Doctoral Thesis

Market potential and value of sustainable freight transport chains

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MARKET POTENTIAL AND VALUE OF SUSTAINABLE FREIGHT TRANSPORT CHAINS

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presented by
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Abstract

The transport sector accounts for 31% of today's total EU energy consumption and has become the largest emitter of greenhouse gases, which in 2005 was responsible for 27% of the EU’s total annual volume. Whilst today most manufacturing companies claim to consider environmental concerns in their management strategy (e.g. by introducing environmental management systems), logistics are often not included in this process. This is, because logistic processes are normally not visible to the customer and thus difficult to integrate into an environmental marketing strategy. Nevertheless, recent studies show a trend toward increasing shipper sensitivity to CO₂-emissions in freight transport.

Among logistics service providers (i.e. freight forwarders etc.) and politicians this issue is also being discussed. One idea is to provide the clients (i.e. the shippers) with standardised information on the environmental impacts of their shipments, for example in form of a labelling scheme on transport services. Since nowadays logistics service providers (LSP) normally have no reliable quantitative information on shippers’ perceived relevance of environmental criteria in freight transport, the first step towards such a label must be to quantify their demand for such services. If, as suggested by latest research results, there were insufficient willingness to pay higher prices, LSPs would have little motivation to invest in environmentally friendly transport solutions. This would also affect public policy related to improving freight transport environmental performance through the implementation of labelling schemes.

Therefore, before deciding on the appropriateness of eco-labels in freight transport, shipper decision-making must be analyzed quantitatively to understand the perception of environmental information in this context. From this research gap the following research question was derived:

What impact does information about transport’s environmental performance have on freight transport mode choice as compared to other demand factors, and what is the perceived value of higher environmental performance in comparison to other demand criteria?

In order to analyse the potential revenue of eco-labelled transport services and the potential effectiveness of a freight transport eco-label, the following questions were additionally included in this project: What criteria can be used for measuring the environmental impact of transport chains? What are the expected prices of certified
transport chains compared to conventional solutions? Is the market segment of environmentally friendly transport services a field worth being expanded from a logistics service provider’s perspective? How great is the potential of a labelling scheme to contribute to the EU commission’s energy efficiency goals?

First, a shipper Stated Preference survey was administered in Switzerland to estimate the willingness-to-pay for environmentally friendly transport. It includes Stated Choice experiments to test the shipper sensitivity of price and quality criteria (including environmental impact).

In order to evaluate the potential for optimising existing transport chains in terms of their environmental impact, an environmental benchmark of selected freight transport chains from the survey was performed based on the principles of life-cycle assessment (LCA). These were then subjected to a price analysis to estimate the transport prices, which the transport service provider must calculate for the operation of environmentally friendly transport solutions as compared to the status-quo. A cost-benefit-analysis finally evaluated the price difference for the calculated change in environmental performance and answered the question whether shippers would realistically accept these price differences.

The results from the shipper survey showed that a general willingness-to-pay (WTP) exists among Swiss shippers for reducing greenhouse-gas emissions in freight transport. The value lies in the region of 1.27 CHF per shipment for each percent-point decrease in environmental impact. Shippers of finished products, which are in direct contact with end-consumers, (namely firms in the manufactured goods and food/animal feed commodity sectors) show a higher sensitivity to environmental concerns (ca. 1.50 CHF/%-point per shipment) than the ones of raw materials and other lower value products (0 – 0.70 CHF/%-point per shipment). In other words, the higher the specific value of the cargo and the higher the position of a product in the value creation chain, the more a shipper can be expected to be willing to pay for a reduction of its freight transport’s greenhouse-gas (GHG) emissions. Furthermore, the results allow a ranking of the analysed demand criteria: on-time reliability is generally most relevant, followed by transport price, while GHG-emissions and transit time are at a comparable level.

The use of LCA proved to be a suitable approach for measuring a shipment’s environmental impact. The applied “ReCiPe” method distinguishes between three impact categories: damage to human health (caused e.g. by greenhouse-gas-emissions), to ecosystems (i.e. pollution of soil and water), and resource consumption. The method was extended by impacts from traffic accidents to better comply with the particularities of (freight) transportation. In most cases, independent of sector and distance, road transport has the worst environmental performance across all three environmental impact categories, followed by intermodal transport and rail-only transport. The differences between road and intermodal transport depend mainly on the margin between actual transport distances of the two modes, i.e. in several cases the distance in intermodal transport is much longer than the direct route taken by the lorry.
Finally, logistics service providers cannot generally expect realising positive price margins from offering alternative transport modes as environmentally friendly transport options, because the differences in operational costs generally exceed the margins, which could possibly be compensated by shippers’ WTP. On the other hand the cost-benefit-analysis has revealed certain cases where a modal shift could provoke both, a cost reduction and a decrease in environmental impact. Therefore, environmentally more efficient solutions are not a priori uneconomical, but each transport should be analysed within the context of its specific constraints.

Accordingly, the potential of an eco-label for freight transport services to support the use of environmentally friendly transport modes is low. When comparing different transport mode options for a certain shipment, price differences are mostly too large to be able to provoke a modal shift based on the label information (even when combining the label with a bonus-malus-system). The label could rather be a useful aid for comparing similar transport offers with more or less the same price but differences in environmental performance (e.g. due to the use of enhanced vehicle technology in road transport).
Zusammenfassung

Der Transportsektor trägt derzeit 31% zum Gesamtenergieverbrauch in der EU bei und hat sich zum grössten Treibhausgas-Emittenten entwickelt (27% des EU-Gesamtvolu-
mens im Jahr 2005). Auch wenn heutzutage die meisten verarbeitenden Betriebe angeben,
Umweltaspekte in ihrer Managementstrategie mit zu berücksichtigen (z.B. in Form von
Umweltmanagementsystemen), bleiben die Logistikprozesse häufig aussen vor. Der
Hauptgrund dafür ist, dass diese meist unsichtbar für den Kunden sind und sich deshalb
nur schwer in eine umweltfokussierte Marketingstrategie integrieren lassen. Dennoch erk-
nennen aktuelle Forschungsergebnisse einen Trend hin zu einer stärkeren Sensibilisierung
der Verlader für die Bedeutung von CO₂-Emissionen im Gütertransport.

Auch bei Logistikdienstleistern und in der Politik wird diese Thematik diskutiert. Ein
Ansatz wäre die Bereitstellung von standardisierten Informationen für Verlader über die
Umweltbelastung ihrer Warentransporte, z.B. in Form eines Labels für Transportdienst-
leistungen. Allerdings muss vor der Implementierung eines solchen Standards zunächst
die verladerseitige Nachfrage für umweltfreundliche Transportdienstleistungen abge-
schütz werden, da die Logistikdienstleister heute in der Regel keine belastbaren quanti-
tativen Angaben bezüglich der realisierbaren Erträge für solche Angebote haben. Falls,
wie in der aktuellen Forschung postuliert, die Akzeptanz gegenüber Preiserhöhungen
unzureichend wäre, hätten Logistikdienstleister nur ein geringes Interesse, in umwelt-
freundliche Transportlösungen zu investieren. Dies hätte auch unmittelbare Auswirkun-
gen auf die zu erwartende Wirksamkeit des diskutierten Labels als Lenkungsmassnahme.

Somit muss vor einem Implementierungsentscheid zunächst das Entscheidungsverhalten
von Verladern quantitativ analysiert werden, um den diesbezüglichen Einfluss von Label-
Informationen zu verstehen. Aus dieser Wissenslücke leitet sich die folgende Forschungs-
frage ab:

Welchen Einfluss haben Informationen zur Umweltbelastung von Warentransporten auf
das Verkehrsmittelwahlverhalten von Verladern, und welcher monetäre Wert wird einer
verbesserten Umweltbilanz gegenüber anderen Nachfragefaktoren beigemessen?

Zur Abschätzung von realisierbaren Erträgen für umweltzertifizierte Transportdienst-
leistungen sowie der Wirksamkeit eines solchen Öko-Labels wurden ferner folgende
Fragestellungen berücksichtigt: Anhand welcher Kriterien lässt sich die Umweltbelastung
von Gütertransportketten bewerten? Mit welchen Preisen für zertifizierte Transportketten
ist gegenüber konventionellen Lösungen zu rechnen? Sind aus Sicht der Logistikdienstleister umweltzertifizierte Transportlösungen ein zukunftsträchtiges Marktsegment? Welchen Beitrag könnte ein Transportlabel leisten zum Erreichen der Energieeffizienzziele der EU?


Die Ergebnisse aus der Befragung lassen tatsächlich eine grundsätzliche Zahlungsbereitschaft für eine Verbesserung der Umweltbilanz von Warentransporten der Schweizer verladenden Wirtschaft erwarten. Der Wert liegt im Bereich von 1.27 CHF pro Sendung pro Prozentpunkt reduzierter Umweltbelastung. Für Fertigprodukte und Nahrungsmittel, mit welchen der End-Konsument am häufigsten in Berührung kommt, ist die Zahlungsbereitschaft mit ca. 1.50 CHF/Prozentpunkt pro Sendung höher als im Fall von Rohstoffen und anderen geringerwertigen Produkten (0.0 – 0.70 CHF/%-Punkt pro Sendung). Das heisst, die Zahlungsbereitschaft ist umso höher, je höherwertig das Transportgut und je höher die Position des Produkts in der Wertschöpfungskette. Ferner lassen sich die untersuchten Nachfragekriterien anhand der Modellergebnisse in eine Reihenfolge gemäss ihrer Relevanz für die Transportnachfrage eines Verladers bringen: Am wichtigsten ist in der Regel die Pünktlichkeit, gefolgt von Transportpreis sowie zuletzt Treibhausgas-Emissionen und Transportdauer auf vergleichbarem Niveau.

zen ab, d.h. im KV werden häufig grosse Umwege gefahren gegenüber der Direktroute per Lkw. 


This dissertation project was realised during my time as a research assistant in the Transport Systems group at the Institute for Transport Planning and Systems. It would not have been feasible without the support of many people, to whom I would like to express my gratitude. It is impossible to name everyone, who helped me with new ideas, fruitful comments, or critical questions. However, some of them shall be mentioned explicitly in the following.

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1 Introduction

The transport sector accounts for 31% of today’s total EU energy consumption and has become the largest emitter of greenhouse gases (in 2005 responsible for 27% of the EU’s total annual volume) [EU (2008)]. The continuous growth has not ended, and an increasing discrepancy can be observed between transport and other key sectors. The goal of the Kyoto protocol (also ratified by Switzerland) is to reduce greenhouse gas emissions (including CO₂) until 2012 by an average of 5.2% compared to the level of 1990. Switzerland with its specific reduction goal of 8% is, together with the majority of EU countries, actually off track having realised a decrease of only 0.5% until 2005 [BAFU (2007)].

Rail and waterway transport are often more efficient than road transport for many types of transports, especially of large volumes over medium and long distances, that are becoming increasingly important due to the development of the EU internal market and of the markets in Central and Eastern Asia. Therefore, to reduce greenhouse gas emissions and to raise energy efficiency in transport, the European Commission explicitly promotes in its 2006 Action Plan for Energy Efficiency a consequent development towards a more efficient use of each transport mode [EU (2006)]. The goal is to realise energy savings of 26% by 2020 compared to a status quo-scenario and a reduction of CO₂-emissions to 140 g/km by 2008 (120 g/km by 2012). This would be achieved using each transport mode (or also combining several modes to intermodal transport) in the most energy-efficient way.

Switzerland is also focusing special attention on the environmental impacts of transport. The protection of the Alpine regions from negative impacts of transit traffic is anchored in the federal constitution together with the powerful instruments of a heavy vehicles charge (LSVA) and a ban on driving for lorries during night time. According to article 84 § 2, the transalpine freight transit traffic must be handled by railways. Both, international and national goals can only be achieved if shippers fully accept the concept of multimodality, thus relying not only on road transport, but also considering other modes as real alternatives. A conditio sine qua non is that the quality of intermodal transport can be raised to better meet actual logistic requirements especially in terms of on-time reliability.

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1 See articles 84 and 85 of the Swiss federal constitution (http://www.admin.ch/ch/d/sr/101/index.html)
2 For a definition of the term “shipper” see section 2.1
A major task concerning the greening of freight transport is understanding and influencing the process of choosing an appropriate transport solution for a particular shipment. From the environment’s perspective the optimal way would be to choose the most efficient solution for each shipment, but in practice strategic and operational considerations have a major influence on transport mode choice. For example, if the production site of a shipper (and/or a consignee) is close to a motorway access, the probability of choosing road transport is very high. At the operational level decisions are mainly influenced by logistic (quality) requirements and cost criteria [Bolis and Maggi (1999)], [Infras et al. (2007)]. Interestingly, transport mode choice is not always based on logical decisions: often road transport is chosen, because the shipper does not have the necessary information to compare with alternative modes. Given these factors, innovative approaches must be applied to influence the shipper’s choice and thus to achieve a more efficient use of the transport system as a whole.

There are two basic ways of influencing decision-makers: either penalties can be imposed on certain alternatives (push factors), or other alternatives can be made more attractive (pull factors). Several examples of penalties exist, e.g. the above-mentioned heavy vehicles charge (LSVA) in Switzerland or road toll systems in other European countries. Regulations using “pull factors” are rare in freight transport. The only widely established systems are emission classification systems for motor vehicles (e.g. EURO 1-5) giving tax reductions to buyers of low emission vehicles. An innovative “pull factor” approach used in other sectors of the economy is the use of labels and other consumer behaviour campaigns to raise buyers’ awareness for environmental concerns [EU (2006)].

Whilst today most manufacturing companies claim to consider environmental concerns in their management strategy (e.g. by introducing environmental management systems), logistics are often not included in the environmental controlling process. This is, because logistic processes are normally not visible to the customer and thus difficult to integrate into an environmental marketing strategy. Nevertheless, recent studies show a trend towards shippers’ increasing sensitivity for CO₂- emissions in freight transport (e.g. [BME (2008)], [Cordes (2008)]). The problem is that, despite their increasing awareness, shippers are often not willing to accept higher prices for reducing their transports’ emissions; according to the published results shippers state that only in case of equal prices they would rather choose the transport provider with the lowest CO₂-emissions.

Among logistics service providers (i.e. forwarders etc.) this issue is also being discussed. One interesting idea is to introduce an innovative “pull factor” by providing the clients (i.e. the “shippers” – see definition in section 2.1) with standardised information on the environmental impacts of their shipments, for example in form of a labelling scheme on transport services. If such information would be integrated in every offer for freight

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3 In Switzerland a label called “Energieetikette” was introduced in 2002 on new cars and electric household appliances (www.energieetikette.ch). The label on cars for example informs the buyer about the vehicle’s fuel consumption, CO₂-emissions, and energy efficiency.
transport services, shippers would be able to evaluate them not only based on economic and quality criteria but also from an environmental perspective.

This labelling concept is the initial motivation for this research: since today (according to internal sources) logistics service providers (LSP) have no reliable quantitative information on shippers’ perceived relevance of environmental criteria in freight transport, the first step towards such a label must be to quantify their demand for such services. If, as suggested by the studies mentioned above, there were no willingness to pay higher prices, LSPs would have little motivation to invest in environmentally friendly transport solutions. This would also concern the political issue of improving freight transport’s environmental performance by implementing labelling systems.

Therefore, before deciding on the appropriateness of eco-labels in freight transport, the shippers’ decision-making process must be analysed quantitatively to understand the perception of environmental information in this context. Our hypothesis is that environmental sensitivity differs between commodity groups (e.g. retailers that are directly in touch with the end-consumer might be more sensitive than scrap traders) and that for certain commodity groups the shippers’ willingness to pay is significantly larger than zero. Assuming this research’s results would support this hypothesis, there would be a clear motivation for LSP as well as policy makers to test an eco-label on freight transport services. This research therefore focuses on the general applicability and effectiveness of providing shippers with environmental information thereby delivering important basics needed for economic and political decisions.

1.1 Goal

The goal of this research is to evaluate the influence of information about freight transport’s environmental impact on shippers’ transport mode choice decisions. In other words, would shippers rather choose a more environmentally friendly transport service if they had clear information on the environmental performance of alternative transport solutions, and would they be willing to pay higher prices for this additional value?

The main question to be answered in this research is:

What impact does information about transport’s environmental performance have on freight transport mode choice as compared to other demand factors, and what is the perceived value of higher environmental performance in comparison to other demand criteria?

This implies the following detailed questions:

1. Do shippers consider environmental aspects in transport mode decisions, and how does it vary between specific types of commodities? What is the shippers’ willingness to pay for environmentally friendly transport solutions?

2. What is shippers’ perceived value of reducing environmental impacts compared to the value of “conventional” aspects (e.g. on-time reliability, transit time, etc.)?
3. What criteria can be used for measuring the environmental impact of transport chains?

4. What are the operational costs of certified transport chains compared to conventional solutions? Is the market segment of environmentally friendly transport services a field worth being expanded from a logistics service provider’s perspective?

5. How great is the potential of a labelling system to contribute to the EU commission’s energy efficiency goals?

1.2 Structure of the Project

The above-mentioned research questions are assigned to different work packages, thus leading to the following structure of this report. Chapter two provides a general introduction to the topics this research is related to, including logistics and supply chain organisation, characteristics of freight transport demand, and the impact of labelling systems on companies’ decision making. This is followed by a short section (chapter three) on the overall research hypotheses, before describing in chapter four the different research methods applied (i.e. in the fields of demand modelling, life cycle assessment, and price analysis). Approach and results of the analysis of shippers’ demand for sustainable freight transport are explained in chapter five including a description of and the results obtained from the shipper survey. Next, details on characteristics and results of the environmental benchmark model are provided in chapter six. In chapter seven we then come to the analysis of prices in freight transport, which leads to the final cost-benefit-analysis (chapter eight), before concluding with some key aspects on the obtained results and perspectives for ongoing research (chapter nine).
2 Introduction to Organisation and Demand of Transport Logistics

This chapter provides an introduction to the logistics management of manufacturing companies and their demand for transport logistics services. Since a comprehensive disquisition of companies’ logistics management would exceed the scope of this report, the main focus is laid on the external transport processes, i.e. the organisation of freight transport activities from the shipper’s perspective. For an integrated approach on this topic please refer to the existing standard literature, e.g. SCHÖNSLEBEN (2004), IHDE (2001). The second part of this chapter deals with general characteristics of demand for freight transport services before focusing on the potential impact of labelling systems.

2.1 Basic Definitions

Transport Logistics:

SCHÖNSLEBEN (2004) defines logistics in general as “the organisation, planning, and realisation of the total flow of goods, data, and control along the entire product life cycle”. As part of this concept we understand transport logistics as the organisation, planning, and realisation of the transport processes necessary for the spatial transformation of goods between upstream and downstream production and storage processes.

