FREIGHT TRANSPORTATION AND ITS EFFECTS ON THE SPATIAL ENVIRONMENT

- Product-related transportation analysis -

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1. SYNOPSIS

This paper describes a technique, one which businesses can use to organize their goods transportation operations in a fashion which is sustainable and, in the long term, cost-favorable.

2. ABSTRACT

Freight transportation activity (the product of weight and distance), particularly on streets and roads, has increased greatly in recent decades. The geographic distances covered and the intensity of exchange within the economy have grown but the quantities being shipped have not increased at nearly the same rate as the distances. The extended distances involved in freight transportation are decisive determinant factors for rising energy consumption and environmental and social impact. Even today capacity limits have become evident, signalled in the environmental field by the destruction of natural resources and in sociology by a deterioration in the quality of life.

A product-related transportation analysis model will, as far as possible, include all transportation processes over the life cycle of a product, concentrating on all stages of manufacturing. The analysis is oriented on manufacturers and consumers and shows the conditions and interdependencies associated with the production and consumption of products. The results illustrate the impacts due to transportation such as energy consumption, pollutant emissions and transportation intensity index for a product (the distance over which one unit of product is transported).

This concept has been applied to date in a dairy operation for a yoghurt production and for mushroom growers and reveals options for more environmentally sound, sustainable organization of freight transportation activities. It is remarkable that the so-called "natural" or "biological" products are often not environmental if the transportation distances are taken into account. Manufacturers' expectation to be able to buy anything, everywhere and at any time has direct consequences on freight shipment volumes and the number of kilometers covered by lorries. Increasing this type of demand aggravates the effects on the environment and on quality of life.

3. INTRODUCTION

We are witnessing an unabated increase in the volume of traffic on streets and roads. The inordinate vehicle density not only causes delays in delivering materials required for production purposes; another effect is that finished goods often fail to reach their destinations at the desired time.

The transportation sector is one characterized by extreme growth; at the same time it consumes enormous quantities of resources and exerts an adverse effect on the environment. It is the only sector of the economy in which energy consumption has risen strongly since the 1970s and for which consumption will continue to rise in future. Experts predict that by the year 2005 the overall volume of goods transportation traffic in Germany will have grown by 92% (Höpfner Ulrich; Knörr Wolfram 1992, p. 240).

Here in can be stated that the absolute volume of goods transported (measured in tons) has in general remained level. At the same time, however, the distances covered and speeds travelled have risen while a greater share of goods is being transported by lorry (Deutsches Institut für Wirtschaftsforschung 1993, pp. 202 and 212). These are the primary reasons behind the growing volume of resources dedicated to freight transportation, growth which brings increased environmental impact in its wake.

The rise in the amount of goods traffic on the roads can be traced back to the following factors (Läpple Dieter, ed. 1993):

- Ever smaller volumes of bulk goods such as coal or ores are being moved. This is offset to an ever greater extent by lighter weight and higher-priced goods for which shipping with lorries makes good sense from both the cost and flexibility viewpoints.

- Individual production steps are being shifted to the vendors and subcontractors (reduced manufacturing depth at the final assembly plant). This improves costs structures in production operations since, for example, inventories and warehouse space can be reduced. The additional effort devoted to transportation is usually not relevant for the companies involved, since these shipping costs are almost negligible.

- Sourcing and sales markets are expanding geographically; the reasons are, for example, to exploit cheaper sources of raw materials and to boost the sales of one's own products.

Although the limits of the environment's carrying capacity have been apparent for some time now, there is no sign of a decline in roadway traffic. The associated air pollution makes a contribution both to the demise of forests and to deterioration of the global climate. In addition, loading and stress for soil and water resources along with the sealing of the ground as a result of roadway building all interfere with the ecological balance.

The problems inherent to increasing volumes of roadway traffic are particularly apparent in the metropolitan areas and cities. The rising frequency of traffic tie-ups is just one fact of the problem. The human costs are far more significant. Emissions resulting from motorized traffic have grave impact on health, with pollutants concentrating in the "concrete canyons" and attaining peak values there (Holzapfel Helmut 1990, pp. 43 - 45).

