discuss the available knowledge and technologies which may facilitate co-ordinated distribution, and finally to identify plausible and concrete solutions for the promotion of co-distribution in and around Uppsala.

3.4. Measurements on distribution performance and data processing

Three packages of hardware and software were used for the measurement of distribution performances, optimisation of distribution and for the evaluation of the environmental consequences. Instrumentation of the Global Positioning System, GPS, was used to measure the routes of distribution, geographical locations of the producers and delivery points, vehicle's speed and terrain features of the roads. Times for various activities (loading, unloading, resting, stop with and without motor idling, total distribution) were measured manually.

The second package was the distribution planning software, DPS/LogiX, which enable to simulate and optimise the distribution, and determine distance reduced and time saved in the case of optimisation. The optimisation exercise was made for:

- a single route,
- a single company distributing in many routes,
- companies of the same branch, and
- all companies.

The third package was the dynamic simulation model, MODTRANS developed by Gebresenbet and Oostra, (1996) in the Matlab/Simulink (MatWorks, 1991), which enable to describe material flow and compute air emissions emanated from the vehicles. Simulink (1992) is an extension to the Matlab programme which can be used to simulate dynamic systems. Both the second and the third packages use the measured data on distribution and vehicle performances. Figure 5 views the information flow to the different parts in the project: from field measures to seminars and route optimization and environmental impact calculations.

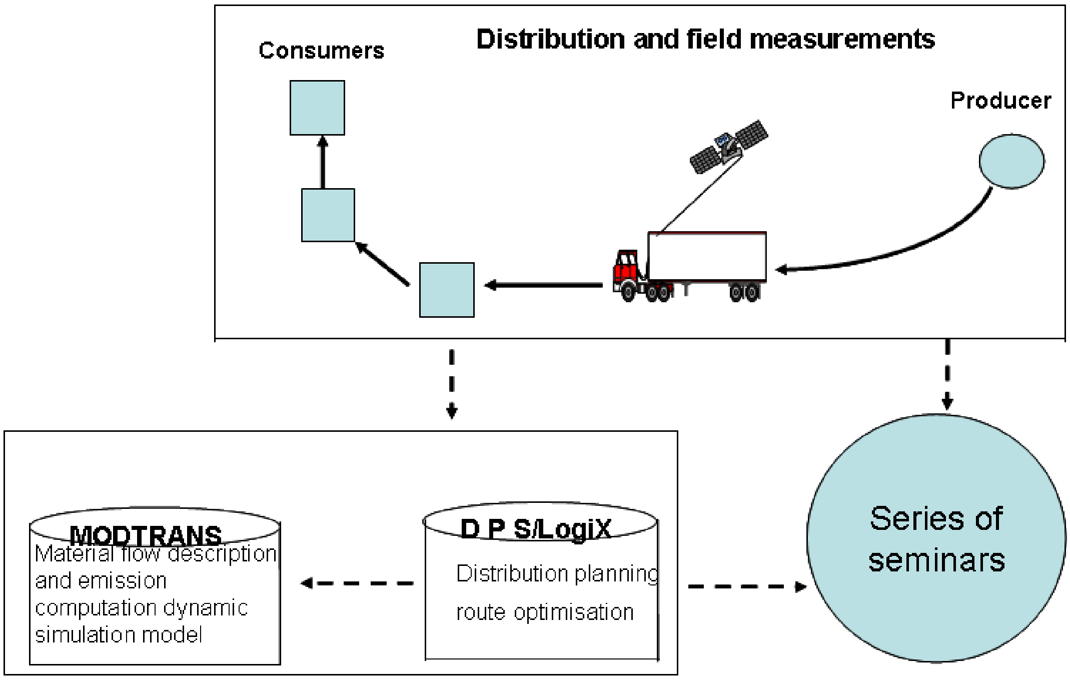

Figure 5 – Distribution performance measurement, optimisation and evaluation packages

4. RESULTS

4.1. Data processing and general results

Totally, field measurements were made for 38 routes and 513 delivery points (most of the deliveries were made in Uppsala town). The total distance covered was 4322 km. Data processing was made with two softwares: Logix (for route and distribution optimisation), and MODTRANS (for material flow description and emission computation).