Shipper:

The term shipper in the proper meaning of the word describes a company (or person) responsible for shipping a given shipment to a remote destination (also referred to as “sender” or “consignor”). We use the term shipper in a wider sense to describe the actor in transport logistics, which is responsible for the organisation of a shipment, be it in the position of the sender or the receiver⁴.

Logistics Service Provider (LSP):

In the EN 14943 [CEN (2005)] the LSP is defined as a specialised service provider, which is responsible for all distribution activities of a shipper (also referred to as Third Party Logistics Provider – 3PL). Expanding this official definition, we use the term “LSP” as a general term for all actors in transport logistics offering some kind of logistics service, be

⁴ Note that it may also be the receiver, which is responsible for the organisation.
it the physical transportation of goods (operator, carrier), the organisation of transport chains (forwarder), or other services (such as storage, commissioning, etc. – see section 2.2.2).

**Transport Chain**

IHDE (2001) describes this term based on the definition given in the German standard DIN 30 780 as follows: a *transport chain* is sequence of technically and organisationally linked processes, during which persons or goods are transported from an origin to a destination. It should be regarded as a complete system, in which the linkage of the single elements is based on the system compatibility of the employed technical means. The organisational linkage of the elements is achieved by a coordination of the different information and control systems as well as of the legal and commercial structures.

**Disability-Adjusted Life Years (DALY)**

DALY is a measurement unit for quantifying the human burden of disease from mortality and morbidity. According to the WHO definition\(^5\), one DALY can be thought of as “one lost year of "healthy" life”. The sum of these DALYs across the population, or the burden of disease, can be thought of as “a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.”

### 2.2 Introduction to Logistics and Transport Chain Organisation

#### 2.2.1 Introduction

Any manufacturing company is necessarily involved in transport logistics by its trading activities (procurement on the one hand, and sales and distribution on the other). Transport logistics activities are, however, not isolated but closely linked to other logistics activities supporting the value creation process within the company (compare Figure 2-1).

Transport logistics processes are the remotest elements in a company’s logistics management (as seen from the core production process) but nevertheless form the only physical interfaces to suppliers and clients thereby establishing a link between two different logistics concepts. Since the logistics management of two companies linked by their trade relations are in most cases organised in different ways, transport logistics processes must be carefully organised to be able to cope with both of them.

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Figure 2-1: Role of Logistics in the Value Creation Chain

Source: [SCHÖNSLEBEN (2004)]

Figure 2-2: Constraints Influencing Transport Logistics Organisation

Source: Author
Several organisational and technical constraints have a direct influence on a company’s transport logistics. These constraints (except the characteristics of the shipped commodity) often differ between the sender and the receiver of a shipment and thus must be considered twice in the freight transport planning process, as illustrated in Figure 2-2.

The most important constraints influencing the freight transport planning process are the specific characteristics of the goods to be transported and the transport relation. Goods characteristics are highly relevant, because size and nature of the goods predetermine the general logistics concept of a company (i.e. mainly the option of outsourcing certain processes). This implies that, the greater the product portfolio of a company, the more complex its logistics management. Furthermore, the degree of outsourcing together with the product characteristics impact the decision about what kind of logistics service provider (LSP) to choose (e.g. carriers, 3PL, 4PL, or freight integrators – for details see section 2.2.2). Finally, the product characteristics represent a tight constraint during the detailed planning of transport chains concerning the choice of transport mode including vehicle type and size. This is also linked to the question, which kind of packaging is required for a shipment (e.g. simple cardboard boxes can easily be stacked on pallets, while dangerous liquids need special transport containers).

Transport relation, as the second general constraint, is often a predetermining factor for transport mode choice. In case of an export shipment to the USA, for example, mode choice is limited to sea or air transport. In the intra-European transport market, however, this is a less relevant factor, because from a geographical viewpoint (with certain exceptions) basically all modes are available for any transport relation. On the other hand in this context transport distance can be a limiting factor for mode choice, since over short distances (below 50 km in Switzerland [RAPP TRANS AND IVT (2008)]) transport modes other than road transport are only a theoretical option due to the more complex transport chains and thus higher production costs.

A similar importance for the logistics concept has the shipper’s production process together with its total stock capacity, which determine the necessary frequency and reliability of the freight transport process. This is closely linked to one of the basic optimisation problems in logistics management: this is to find the optimum between required stock capacity and reliability of the transport chain in order to minimise total costs. “Just-in-time” production is just one common concept focussing on the minimisation of stock capacity. However, it is important to keep in mind that with increasing requirements concerning freight transports’ reliability, transit time, frequency etc. the prices for transport services tend to increase disproportionally.

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6 3PL/4PL – third/fourth party logistics provider
7 Exceptions can be large volume shipments over short distances (e.g. excavated material from construction sites).
8 For details and other concepts please refer to SCHÖNSLEBEN (2004)
Generally, the constraints of production process and stock capacity on the transport planning process are more relevant on the receiver side than for the sender. This is because low on-time reliability in case of low or no inbound stock capacity on the receiver side can easily lead to production downtimes thus causing high follow-up costs.

The other two important elements impacting transport logistics are infrastructure and vehicle availability. Both concern rather the concrete transport chain planning than the transport logistics concept in general, although certain interactions exist. For example the availability of a rail siding would enable the company to use the rail cars as additional stock capacity thus reducing the necessary fixed stock capacity. Infrastructure availability is an important predetermining factor for transport mode choice, since only the necessary facilities (e.g. rail siding, port etc.) allow choosing other modes than road transport. Here again, during transport chain planning both, the sender’s and the receiver’s sites must be considered.

Vehicle availability is rather linked to the decision of whether to outsource transport activities to a LSP or not (see section 2.2.3). There is often a close link between commodity characteristics and vehicle availability, because certain products require special vehicles (e.g. liquid concrete). If special vehicles are required, the probability is lower to find an appropriate LSP offering such transport services; therefore in these cases the company would rather not outsource its transport activities or is at least very limited in its choice of LSPs. Many such shippers have long-term contracts with specialised LSPs offering the required vehicles and services.

### 2.2.2 Types of Logistics Service Providers

The classification of actors in the market of logistics services is not straightforward due to two main reasons:

1. The logistics services market is very disperse with a large number of actors;
2. The range of logistics services offered by one provider is highly variable.

As described in section 2.2.1, logistics services accompany the entire value-creation process of a manufacturing company. A suitable approach is to divide the whole range of services into different service segments. IHDE (2001) distinguishes between five different groups of logistics services, as illustrated in Figure 2-3.

The traditional core business of an LSP is the forwarding service, i.e. the planning and coordination of transport chains on behalf of a shipper including the freight contract conclusion and the preparation of the necessary transport documents. Historically the basic logistics services (such as transport, transshipment, or storage) were rendered by specialised providers other than the forwarder.

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9 We assume that almost 100% of the companies’ locations are accessible by road and that loading or unloading a lorry requires no special infrastructure.
Today delimitations are less clear: on the one hand so called “freight integrators” established, which offer the whole range of logistics service (often tailor-made) to their customers, while on the other hand different service specialists (focussing on certain services) entered the market. Some of them concentrate on additional (logistics or information) services, while others position themselves in the above mentioned traditional market segments.

**Figure 2-3: Overview of Logistics Services**

![Figure 2-3: Overview of Logistics Services](image)

Source: [IHDE (2001)]; Illustration: Author

Since this project focuses on evaluating shippers’ demand characteristics for transport services, we mainly differ for this purpose between actors, which are most relevant in this case: on the one hand providers of forwarding services (plus additional logistics services) and, on the other hand, actors, which provide basic logistics services, i.e. mainly carriers (according to the above structure in Figure 2-3). The forwarder (which often represents the shipper in terms of transport demand) is in charge of organising the entire transport chain including all required additional services. If the shipper explicitly demands an environmentally friendly transport chain, it is the forwarder’s task to contract one (or several) appropriate transport service provider(s) (carriers), which fulfil the environmental requirements of the proposed labelling system (see section 8.3.1). In case the shipper contracts a freight integrator, which transports the shipment (at least part of the way) itself, then the latter must guarantee that its own transport solution complies with the requirements of the label. Note that the forwarder’s role is not needed, if the shipper organises the transport chain itself by directly contracting (one or several) carriers.

Also it is important to point out that the proposed label would rather be limited to basic logistics services including transport and transhipment services. Additional logistics

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10 Note that the services assigned to each group are only the most common examples, i.e. the list is not necessarily complete.
services are not included in this concept but could be integrated in a further step, if the initial label stands its test. Nevertheless, especially storage and commissioning services can have a strong (though indirect) impact on environmental performance of a transport service, because they influence its frequency and thus shipment sizes. In case of high frequencies and small shipment sizes bundling of shipments, which contributes to higher transport efficiency, is often not possible.

To summarise: several different combinations of LSP can exist for a shipper’s transport chain organisation, which basically depend on the shipper’s role in logistics organisation (i.e. its degree of outsourcing logistics processes). The principal functions of LSP, however, are forwarding and transport services. Concerning the labelling concept for logistics services, we will entirely focus on the transport services segment.

Details on the principles of transport chain organisation are given in the following section.

### 2.2.3 Transport Chain Organisation

#### 2.2.3.1 Overview of Transport Chains

According to the definition given in section 2.1 a transport chain is “a sequence of technically and organisationally linked processes, during which persons or goods are transported from an origin to a destination.” This definition includes a wide range of different transport chain designs. In the context of this research, where we deal with land-based freight transport chains, the possible design can be summarised as illustrated in Figure 2-4.

**Figure 2-4: Overview of Land Transport Chains**

![Transport Chain Diagram]

Source: adapted from [PFOHL (1985)]
A general difference exists between single leg and multi leg transport chains. The former represent direct door-to-door transport processes without any change of transport mode or container\(^{11}\). This is the least complicated transport chain design. Examples are full truckload (FTL) shipments to a client by lorry or single railcars as well as block trains (e.g. dedicated oil trains) from a single origin to a single destination.

For multi leg transport chains a difference is made between multimodal and intermodal transport. Multimodal transport describes transport chains with an intermediate change of the transport container. This is mostly done in distribution centres often including intermediate storage and commissioning of (less than truck load – LTL) shipments to larger (FTL) shipments and vice-versa.

The term “intermodal transport” is used for transport chains, where different transport modes are employed including intermediate transhipment processes but without changing the transport container. Here a difference is made between horizontal and vertical transhipment processes. Horizontal transhipment of whole lorries or semi-trailers is used in rail (“Rolling Motorway”) and waterway (Ro/Ro) transport with ferries. In case of vertical transhipment standardised containers or swap bodies but also suitable semi-trailers are transhipped from one transport mode to another by crane.

Generally it is important to note that the complexity of a transport chain increases with the number of its legs. Since each leg can be organised and managed in different ways including different service providers, it becomes increasingly difficult to overview all possibilities to organise such a transport chain.

### 2.2.3.2 Concepts for Transport Chain Organisation

THIERSTEIN ET AL. (1999) underline that no clear pattern of shippers’ strategic behaviour can be identified to deduce clear recommendations for their freight transport planning. There is, however, just a limited number of possibilities to organise a shipper’s transport logistics processes [BUCHHOLZ ET AL. (1998)]. The core issue in a transport logistics concept is the “make or buy decision”, i.e. the shipper must decide whether to outsource at least part of its logistics activities. The different degrees of outsourcing are illustrated in Figure 2-5.

The first degree concerns the shippers’ in-house logistics activities, i.e. the internal handling of the products, which includes activities such as storage, packaging, labelling, commissioning, etc. This can be done either by an internal logistics department or by an external LSP. In either case this logistics department emits transport orders for the prepared shipments on behalf of a transport service provider (carrier).

\(^{11}\) We use this term in the broader sense for any kind of transport unit (box). Standardised containers are referred to as “ISO-containers”.
The choice of carrier represents the second degree of outsourcing: the shipper can choose to use own vehicles (own-account haulage) or to assign an external carrier. At this level there are three options depending on the responsibility for the logistics department: own-account haulage by the shipper is realistic only if the shipper is also in charge of the (internal) logistics department (internal placing). We use the term “external placing” for assigning an external carrier independent of who operates the shipper’s logistics department. If it is operated by an LSP, this (internal) LSP contracts a third provider (i.e. a carrier specialist) for the transport service. The alternative would be internal placing, i.e. own-account haulage by the LSP. In this case the same provider is in charge of the logistics department and the transport service (i.e. it acts as an “integrator” – compare section 2.2.2).

In addition to the influencing factors listed in Figure 2-2 the decision about outsourcing transport activities also depends on the different transport chain options the shipper considers in its transport logistics concept. If for example all shipments have full truckload (FTL) size and must be transported directly to a single receiver (door-to-door transport), the transport chain is much less complex as compared to for example intermodal transport (compare Figure 2-4). In this case own-account haulage would be a realistic option.
The more transport chain options (and transport modes) a shipper wants to consider, the higher the probability of contracting an external LSP for the transport services. While many shippers own lorries, own-account haulage by modes other than road transport is extremely rare. This is because special know-how is required and investment costs for vehicles and other equipment are much higher. It therefore pays off only in case of very large transport volumes (e.g. in the steel, building materials or chemistry sector).

Especially in intermodal transport the large number of actors involved is another reason for working with LSPs, because the more actors involved, the less it is clear which of them has the overall responsibility for the transport chain [Wichser et al. (2006)]. In this case it is important for the shipper to have a coordinating LSP contracted, which takes the overall responsibility for the intermodal transport chain and coordinates the single actors. One recommended example for such an organisation is illustrated in Figure 2-6.

Figure 2-6: Actors in Intermodal Transport Chains

Source: [Wichser et al. (2006)]

2.3 Characteristics of Freight Transport Demand

Once a shipper has determined its freight volumes to be shipped and the destinations to be served, it comes to the proper transport chain organisation. As described in section 2.2.3.2, this can be done either by the shipper itself or by an external LSP. This section deals with the demand criteria influencing the design of freight transport chains, i.e. in a first step the choice of transport mode (or a combination of several modes).
2.3.1 Derivation of Relevant Demand Criteria for Transport Chain Organisation

The first question to ask is about the relation between the shipper’s constraints (as illustrated in Figure 2-2) and the resulting demand criteria for the freight transport process itself. Most relevant in this context are the shipper’s production processes together with the available stock capacity and the characteristics of the commodities to be shipped.

As mentioned in section 2.2.1 there is a close dependence between the design of the shipper’s production process, the incoming goods inventory, and the requirements for on-time reliability of the transport chain. The more the internal processes are focussed on lean production, the more crucial it becomes for the receiver to have a highly reliable transport chain, where the incoming shipments arrive in high frequency within a short time slot and (in case of “just-in-sequence” or other comparable production processes) in the right order (compare [McKinnon and Ge (2006)]). If in such cases expected goods arrive late, the delay may easily cause production downtimes thus directly leading to high costs [IHDE (2001)]. Since these costs often exceed the price margins additionally paid to the LSP for guaranteeing higher on-time reliability of the transport chain\textsuperscript{12}, many shippers consider the factor of on-time reliability as more important than transport price (see following section).

The goods characteristics of a shipment have at least an equal impact on a shipper’s demand criteria as production process and stock capacity. According to own observations and empirical results from the paper, printing and publishing sector [Jeffs and Hills (1990)], their most important aspects are:

- Physical condition and external dimensions (size);
- Commodity value;
- Perishableness; and
- Hazardousness.

The good’s physical conditions and external dimensions may have a direct impact on transport mode availability (e.g. in case of extremely heavy or voluminous goods). The market value of the shipped commodities is in direct interrelation with transport price: the lower the specific value, the lower the perceived relevance of transport price [Ruesch et al. (2000)]. It has also an indirect impact on reliability requirements, since for low-value (mass) products stock capacity is generally higher thus not requiring high quality transport chains, which are reliable “on the minute”.

\textsuperscript{12} This statement was made by several interview partners when asked why on-time reliability would be especially relevant for their choice.
Quite evidently, perishableness is linked with transit time\textsuperscript{13} requirements due to the limited durability of the commodity. Furthermore, transit time is influenced by the time delay between a client’s ordering of a product and the shipping of this product: in case of short-dated orders shippers will give higher priority to transit time requirements [IRE AND RAPP TRANS (2005)].

The higher a product’s hazardousness, the more important it is to minimise probability of damage to the cargo (including its container). This goes along with high financial risks for the shipper in case of an accident causing damages to human health or the environment. Therefore, to reduce damage risk, special vehicles or intermodal transport units with special protection are often used.

\textbf{2.3.2 Relevance of the Criteria}

In recent years a large number of research projects have been completed on the identification and weighting of these demand criteria. Interestingly, most of the published projects agree that basically shippers’ demand can be described by a few dominant factors, independent of the respective external preconditions. Certainly there are exceptions, and the list of criteria can be longer in certain cases, but generally the most important factors are:

- On-time reliability (punctuality – in terms of the share of shipments arriving on time);
- Price for transport service;
- Transport mode;
- Damage rate (share of shipments lost due to damage or theft);
- Total transit time; and
- Flexibility (i.e. the LSP’s ability to react on short-term orders).

Not constant, however, is the ranking of the elements within this list, because this is strongly influenced by commodity characteristics and other particular constraints of each single shipper. In the following, relevant literature is reviewed to support the above statements.

Valuation approaches (e.g. value of time (VOT) or value of reliability (VOR) estimations) based on RP and/or SP data are most commonly used to compare the perceived importance of different criteria from a shipper’s perspective. TAVASSZY AND BRUZELIUS (2005) provide an overview of such studies from Europe, the US and Australia, several of which are limited to VOT estimation. Nevertheless, a couple of documents also provide results for the value of reliability.

\textsuperscript{13} Transit time term refers to the total time needed for a shipment from sender to receiver (including total travel time plus possible additional time for transhipment, storage, etc.).
A summary of the criteria ranking from the reviewed literature is provided in Table 2-1 ("1" represents the most relevant factor, followed by increasing numbers with decreasing relevance). It is important to bear in mind the limited comparability of the different studies given their specific experimental setup (geographical scope, different commodity groups, etc.). Nevertheless, several literature sources support our own experience from Switzerland that shippers tend to consider reliability as more important than price and transit time.