The quality of living for urban residents is being further and further diminished by adaptations in the infrastructure required to accommodate rising traffic volume, by increasing noise levels and by the concomitant rise in emissions. Affected in particular are pedestrians and bicyclists.

4. RESEARCH APPROACH

How can the growth of motor vehicle traffic and its effects be reduced? It is decisive to note that only the aggregate of all changes in decisions made by individual firms and private citizens will make any appreciable contribution. Every business is, of course, dependent on an exchange of goods and this foundation for business activity must be maintained. How can individual businesses reconcile these basic requirements in an acceptable fashion and what goals can be derived as regards commercial freight traffic?

The following targets devolve from such considerations:

- reducing environmental impact by, for example, shortening the distances to suppliers or using more environment-friendly transportation modes;

- attaining long-term dependability in transportation on both the sourcing and the distribution sides;

- responding to the demand for environment-friendly products which are made locally, and

- keeping the costs for transportation stable in spite of rising fuel prices or the introduction of road use fees.

Keeping these goals in mind, businesses can undertake concrete action to reduce environmental impact resulting from freight traffic and, beyond that, to respond in a forward-looking manner to foreseeable changes in the goods transportation sector (e.g. overloading of the street and roadway infrastructure or increases in fuel costs). Product-related transportation analysis serves as an information system with which essential business-related goods transportation can be carried out in a fashion more compatible with environmental needs. The results of the analysis can be used in designing appropriate marketing activities, e.g. identifying goods which are produced locally and indicating in consumer information labelling the distances covered in putting that item on the retailer's shelves.

4.1 Procedure

The techniques used in product-related transportation analysis are designed for the manufacturers of consumer goods as well as for producers of basic materials, auxiliary materials or raw materials. The purpose is to register and evaluate the volumes of freight traffic triggered by production operations, beyond the horizon normally used for business management purposes. This makes it possible to identify and implement specific options for action aimed at an ecologically acceptable and cost-favorable design of commercial traffic.

A more environment-friendly organization for business-related goods traffic can be achieved by reducing the amount of transportation involved in the manufacture of individual products. The overall amount of resources which a business devotes to transportation depends on the products manufactured and offered in each case and on the location of the production site.

The analysis is broken down into three steps:

1. compiling transportation data,

2. evaluating the data thus acquired, and

3. defining relevant areas for action.

The analysis references freight transportation operations upon which a company can exert immediate influence.