- Computer based optimisation experiments were made for different levels, i.e., all the involved companies, and in groups (for instance companies distributing bread in one group and those distributing meat in another group)
- Route optimisation for each trip
- Computation of emissions for each trip, route, company, group of companies and for the whole companies involved.

It may be worth to note that the accuracy of the measurement and problem noticed during the field measurement prior to the presentation of the results. The accuracy of the estimation of vehicle's load rate was low. To obtain the exact weight of goods delivered at each point was not easy either.

4.2. Initial load rate

Effective utilisation of vehicles is one of the strategies that mentioned earlier in the previous chapter, to reach the visions of promoting environmentally sustainable transport system. Thus, for the current work, the load rate in terms of volume was estimated for each route. All the haulage trips were simple where vehicles travelled loaded in one direction and unloaded on the way back from the distribution to the producers' garage. In the study load rate was estimated only after the initial loading.

Load rate for the initial loading varied widely between companies transporting in city and rural areas. The studied load rates for all routes lied within the range of 5% to 90%. The average rate for all the 38 routes was 47.7± 26%. The average values for each company are presented in Figure 6. As it may be observed there, companies, for instance companies C and H, which distributed in town delivered in frequently small volume. The average load rate of those vehicles that distributed in rural, city and both in rural and city were 65± 24, 38±23 and 49±23 respectively. The above given values can be more than halved if efficiency over the whole route is considered.

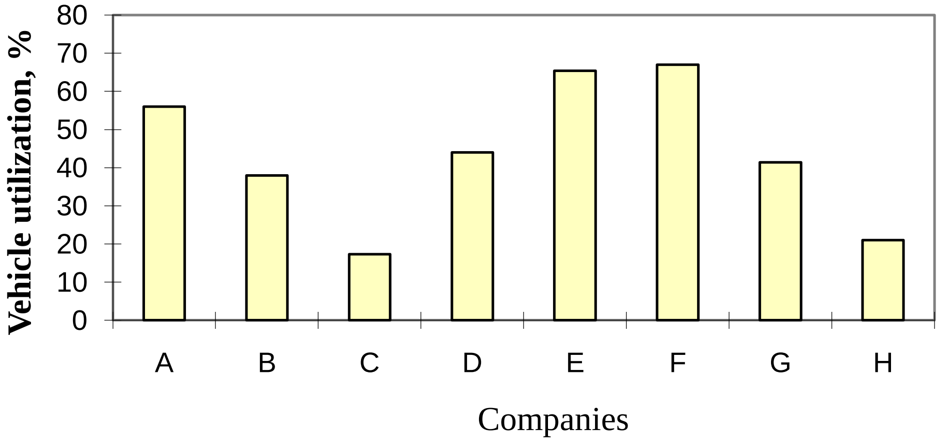

Figure. 6 – Average vehicle's initial load rate for each company

4.3. Route optimisation

In all the 38 routes, drivers planned each route, taking into consideration the possible shortest and quickest routes, and the sequences of deliveries. The sequence of delivery was governed by the delivery time demanded rather than the geographical locations, but in the end, the routes were determined by driver's experiences.

As mentioned earlier, simulation and optimisation both in terms of network and sequences of delivery, was made to estimate the distance reduced and the time could have been saved if the optimisation was made prior to distribution. Figure 7 compare the actual and optimised routes. Optimisation reduced both distance and time by about 34%.

About 15.8% of the total routes planned perfectly by the drivers. Distribution in the suburb and region were relatively planned better than those routes in the town. The optimisation result showed that the maximum distance which could be reduced up to 34% and the maximum time which could be saved ranged up to 40%.