**Table 2-1: Relevance of Demand Criteria**

<table>
<thead>
<tr>
<th>Source</th>
<th>Ranking of Relevance (1 = highest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAPP TRANS AND IVT (2008)</td>
<td>X¹</td>
</tr>
<tr>
<td>IRE AND RAPP TRANS (2005)</td>
<td>X²</td>
</tr>
<tr>
<td>BOLIS AND MAGGI (1999)</td>
<td>1</td>
</tr>
<tr>
<td>VELLAY AND DE JONG (2003)</td>
<td>X¹</td>
</tr>
<tr>
<td>DANIELIS ET AL. (2005)</td>
<td>-</td>
</tr>
<tr>
<td>BOUFFIOUX ET AL. (2006)</td>
<td>-</td>
</tr>
<tr>
<td>PATTERSON ET AL. (2007)</td>
<td>1</td>
</tr>
</tbody>
</table>

1) Transport mode included as label of choice alternatives ("mode choice study")
2) Transport mode included as attribute but not as explanatory variable in model

The results of a Stated-Preference (SP) survey in Switzerland [RAPP TRANS AND IVT (2008)] covering all relevant commodity groups revealed that, concerning the internal transport sector, in most commodity groups shippers weighted on-time reliability about 20-100% higher than transport price and up to 14 times higher than transit time. Only in the building materials group transport price showed to be of higher relevance than on-time reliability. The same tendency was observed for border crossing transport (import, export, and transit).

This appraisal is also supported by earlier research. An empirical study carried out by IRE AND RAPP TRANS (2005), based on an SP-survey among 35 shippers in Switzerland, states that willingness-to-pay for an increase in on-time reliability of 1% is about three times higher than the one for reducing transport time by 1 hour, measured in CHF/t.

Six years earlier the same research group had performed an adaptive SP-analysis based on real transport samples [BOLIS AND MAGGI (1999)]. 22 companies covering five different commodity groups were interviewed. In order to model shippers’ mode choice a Binary Logit Model was used. The results showed that transport mode was considered the most important criterion followed by on-time reliability, time and frequency.
The relevance of transport mode is difficult to compare with the other criteria, because some studies include mode as label for the choice alternatives, while others list it as a choice attribute in addition to other criteria. Nevertheless, the fact that mode is included in most of the reviewed studies underlines the general relevance of this criterion.

Comparing these findings with other recent studies in Europe, varying results can be found. These, however, support the initial statement that the list of demand criteria is more or less the same throughout the different commodities and regions. VELLAY AND DE JONG (2003) carried out a combined SP/RP\(^{14}\) analysis to model the choice of transport mode in freight transport in the Nord-Pas-de-Calais region. The resulting values vary significantly between the chosen transport modes: the value of on-time reliability in most cases was found to be ten times higher than the one of transport time except for own-account road transport, for which the values of time and on-time reliability were at a comparable level.

DANIELIS ET AL. (2005) investigated the preferences of shippers’ logistics managers for freight transport service attributes in two Italian regions (Friuli Venezia Giulia and Marche) using Adaptive Conjoint Analysis (ACA). Besides transport cost, transit time, and reliability they added an explanatory variable for damage of the shipment. Damage showed to be by far the most significant variable followed by cost, reliability, and transit time, where reliability and time have about the same level of significance.

The research of BOUFFIOUX ET AL. (2006) had a similar goal for a Belgian study. The researchers administered an SP survey among 113 shippers including a couple of third party logistics providers (3PL). Considering the relative weights of the 6 tested attributes, transport cost is by far the most important factor (64%) followed by transit time (16%), reliability (8%), and flexibility (6%), while frequency and safety have a weight below 5%.

This result is also supported by a recent study by PATTERSON ET AL. (2007) on the Québec City – Windsor corridor in Canada, which ranks damage rate and security risk (defined as two separate criteria) higher than on-time reliability and cost. However, this study furthermore includes transport mode as a choice attribute (while using unlabelled alternatives), which was of even higher relevance to shippers than damage rate and security risk.

This review makes clear that the demand characteristics for freight transport services depend strongly on the experimental setup of the specific survey. Astonishingly, not all research projects included the valuation of transport price as an explanatory variable, although it represents a good benchmark for the comparison of the single quality criteria. Nevertheless, this review shows that mode, on-time reliability, cost, and transit time are included in most of the studies and are of high relevance to shippers. These criteria can therefore be considered as generally relevant for choosing freight transport services.

\(^{14}\) RP – Revealed Preferences
2.4 General Remarks on Environmental Impacts of Freight Transportation

Since the long-term goal of this research is to contribute to a higher environmental efficiency in freight transportation, a quick glance at today’s situation will help the reader to get an idea of the overall improvement potential concerning development of greenhouse-gas emissions. Figure 2-7 illustrates the development of greenhouse-gas (GHG) emissions in Switzerland of relevant economic sectors since 1990.

**Figure 2-7: Development of Greenhouse-Gas Emissions in Switzerland**

![Graph showing development of GHG emissions](image)

Source: Swiss Statistics (www.bfs.admin.ch); Illustration: Author

While most sectors could keep emissions levels more or less constant (energy) or even decrease them significantly (industrial processes, agriculture, and waste treatment), emissions caused by transportation increased (after a short drop below the 100% level in the mid-nineties) until 2006 to a level of more than 8% above the one of 1990. This development is especially worrying when looking at the reduction targets in the Kyoto Protocol, which demand from Switzerland to reduce its CO₂-emissions by 8% until 2012. Although Figure 2-7 includes total emissions of all relevant greenhouse-gases, the country is actually off track also when looking at CO₂-emissions only with a decrease since 1990 of only 0.5% until 2005 [BAFU (2007)].

Also in terms of absolute numbers transportation in Switzerland is the sector with the second largest share of GHG emissions: land-based and domestic air traffic only (i.e. excluding international air traffic) represent 30% (16.1 Mt CO₂-equivalents) of total GHG emissions in 2006 (see Figure 2-8).
Taking a closer look at freight transport’s contribution to total transport emissions in Switzerland is not easy due to a lack of high quality data. Most recent figures come from 2004 [BAFU (2007)] and consider CO$_2$-emissions only (see Figure 2-9). The overall picture is nevertheless clear with 75% of total amount of CO$_2$ emitted by transportation originating from passenger cars (including “fuel tourism” – i.e. foreigners driving into Switzerland for the purpose of buying cheaper petrol). Freight transport emissions are not displayed explicitly, but these clearly fall upon the sectors “Railways$^{15}$”, “Shipping”, “Lorries/Buses”, and “Light Duty Vehicles”. Since the latter is the only category entirely representing freight transport activities, one can roughly estimate the share of CO$_2$-emissions originating from freight transport to 15 – 20% in 2004 (i.e. between 2.35 and 3.14 Mt CO$_2$).

$^{15}$ Note that CO$_2$-emissions from railways are very low especially in Switzerland, since only direct emissions during operation processes are included in the data and most trains use electric traction energy from the overhead wire. However, in Switzerland also CO$_2$-emissions from energy production are low due to its high share of water and nuclear power plants.
In the light of this rather low share one might expect action rather be taken in other sectors, but freight transport must not be neglected especially against the background of reports forecasting a continuous growth of freight transport volumes (and distances) in Switzerland and abroad, even if short-term development caused by the actual economic crisis is currently reversing [ARE (2004)].

2.5 Impact of Labels on Decision Making

2.5.1 Theory of Decision Making

Labelling schemes are a means to encourage the achievement of policy goals, such as higher energy efficiency, by trying to influence the consumers’ behaviour. In a free market (i.e. without any trade restrictions), directly steering the consumers is not possible; so labelling schemes are often employed to provide consumers with additional information, thus making their decision-making process more rational.

The decision-making process in freight transport is driven by different factors than in passenger transport, but in both cases the optimisation criterion is the maximisation of the specific utility function [McFadden (2001)]. Therefore, important lessons can be learned from travel choice behaviour in passenger transport for understanding the impact of labels on freight transport demand.

Generally, behaviour is determined by past behaviour, intention and the situation (opportunities and/or constraints), as identified by Eagly and Chaiken (1993) and Gärling et al. (1998), where intention is defined as the probability consciously assigned by the actor to engagement in a particular behaviour [Fishbein and Aizen (1975)]. The relationship between how strongly past behaviour (habit) and intention determine a
behaviour is assumed to be reciprocal, i.e. the stronger the influence of habit, the weaker
the influence of intention, and vice versa [Triandis (1977)]. If we assume that the
formation of an intention is based on deliberate information processing, then the converse
conclusion is that behaviour driven by habit is based on little or no information
processing. This does not mean that such behaviour is entirely irrational, since at a certain
point of time an intention leading to habit has once been formed based on actual
information. The problem is that the external conditions are generally not constant, i.e. the
information, on which the intention was based, might no longer be valid.

Transport mode choice for passenger as well as freight transport is strongly driven by
habits, since most transports are no singular events but rather part of frequent and regular
processes (e.g. the daily journey from home to work, or regular deliveries of commodities
to a customer). Habit or habitual choice is defined as choosing to perform behaviour
without deliberation [Ronis et al. (1989)]. This leads to the problem that a non-
deliberate (or non-rational) choice may be difficult to influence with rational arguments,
since the decision-maker may discount relevant information. Furthermore, the cost of
searching for and constructing new transport alternatives is often too high and the
expected gains too uncertain to change habitual behaviour [Gärling and Axhausen
(2003)]. This is especially relevant in freight transport concerning shipping companies,
because changing transport modes also often implies an adaptation of surrounding logistic
processes, such as storage, commissioning, accounting etc.

One way to solve the problem of habitual behaviour is to force a change of a routine
choice [Fujii et al. (2001)]. If the routine choice is no longer available, the impact of
habit on the behaviour instantly drops to zero, and the behaviour is influenced by the
intention and the situation only. Up-to-date information must then be considered in
making a new choice leading to more rational behaviour. A less radical way to reduce the
impact of habit is to reduce the cost of searching for and constructing new alternatives. A
label is a good way to reduce the consumer’s cost of gathering up-to-date information.

2.5.2 Introduction to Labelling

In general, political measures designed to influence travel behaviour are referred to as
travel demand management (TDM) measures [Kitamura et al. (1997)]. These measures
differ in efficiency, cost, technical feasibility, and political feasibility and can be ordered
from highest to lowest according to their level of (political) coercion as follows [Vlek
and Michon (1992)]:

1. Physical changes (prohibition of certain travel alternatives);
2. Law regulation;
3. Economic incentives and disincentives;
4. Information, education, and prompts;
5. Socialisation and social modelling (changing social norms);
6. Institutional and organisational changes (e.g. flexible work hours, telecommuting).
Labelling approaches are part of group 4 (information, education, and prompts). The ISO 14020 series distinguishes three basic types of environmental labels [OECD (1997)]: Type I labels indicate a product’s environmental impact and are meant to promote more environmentally friendly consumption behaviour. These voluntary labels are normally government supported and are subject to third party certification programmes, which define lifecycle-related pass/fail criteria. Examples are the EU eco-label or the German label “Blauer Engel”. Type II labels consist of un-certified environmental claims made by manufacturers, importers or distributors that refer to special product attributes, such as “CFC-free”. Type III labels use pre-set categories of parameters, which are determined from Life Cycle Assessment (LCA) and provide quantified, independently verified product information. In contrast to Type I, Type III is not a pass/fail system.

Type I labels (commonly referred to as “eco-labels”) can be further characterised by the following attributes [UNCTAD (1994)]:

- The labels’ implementation is voluntary and controlled by third party supervisors;
- The certification includes the environmental impact of the product together with its entire life-cycle;
- External experts determine product categories and certification criteria, which have to be publicly available;
- After successful certification the label may be used for a fixed period of time only.

The question arises, whether eco-labels are really an appropriate response to today’s environmental problems. According to MORRIS (1997), the most commonly used arguments in favour of labelling schemes are the following:

- Since consumers are not actively gathering environmental information about products, a recognisable and reliable label can help to fill this gap;
- Labels can improve the image (and thus the sales) of producers and encourage them to account for their production’s environmental impact;
- Labels help to raise consumers’ awareness of environmental issues and problems.

Furthermore, labels can support producers in gaining competitive advantage [MARKANDYA (1997)].

However, other literature sources (e.g. [ERSKINE AND COLLINS (1996)], [ZARILLI ET AL. (1997)]) report a number of drawbacks of labelling schemes. These include: the risk of lacking objectivity and the arbitrariness in determining and updating the certification criteria, the lack of estimated demand for certified products, and the shortness of the label’s validity period before its revision, which is especially problematic for capital-intensive industries, such as transport. Furthermore, the initial goal of labelling to increase market transparency for the consumer is more and more being foiled by the growing
number of labels. The German database “Label online”\(^\text{16}\) for example lists 300 different labels, which are in use on the German market.

### 2.5.3 Demand for Labelled Products

What do we know so far about the demand for eco-labelled products? GALLASTEGUI (2002) states, that “unfortunately it is still not clear what are the main characteristics determining ‘green’ consumerism [because] environmental consciousness does not necessarily affect purchasing behaviour directly.” A number of exogenous factors affecting consumer-awareness, as identified by HEMMELSKAMP AND BROCKMANN (1997), are:

- Consumer satisfaction (environmentally friendly products must meet consumers’ basic criteria, such as price, performance, quality);
- Social values (these may result in behaviour influencing environmental impact);
- Reliable identification of the product;
- Cost; and
- Availability.

In two reviews, the OECD [OECD (1997), (2005)] has summarised the main effects observed by studies on a number of widely established labelling-schemes for industry products. These schemes are the EU Eco-Label Award Scheme, the “Swedish Environmental Choice”, the “Nordic Swan”, the “Canadian Environmental Choice Programme”, the German “Blue Angel”, the “Green Seal”, the Japanese “Eco Mark”, the “New Zealand’s Environmental Choice”, the Korean eco-label, and the “NF Environnement”.

Some of these studies show a consumers’ willingness to pay higher prices for eco-labelled products. In case of the Nordic Swan, BJÖRNER ET AL. (2002) found several reasons for consumer willingness to pay including the consumers’ great confidence in the government (which certifies the label), media attention for environmental issues, and a wide acceptance of policies pursuing relatively ambitious environmental goals. Consumers’ levels of education and environmental involvement as well as the type of additional information available seem to have an influence, too. The studies also discuss negative impacts on consumer behaviour, such as an increase in total consumption due to the belief (among consumers) that the lower environmental impact of one specific product would allow them to raise their total consumption without destroying the environmental balance. While the average market share of certified products is about 3-4% (in the Korean case), in certain cases it reaches up to 46% (for fluorescent lamps) or even 60% (in case of Blue Angel-labelled paint in the German do-it-yourself sector).

\(^\text{16}\) [http://www.label-online.de](http://www.label-online.de)
Experiences from established labelling schemes in the transport sector are scarce. A study by Peters et al. (2006) at the ETH Zurich reveals the impact of the Swiss energy efficiency label (“Energieetikette”) on car purchasing behaviour. The study, based on a broad consumer survey, concludes that the label has had no significant influence on the buyer’s decision to choose a particular model, although they tend to appreciate additional information on the label and are generally willing to accept measures to reduce CO₂-emissions. Among the measures proposed for reducing emissions, bonus-malus-systems on CO₂-emissions are much wider accepted among consumers than higher fuel prices.

A review of national experience and impacts of fuel-economy labels in the USA, Sweden and South Korea can be found in Wahnschafft and Huh (2001). They state that, driven by yearly readjusted energy efficiency standards (CAFE), the average fuel efficiency of cars in the USA has risen from 18.7 miles per gallon (mpg) in 1978 to 26.3 mpg in 1985. Greene (1998) calculated the total fuel savings during that period to some 55 billion gallons, equal to roughly US$ 70 billion (at a 1995 level of the US$). In Sweden, however, a fuel economy information programme had no significant effect on car buyers’ decisions. Reasons may be that a large fraction is enjoying company car benefits or that buyers decide strongly based on habit, thus tending to stick to the same model they have. The Korean results are somewhat contradictory, because, according to the results of an empirical survey [Kama (1999)], more than 70% of the potential car buyers consider fuel efficiency an important criterion for car choice, while statistics show, that between 1992 and 1998 average fuel efficiency levels have not increased significantly. This illustrates the discrepancy between intention (declared in an interview) and actual behaviour: a subject to be further discussed in this report (see section 4.1.2).

However, it must be underlined that these results concern labels for the information of end-consumers. As mentioned above, the proposed label would be a means of information and certification between companies (i.e. logistics service providers and shippers). Transport mode decision-making processes of companies follow not the same rules as the one of individuals (compare section 2.3). Furthermore, we conclude from these results that the effect of mandatory measures (such as CAFE) tends to be superior to the one of simple information programmes.

### 2.5.4 Review on Shippers’ Demand for “Green” Transport

After having reviewed the demand for labelled products and the effectiveness of labels in the passenger transportation sector, we will focus in the following on shippers’ demand for environmentally friendly freight transport in general. Some literature is reviewed focussing on the questions of, first, what motivation shippers have to consider environmental aspects in their negotiations with transport service providers and, second, whether they are willing to accept higher prices for such added value.
Basically, any private company (i.e. most shippers) acts out of an economic motivation [KASPAR ET AL. (2000)]. It expects a return of investment either at short or at long term, i.e. also investments that seem not economically driven (such as corporate citizenship) are expected to contribute to the company’s long-term competitiveness. Against this background shippers expect some internal benefit (i.e. economic advantages) from their environmental commitment in transport logistics. This can be realised either by raising the economic efficiency of the logistics processes and/or by enhancing market share through an incorporation of environmental aspects in the company’s marketing strategy [ANDERSON ET AL. (2003)].

Based on a number of expert interviews, KASPAR ET AL. (2000) conclude that the link between transport logistics and ecology is considered a challenge among most shippers, which is associated with additional costs, organisational efforts and benefits that are difficult to illustrate and communicate. An important insight in this context is that the transport logistics market is strongly demand-driven. The consequence is that the often resulting low prices (caused by over-capacities on the offer side) have a much stronger effect on shippers’ demand than environmental aspects.

Since reducing environmental impacts of the transport sector is also a strategic political goal (compare chapter 1), the question arises how political measures interact with shippers’ demand for environmentally friendly transport chains. From the results of a broad shipper survey in Spain, GONZALES-BENITO (2006) conclude that high regulatory pressure from the regulatory bodies is counterproductive for companies’ environmental commitment in logistics. Interestingly, the opposite effect is reported for the influence of the stakeholders: these have a direct and positive impact on a firm’s perception of environmental concerns in logistics planning. In Sweden, on the other hand, experiences from the timber industry [LAMMGÅRD (2007), p. 115] suggest that regulatory pressure can also drive companies towards a progressive attitude in environmental concerns. An interviewed shipper stated that, initiated by regulatory force, the company had learned to understand environmental performance as a competitive advantage.

Thereof we conclude that the proposed labelling approach could be an interesting option to support shippers’ environmental commitment by a “soft” steering instrument. First approaches in this direction were already reported more than ten years ago by WU AND DUNN (1995), who cite an example of environmental certification of a carrier in the U.S. specialised in transports of chemicals.