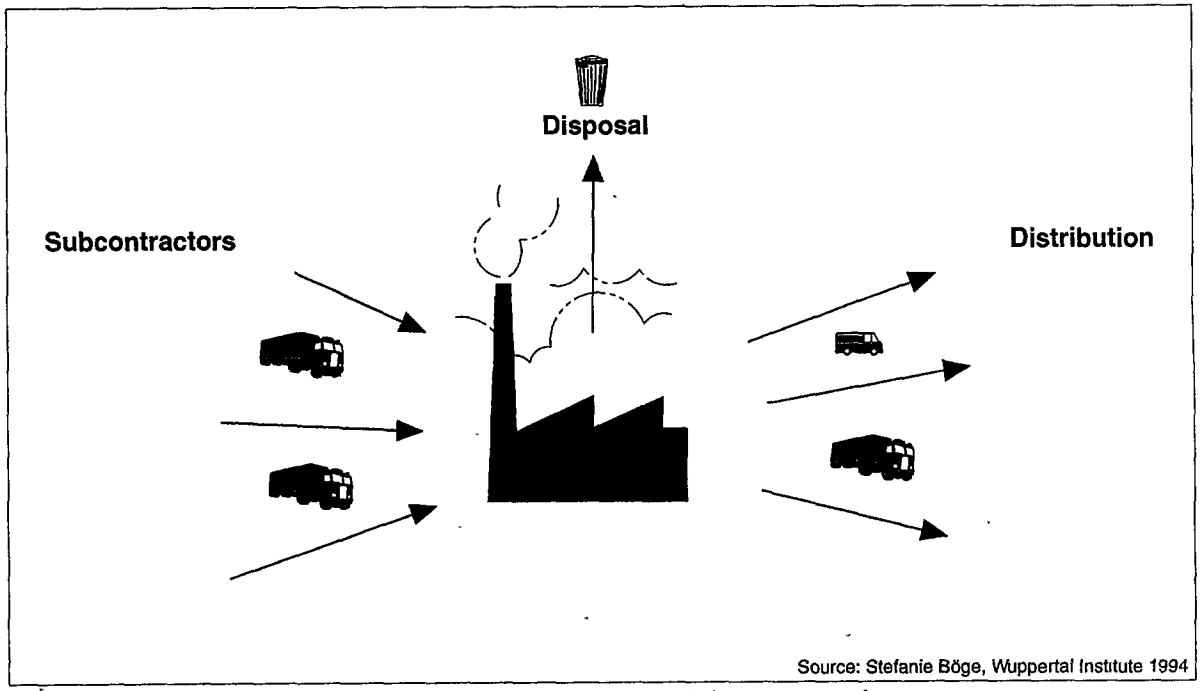

Figure 1: Compiling data on expenditures for commercial transportation

Included here, product by product, the are transportation involved in all types of shipment and the mileage resulting from disposal requirements. On the distribution side, only transportation which is carried out by a company vehicle fleet or between the company's own plants can be influenced directly. Shipping which is handled by direct subcontractors (and transportation to subcontractors by their suppliers) is not taken into consideration in the study.

Transportation carried out by customers who have their own transportation organization or by commercial forwarders is accounted for by way of rough estimates and included in the calculations. It is important, however, that the entire chain of transportation services for a product ("from the cradle to the grave") be designed so as to be more environment-friendly. Thinking should therefore extend beyond the systemic borders of the analysis and should also include, at least conceptually, those transportation services upon which we can exert only indirect influence. Such influence can be exercised by striving to establish an exchange of information among operatives in the transportation chain both upline and downline from our own operations and in passing along information on ideas and conceptual targets.

4.1.1 Compiling data

The analysis is based upon annual output of a product, i.e. the volume (measured in tons) transported each year. The following data are compiled for analysis purposes:

1) The volume of all the components required for the production (raw materials, packaging, shipping materials, auxiliary substances and return transportation for re-usable packaging, where applicable),[1]

2) the quantity of materials generated during production which will have to be disposed of, together with the shipping packaging,[2]

3) the quantity of the products sold.

In a second step the distances covered (measured in kilometers) are calculated for each of the products and materials mentioned above. This will be either the distance to the particular supplier or, where several suppliers are involved, the distance to the largest-volume supplier or an average figure for distance. When compiling data on the distribution of finished products, it can under certain circumstances make good sense to subdivide distances according to local and long-distance traffic.[3]

On the basis of this data it is possible to calculate the transportation involved annually in each item of material or product, expressed in ton-km (tkm). This transport activity makes clear the value transported in each case for a particular material or product across a specific distance and its relationship to the overall transportation expenditures invested in the product being examined. The effects of these transportation events, which are relevant to the next step in the analysis, will depend on which transportation mode is utilized. It is for this reason that this information is listed in addition.

Shown by way of example in the following table are some of the steps involved in calculating these data using yoghurt in a returnable jar as the example. The listing of the materials and products is, however, not complete. The production volume in this example was 200,000 jars of yoghurt (this corresponds to a gross weight of 170 tons for the entire annual production volume).