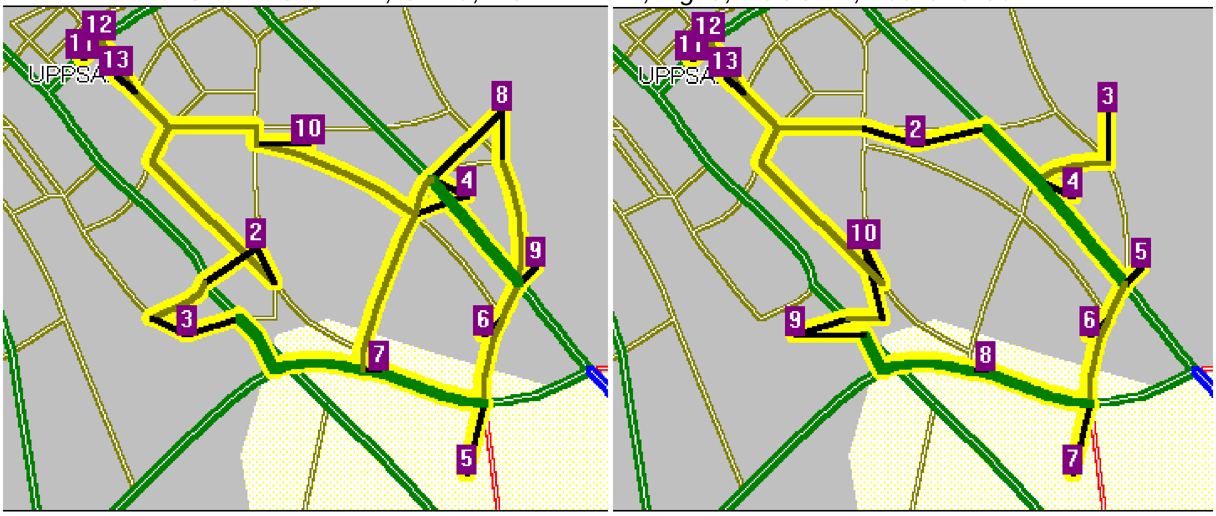

Figure 7 – Actual and optimised route

4.4. Total optimisation of distribution

Investigations were made to search for possible co-ordination of distribution on various levels, i.e., distribution of the same categories of food, for instance bread or meat, and co-distribution of foods of different categories. Distribution routes, delivery points, vehicles' utilisation level of each distributor were first determined. Thereafter, common delivery points and routes were determined and simulation experiments were made both for specific groups and for all the routes.

Total optimisation of distribution has also been conducted for all the routes and vehicles. The result showed that the total distance, number of vehicles and routes could be reduced by 39%, 42% and 58% respectively if the distribution was optimised beforehand. For numeric values see Table 1.

The major factors which may enhance co-distribution observed by this study were that many of the participated companies acquire common customers, follow similar routes and vehicle load capacity utilisation level is low. Moreover, most of the producers/distributors are located very near to each other (Figure 4), so that co-distribution can be made without the requirement of common terminal. Six of the producers lie within the radius of one kilometre.

From the current investigation, it may be noted that there is high potential of co-distribution without the requirement of making significant structural change. Particularly, companies distributing similar goods may kick off' co-distribution without any design modifications of vehicles.

4.5. Examples of possible co-ordination

The coordination was divided into three categories: (a) Distribution in rural areas and small villages (12 routes), (b) Distribution in Uppsala city (22 routes), and (c) Distribution in both rural and Uppsala city (4 mixed routes). After optimization, the 12 routes in the rural areas were reduced to 6 routes, and the 22 routes in Uppsala city were reduced to 8 routes, where as the 4 mixed routes were reduced to 2 routes. Typical example of combination of two routes is illustrated in Figures 8 and 9 to demonstrate the benefits in terms of distance and time.