If we look at more concrete results on shippers’ demand for reducing their shipments’ CO₂-emissions, the numbers are also promising: two shipper surveys were carried out recently in Germany asking whether shippers were willing to pay higher prices for reduced CO₂-emissions. The results of the survey by the journal “VerkehrsRundschau” [CORDES (2008)] show that already today 16% of the survey population seem to be willing to accept higher prices for this extra value, while 63% stated that they would appreciate the carrier with better environmental performance only in case of price equality.
with “conventional” providers. Similar results are reported from a BME\textsuperscript{17} survey [BME (2008)], according to which 11% of the survey population would accept higher prices; 81% would favour the more CO\textsubscript{2}-efficient carrier in case of equal prices. It is, however, important to keep in mind the difference between declared intention and reality: the real figures would be lower than the ones resulting from these surveys. On the other hand the results are promising in the sense that there is a significant demand for environmentally friendly transport chains, which can be expected to be growing in the near future in the face of current discussions about introducing taxes on CO\textsubscript{2}-emissions.

This report goes further into detail for the case of Switzerland. The literature results will be compared with the shippers’ willingness-to-pay in Switzerland while taking a closer look at the different freight market segments (commodity groups, transport distances, etc.). Our hypothesis is that there exists a significant willingness-to-pay also in Switzerland but that differences must be made especially between the commodity groups.

\textsuperscript{17} BME – Bundesverband Materialwirtschaft, Einkauf und Logistik
3 Research Hypotheses

Before coming to the applied research methodology and the results obtained in the course of the project, this chapter introduces the general hypotheses, which stand behind the research questions raised in chapter 1.1.

3.1 Drivers for the Incorporation of Environmental Aspects in Transport Logistics

Do shippers consider environmental aspects in transport mode decisions, and how does it vary between specific types of commodities? What is the shippers’ willingness to pay for environmentally friendly transport solutions?

So far no literature sources exist including environmental aspects in a quantitative analysis of shippers’ freight transport demand. Basically, when comparing environmental aspects to “conventional” quality criteria (i.e. basically transport price, on-time reliability, and transit time), it is difficult to find arguments for the relevance of the former criterion. There are nevertheless reasons for optimising freight transport chains in terms of environmental performance.

The first, which has a direct influence on transport price, is energy consumption. The second reason concerns the shipper’s marketing strategy together with its customer relations. Many of them are meanwhile certified for running an environmental management system (e.g. ISO 14001, the European Eco-Management and Audit Scheme – EMAS, etc.). When actively promoting environmental certificates to their customers, shippers often have a direct interest to control the environmental performance of their supply and distribution chains. This trend is supported by a 2008 market research study among 450 firms from industry, trading, and logistics, according to which 75% of the shippers include clauses on environmental efficiency in their calls for tenders of logistics services [VERKEHRSRUNDSCHAU (2008)].

Hypothesis

In certain cases environmental concerns do play a role in shippers’ transport logistics planning, and shippers can be convinced to pay higher prices for better environmental performance of their shipments.

Differences will nevertheless emerge when comparing between specific commodity groups: shippers in direct touch with end-consumers or in sectors of general public
mistrust (such as the chemical industry) are expected to show higher awareness of environmental concerns than shippers of low value commodities, which are expected to show few or no sensitivity to changes in environmental efficiency of their shipments. This hypothesis will be verified by the modelling results from the shipper survey (see chapter 5).

3.2 Relevance of Demand Criteria

What is shippers’ perceived value of reducing environmental impacts compared to the value of “conventional” aspects (e.g. on-time reliability, transit time, etc.)?

Literature sources generally agree that price and on-time reliability are most relevant for shippers in general (i.e. independent of the commodity shipped). Concerning the ranking of these two criteria, results from RAPP TRANS AND IVT (2008) suggest that shippers tend to weight on-time reliability slightly higher than price; but this differs between commodity groups. Transit time has been observed to be of minor relevance as compared to these two criteria. Special cases are perishable commodities, which do not allow exceeding a maximum transit time. Further criteria, such as damage rate and flexibility, have been analysed by BOLIS AND MAGGI (1999) and IRE AND RAPP TRANS (2005), but due to reasons explained in section 5.1.4.2 these were not included in this research’s Stated Choice experiments. A direct quantitative comparison with the relevance of environmental aspects could not be found.

Hypothesis

Higher transport prices and an increase in transit time are expected to have a negative impact on choosing the according alternative, while an increase in on-time reliability should have a positive influence. We see the relevance of transit time as generally lower than the ones of price and on-time reliability but still higher than the one of environmental performance.

Detailed hypotheses on the above criteria including interaction terms are formulated in context of the description of the detailed model structure in section 5.1.4.3. These, together with the above-stated hypotheses, are then verified using the modelling results from the SP-analysis.

3.3 Transport Modes and their Environmental Efficiency

What criteria can be used for measuring the environmental impact of transport chains?

A key factor influencing environmental efficiency (when measured in energy consumption and emissions per tonne-kilometre) is the vehicle load factor, i.e. the ratio between net and gross weight. In the market segment analysed in this research (i.e. shipments of at least full truckload (FTL) size over distances of above 50 km), load
Research Hypotheses

Factors are assumed to be at least 50% in rail and intermodal transport. High load factors together with trains of 1000 gross-tons and more permit an efficient use of rail traction energy (and thus a low level of environmental impact per shipment) \cite{PSI AND ESU (2007)}. Furthermore, in Switzerland rail transport has the advantage of using mostly electric traction energy, which is produced mainly from water and nuclear power, thereby minimising greenhouse-gas emissions \cite{IFEU (2008)}.

Certainly not all transport chains allow for such efficient rail transport, either because of long distances between origin (or destination) and the nearest consolidation yard or simply due to a missing access to the railway infrastructure. In the latter case intermodal transport (with pre- and post-haulage by lorry) can be a valuable alternative, but given the actual network of intermodal terminals in Switzerland, pre- and post-haulage distances of 100 km and more are not rare often including large detours when compared with door-to-door road transport.

Hypothesis

We expect road transport’s environmental efficiency to be generally lower than the one of rail and intermodal transport. However, we see that road-only transport for FTL-shipments over up to 200 km is the better alternative in terms of environmental efficiency. Rail or intermodal transport is recommendable rather for larger shipments and/or higher transport distances.

These hypotheses will be verified by the environmental benchmark in chapter 1.

3.4 Economic Potential of Labelled Transports

Is the market segment of environmentally friendly transport services a field worth being expanded from a logistics service provider’s perspective?

Clear hypotheses on the outcomes of this work package are difficult, because these depend on a number of external parameters, such as commodity shipped, shipment size, and transport distance. Whether the logistics service provider (LSP) would be able to pass on the expected cost surplus to the shipper will differ strongly from case to case. Results from a recent shipper survey in Germany \cite{CORDES (2008)} suggest that in certain sectors shippers might be willing to pay up to 10% higher prices for increased environmental performance. So it is not impossible that in such cases the LSP might realise positive margins from labelled transport chains.

Hypothesis

In most cases the economic potential of labelled transport chains is expected to be low. In other words, the LSP would often not be able to realise positive margins from offering environmentally friendly transport services thus having little interest to make strategic investments in this field. Eco-labelled transport services might however become an interesting object for niche players in specific commodity sectors.
For verification of this hypothesis, a cost-benefit-analysis will be carried out (chapter 1) using the results of demand modelling, environmental benchmark, and operational cost analysis.

3.5 Potential of Environmental Information as a Political Steering Instrument

*How great is the potential of a labelling system to contribute to the EU commission’s energy efficiency goals?*

The answer to this question also depends on shippers’ demand and perception of environmental information in transport logistics planning. If differences in environmental performance have an impact on a shipper’s choice of freight transport services, then the conclusion would be that providing environmental information has a positive impact on the shipper’s behaviour. Since higher sensitivity is expected especially in end-consumer markets, the approach to combine the transport label with existing consumer eco-labels seems promising thereby allowing the end-consumer himself to put pressure on the shipper and its logistics strategy towards an integrated “green” supply-chain of the purchased product.

*Hypothesis*

Additional environmental information could have a measurable impact on shippers’ demand but with differences between commodity groups (compare section 3.1).
4 Research Methodology

In order to verify the hypotheses formulated in chapter 1 the research methodology was structured as illustrated in Figure 4-1.

The left column represents the shipper survey to estimate the willingness-to-pay for environmentally friendly transport, while the right column illustrates the benchmarking process. The shipper survey (see section 4.1) includes the SP-experiments to test the interviewee’s sensitivity of price and quality criteria (including environmental impact). The models to be derived from the survey results allow quantifying shipper sensitivities for the selected criteria and deriving the according monetary values. We are also able to show which commodity groups are especially sensitive to environmental concerns.

For answering the research questions nos. 4 – 6 an environmental benchmark of the freight transport chains is necessary. The goal is to evaluate the potential for optimising existing transport chains in terms of their environmental impact including a comparison between different transport modes for a given O/D-relation. Therefore a suitable assessment method including appropriate criteria needs to be selected to cover all relevant aspects of transport’s environmental impact (see section 4.2).

The benchmarked transport chains were then subjected to a price analysis (see section 4.3.2) This analysis helps estimating the transport prices the transport service provider must calculate for the operation of environmentally friendly transport solutions as compared to the status-quo.

The final cost-benefit-analysis (see section 4.3.3) compares the change in transport price with the difference in environmental performance of the benchmarked transport chains and furthermore answers answer the question whether a transport service provider might be able to pass on additional operational costs (for operating environmentally friendly transports) to its clients (i.e. the shippers). If the realistic price margin is equal or even less than the shippers’ willingness-to-pay, then its incentive will be strong enough to support investments into this market segment of environmentally friendly freight transport (e.g. into new vehicle and infrastructure technology).

From the state’s perspective, the results of the experiments (i.e. the shippers’ willingness to pay) allow judging the effectiveness of a potential labelling system providing the shipper with additional environmental information as a political steering instrument to reduce freight transport’s environmental impact.
Figure 4-1: Methodological Concept

Impact of environmental information on shippers’ demand for freight transport services?

Political aspects

Preparation of shipper survey (SP-experiments)

Development of benchmark criteria for env. impact

Economic aspects

Administration of shipper survey

Environmental benchmark of sample transport chains (from shipper survey)

Transport chain samples

Evaluation of survey results; Model building

Price analysis of benchmarked transport chains

Shippers’ willingness to pay for environmentally friendly transport

Estimated Price of environm. friendly transport chains

Cost-benefit-analysis from LSP’s perspective

Effectiveness of eco-label as political measure

Market potential of env. friendly transport chains
4.1 Methodology of Demand Modelling

4.1.1 Review of Existing Freight Demand Models

Transport demand models have been used since the 1960s to support all aspects of the transport planning process from transport mode choice to network planning and from productivity measurement to value-of-time estimation. In freight transport the process of model building is more complex as compared to passenger demand models. The main reasons are, first, the different quality requirements to the transport service (compare section 2.3), and, second, that the identification of the actual decision maker and the decision making process itself is not straightforward. The decision maker can be a shipper’s logistics manager, a contracted logistics service provider, or a combination of both.

There are two basic types of freight transport models: aggregate and disaggregate models. According to Winston (1983), aggregate models are used to forecast the behaviour of an entire transport system, while disaggregate models are used to predict the behaviour of individual agents within a specific transport system [GARCÍA-MENENDEZ ET AL. (2003)]. For certain problems aggregate models can be more useful, because they are comparatively easy to handle and avoid extensive data requirements that are unavoidable for disaggregate models. Nevertheless, theoretical and empirical advantages of disaggregate models stimulated their use. The principal advantages of disaggregate models are [GARCÍA-MENENDEZ ET AL. (2003), WINSTON (1985)]:

1. Individual behaviour is considered;
2. Richer model specification, because important characteristics of the decision maker are captured;
3. Better understanding of intermodal competition since the actual attributes of transport modes and characteristics of the specific goods are taken into account.

Winston (1983) distinguishes two types of disaggregate freight demand models: inventory and behavioural models. Inventory based models assume that the decision making process is closely related to the production processes and inventory management of a firm. In this case, decision-making is directly influenced by the firm’s profit maximisation problem by minimising the total of inventory and transport costs. Behavioural models are based on mode choice decisions focussing on utility maximisation. In this case, random utility models, rather than deterministic models, are used to estimate freight transport demand. This is because decision makers do not always follow perfectly rational and predictable rules, and they do not always possess perfect information about alternative transport options [GARCÍA-MENENDEZ ET AL. (2003)].

One of the typical problems disaggregate freight demand models are used for is estimating the consequences of political measures on transport systems. For this purpose, regional, national or international transport models have been built in different countries.
Most of them are based on the proven four-step approach originally developed for passenger demand modelling. These four steps are [McNally (2000)]:

1. Estimating the quantities of goods to be transported from each origin to each destination (production and attraction);
2. Estimating the transport flows between origins and destinations (O/D-matrix);
3. Allocating the commodity flows to modes; and
4. Converting the volumes to vehicle-units and the assignment to the network.

Table 4-1 shows a (non exhaustive) list of frequently referenced models in Europe. For further examples outside Europe please refer to ME&P (2002).

**Table 4-1: Overview of Existing Freight Transport Models**

<table>
<thead>
<tr>
<th>European Level</th>
<th>National Level</th>
<th>Regional Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCENES&lt;sup&gt;a)&lt;/sup&gt; (EU 15)</td>
<td>LMS&lt;sup&gt;d)&lt;/sup&gt;, TEM-II&lt;sup&gt;e)&lt;/sup&gt;, SMILE&lt;sup&gt;f)&lt;/sup&gt; (Netherlands)</td>
<td>WFTM&lt;sup&gt;i)&lt;/sup&gt; (Wallonia)</td>
</tr>
<tr>
<td>NEAC&lt;sup&gt;b)&lt;/sup&gt; (EU 15 + Central/Eastern Europe)</td>
<td>SAMGODS (Sweden), NEMO&lt;sup&gt;g)&lt;/sup&gt; (Norway)</td>
<td>STEMM (applied e.g. for transalpine freight transp.)&lt;sup&gt;j)&lt;/sup&gt;</td>
</tr>
<tr>
<td>EXPEDITE&lt;sup&gt;c)&lt;/sup&gt;</td>
<td>SISD&lt;sup&gt;h)&lt;/sup&gt; (Italy)</td>
<td>Brenner model&lt;sup&gt;m)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>NPVM&lt;sup&gt;i)&lt;/sup&gt; (Switzerland)</td>
<td>Fehmarnbelt Model&lt;sup&gt;n)&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Notes:**

a) Macro-economic model using monetary units to forecast trade flows [SCENES (2001)]
b) Macro-economic model forecasting freight and passenger flows per mode [Chen and Tardieu (2000)]
c) Aggregate meta-model integrating results from different national and international passenger and freight transport models; forecast for transport volumes and costs [EXPEDITE (2002), De Jong et al. (2004)]
d) Disaggregate model forecasting only passenger flows; freight flows are integrated using forecasts from the TEM-II model [ME&P (2002)]
e) Uses an input-output based demand model to forecast freight flows per mode [Franke (2000)]
f) Dynamic model including logistic processes for the forecast of freight flows using tonnage and monetary units plus environmental impact [ME&P (2002)]
g) Both models use an input-output based demand model to forecast trade flows based on monetary units; STAN software employed for mode and route choice [ME&P (2002)]
h) Integrated set of databases and simulation models for the forecast of passenger and freight flows; disaggregate models used for mode choice; traffic assignment on OD level [Cascetta (1997)]
i) Disaggregate model forecasting only passenger flows; national freight transport model currently under development
j) Model built around a network model (implemented in NODUS); uses a virtual network representing operational transport costs; demand forecast based on disaggregate input-output model [Geerts and Jouquin (2000)]
k) Freight transport model developed for forecasting mode and route choice in major international corridors [ME&P (2002)]
l) Freight transport model based on the Transalpine Model with focus on the Brenner corridor; network modelled in VISUM; route choice based on stochastic equilibrium model [ME&P (2002)]
m) Disaggregate model forecasting passenger and freight flows across the planned fixed Fehmarnbelt crossing [FTC (1999)]
The disaggregate modelling approach is used not only within the framework of comprehensive transport models but also to identify demand characteristics of certain actors. In this context several studies have been completed to determine shippers’ principal factors influencing transport demand. Valuation approaches (e.g. value of time (VOT) or value of reliability (VOR) estimations) based on Revealed Preference (RP) and/or Stated Preference (SP) data are most commonly employed to compare the perceived importance of different criteria from a shipper’s perspective. The relevant literature was reviewed in section 2.3.2.

4.1.2 Limits of Freight Demand Modelling

Since freight demand modelling was developed based on experiences from passenger demand modelling, the proven four-step approach developed for the passenger sector has established itself also for freight modelling. However, the complexity of freight logistics, as described above, plus the frequent problem of limited data availability (at least on the disaggregate level) lead to strong discrepancies between passenger and freight models [De Jong et al. (2004)].

When focusing on willingness to pay (WTP) estimations (as applied in this research), certain aspects, which lead to inaccuracies of the models, must be kept in mind when interpreting the results. Since most WTP estimations are derived from models based on Stated Preference (SP) survey data, the principal drawback of SP experiments unavoidably comes into play: the bias between stated and revealed preferences. In other words, a respondent taking part in an SP experiment (which includes hypothetical choice tasks) sometimes decides differently as compared to the real world situation, where decisions have real consequences. This bias is significant especially in case of choice tasks including monetary expenses, because “hypothetical money” is spent much more easily than real money.

This problem can be overcome by combining SP data with RP data, i.e. comparing a respondent’s stated choice with the later real choice. Unfortunately, such a combination is rarely possible due to lacking data consistency: it is difficult from an administrative viewpoint to carry out the same survey (ideally with the same survey population) before and after the measure to be tested comes into force.

Since in our case an RP survey could only be conducted after implementation of the proposed labelling system, the mentioned bias was minimised as far as possible by pointing out to each interviewee the importance to make realistic decisions in the choice experiments. This can be controlled by comparing choices with a preliminary ranking question in the first part of the questionnaire (see section 5.1.4.1). In case of implausible choices the respondent was asked for the reasons for having chosen the specific alternative and thus had the chance to reconsider the choice.

Another aspect, which is not limited to SP experiments, is the sometimes not rational behaviour of the respondents. As explained in detail in section 2.2.3.2, freight transport
services are often contracted out to logistics service providers (LSP) based on habit-driven decisions due to either good experiences with the ancestral provider and/or a lack of information about possible alternatives. Such behaviour cannot be predicted by stated choice models (unless they are designed for this special purpose).