Table 1: Compiling data for freight transportation

Component designation	Quantity (t)	Distance (km)	Transportation output (tkm)	Transportation mode
Raw materials				
Milk	100	35	3,500	Tanker truck, 18 t
Packaging materials				
Glass	60	250	15,000	Truck train, 40 t
Shipping packing				
Cases	16	250	4,000	Truck train, 18 t
Return shipments for packaging				
Glass	55	150	8,250	Lorry, 18 t
Auxiliary substances				
Cleaning agents	15	325	4,875	Lorry, 18 t
Production disposal				
Broken glass	10	40	400	Lorry, 18 t
Shipping packaging wastes				
Plastic film	5	50	250	Lorry, 18 t
Local distribution	70	30	2,100	Lorry, 18 t
Long-distance distribution	100	200	20,000	Lorry, 40 t
Total			58,375	

In a further step the transportation intensity for the materials and products shipped can be calculated, as can that for the annual production volume of the ultimate product. The transportation intensity index is an indicator for the overall shipping distance covered in the production and distribution of a given product. It is the sum of all travel, adjusted for the type of vehicle used, devoted to the manufacture and distribution of the products, taking into account the quantities transported and the vehicles used, together with the degree of capacity utilization in each case.

The transportation output is based in each case on the transportation expenditures for each item of material (expressed in ton-kilometers), taking into account the characteristics of the vehicle used and the specific payload utilization ratio in each case. If the total for all the transportation output is divided by the overall production volume, the result is an index for transportation intensity. It indicates the shipping distance "consumed" by the product being examined. Going a step further, the transportation intensity per retail sales unit can be calculated. This makes transparent the distance which is covered, appropriated to each sales unit, based on overall transportation intensity.

When optimization potentials are exploited, the transportation intensity will be reduced and, with appropriate labelling or other identification, the successes of environmental protection activities undertaken by an individual business in regard to transportation could be made clear to the consumer.

In the yoghurt product used here, the result is transportation intensity of about 20.5 m per jar (assuming average vehicle loading). If the compilation of all germane data were complete and exhaustive, this distance would be somewhat greater, since components which are significant in terms of weight - such as the fruit mixture and twist-off caps - are not taken into account in the present calculations.

4.1.2 Evaluation

When evaluating freight transportation events it makes good sense to register further steps product-by-product and cartographically. This makes it possible to draw detailed conclusions regarding environmental and cost-related optimization potentials.

Product-related evaluation

Taking the traffic output determined for each item of material or product moved by specific transportation modes, it is possible to estimate environmentally relevant influences. These are, for example, CO_2 emissions, which in turn are dependent on the specific fuel consumption values.[4] Emission factors for oxides of nitrogen (NO_x), hydrocarbons (HC) and carbon monoxide (CO) are currently being updated by a number of institutions. Decisive in these calculations is the degree to which the lorry's carrying capacity is utilized. The individual businesses will themselves have at their disposal the expert knowledge required to determine transportation and fuel costs.

The data for each item of material and product will be recorded in an evaluation table. Thus a survey of specific loads and costs is generated.

Cartographic evaluation

To further clarify the transportation events referenced to individual products, it is helpful to plot the transportation relationships on a map. This creates a depiction of the distances covered in the transportation dedicated to the manufacture of a product and provides indications as to where a change in vendors might reduce product-related distances and, in turn, the environmental impact. An example of a cartographic portrayal is shown in Figure 2.

4.1.3 Identifying promising areas for action

The above-mentioned table for the product-related evaluation can be used as a so-called weak-point matrix. Particularly in regard to transportation expenditures it becomes clear where the effects are greatest and where optimization effects could have the most significant impact on the overall result.

Potentials for reducing environmental impact, determined in relation to transportation and the products, will be found in four differing approaches; these can be analyzed on the basis of the evaluation table. Decisive for optimizing relevant sectors is reducing the distances covered. This can be achieved by

1) modifying the supplier structure (variation 1),

2) utilizing a different transportation mode (variation 2)

3) selecting alternate raw materials, packaging materials and auxiliary substances (variation 3), or even

4) modifying the distribution radii (variation 4).