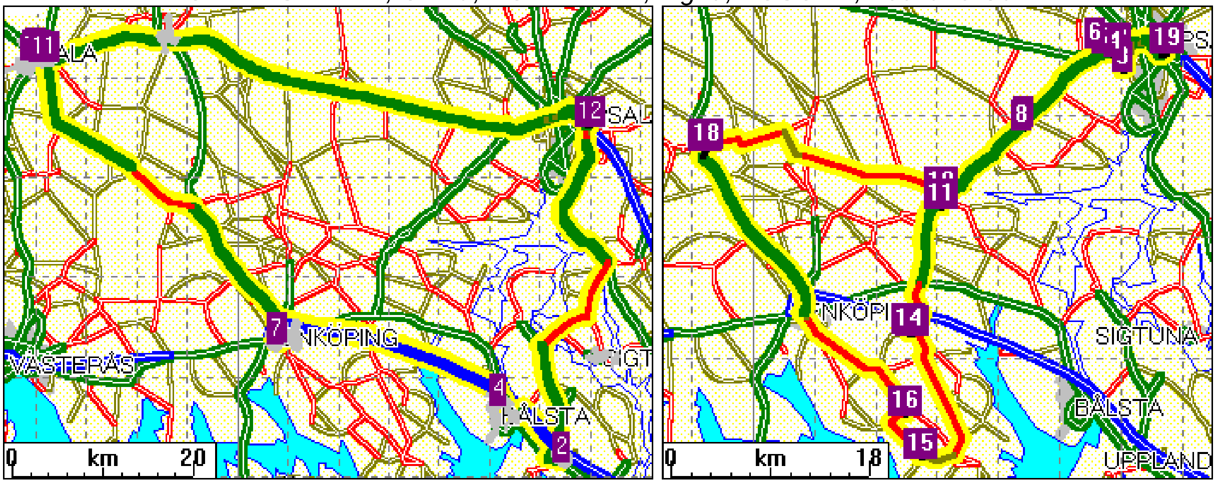

Figure 8 – Routes 21 and 37

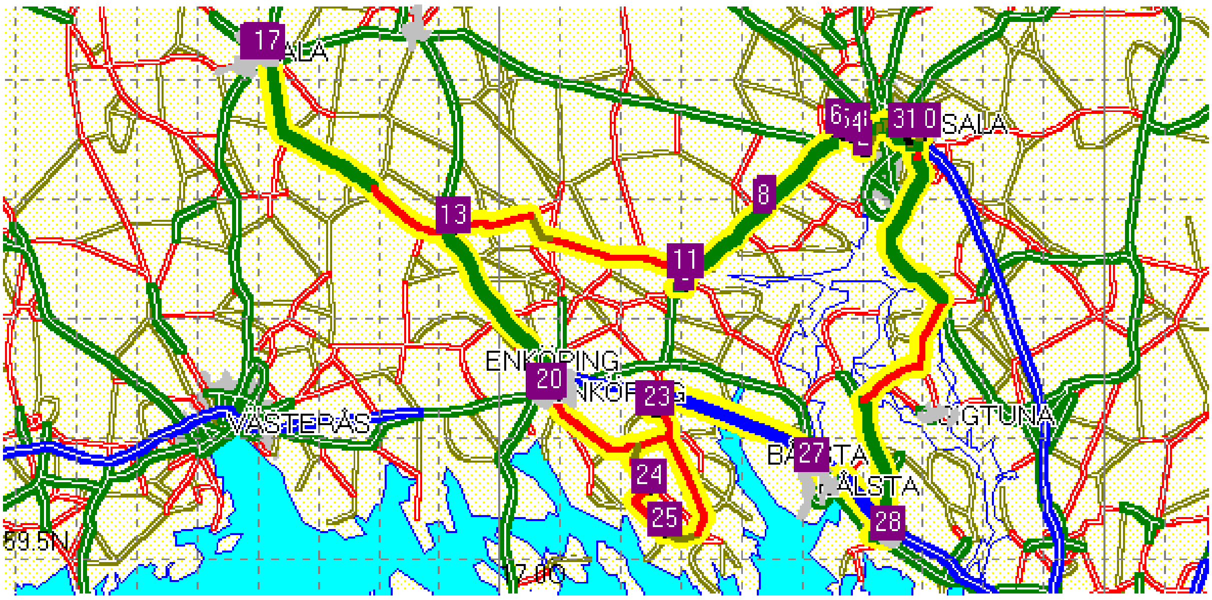

Figure 9 – Combination of routes 21 and 37, reduced distance by 25%

4.6. Motor idling

Observations were made whether the drivers stop the motor during unloading or allow motor idling, to include in the emission computation. In about 66% of the total routes motor idling was observed. Motor idling time, in relation to the driving time, varied between 1.1 and 48.6% for the routes.