A general problem of model-based demand estimations is the sometimes high heterogeneity of the single demand groups. In passenger transport demand modelling this is a less serious problem than in freight transport, because the demand groups are much more homogeneous than shippers in freight transport. However, for statistical reasons also shippers are assigned to demand groups. For the grouping the commodity to be shipped is normally used as relevant criterion (commodity groups classification), but other criteria (such as transport distance, infrastructure availability, etc.) can also be tested in order to optimise the consistency of the single demand groups. The consistency is furthermore influenced by the sample size of the survey: in case of low sample sizes in certain groups a fusion of two groups can be unavoidable to obtain a statistically significant model, which leads to a lower homogeneity of the resulting group and thus to a lower explanatory power of the model results.

### 4.1.3 Applied Modelling Approach

In order to understand the choice of methodology for this research, it is helpful to recall the research questions concerning this part of the project:

1. Do shippers consider environmental aspects in transport mode decisions?
2. If so, how does shippers’ environmental awareness vary between specific types of commodities? Do certain sectors put more weight on environmental aspects than others?
3. What is shippers’ willingness-to-pay for environmentally friendly transport solutions? What is the perceived value of reducing the environmental impact compared to the value of “conventional” aspects (e.g. on-time reliability, transit time, etc.)?

From these questions we can deduce the following requirements to the survey, during which the data necessary for demand modelling is collected:

1. The survey must include questions on shippers’ decision-making process for freight transport services;
2. It must be possible to test shipper’s reaction to environmental information in the framework of the decision-making process, i.e. “conventional” criteria must also be considered;
3. The survey must be able to collect quantitative data of shippers’ demand, esp. for the valuation of different demand criteria; and
4. All commodities relevant for the Swiss (land-based) freight transport market should be included.
Although the problems mentioned in section 0 must not be neglected, the Stated Preference approach is the only method leading to a detailed quantitative estimation of the shippers’ willingness-to-pay for decreasing their shipments’ environmental impacts. Observing the real impact of additional environmental information by interviewing the decision maker after the actual decision (Revealed Preference) is not possible, because systematic information on freight transports’ environmental performance is not available so far. Even if certain LSPs provide tools to calculate CO$_2$-emissions and allow shippers to consider results in transport mode choice, the comparability between such independent samples would be limited when combining such data from different sources to a larger RP data set. Therefore, possible scenarios must be created based on existing transport examples of the respondent’s company, to which information on these transports’ environmental performance is added. These scenarios are then presented to the respondent using the SP experiments.

Furthermore, the SP approach was chosen, because it is the only method allowing detailed modelling of the demand elasticities in freight transport subject to different parameters, such as the shipper’s logistics strategy, shipment characteristics, etc. Not only it is possible to estimate the direct dependence between transport emissions and price, but also to understand the coactions of additional parameters (including on-time reliability, transport time etc.). For transport choice it is more realistic to consider more than just two influencing factors, and this is possible only by confronting the interviewee with a number of different choice situations (experiments).

As compared to simpler modelling approaches, the SP experiments enable us to estimate demand elasticities based on real-life transport examples. Experts contacted from industry and the transport logistics sector underlined that respondents would have strong difficulties stating their preferences in case of purely hypothetical situations. This close relationship to reality would also prove of value, if the estimated models were later used in a larger disaggregate freight model (e.g. for updating the modal-split functions of the Swiss national freight transport model).

In each SP-experiment the person answering the questionnaire must choose his or her preferred offer out of three alternatives (referred to as “Stated Choice”). This method’s advantages (as compared to e.g. ranking experiments) are that it is easy to understand, easy to perform and that it reflects real conditions well. On the other hand, it provides less information than other methods, because the interviewee can only give information for the chosen alternative. However, using other more complex methods was rejected since these would have much higher risk of errors and imprecision given the complexity of decision making in intermodal freight transport [DE JONG ET AL. (2004)].
4.2 Environmental Benchmarking Methodology

4.2.1 Introduction

In order to provide shippers with environmental information based on a labelling system, an environmental benchmark of freight transport chains is necessary. Basic requirements to such a benchmark system are that it must be a) generally applicable (i.e. results must be comparable) and b) transparent, i.e. based on a defined set of criteria.

Today it is more and more common practise to calculate e.g. “carbon footprints”\(^{18}\) of products and services or, more generally, to communicate CO\(_2\)-emissions (induced by their production or during the entire life-cycle) to customers and end-consumers [ERNST (2008)]. As a first approach to balance the environmental impact of products and services, and especially in terms of using compensation mechanisms via the CO\(_2\) certificates trading scheme, CO\(_2\) is indeed a suitable indicator.

However, CO\(_2\) is not the only relevant substance when analysing the environmental impacts of products and services. If for example the focus lies on greenhouse-gas (GHG) emissions only, CO\(_2\) is just one substance besides other gases (e.g. methane) supporting the greenhouse effect. Therefore, to provide a comprehensive benchmark system, other environmental impact categories (such as ozone depletion, particulate matter formation, eco-toxicity, etc.) must also be taken into account. Today, state-of-the-art for analysing the environmental impact of products and services is to consider their entire lifecycles, i.e. from raw material production to end-of-life treatment. According to REMMEN ET AL. (2007), the main goal of life cycle thinking is to reduce resource use and emissions from and to the environment as well as to improve social performance in various stages of a product’s life.

Dedicated methods have been developed and applied for this purpose, which are generally referred to as lifecycle assessment (LCA) [PRÉ (2006)]. These methods are standardised within the ISO 14040 series with a definition of their goal and scope to be found in ISO 14040:2006 [ISO (2006a)] and specific requirements plus guidelines for application provided in ISO 14044:2006 [ISO (2006b)].

4.2.2 Principles of Life Cycle Assessment (LCA)\(^{19}\)

According to ISO 14040:2006, life-cycle assessment (LCA) “addresses the environmental aspects and potential environmental impacts […] throughout a product’s life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal” and supports the user in:

\(^{18}\) For details please refer to www.carbonfootprint.com
\(^{19}\) This section draws on ISO (2006a).
• “Identifying opportunities to improve the environmental performance of products at various points in their life cycle”;
• “Informing decision-makers in industry, government or non-government organizations”;
• “The selection of relevant indicators of environmental performance”; and
• “Marketing (e.g. implanting an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration)”.

LCA consists of four main phases as illustrated in Figure 4-2.

**Figure 4-2: Main Phases of Life-Cycle Assessment (LCA)**

The first phase consists of formulating and specifying the goal and scope of study in relation to the intended application. The scope, including system boundaries and level of detail, depends on the subject and aim of the LCA. Quantification of a product’s performance characteristics (“functions”) is defined by the so-called “functional unit”. Its primary purpose is providing a reference for comparability, to which inputs and outputs are related. The system boundary determines, which unit processes to be included in the LCA. The choice of elements of the physical system to be modelled depends on the goal and scope of the study, its intended application and audience, the assumptions made, as well as data and cost constraints and cut-off criteria.

The life cycle inventory analysis phase (LCI phase) is an input/output data inventory involving data collection and modelling of the product (or service) system as well as description and verification of data. This encompasses all data related to environmental (e.g. CO₂) and technical (e.g. raw materials) quantities for relevant unit processes within the system boundaries. Examples of technical input/output quantities include flows of material, energy, and chemicals, while environmental inputs and outputs (“elementary flows”) occur in the form of resource use and emissions to air, water, and soil. The final
result of the analysis is an inventory of the defined system for all unit processes and for
the defined functional unit of the product system to be modelled.

In the third phase (“Life Cycle Impact Assessment” – LCIA) the contribution of the
analysed system to impact categories (such as global warming, acidification, etc.) is
evaluated. This phase consists of four steps, including

1. The selection of impact categories, category indicators, and characterisation
   models;
2. The assignment of LCI results (classification);
3. Characterisation, i.e. the calculation of category indicator results; and
4. Optional elements (normalisation, grouping, and weighting).

For normalisation, the magnitude of the category indicator results is calculated relative to
available reference information (such as total inputs/outputs for a given area). Grouping is
the assignment of impact categories into one or more sets as defined in the goal and scope
of the LCA, and it may involve sorting and/or ranking. Weighting implies assigning a
weighting factor to each impact category depending on its relative importance.

Finally, in the interpretation phase the findings from inventory analysis and impact
assessment are considered together. An analysis of major contributions (including a
sensitivity analysis) leads to the conclusion of what can be learned from the LCA and how
the analysed product or service can be optimised. This interpretation should consider that
LCIA results a) are based on a relative approach, b) indicate potential environmental
effects, but c) do not predict actual impacts on category endpoints, the exceeding of
thresholds, safety margins, or risks.

4.2.3 Impact Assessment

For the life cycle impact assessment phase several different methods exist, which
basically differ in

- Environmental modelling approach;
- Number of impact categories;
- Number of environmental interventions assessed;
- Aggregation level; and
- Weighting approach (if applied).

Each method contains a different selection of impact categories, but only some of the
methods allow results aggregation into a single indicator.

The selection of the appropriate method including relevant impact categories to be
included must be based on the goal of the study. For the impact categories so-called

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20 This section draws mainly on [PRé (2006)].
endpoints (see Figure 4-3) are defined, which can be understood as issues of environmental concern like human health, extinction of species, availability of resources for future generations, etc. ISO 14044 does not recommend certain endpoints explicitly but requires a careful selection and definition (most available methods have their own endpoint definition). The modeller selects appropriate impact categories and defines the environmental model, which links the impact category to the endpoint. The model is normally directly included in the applied method, thereby defining for each impact category (endpoint) a quantitative relationship between the related inventory results used and the according impact.

**Figure 4-3: General Structure of an Impact Assessment Method**

Some of the methods use the endpoint categories described above for impact characterisation, while others employ impact category indicators at the midpoint level (see Figure 4-3). Midpoint indicators have the advantage of lower uncertainty, since only a small part of the environmental mechanism needs to be modelled, but they are much more difficult to understand and interpret by decision makers – a tradeoff, which still needs to be resolved. Both approaches are approved and, again, depend on the goal of the LCA, but results from different methods are not directly comparable. While the Eco-indicator 99 method [PRÉ (2001)] (one of the most widely used methods) or the updated version of the “Swiss Ecological Scarcity Method” [FRISCHKNECHT ET AL. (2008)] use endpoint category indicators, other relevant ones (e.g. the CML method\(^{21}\)) employ midpoint category indicators.

\(^{21}\) For details please refer to http://www.leidenuniv.nl/interfac/cml/ssp/lca2/index.html
4.2.4 The ReCiPe 2008 Method

One promising approach to deal with the above mentioned tradeoff between different LCIA methods is a new method called “ReCiPe 2008”, which offers results indicated at both, midpoint and endpoint level. It aims for harmonising methods at the level of detail while still allowing a certain freedom in terms of main principles (i.e. mainly the choice between midpoint and endpoint category indicators). The motivation to calculate endpoint indicators, which are derived from midpoint indicators, is that the high number of midpoint indicators is very difficult to interpret, partially since there are too many, partially because they have an abstract meaning.

The principle of this method is illustrated in Figure 4-4 using the example of climate change.

**Figure 4-4: Example of climate change illustrating the ReCiPe 2008 Model**

The impact indicator for climate change at midpoint level is “Infrared radiative forcing”, which has relatively low uncertainty and high acceptance, because it is a simple aggregation of the inventory results concerning emissions of CO₂, methane (CH₄), dinitrogen-oxides (N₂O), and chlorofluorocarbons (CFC). In this example the midpoint category is linked to two endpoint categories (i.e. damage to human health and damage to ecosystem diversity).

ReCiPe 2008 comprises 18 midpoint and 3 endpoint impact categories (see Figure 4-5). Most midpoint categories are linked to only one endpoint category, but as shown in the example of climate change, one midpoint category can also be connected with two endpoint categories. This example, however, is the only one with a quantitative relationship between midpoint and two different endpoint categories. For others (e.g. ozone depletion or photochemical oxidant formation), although the link to a second endpoint category is important, so far no quantitative relationship could be established.

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22 This section draws mainly on [GOEDKOOP ET AL. (2009)].
The decision to employ the ReCiPe 2008 method in this research was based on two main arguments:

1. It is the most recent LCIA method representing the state-of-the-art in LCA; and
2. Missing impact categories affecting human health (see below) can easily be integrated into the basic framework of this method.

Using the ReCiPe 2008 method, a selection of representative transport chains collected during the shipper survey are benchmarked by comparing the environmental impact of the given transport using different transport modes. Detailed setup and results from the benchmarking system are described in chapter 6.

Figure 4-5: Relationship between LCI Parameters, Midpoint Indicator, and Endpoint Indicator

Source: [GOEDKOOP ET AL. (2009)]
4.2.5 Missing Impact Categories Relevant in Transport LCA

LCIA methods were developed for a wide range of applications including industrial products as well as services (e.g. transportation). The drawback of this wide applicability is that application-specific impact categories are likely to be missing, although they are of high relevance in the specific case. In transportation this notably concerns the damage to human health caused by noise emissions and traffic accidents.

4.2.5.1 Noise

The LCA research community is aware that noise is a factor, which cannot be neglected in this context due to its relevance not only in transportation but also in connection with industrial processes [PRé (2006)]. The main problem with noise is the difficulty to quantify its impact on human health, especially in case of traffic noise. MÜLLER-WENK (1999) proposed an impact assessment method for road traffic noise, which is compatible to the Eco-indicator 99 method [PRé (2001)]; but, as the author himself admits, uncertainties remain high, since the impact on human health is a question of each individual’s subjective perception. In other words, a noise level, above which an individual is feeling disturbed, cannot be determined in an objective way. The second problem is the determination of disability weights for the endpoint category, which was done by a medical panel: even for medical experts it is difficult to quantify disabilities for a person disturbed by noise under variable conditions (e.g. differing between day- and night-time).

Therefore, noise is so far not included in most of the common LCIA methods\(^\text{23}\). Our own attempt to adapt and test the method of MÜLLER-WENK (1999) in this research was not successful, since, even if the described uncertainties would have been accepted, an application of this method for rail and intermodal transport is not realistic. Traffic volume (number of independent vehicles) on the rail network is much lower and much more unevenly distributed than on the road network. These were, however, two basic assumptions for the methodological approach of MÜLLER-WENK (1999).

Also ALTHAUS ET AL. (2009) (one of the most recent literature sources in the field of noise in LCA) including a review of possible modelling approaches point out the lack of an appropriate method, which would allow the comparison of noise impacts between different transport modes.

\(^{23}\) The EPS 2000 method (http://eps.esa.chalmers.se/introduction.htm) does include noise, but the implementation approach is rather coarse [PRé (2006)].
4.2.5.2 Traffic Accidents

Accidents as having an impact on human health are relevant in most industrial production processes but especially in transportation. So far none of the common LCIA methods include accident damages as an impact category, and literature sources in this context are surprisingly scarce.

We therefore decided to extend the ReCiPe 2008 method by an according impact category, which contributes to the endpoint factor “Human Health”. For this purpose a similar approach in the field of work safety on oil and gas rigs [PETTERSEN AND HERTWICH (2008)] was adapted for application in the Swiss freight transport sector. A detailed description of this approach including results for Switzerland is given in section 6.1.1.

4.3 Methodology for Price and Cost-Benefit Analysis

4.3.1 General Remarks

Before going into detail it is important to make clear how we understand the terms “costs” and “prices” in the context of this analysis. Since the survey, from which the analysed case studies were drawn, based on a shipper’s perspective of the freight transport market, this perspective is retained throughout the whole study. This implies that we analyse and compare prices, which a shipper pays for buying transport services from an (external) logistics service provider (LSP). The cost-based analysis presented in the following uses a model, which is based on the operational cost structures of an LSP: it estimates transport prices by calculating the operational costs for a shipment from an LSP’s perspective and adding a margin for all operators included. These results are then compared with actual prices as recorded during the shipper survey. The term “cost-benefit-analysis” is nevertheless held, because it is a common term describing the general comparison of efforts vs. benefits for a certain object.

4.3.2 Price Analysis in Freight Transport Operation

Price analysis in transportation does not require any specialised methodology. Nevertheless, like in life cycle assessment, it is important to define clear system boundaries and state the assumptions made for the different input parameters. In other words, is must be clearly defined, which cost elements with which values are considered in the analysis.

4.3.2.1 Rail-Only and Intermodal Transport

The price analysis approach of this project for rail-only and intermodal transport bases mainly on a cost model set up for a software tool, which is designed for intermodal
transport chain planning in European freight transport across the Alps [IVT AND PTV (2009)]. The implemented cost model for intermodal transport was developed by the Institute for Transport Planning and Systems (IVT) at ETH Zurich and can therefore be reused in this project. Only minor changes are necessary to adapt this model for cost calculation in rail-only transport.

For calculating the main-haulage part (by rail) of the intermodal transport chain, a reference train is defined based on the size of a typical train operating on international connections in Europe\textsuperscript{24}. Train path costs are evaluated using country-specific data from the so-called “Network Statements” of the according infrastructure operators. Subsidies in Switzerland on train path prices in intermodal transport are also considered. Traction costs comprise costs for engine, driver, and traction energy; they also differ between countries, since topographical characteristics as well as engines’ higher operational performance in larger countries are incorporated. Further main haulage cost elements are terminal handling costs, costs for the freight cars, as well as overhead and profit of both, train operating company (TOC) and intermodal operator.

Based on these cost elements, total costs per shipment for the main haulage part are calculated as follows:

1. Summing up all single cost elements to derive costs per train;
2. Dividing total costs by the average number of shipments per train to derive costs per shipment;
3. (if applicable) subtract Swiss subsidies from costs per shipment to derive resulting total costs per shipment.

The detailed description of the cost data used is given in sections 7.1.2 and 7.1.3, respectively. Note that for calculating the pre- and post-haulage costs of the intermodal transport chain, the same setup is used as for road-only transport (see below).

Since cost-based calculations of rail operation processes are necessarily based on a number of assumptions with significant uncertainties, a price-based approach is tested as an additional alternative to evaluate the better match with the actual prices reported by the respondents of the shipper survey. SBB Cargo publishes detailed price lists for internal and border-crossing transports to and from Switzerland. The general problem about rail freight price lists, however, is that the published prices are almost never charged without reductions, which strongly depend on the volumes shipped by a single customer and are specified in individual contracts. Therefore, to obtain realistic price estimates, suitable assumptions must be made concerning these reductions.

\textsuperscript{24} This means trains with a length of 500 m to enable operation into Italy without train splitting.
4.3.2.2 Road Transport

The cost analysis for road transport operation (including pre- and post-haulage in intermodal transport) is based on a calculation table provided by the journal “Verkehrsrundschau” [NFZ-KATALOG (2007)]\(^{25}\).