Reduction potentials can be determined for these and for other conceivable approaches on the basis of the table. They show ways in which, either individually or in combinations, the product-related trips could be made more environment-friendly and cost-favorable as well. In addition, the remaining required shipping runs could be logistically optimized.

The cartographic evaluation makes clear what modified supplier and distribution structures might look like and how distances could in fact be shortened.

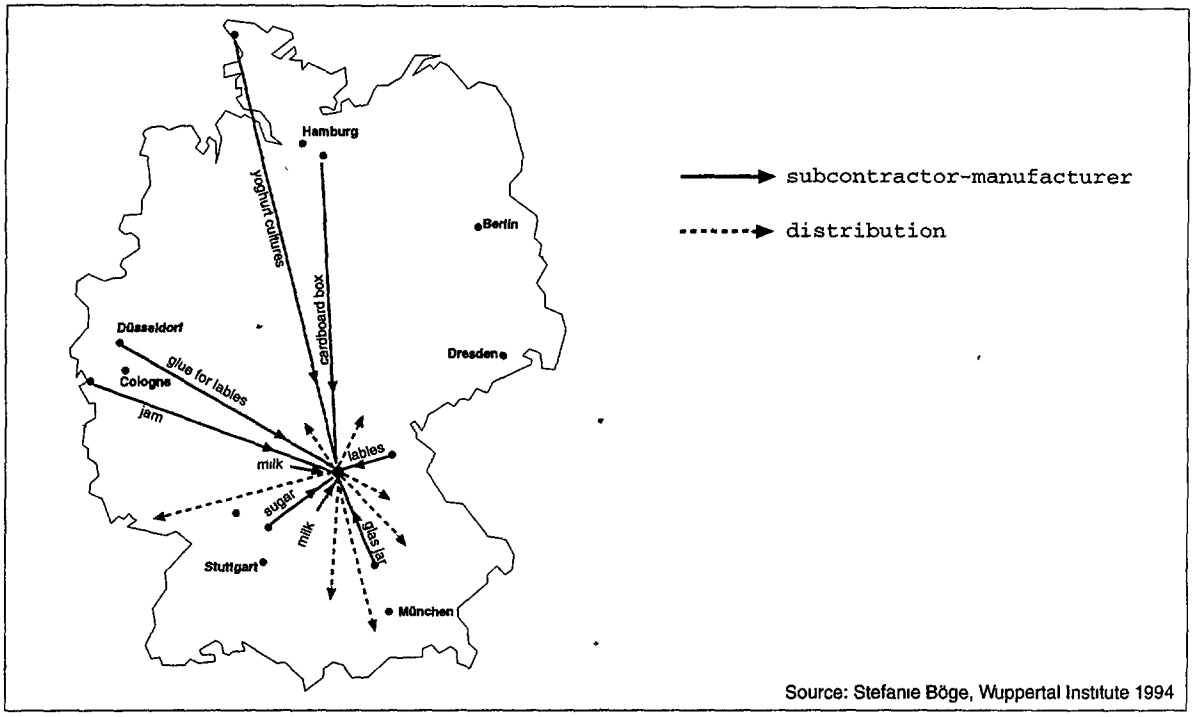

Figure 2: Example of a cartographic representation of operations-related freight transportation

5. OPTIONS FOR ACTION

The options for action listed below are provided by way of suggestion. It is not possible to cover all the specific situations applicable to a variety of businesses. Much will depend on where a company is located, which products are manufactured, the structures and infrastructures in the immediate region.

The suggestions are given in the form of questions and are divided into three major areas: reducing transportation, shifting to other modes and optimization. Under certain circumstances it may be necessary to undertake modifications and additions; these will depend on the details of the situation prevailing in each individual case.

5.1 In the interest of reducing transportation volumes

- Are materials already being ordered occasionally from vendors who are closer to your own operations?

- Are there manufacturers located closer to your operations who can provide the same materials at good quality and favorable costs?

- Might a supplier even be persuaded to set up production facilities near your plant?

- Are identical or similar products ordered from a number of different manufacturers?