Allowing the motor idling was common for those routes performed in the town, and thus the relation between motor idling and driving time reached about 48,6% for some cases during distribution in Uppsala city. The mean value for all distribution in city and rural areas were 18.32±15 and 7±5 respectively. The average time distribution of driving, stop with and without motor idling of those routes where motor idling observed were 71%, 21% and 8%.

Motor idling at the delivery points is unnecessary and its environmental impact is significant. Usually, continuous motor running may be required for the ventilation system to control the temperature in the loading zone. However, many of the routes which had higher percentage of motor idling time never required such operation.

4.7. Environmental impact

Scrutinising the environmental impact of the contemporary distribution system in and around Uppsala town was among the main objectives of the current investigation. Emissions generated from the vehicles were computed with the MODTRANS model for each route and the gathered data of load, speed, road conditions and motor idling duration. However, because of technical constraints during the measurement, for many of the routes only the locations of producers and delivery points were recorded. Table 1 reports the summary of the total optimisation and of the total emissions of CO, CO_2, NO_X, HC and SO_2.

Table 1 – Summary of total optimisation and calculated environmental impact (factors such as load, motor idling and area of distribution were considered, and emissions were calculated g/tkm)

	Number of routes	Distance, km	Number of vehicles	Emissions, kg				
				CO	CO_2	NO_X	HC	SO_2
Before optimisation	38	4322	19	3.98	1289.5	25.8	3.00	0.02
After optimisation	16	2636	11	2.07	670.6	13.4	1.6	0.01

4.8. Series of seminars

Four seminars were conducted during the progress of the project. The main topics discussed were: (a) basic concepts of coordination and collaboration, (b) Technical solutions and support, (c) economic incentives, (d) competition, and (e) results from field measurement. At the end of the project, special seminar was organized where about 50 stakeholders were invited to participate in the discussions of the outputs of the project. The participants were impressed and surprised by the results of route optimization and total optimization and the potential for economic and environmental benefits for food distributing companies.

5. CONCLUDING REMARKS

The study made to map out the distribution activities within and around Uppsala showed that many of the participated distributors are situated very near to each other, acquire many common customers and follow similar routes. Especially those delivered bread, very often meet at the delivery points at the same time and follow each other for the next delivery point. This implies that there is a high potential, for these companies to co-ordinate their distribution.

It was noticed that deliveries were made not according to the shortest driving distance, but rather priorities were made in the following order: shops, restaurants, schools or nurseries. Some drivers,(about 66% of the total route) particularly those distributing in the town, allowed the vehicles' motor idling while unloading and delivering. Emission computation has showed that emissions per kilometre in the town is much more higher than in the region due to mainly lower speeds and motor idling at the delivery points. To avoid unnecessary motor idling, sensitisation of the drivers is required to lift up the environmental issue associated with distribution.

The optimisation made showed that route and sequences of delivery planning of individual route could reduce distance by 39% and saved time by 40%. The total optimisation reduced the routes, the number of vehicles, and the total distance by 58%, 42% and 39%

respectively. Consequenly, the optimization results could reduce emissions that generated from vehicles by 48%.

Examples of several possibilities of combination of routes without any technological modification of vehicles and the requirement of common depots were identified and illustrated with the network digital map.

This study confirms that IT-supported route optimisation for various levels of distributions are among the main strategies which may enhance the promotion of economically effective and environmentally sustainable distribution system.

The observed constraints which may retard co-distribution were competition among the producers, between large scale and small scale transport companies, the nature of goods, and un-clarity around the question of who takes the initiative.

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