Basically, total costs per full truckload (FTL) are derived from two sets of a) time-dependent cost elements and b) distance-related cost elements. Time-dependent costs (also referred to as fix costs) include vehicle costs (i.e. depreciation, interests, taxes, and insurances), driver wage costs, and overhead costs; distance-related costs (also termed variable costs) comprise depreciation, costs for fuel, oil, tyres, maintenance/repair, and road tolls. Variable costs are then converted into time-dependent costs using the vehicle’s annual operational performance and added to the fix costs to derive the total costs per kilometre per lorry (i.e. per shipment in case of FTL).

This calculation can also be applied for pre- and post-haulage operation costs in intermodal transport with only minor changes in some elements of the input data (e.g. annual operational performance of vehicle). A detailed description of costs elements and input data used is given in section 7.1.1.

4.3.3 Cost-Benefit-Analysis

Based on the environmental benchmark of the selected case studies concerning their environmental performance and on the prices analysis for the available transport modes, a cost-benefit-analysis is carried out to compare a potential gain in environmental performance with the related change in transport price.

For each transport sample and each available mode per sample changes in transport prices for using the indicated mode instead of the one currently employed were compared to the relative change in environmental impact due to the mode change. The analysis differs between the three environmental impact categories of the ReCiPe method as introduced in section 4.2.4. The results are then classified into four categories according to the methodology illustrated in Figure 4-1 on page 33: samples with higher prices and increased environmental impact, cases with both lower prices and lower environmental impact, and the two combinations of these scenarios.

Based on this evaluation, the case studies with higher prices for a change of mode but reduced environmental impact are finally compared with the shippers’ willingness-to-pay (WTP) for this reduction according to the results from section 5.3.5. The goal is to estimate whether the WTP might compensate the potential cost surplus for using a different transport alternative.

\(^{25}\) An online tool and example calculation are available at http://www.verkehrsrundschau.de/sixcms/detail.php?id=630552
5 Shipper Demand for Environmentally Friendly Freight Transport

This chapter deals with the empirical estimation of shipper demand for environmentally friendly freight transport. The first section presents the experimental setup of this survey including the choice of survey population, design of the questionnaire including Stated Preference-experiments, and administration of the survey. The results of the survey are discussed in sections 5.2 and 5.3. These comprise basically the output of different models tested with the survey data. A conclusion will finally be drawn on shipper willingness to pay for higher environmental performance of their freight transports.

5.1 The Shipper Survey

5.1.1 General Concept

The general survey concept is based on the setup of a previous survey in Switzerland in the framework of a new Swiss national freight transport model. The survey is described in detail in [RAPP TRANS AND IVT (2008)]. The participation in this project brought fruitful experiences, from which we could profit during the setup of the survey as described in the following. The employed source data from 2003 was also reused, since until 2008 the general Swiss freight transport survey (“Gütertransporterhebung” – GTE) was carried out in a five-year frequency only, and the 2008 data was not yet available at the time of setup and administration of the new survey.

Since a questionnaire including Stated Choice experiments is rather complex as compared to e.g. simple ranking questions, we decided to conduct computer-assisted interviews where interviewer and respondent complete the questionnaire during the interview together. This approach avoids unclarities and misunderstandings, which easily lead to implausible or wrong answers.

In the past, similar interviews were often conducted face-to-face, which is very time consuming and expensive. In the meantime, Internet applications have become available thus allowing replacing the in situ interviews by telephone interviews with the questionnaire available on the Internet. With this solution not only the time-consuming journeys can be omitted, but also it is much easier and more flexible to arrange a date for
50

a telephone call. A further advantage is that this concept was already successfully tested in the above-mentioned survey.

Given this general survey setup, further details of the survey design are described in the following sections.

5.1.2 Market Segmentation

5.1.2.1 Introduction

Before we come to the setup of the survey itself, it is important to understand the structure of the Swiss freight transport market, i.e. to get an idea of the volumes transported in the single market sectors. Since one focus of this project lies on estimating shipper sensitivity to environmental aspects in transport demand in connection with the type of commodity shipped, a segmentation of the freight transport market to specific commodity groups is required.

The second aspect relates to the “transferability” of freight volume from one transport mode to another. Since the SP experiments are based on real-world transport samples reported by the interviewee (see section 5.1.4), it is essential that they include choice alternatives, which differ significantly in environmental performance. Since the strongest differences exist between different transport modes (e.g. [BFS (2007)], [DLR ET IFEU (2006)]), the approach was chosen for the experiment design to offer the respondent different transport modes. The respondent, however, can only choose between different modes, if his or her sample shipment could realistically be carried by other modes than the one currently employed. In the following we will denominate such shipments as “transferable” transports.

Transferable transports represent only a minor part of the total transport volume, because several factors, such as commodity characteristics or operational constraints, impede the use of alternative transport modes from an economic viewpoint. Most of the non-transferable transport volume is bound to road transport, but in case of very large volume shipments of raw material (e.g. petroleum products), rail (or inland waterway) transport is often the only realistic alternative (when talking about land-based transport). The goal was therefore to select transport samples, which fulfil the general criteria of “transferability” to not *a priori* restrict the respondent’s choice in the SP experiments through an unsuitable selection of interview partners.

The following sections comprise a detailed description of the actual Swiss freight transport market focussing on the definition of suitable commodity groups and the “transferability” criteria.

5.1.2.2 Transport Distances

The transport distances in Switzerland are an important factor concerning the transferability of freight volume between different transport modes. As illustrated in
Figure 5-1, almost 75% of the internal transport volume is carried not further than 50km from origin to destination. 63% (218 Mt) of the total volume (including all transport segments) are shipped within a 50km-band, and thereof 95% by road transport.

**Figure 5-1: Total Freight Volumes per Distance Class**

Source: adapted from [RAPP TRANS AND IVT (2008)]

Due to this quasi mono-modality in the lower distance classes we decided to exclude from the survey all shipments of less than 50 km overall transport distance. Realistically it would make no economic sense to use rail or even intermodal transport (including intermediate transhipment) on such short distances, except in case of very large volumes (e.g. block train operations).

**5.1.2.3 Commodity Groups**

Since one focus of this research lies on capturing the differences in environmental perception between specific commodity groups, all relevant economic sectors in Switzerland were included in the survey sample. In the first instance the standard goods classification for transport statistics used by Eurostat (see Table 5-1) was drawn on for a segmentation of the transport market.

An analysis of the repartition of the total freight volume to Eurostat commodity groups (based on 2003 data) makes clear that certain groups have few or no relevance for the Swiss freight transport market (see Figure 5-2). 70% of the volume fall upon only five commodity groups, which have a volume share of between 7% and 25% each. Group 24
(“Miscellaneous articles”) is the one with the highest volume (24.06 million tons). This is due to the (unfavourable) classification of all containerised shipments\(^{26}\) in this commodity group.

Table 5-1: Standard Goods Classification for Transport Statistics

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>NST/R Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Cereals</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Potatoes, other fresh or frozen fruit and vegetables</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Live animals, sugar beet</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Wood and cork</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Textiles, textile articles and man-made fibres, other raw animal and vegetable materials</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>Foodstuffs and animal fodder</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Oil seeds and oleaginous fruits and fats</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>Solid mineral fuels</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>Crude petroleum</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Petroleum products</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>Iron ore, iron and steel waste and blast furnace dust</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Non-ferrous ores and waste</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>Metal products</td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>Cement, lime, manufactured building materials</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Crude and manufactured minerals</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
<td>Natural and chemical fertilizers</td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>Coal chemicals, tar</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Chemicals other than coal chemicals and tar</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Paper pulp and waste paper</td>
</tr>
<tr>
<td>20</td>
<td>9</td>
<td>Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>Manufactures of metal</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>Glass, glassware, ceramic products</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>Leather, textile, clothing, other manufactured articles</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>Miscellaneous articles</td>
</tr>
</tbody>
</table>

Source: European Commission – Directorate-General Energy and Transport\(^{27}\)

The scheduled sample size of 200 SP-experiments, however, does not allow constructing specific models for each of the 24 groups with a sufficiently high statistical significance; but Figure 5-2 shows that several classes can easily combined and modelled together: some classes are negligible due to their low volumes (e.g. “Solid mineral fuels” and “Crude Petroleum”), others contain similar products with comparable logistics

\(^{26}\) Herein are included all kinds of intermodal transport containers, such as ISO containers, swap bodies, semi-trailers, etc.

requirements (e.g. class 11 – “Iron ore, iron & steel waste and blast furnace dust” – and class 12 – “Non-ferrous ores and waste”).

**Figure 5-2: Freight Volumes per Commodity Group (Eurostat) in Switzerland 2003 (Road, Rail, and Intermodal Transport)**

Since during the preparation of the 2007 survey the same problems had arisen, we decided to reuse the same classification for this survey, which is a list of seven commodity groups based on the 24 Eurostat groups. During the consolidation process special attention was paid to two aspects:

- Modal-split values of the commodities within each group should be as similar as possible in order to avoid especially road-dominated and rail-dominated products in one group;
- Demand characteristics of the respondents in one group should be as similar as possible to augment the statistical significance of the relevant criteria in the resulting model.

The resulting commodity groups are listed in Table 5-2, followed by a short description of each group.
Table 5-2: Resulting Commodity Classification

<table>
<thead>
<tr>
<th>No.</th>
<th>Commodity group</th>
<th>Eurostat groups included</th>
<th>Tonnage Mtons</th>
<th>Share of total tonnage (%)</th>
<th>Modal share road (%)</th>
<th>Modal share rail (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agricultural raw material</td>
<td>1, 4, 5, 7, 19</td>
<td>7.02</td>
<td>7.2</td>
<td>71</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>Food/animal feed products</td>
<td>2, 3, 6</td>
<td>20.81</td>
<td>21.5</td>
<td>93</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Chemical/mineral products</td>
<td>8-10, 16-18</td>
<td>12.09</td>
<td>12.5</td>
<td>76</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Iron/metal products</td>
<td>11-13</td>
<td>5.19</td>
<td>5.4</td>
<td>83</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Building material</td>
<td>14, 15</td>
<td>18.01</td>
<td>18.6</td>
<td>67</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>Manufactured goods</td>
<td>20-23</td>
<td>9.82</td>
<td>10.1</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Other products and containers</td>
<td>24</td>
<td>24.06</td>
<td>24.8</td>
<td>82</td>
<td>18</td>
</tr>
</tbody>
</table>

Source: adapted from [RAPP TRANSPORT AND IVT (2008)]

Agricultural raw material

This group comprises all kinds of agricultural and forestal raw material including waste paper and textiles. It represents 7.2% of the total volume in 2003 and has a road transport share of 71%. Our hypothesis is that in this group the most important demand factor is transport price because of the low specific values of the products. Due to the same reason environmental aspects are expected to be of low importance to the shippers.

Food and animal feed products

With almost 22% of the total volume this group is the second largest of the seven. It contains all kinds of food products and fodder. The high share of road transport of 93% underlines the high quality requirements of this group especially in terms of on-time reliability and transit time (in case of perishable products). We expect valuation of environmental aspects to be high, because many shippers (esp. retailers) are in direct contact with end-consumers and have environmental aspects often included in their marketing strategy. Eco-labels also play an important role in this sector.

Chemical and mineral products

For the design of this group the similar modal-split values of the incorporated Eurostat commodity groups were decisive with road transport shares of around 76%. The group represents 12% of the total freight volume. Note that Eurostat groups 9 (“Crude petroleum”) and 17 (“Coal chemicals, tar”) have different modal-split values but can be neglected due to their volumes (0.01% and 0.24% respectively of the total volume). The hypothesis is that in this group there is a significant willingness-to-pay for higher environmental performance, because the chemical industry is generally highly sensitive to environmental concerns.
Iron and metal products

With 5.4% this group has the smallest volume share of the seven groups (5 million tons). Thereof, 83% are shipped by road and 17% by rail transport. We expect environmental aspects to be of low importance to the shippers of this group, because most of the products are of low specific value and also no finished products, which are directly sold to end-consumers.

Building material

This group comprises a volume of 18 million tons (19% of total volume), of which 67% are transported by road transport (33% by rail). Due to the same reason stated above for the case of iron and metal products we hypothesise that environmental criteria have no significant impact on freight transport demand.

Manufactured goods

To this group are assigned all manufactured goods (including vehicles and other machinery). Since most of these commodities are high value finished products, logistics requirements in this group are high especially concerning damage/loss and on-time reliability. Price sensitivity is comparatively low compared with other commodity groups. Not surprisingly, road transport has a share of 95% of the volume vs. 5% on rail. Due to the above-mentioned high quality requirements, environmental sensitivity is expected to be low.

Other products and containers

This commodity group is identical to the Eurostat group 24, to which are assigned (in addition to all commodities not fitting in one of the other groups) all shipments in containers and swap bodies, independent of the commodity. Since containerisation has advanced quickly in Europe (including Switzerland), almost 25% (24 million tons) of the total volume are classified in this group. Thereof 82% are carried by road transport, 18% by rail. We decided to assign all intermodal shipments collected in the shipper survey to their proper commodity groups (depending on the product shipped). Since no further “not classifiable” shipments remained, we could then omit this commodity group in the model building step (see section 5.3).

5.1.2.4 Shipment Sizes

The size (or volume) of shipments is another criterion for restricted transferability of transports between modes. Shipments of less than one pallet are normally tied to road transport unless they can be consolidated to larger shipments, which then fit the capacity of railcars or intermodal containers/swap bodies. Today most shipments carried by rail or
intermodal transport have at least full truckload (FTL) size, although in Switzerland intermodal transport is offered also for less than truckload (LTL) shipments. There is no clear lower limit in shipment size, down to which a shipment can be counted as transferable. We nevertheless had to fix a lower bound for shipment sizes to be considered in the survey to avoid unrealistic choice experiments. One pallet was chosen as the smallest potentially transferable shipment size, because below this the probability is very low to have a realistic choice between different land transport modes.

### 5.1.3 Survey Population

In order to define a suitable survey population for the shipper survey, it is advisable to recall the main goal of the survey, i.e. the estimation of shipper valuation of environmental criteria in transport demand in consideration of quality and cost factors. This brings us to three important aspects to be considered during survey setup: the geographical delimitation, the type of shippers to be contacted for the interviews, and the required sample size, each of which are described in detail in the following sections.

#### 5.1.3.1 Geographical Delimitation

In view of a limited time and monetary budget, it was decided to limit the survey to the Swiss freight transport market including inbound and outbound trans-border transports but excluding border-to-border transit traffic. Although the territory of Switzerland is rather small compared to other European countries, the share of the imported and exported volume, respectively, in the total volume (excluding transit) is comparatively low (11% for import, 6% for export). The main focus of the survey lies therefore on the internal transport sector.

In case of interviewed companies with relevant import or export volumes from or to overseas destinations, the geographical scope was limited to Europe, i.e. only the surface transport leg (hinterland transport) of the intermodal transport chains was taken into account.

#### 5.1.3.2 Relevant Shipper Types

Relevant in the context of this survey are all companies that regularly buy freight transport services from a provider. The majority of companies fulfilling these requirements are certainly manufacturing companies, which organise their own inbound and/or outbound transport flows (i.e. shippers in the proper sense). However, also

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28 This transport service is offered by a company called “Cargo Domizil AG”. For further information please refer to www.cargodomizil.ch

29 This refers only to the small size of non-consolidated shipments (e.g. parcels); but certainly several of such shipments can be consolidated into a larger shipment to be transported e.g. in an intermodal swap body.
classical forwarding companies (3PL/4PL) can be considered, because their business is to take over shippers’ logistics activities including the contracting of transport service providers. These replace the shipper in its role as relevant actor for transport demand.

As a consequence, in addition to “real” shippers we decided to include all 3PL/4PL in the survey population, which do not act as proper transport service providers (carriers). Shippers themselves, however, were allowed for, irrespective of whether they were in possession of vehicles or not.

5.1.3.3 Sample Size

In order to obtain models able to demonstrate these differences, the aim was a minimum sample size of 200 examples. If preliminary modelling tests had shown that this number was insufficient, further interviews would have been conducted.

Experiences from the 2007 survey [RAPP TRANS AND IVT (2008)] show that with the proposed adaptive design it is realistic to conduct two SP-experiments with each interviewee thus requiring a minimum total of 100 interviews. Keeping in mind that there will always be some respondents not willing or not able to deliver two different transport examples, a more realistic estimation would be a minimum of 120 interviews to get the total of 200 examples.

5.1.4 Design of the Choice Experiments and the Questionnaire

For the design of the questionnaire to be used for the interviews we could again profit from the experiences made in the above-mentioned 2007 survey, where also an online questionnaire was employed including comparable Stated choice experiments. However, only the general structure of the questionnaire could be reused for this survey, while the specific questions and especially the experiments had to be redesigned.

This section provides a detailed description of the design of the questionnaire and the concept of the choice experiments.

5.1.4.1 Questionnaire Design

Basically, the questionnaire is divided in two parts: a first part with general questions on the company’s logistics structures followed by more detailed questions on the reported transport samples, and a second part with the Stated Choice experiment, which are based on the transport sample described in the first part. Since the goal was to make two experiments with each respondent, the questionnaire is in fact doubled with both parts being repeated after the first experiment (but leaving out the introductory questions of the first part). Appendix A provides a complete example of a questionnaire (including a fictitious transport sample).
The introductory questions focus on the following aspects:

- Freight volumes shipped by the respondent’s company;
- Its organisation of transport logistics activities (i.e. contracting of LSP’s vs. own-account haulage plus transport modes currently used); and
- Infrastructure availability (private sidings or comparable installations).

The following questions relate to the specific transport example to be reported by the respondent. We decided to base the choice experiments on real-life transport samples, because by using this approach, the probability is higher that the interviewee can give detailed information on that special example (e.g. cost data). The alternative would be to use fictitious made-up transport examples (the same for each respondent), but several logistics experts confirmed that shippers have great difficulties to decide on a certain transport solution without knowing details about the logistic requirements of the shipment to be transported. The specific characteristics of the specific commodity type would therefore get lost in the experiment data.

Interviewees were asked to describe a transport of a typical shipment shipped regularly by their company, which satisfies the requirements described in sections 5.1.2 and 5.1.3 (i.e. basically transports with shipments sizes of at least one pallet and a minimum transport distance of 50 km). It can be either an outbound or inbound transport, as long as the organisational responsibility lies with the respondent’s company. The following parameters of the given transport were collected:

1. Commodity description and value;
2. Type of shipment (e.g. LTL, FTL, intermodal shipment etc.);
3. Shipment size (weight and volume);
4. Transport mode employed;
5. Transport distance (including origin and destination);
6. Transit time;
7. On-time reliability requirements (i.e. how tight the time slot is, in which the shipment must be delivered); and
8. Transport price.