- Is it possible by re-examining product concepts and designs to do entirely without certain bought-in materials?

- Are there substitutions for certain types of packaging, which could be adopted by introducing returnable transportation containers or other transportation systems?

- Would it be possible through the use of returnable transportation containers to eliminate entirely the transportation of other packing materials? (This also has effects on refuse disposal and related costs.)

- Is your company participating in committees working on conceptions and harmonization for returnable packaging and shipping containers?

- Would it be possible to reduce the immediate distribution radius by, for example, planning several decentralized production locations over the long term?

- Could the products be manufactured by other companies under a licensing arrangement?

5.2 In the interest of shifting to other transportation modes

- Would it be possible to transfer to the railway (or inland waterways) shipments now being made by lorry?

- Is the company vehicle fleet suitable for combination trips (shipping your own products on the outward journey and picking up goods from other firms for the return trip)?

- Is it possible to use railway passenger transport facilities for materials which are required only rarely and in small volumes?

- Are vendors' offers to ship materials by rail (or inland waterways) accepted?

- Could certain vendors be encouraged to use railways or barge capacities?

- Is the company's purchasing department organized appropriately?

- Would it be possible to reactivate a railway spur on the plant grounds or to build a new spur; are subsidies or tax incentives available for this purpose?

- Can transportation be handled more economically and more effectively by a services provider (logistics center, freight transportation, distribution or transshipping center)?

- Is it possible to coordinate with other firms to consolidate shipments and to utilize more environment-friendly transportation modes at favorable costs?

5.3 In the interest of optimizing shipments

- Do you use several suppliers located in a particular region and would it thus be possible to consolidate shipments?

- Are the delivery routes optimized?

- Is there a central point at which you can register dead-head trips (opening the option for picking up a load on the return trip)?

- Is it possible to use low-emission and low-noise vehicles and those which are designed specifically for minimized-impact use within conurbations?

- Are training sessions held for lorry drivers?

- Can materials which are required only in small quantities be consolidated with other loads?

- Can suppliers or forwarders be encouraged to use low-emission and low-noise vehicles along with those designed specifically for use in metropolitan areas?

6. SUMMARY

Some of the suggestions given in the preceding chapter may seem utopian. Innovative activities in companies, however, often pay for themselves in a much shorter time than had been projected in advance. It is necessary, nonetheless, to overcome certain difficulties in order to loosen up existing structures.

It will certainly not be possible to effect a modification in vendor structures in the short term. Contacts with certain vendors will have stabilized over the years; both parties will want to dependably honor agreements. The same applies to shifting transportation to more environment-friendly modes and setting up the appropriate infrastructure. But particularly those situations where new vendors must in any case be identified can be exploited to effect changes. Neither will it be an easy matter to analyze objectively one's own production and distribution structures. Against the background of the environmental problems created by motor vehicle traffic and increasing public awareness regarding these problems, there is no question that reorientation will be worthwhile in the long run.

7. ACKNOWLEDGMENTS

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8. ENDNOTES

1. Raw materials are those materials which are associated directly with the product, such as, for example, milk, a fruit mixture and the sugar used in making up yoghurt. Packaging is the material which serves directly to protect the product, e.g. the glass, label and the glue for the label. Shipping materials are those materials required during transportation, such as cardboard crates, cartons or flats, glue for the cardboard, packing tape and plastic film. Auxiliary substances are, for example, lubricants or cleaning agents for the production machinery. In the case of re-usable packaging (jars) or shipping materials (pallets), their data are included in the figures for supply transportation.

2. Disposal from production includes, for instance, rejects or non-recoverable waste. The disposal of shipping packaging takes into account packing materials for the feedstock materials delivered to production, such as plastic wrap and films, cartons, etc.

3. Local traffic is defined as transportation covering a distance of up to 75 km. Designated as long-distance traffic are all shipments beyond a radius of 75 km.

4. 1 liter of diesel fuel ≈ 2,950 g of CO_2.

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