Before the actual SP-experiment a ranking question was inserted asking the respondent to rank a list of attributes (including transport cost, on-time reliability, transit time, damage rate, flexibility, and transport’s environmental impact) on a five-point Likert scale according to their perceived relevance. This question served as a plausibility check for the answers given during the SP-experiment and also represents an extension of the list of attributes tested in the experiments. This allows getting at least a rough idea of the impact on transport demand of the criteria not tested in the experiments.
5.1.4.2 Choice of Attributes for the Stated Choice Experiments

5.1.4.2.1 General Approach

Next, interviewees were given a set of 14 choice tasks, each of which presented to them three (unlabeled) offers for transporting the sample shipment. Each of the alternatives was described by a fixed set of five attributes (fixed design), the levels of which depended on the data reported by the respondent (see below). All criteria, which were not explicitly mentioned, were assumed to remain constant at their status quo values.

In order not to overstrain interviewees with too complex choice tasks (which can easily lead to inaccurate results \[\text{SAWTOOTH (2005)}\]), the number of attributes must be limited to the most important criteria. The set of attributes was fixed for each experiment and each respondent, even if some interviewees might consider other criteria (that are not shown) as more important; this was to avoid unmanageable complexity of the resulting models.

If the interviewee considered one of the attributes as irrelevant for the given shipment, he was expected to neglect it in his choice thus also indirectly providing valuable information on this variable. The same can be said for the choice of transport mode. Because of certain preconditions (such as missing rail sidings), the interviewee may not always have the option to choose between all three modes (road, rail and intermodal transport). However, the choice was fixed for all experiments in order to model real market inflexibilities: i.e. in cases, where shippers are dependent on a single transport mode, they should show no reaction to changing values of any variable.

Since with an increasing number of attributes the complexity of the experimental design increases disproportionately, it is advisable to limit the number of attributes to a necessary minimum \[\text{Louvier et al. (2000)}\]. Based on literature review, five (primarily independent) attributes were chosen, which are transport mode, transport price, on-time reliability, transit time, and greenhouse-gas emissions. In order to limit the number of possible combinations, which can be shown to the interviewee, the number of levels one attribute can take should be limited to three or four. Still, for such an experimental setup a complete factorial design\(^{30}\) is impossible, although in this experimental setup only three levels per attribute were modelled. With 5 attributes each having 3 levels, the total number of possible combinations would, however, still be \(3^5 = 243\). A randomised design was therefore used instead to represent a complete design as well as possible and to control the orthogonality of the single variables (for details on this design see section 5.1.4.4).

An overview of the single attribute levels is provided in Table 5-3. A detailed discussion about the choice of attributes and their specific levels is provided in the following.

\(^{30}\) Factorial designs are designs, in which each level of each attribute is combined with all levels of all other attributes \[\text{Louvier et al. (2000)}\].
5.1.4.2.2 Transport mode

The question whether or not to add transport mode as an attribute was subjected to careful consideration. In order to gain empirical evidence, a number of shippers from the 2007 survey were contacted again to state whether they tend to choose between offers of different LSP or rather directly between transport modes. Although a sum of 18 responses cannot be considered as representative, the results show a clear tendency (see Table 5-4). Generally it must be differed between shippers using own-account trucking (i.e. an own vehicle fleet) for at least part of their shipments and others that are not in possession of own vehicles.

5.1.4.2.2 Table 5-3: Overview of Attribute Levels

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport mode</td>
<td>Road</td>
<td>Rail</td>
<td>Intermodal</td>
</tr>
<tr>
<td>Transport price</td>
<td>Status quo value – 20% if Status quo value</td>
<td>Status quo value</td>
<td>Status quo value + 20% if Status quo value</td>
</tr>
<tr>
<td></td>
<td>&lt;1000 CHF, otherwise</td>
<td></td>
<td>&lt;1000 CHF, otherwise</td>
</tr>
<tr>
<td></td>
<td>Status quo value – 10%</td>
<td></td>
<td>Status quo value + 10%</td>
</tr>
<tr>
<td>On-time reliability</td>
<td>85%</td>
<td>92%</td>
<td>98%</td>
</tr>
<tr>
<td>Transit time</td>
<td>Status quo value – 30%</td>
<td>Status quo value</td>
<td>Status quo value + 20%</td>
</tr>
<tr>
<td>GHG-emissions</td>
<td>“Reduction by 50%”</td>
<td>“Status quo”</td>
<td>“Increase by 50%”</td>
</tr>
</tbody>
</table>

Table 5-4: Results of the preliminary survey
(number of responses counted per category)

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Logistics service provider (LSP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own-account trucking</td>
<td>7</td>
</tr>
<tr>
<td>No own-account trucking</td>
<td>4</td>
</tr>
</tbody>
</table>

The result that 100% of the shippers using own-account trucking choose the transport mode themselves appears logical, since the shipper himself must decide for each shipment whether to “make” or to “buy”. In case the shipper has outsourced all of his own transport activities, the situation is less clear. Seven shippers out of eleven (64%) stated that they tend to choose between different LSPs.

There are several reasons for different decision-making processes among the specific firms, but one central aspect are certainly the shipment characteristics: if a shipment’s special logistic requirements (e.g. careful handling, cooling, etc.) are low and if it can be shipped in standardised transport units (e.g. pallets, containers, etc.), then no special equipment is needed for transport, transhipment, and storage. In this case the specific characteristics and abilities of the single transport modes are less important to the shipper so that it can rather leave the proper mode choice to the LSP. This hypothesis is also
supported by the empirical results: 69% of the transport samples of the shippers choosing between LSP were paletted goods and other general cargo with no special logistic requirements.

The decision to include transport mode in the SP experiments was finally made based on the idea not to limit the survey to only one of the shipper groups (i.e. with or without own-account trucking), since this would have reduced the total survey population significantly. The result was a compromise: the alternatives in each choice task were not labelled as “modes” explicitly but rather as neutral transport service offers (denoted as A, B, and C). Transport mode was included as a characteristic attribute of these offers. In other words, interviewed shippers had to choose between offers of different LSP. Mode is just one attribute out of five characterising the transport service offer of a specific LSP. Using this experimental set-up the respondent does not necessarily have to consider mode in his/her choice, but it is equally possible for him to exclude a given alternative due to mode-specific constraints.

Since this project focuses on shipper demand for land-based freight transport in Switzerland, the three most relevant transport modes used in this context were selected for the mode attribute, i.e. road-only transport, rail-only transport, and intermodal transport road-rail. Rail transport refers to monomodal transport chains, where the shipment is carried by single railcars from siding to siding (without intermediate transhipment of the transport container. The latter is referred to as intermodal transport with at least one intermediate transhipment between different modes.

A special case for seaport hinterland traffic to and from Switzerland is the river Rhine axis, on which a substantial volume of the traffic to and from Rotterdam is carried. Transport samples using inland waterway transport were also classified as intermodal transports (i.e. use of waterway plus road or rail transport, respectively). In the experiment, this specific intermodal option then replaced the intermodal road-rail transport.

5.1.4.2.3 Transport price

The price for transport services is certainly one of the most important criteria for the shipper, since logistics costs are generally major cost drivers in shippers’ overall costs [IHDE (2001)]. In the context of the SP-experiments we use the term “price” rather than “costs”, because we assume that shippers buy a transport service from an external LSP and thus must compare between prices for the transport alternatives offered.

For the three levels of the price attribute the status quo value was taken as stated by the respondent in the first part of the interview. Although this value refers only to the transport mode actually used, it was applied for all three available modes. The option to ask respondents also for prices for the transport modes not used was discarded due to negative experiences during the 2007 survey of RAPP TRANS AND IVT (2008): most respondents had shown difficulties even when asked to give just rough estimations.
Since also shippers with own-account haulage were included, reported transport prices reflect either the total price paid to the LSP or (in case of own-account haulage) the operational costs for carrying the sample shipment from origin to destination, including at least wage costs and variable costs for the vehicle\(^ {31}\).

For upper and lower levels the reported value was then increased and diminished, respectively, by 20%, if the value was below 1000 CHF, and by 10% from 1000 CHF upwards. The choice of these values is based on separate interviews with logistics experts and experiences from the pilot survey, which was carried out before launching the actual survey.

### 5.1.4.2.4 On-time reliability

Of similar importance as price is the shipment’s on-time reliability, at least for high-value commodities (compare section 2.3.1). In the experiments, reliability values are given in percentage of shipments arriving on time (i.e. punctual) at their final destination, where punctuality is defined by the time frame given by the receiver. If, for example, a shipment is required to arrive between 6 a.m. and 7 a.m., an on-time reliability value of 95% means that 5% of the transports arrive later than 7 a.m.

The attribute levels were fixed for all experiments at 85%, 92%, and 98%. These values were approved by different logistics experts and reflect the experience that many shippers consider values of less than 90% as unacceptable, while their sensitivity is less significant for values between 92% and 98%. This behaviour proved true in several of the conducted experiments.

### 5.1.4.2.5 Transit time

Transit time is the third of the three relevant demand criteria in freight transport and thus incorporated as a separate attribute in the experiments. The values are given in absolute numbers and are derived from the status-quo value given by the respondent (measured in hours). According to the attribute levels chosen for the price attribute, the status-quo value is transferred directly into the experiment and then increased by 20% for the upper value and decreased by 30% for the lower value, respectively.

These values are based on the consideration that from a transport system viewpoint (be it road, rail, or intermodal transport) it is technologically and economically difficult to increase system speed by far more than 30% for any transport mode. The greatest potential lies in wagonload rail transport by reducing the very long dwell times of railcars in shunting yards. Freight trains’ low priority in the European railway network furthermore lead to frequent stops of freight trains in general thereby also increasing point-to-point travel time. An increase in travel time of more than 20%, however, appears

\(^{31}\) The respondent was not asked explicitly, whether fixed costs for vehicles (i.e. taxes, insurance, and annuity costs) were included in the cost estimation or not.
also unlikely, because, in case of road transport, this would mean an increase in time lost in traffic congestions enough to decrease average speed by more than 20%. Such would not be accepted by the carrier due to an unacceptable increase in operational costs causing it to reroute the transport or (if possible) shift it to less congested times of the day. Similarly, due to operational cost limits rail operators would not accept such low quality train paths, which further reduce average speed of the train by more than 20%.

The difference in transit time between transport modes (which can easily exceed 50% especially over shorter distances) was not accounted for directly in the attribute levels, i.e. both attributes were independent of each other. This is due to limited comparability of actual transit times of the different transport systems: while in road transport shipments (at least in case of full truckloads) are normally transported directly to the receiver immediately after loading of the lorry, in rail and intermodal transport the concept of overnight delivery is frequently used (i.e. collection of the shipment in the evening, delivery in the early morning). Although in the latter case the effective transit time is much higher than for a comparable road transport over the same distance, the difference is often irrelevant to the shipper, because the shipment is only required the next morning.

5.1.4.2.6 Greenhouse-gas emissions

For the additional variable representing the environmental impact relative values for each level were chosen rather than absolute ones. The main problem using absolute numbers for e.g. greenhouse gas emissions is that it would be difficult to calculate these values online during the interviews according to the specific transport chain given by the respondent. The difference for the interviewee, however, is small, because we expect that he would have difficulties comparing the absolute numbers with numbers from other processes, such as production. Therefore he is likely to just compare between the levels of each of the different options to choose between so that there will be no lack of information when using relative numbers.

The attribute levels were therefore set in analogy to the other attributes to a Status quo level (without giving an absolute number) plus a 50% reduction and increase of this value, respectively. The idea was to get values as realistic as possible, which apply for all transport examples and at the same time show significant differences between the three levels. These margins of 50% in GHG-emissions between transport modes were also verified for a number of fictitious transport samples using a publicly available online calculation tool\textsuperscript{32}.

A couple of unrealistic constellations in the experiments’ transport offers could not always be avoided due to the independence of the emissions attribute of the mode attribute: the rail alternative could well be offered with an increase by 50% of GHG-emissions compared to the road alternative. For short distance transports this is indeed a

\textsuperscript{32} EcoTransIT (for details see www.ecotransit.org)
rather theoretic constellation; but for longer transport distances the margin could be explained with higher emissions of rail transport for certain transport chains due to possibly longer transport distances (if rail transport includes large detours via a classification yard) and additional emissions from e.g. shunting processes. Furthermore, older diesel locomotives can have much worse emission balance sheets as compared to lorries complying with the Euro 5 emission class.

5.1.4.2.7 Attributes not included in the experiments

As explained above, more than these five attributes could not be included in the experiments thus leaving out a number of possibly also relevant demand criteria. If we look at the ones additionally included in the ranking question, the frequency attribute was left aside because of the results of the literature review on relevant demand factors and based on the 2007 survey results.

Furthermore, shippers would certainly react very strongly to changes in damage rate of a shipment, but generally it is difficult to clearly identify the responsible actor in case of damage. Damage most often occurs during loading and unloading of the transport container (lorry, railcar, or intermodal container). This damage cannot be assigned to the transport service provider thus making this aspect not directly relevant to the choice of transport service. Damage rate was therefore left out as an attribute in the SP-experiments.

Finally, flexibility in reacting to short-term demand for transport services is another aspect, which is generally not irrelevant to shippers (and sometimes even more relevant than transit time [RAPP TRANS AND IVT (2008)]). However, we decided not to include it in the design, mainly because it can be interpreted in different ways and is thus easily misunderstood by respondents. In our survey, flexibility was defined as the provider’s minimum reaction time to provide additional transport volume (e.g. a short-term transport in case of a client’s urgent order), but it can also be understood as “on-line” flexibility along the transport chain (e.g. changes in delivery time, spontaneous change of transport mode, etc.). Furthermore, the decision to include transit time rather than flexibility was made to ensure comparability of results with previous studies, especially the ones for Switzerland, which all included time but flexibility only in two cases ([RAPP TRANS AND IVT (2008)], [BOLIS AND MAGGI (1999)], [IRE AND RAPP TRANS (2005)]).

5.1.4.3 Hypotheses Concerning Impact of Attributes on Shipper Choice

With respect to the above-mentioned attributes included in the choice tasks the following hypotheses can be formulated concerning their impact on shipper choice: an increase in transport price and transit time would most probably decrease the probability of choosing the respective alternative, while an improved on-time reliability would have a positive influence. These hypotheses are also supported by empirical results (see e.g. [RAPP TRANS AND IVT (2008)], [VELLAY AND DE JONG (2003)]).
The impact of transport mode on choice behaviour is less evident, since several characteristics (in addition to the attributes explicitly included in the choice tasks) are often associated with one of the available modes: rail-only and intermodal transport for example are often thought of to be safer (in terms of shipment damage) than road transport, while the latter is expected to be for instance more flexible. However, we assume that infrastructure and vehicle availability would often have the most significant impact on the acceptability of a certain mode: rail-only transport for example can only be chosen if both, origin and destination of the shipment are accessible by rail. Furthermore, special vehicles are sometimes required for certain shipments (e.g. a building material delivery to a construction site requiring a lorry with on-board crane equipment). Therefore, a simple hypothesis on transport mode impact is not possible; we rather expect to get diverging (commodity- and location-specific) results.

A hypothesis on the influence of increasing pollutant emissions is not straightforward either. However, our assumptions are based on the general research hypotheses formulated in chapter 1, according to which an increase of emissions is expected to have a significant negative impact on choosing the according alternative (at least in some commodity groups). Experiences made during the 2007 survey [RAPP TRANS AND IVT (2008)] let us assume that shippers, which are in direct touch with end-consumers (e.g. retailers or nutrition producers) or are regularly shipping dangerous goods, are more sensitive to environmental concerns than others. This can be accounted for by the fact that end-consumers are increasingly concerned by sustainability issues and expect manufacturers and retailers to behave in a similar way. Furthermore, shippers of dangerous goods (e.g. from the chemical industry) often set value on their “green image”, because public awareness of their activities (especially in case of accidents) is especially high. The German chemical company BASF for example is currently actively promoting the information that it “is the world's first company to present a comprehensive carbon balance". On the other hand, other sectors (such as the building materials industry) are expected not to take much notice of their freight transports’ environmental performance. These four attributes (i.e. price, on-time reliability, time, and emissions) are characteristics of the transport chain chosen. However, it is common knowledge (e.g. [PATTERSON ET AL. (2007)]) that interactions exist between these attributes and the shipper and/or shipment characteristics (e.g. infrastructure availability, shipment size, transport distance, etc.). For a selection of interactions with an expected relevance our hypotheses are as follows.

33 This is illustrated by the development of the Swiss market of bio-products: its share is continuously growing by an average of 18% having meanwhile reached a share of 4.5% of the total food products market. For details please refer to http://www.coop.ch/pb/site/common/node/7115/Lde/index.html (accessed 29/APR/2009).

A direct rail access (rail siding) at the shipper’s location should increase probability of choosing the alternative with rail-only transport, although this does not guarantee the ability of using this mode, since both ends of the transport chain must be equipped accordingly.

Increasing distance of a transport is likely to raise a shipper’s sensitivity to price because of an increasing share of transport costs in total production costs of a product. It might on the other hand decrease sensitivity to on-time reliability requirements, since shippers should be aware of the higher delay risk in case of long distance transport chains.

Concerning shipment characteristics, perishable goods are (quite evidently) expected to increase transit time (and maybe on-time reliability) requirements of the shipper, while in case of dangerous cargo rail and intermodal transport are likely to be appreciated compared to road-only transport because of their (perceived) lower damage risk. Furthermore, as mentioned above, it is possible that shippers of dangerous goods are more sensitive to GHG-emissions than others.

These hypotheses will later be verified using the results of the estimated choice models (section 5.3).

5.1.4.4 Design of SP-Experiments

For SP-studies different methods can be used to collect the respondents’ answers during an interview. The experiments applied in this project are often referred to as choice based conjoint (CBC) studies. Generally, CBC studies are employed for analysing respondents’ preferences for different combinations of features, by which products or services are characterised. Their characteristic, as compared to other SP-methods, is that respondents express their preferences by choosing one of the presented concepts rather than by rating or ranking them [SAWTOOTH (2005)]. In our questionnaire each choice task was presented to the interviewee in the following form (Figure 5-3):

**Figure 5-3: Screenshot of a Choice Task in the Questionnaire**
Each choice task consists of three alternative transport service offers (“Angebot”), one of which the respondent must choose. The five attributes characterising the alternatives (see above) are listed in the table. In each choice task all three different levels of each attribute are displayed. By combining the levels of the alternatives in different ways, different choice tasks were created (see below). This was done automatically using a software tool called “CBC/Web”, a special module for creating CBC designs within the software package SSI Web (see section 5.1.4.5).

As mentioned above, the experimental design with five attributes each having three levels does not allow using a complete factorial design. The alternative consists in applying fractional designs. In such designs a particular subset (or “fraction”) of complete factorials is selected so that particular effects of interest can be estimated as efficiently as possible [LOUVIERE ET AL. (2000)]. Fractional designs are based on the assumption that interactions between one or more attributes are not significant.

In this context the so-called efficiency of a design is relevant. One design is called efficient relative to another design, if its variance is lower [MAIER AND WEISS (1990)]. There is, however, a difference between a design’s efficiency for estimating on the one hand main effects and on the other higher-order interactions (i.e. effects, for which the design was not originally produced). Therefore, although fixed orthogonal designs are generally most efficient in estimating main effects, they have difficulties estimating higher-order interactions.

The alternative consists in using randomised designs. This is facilitated by the fact that the CBC/Web software provides four different randomised design strategies. The “complete enumeration” strategy was chosen, because the focus of the survey lies on the estimation of main effects, i.e. the utilities of the single attributes, especially the one of the environmental performance.

The complete enumeration method is not, strictly speaking, random, but the designs are optimised in a way that each attribute level is shown as few times as possible in a single choice task and shown approximately an equal number of times. Furthermore, attribute levels are chosen independently of others so that each attribute level's effect (utility) may be measured independently of all other effects [SAWTOOTH (2005)]. A simulation study comparing the so-called “D-efficiencies” of different design strategies (as recommended by KUHFELD ET AL. (1994)) showed that the complete enumeration method is most efficient of all strategies for estimating main effects and has a relative efficiency of 94% of the best strategy for estimating interactions [CHRZAN AND ORME (2000)].

The design created by CBC/Web was used for all experiments in all interviews (i.e. there were no different versions of the questionnaire. The absolute values presented to the specific respondent were of course different in every experiment, since they were derived from the data provided by the interviewee during the first part of the interview.

Basically, there is no way of calculating the optimal number of choice tasks in one experiment, but experiences from the interview software provider (Sawtooth Software,
Inc.) show that for such experimental designs respondents can realistically answer between 10 and 20 choice tasks before getting tired or annoyed [Johnson and Orme (1996)]. Based on our experiences from the 2007 survey, we decided to include 14 choice tasks in each experiment (thus obtaining 28 observations per respondent, since each interview contains two experiments). After survey completion it can be stated that this proved to be a suitable number, which caused no problems with respondents during the interviews.

This was furthermore verified by comparing two Mixed Logit (ML) models with the same variables as the definite model for the total survey sample (this is introduced in detail in section 5.3.3): one including the first seven choice situations of each respondent, and the other one covering the second half of situations. A comparison of the two Likelihood ratio test results shows that the quality of both models is at a comparable level but that the second model (with a value of 1094.789) actually fits the survey data slightly better than the first (1082.225). An increase in irrational choice decisions at a higher number of choice tasks is therefore not observable thereby justifying the total of 14 choice tasks.

5.1.4.5 Implementation of the Questionnaire

The complete questionnaire was implemented using the “SSI/Web” software package, a product of Sawtooth Software, Inc. This program allows creating and administering entire computer-based (online and offline) surveys. For this survey the CBC design for the experiments was directly integrated into the general questionnaire including the introductory and data collection part (see section 5.1.4.1).

After implementation and testing, the questionnaire was uploaded to a web server, which provided the (password-protected) online access for respondents. A web interface allows the survey administrator to access the survey data at any time (e.g. for deleting invalid data sets).

5.1.5 Realisation of the Survey

5.1.5.1 Interview Procedure

The main survey took place between April and December 2008. Respondent firms were recruited mainly from two sources:

1. Respondents from the 2007 survey having agreed to participate also in the second survey; and
2. A list of the largest companies in Switzerland 2007 [Handelszeitung (2007)].

Potential respondents (i.e. manufacturing and freight forwarding companies) were contacted according to the following schedule:

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35 For details please refer to www.sawtoothsoftware.com/products/ssiweb/
1. First contact via telephone trying to identify the appropriate logistics expert within the firm;
2. After establishing contact with the potential respondent, the project was roughly explained and asked, whether he would be willing to participate and whether the company would generally fulfil the basic requirements (compare section 5.1.3);
3. If the respondent agreed, additional information was sent via e-mail;
4. Second telephone call to determine, whether the respondent could provide suitable transport samples; if so, fixing of a date for the interview; and finally
5. Third telephone call for actually conducting the interview.

Since for most companies no direct contact to a logistics manager is published on the Internet, the switchboard had to be contacted first to ask for the appropriate person. When contact was established to the appropriate logistics manager, the purpose of the project was briefly explained, and, in case of no immediate refusal, an e-mail was sent with detailed information including the data to be collected during the interview and a confidentiality undertaking. Often a second phone call was necessary to fix a date for the interview, because many respondents preferred to first check the e-mail documents in detail before giving a definite OK.

The interviews were conducted entirely by the author himself. First, the interviewee was contacted on the telephone and asked to access the survey web page using the password preliminarily provided via e-mail. The interviewer could see the active page of the questionnaire using the same link. During the interview’s first part it was important to assist the respondent in the choice of a transport sample and in explaining to him the single questions to avoid misunderstandings.

During the experiments (in the second part of the interview) the interviewer was reading out the values of the attributes to the respondent, starting with the more important ones according to the results of the ranking question (in which the respondent must rank the relevance of the single attributes on a five-point Likert scale). By this procedure many implausible answers could be avoided, because the interviewee was forced to actually read the different values thus actively comparing the presented alternatives. Otherwise the risk would have been great that the respondent would click more or less unconsciously through the choice tasks.

After completion of the first experiment the respondent could choose whether to participate in a second experiment or not. This option was also omitted if transport logistics processes of the interviewed firm were more or less uniform. This would be the case, for example, if the company produced but one product to be shipped, the logistic requirements thus being more or less identical. The question concerning environmental management system and labelling schemes used were asked at the very end of the questionnaire in order not to put too much weight on this point and thus influencing the respondent in this direction during the experiments.
5.1.5.2 Experiences from the Interviews

Basically, the overall positive experiences made during the 2007 shipper survey [RAPP TRANS AND IVT (2008), p. 39] were supported: first contacts via telephone were rarely rejected immediately by the reception, so that logistics managers could be reached to ask for their willingness to participate in an interview (although a second or third phone call was often necessary due to their frequent absence from the office). In case a shipper could not participate, this was mostly due to non-compliance with general requirements to sample shipments (compare sections 5.1.2) or to general transport logistics organisation (compare section 5.1.3). A minor part of potential respondents refused due to lack of time or general disaffirmation of the project.

During the interviews problems frequently arose, when interviewees had not properly read the instructions to the interview provided beforehand via e-mail: the transport examples reported did sometimes not match the above-mentioned requirements and could therefore not be used. Furthermore, several respondents could not answer all of the questions asked to characterise the given transport chain (e.g. shipment value); in this case assumptions had to be made for mandatory data fields in agreement with the interviewer.

General problems of respondents with the interviews and especially with the Stated Choice experiments were rare, and most interviewees did not complain about the number of choice tasks (14 for each transport example), which confirms the empirical results of JOHNSON AND ORME (1996). On the other hand, the interviewer had to point out repeatedly the hypothetical character of the alternatives presented in the choice tasks; most confusion was caused by the GHG-emissions attribute, because its levels were independent of the transport mode of the respective alternative. Therefore, many respondents had problems believing that for example the use of rail transport could produce 50% more GHG-emissions compared to road-only transport.

55% of the respondents provided a second transport example; the remaining 45% refused due to time reasons or (in often in case of smaller shippers) because the first example was the company’s only one matching the survey requirements.

5.2 General Survey Statistics

5.2.1 Resulting Survey Sample

5.2.1.1 Overview

Before coming to the modelling process, a couple of general statistics of the survey sample will facilitate the interpretation of the resulting demand characteristics. In total a sum of 198 transport samples were recorded during 128 interviews (thus equalling an average of 1.5 transport samples per respondent). A detailed overview of the total survey sample is given in Table 5-5.
Table 5-5: Overview of survey sample

<table>
<thead>
<tr>
<th>Sector</th>
<th>Agricult. raw mat.</th>
<th>Food/animal feed products</th>
<th>Chemical/mineral products;</th>
<th>Iron/Metal products</th>
<th>Building materials</th>
<th>Manufact. goods</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal</td>
<td>2</td>
<td>32</td>
<td>3</td>
<td>8</td>
<td>14</td>
<td>26</td>
<td>85</td>
</tr>
<tr>
<td>Import</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>16</td>
<td>34</td>
</tr>
<tr>
<td>Export</td>
<td>3</td>
<td>2</td>
<td>17</td>
<td>6</td>
<td>0</td>
<td>40</td>
<td>68</td>
</tr>
<tr>
<td>External/Transit</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6</strong></td>
<td><strong>40</strong></td>
<td><strong>35</strong></td>
<td><strong>18</strong></td>
<td><strong>15</strong></td>
<td><strong>84</strong></td>
<td><strong>198</strong></td>
</tr>
</tbody>
</table>

43% of the total sample are internal transports in Switzerland, 51% border crossing (import/export), and 6% transit transports or other transports outside of Switzerland. With 34 transport samples the import segment is underrepresented compared to the export segment (68 shipments). This can be reasoned by shippers’ logistics organisation: since most of them are not responsible for the planning and organisation of inbound shipments and most of the interviewed shippers are located in Switzerland, the likeliness of reporting an import transport into Switzerland is lower than choosing an export as typical transport for the Stated Choice experiment.

When looking at commodity groups, three groups are fairly well represented (Food & animal feed products: 20%, Chemical & mineral products: 18%, and Manufactured goods: 42%), while for the remaining ones it was difficult to find more companies willing to participate in the survey. This is mainly due to the specific structure of each economic sector: while the manufactured goods sector is dominated by many small and medium size companies, the number of independent firms for example in the agricultural sector is much smaller.

5.2.1.2 Distance Classes and Transport Segments

Figure 5-4 shows the repartition of transport samples to distance classes and transport segments: (except in the two highest distance classes) their distribution corresponds well with total freight volumes in Switzerland (compare Figure 5-1), i.e. the number of transport samples decreases with increasing transport distance.
Most of the recorded shipments are either internal transports up to 200 km or border crossing relations of more than 700 km. This high share of long-distance shipments is due to the required transport chain characteristics with minimum shipment size of one pallet and transport distance of at least 50 km. The latter aspect is also the reason why the lowest distance class of up to 100 km has only 30 samples (it effectively represents a distance band of only 50 km).

Most of the long-distance shipments are seaport hinterland connections to and from the north range ports (between Hamburg and Le Havre). Considering the geographical characteristics of Switzerland, it is plausible that internal transports are limited to 300 km (except one example above 400 km, which is a shipment between Ticino and the Geneva region).

5.2.1.3 Modal Split

In terms of modal split the survey sample can also be considered as representative (Figure 5-5): in total (over all transport segments) road-only transport has a share of 70%, while rail and intermodal transport are on a comparable level of 14% and 17%, respectively. Road share is relatively high when compared to the 2003 freight transport performance statistics, but this is due to the low fraction of transit transports in the survey sample.
When looking at specific transport segments, results match even better with statistics: road has a share of about 80% in internal transport and of around 60% in import/export. Intermodal transport is slightly over-represented in the survey sample; but the fact that rail has a comparable share in internal and export transport and a greater share in import again complies well with 2003 transport performance data. This has to do with the high share of raw materials imported into Switzerland, which are more suitable for rail-only transport than manufactured goods.

**5.2.2 Shipment Sizes of the Survey Sample**

A comparison of shipment sizes between commodity groups is given in Figure 5-6. Over the whole survey sample the median shipment size is at 12 t with 50% of the sample shipments having a size between 3.2 and 22 tons. This wide spread can be observed also in the single commodity groups; group 1 (agricultural raw material) has the widest spread ranging from 21.3 to 50 tons. The median values nevertheless appear plausible keeping in mind the focus of the survey on full truckload (FTL) shipments and the lower limit set to one pallet. While the median values of commodity groups 2 to 5 are between 15 and 20 tons (i.e. in the range of a typical FTL), group 1 has a much higher median of 37.5 t due to its high share of larger bulk shipments. The manufactured goods group (no. 6) has a median more than 50% below the global median (4.9 t vs. 12 t). This result illustrates well the typically low batch sizes for high value commodities, which are mainly part of this commodity group.
Figure 5-6: Median Shipment Sizes of the Survey Sample per Commodity Group

5.2.3 Commodity Values of the Survey Sample

The significantly higher commodity values in this group as compared to other commodities become clear when plotting specific values per ton (Figure 5-7): the median for group no. 6 is at 15’000 CHF/t. Although the dimension is correct, this value is not very resilient because of the large variance in the survey sample (50% of the sample shipments between 1’150 and 47’500 CHF/t; the global maximum is at 30 million CHF/t for a transport of precious metals). The values of the other commodity groups are more consistent. Medians of the agricultural raw materials (575 CHF/t) and the building materials groups (175 CHF/t), respectively, are far below the ones of groups two, three, and four, which is due to the same reason as mentioned above: groups one and five consist mostly of rather low value raw materials, while commodity values in the nutrition, chemical, and metal processing sectors are generally higher due to their position in the value creation chain.
Figure 5-7: Median Commodity Values of the Survey Sample per Commodity Group

The relative margins between commodity groups match quite well with the statistics of the 2007 survey sample [RAPP TRANS AND IVT (2008), p. 31], but absolute numbers are between 1.5 and 4 times higher (except in group no. 1). This might be reasoned with the allowed minimum shipment size for the survey sample, which was at 5 t in the earlier survey. Anyway, the illustrated results of this survey are taint with rather large uncertainties, since in most cases respondents could only give rough estimations on specific commodity values of the sample shipments.

5.2.4 Transport Prices of the Survey Sample

5.2.4.1 Prices per Transport Mode

Maybe the most interesting results of this section are the transport prices actually paid for the reported transport services. The comparison of prices per transport mode (Figure 5-8) shows a generally plausible picture but again with large variances around the median values. Since prices are calculated per ton-kilometre, it makes sense that road prices are significantly higher than the ones for rail and intermodal transport: most shipments carried by lorry are either of less than truckload size (LTL) or volume goods with low density. This is also illustrated by the high variance of road prices. Furthermore, road transport shipments generally have lower transport distances than rail and intermodal
shipments. Total results over the whole sample are strongly influenced by the high share of road shipments thus resulting in a rather high median\textsuperscript{36} of 0.31 CHF/tkm.

**Figure 5-8: Median Transport Prices of the Survey Sample per Transport Mode**

When comparing these results with the ones from the 2007 survey [RAPP TRANS AND IVT (2008), p. 34], values for rail and intermodal transport match well, while road transport prices are more than 40% higher (0.37 vs. 0.26 CHF/tkm). This can again be reasoned with the difference in minimum shipment size (as mentioned above). We recommend these new results as a more representative reference, since in the 2007 survey an important fraction of the freight transport market (shipments below 5 t) was not taken into account.

\textsuperscript{36} This is the unweighted median of the total sample.
5.2.4.2 Prices per Commodity Group

The comparison of commodity-specific transport prices (Figure 5-9) shows that in most commodity groups, median values are between 0.13 and 0.31 CHF/tkm, while the manufactured goods group has a median of 0.56 CHF/tkm with a strong variance (50% of the values between 0.19 and 2.08 CHF/tkm). More surprising is that values of the iron and metal products group also show a strong variance (50% between 0.11 and 1.90 CHF/tkm). It is true that for example steel coils have high quality requirements for the transport process and need special transport equipment, but the main reason for this high variance probably lies mainly in the small number of transport samples in this group. Finally, the low and homogenous prices in the combined group of agricultural raw materials and chemical/mineral products originate mainly from the typically long transport distances of FTL-size (and larger) shipments.

Figure 5-9: Median Transport Prices of the Survey Sample per Commodity Group

Note that for the model building process (including price analysis) commodity groups 1 and 3 were combined due to statistical reasons (see below). The low variance of prices within this twin group shows that the combination is justified for price analysis.
5.3 Estimating Shippers’ Transport Demand

The main goal of the survey is to estimate relevance of shipper demand criteria using Stated Choice experiments. Therefore, a selection of different econometric models (so-called “discrete choice models” – see e.g. [DOMENCICH AND MCFADDEN (1975)], [LOUVIERE ET AL. (2000)]) was tested on the resulting data sets to derive willingness-to-pay (WTP) estimations, which are statistically significant and reliable. This process is described in the following sub-sections.

5.3.1 Data Preparation

For setting up and testing the models, the open source application “Biogeme” (version 1.6)\(^{38}\) was used [BIERLAIRE (2003)]. Before feeding Biogeme with sample data, the data had to be extracted from the web server using the web interface provided by SSI/Web (compare section 5.1.4.5) and then converted into the required data format\(^{39}\). Data conversion was done in Microsoft® Excel® using Visual Basic programming.

The conversion process also included a general check on data plausibility. Since during the interviews respondents had to type their answers themselves into the data fields of the online questionnaire, typing errors occurred quite frequently. These could later be corrected after extracting the data sets from the web server, but this did not solve the problem of implausible answers during the experiments (be it unintentionally or on purpose). Therefore, after termination of the survey three types of plausibility checks were performed automatically on the survey data:

- Did respondents (always or by the majority) choose alternatives in the same position on the screen (i.e. left, middle, or right)?
- Did a respondent prefer a specific transport mode (i.e. always choosing road, rail, or intermodal transport) while ignoring differences in price, on-time reliability etc.?
- Did respondents choose an alternative including rail transport although not being equipped with a rail siding? (It was assumed during the interviews that in case of missing rail access at either end of the transport chain the rail transport alternative should be neglected in each choice task.)

Conspicuous observations were then checked manually and, in case of obvious implausibility, removed from the data file fed into Biogeme. These checks reduced the original survey sample by 63 observations to 2709. Actually, the problem of a respondent just “clicking through” the choice experiments did not occur. This was due to the fact that during the experiments the interviewer was actually reading out the values of the

\(^{38}\) For details on the current version of Biogeme including user’s manual please refer to http://biogeme.epfl.ch

\(^{39}\) A detailed description of the data formats used in Biogeme is provided in the user’s manual.
attributes to the respondent, thus forcing people to consciously compare each alternative with the others (compare section 5.1.5.1).

5.3.2 The Model Development Process

5.3.2.1 General Approach

In general, the modelling process implies three main assumptions [MAIER AND WEISS (1990), p. 171]:

1. The choice of model type (i.e. the distribution of error terms);
2. The variables to be included in the model; and
3. The functional form of the variables’ combination (i.e. the utility function).

Unfortunately, these three assumptions are not independent but influence each other: if for example a variable tested with a specific model appears to be insignificant, this result may be influenced by the choice of model type, i.e. it might be significant when being tested with a different model. Therefore, in this research it was decided to make initial assumptions concerning error terms distribution and form of the utility function and to test for significance of the variables expected to be relevant for shipper choice (for the hypotheses compare section 5.1.4.3). The most important statistical instruments for testing the significance of variables are a) the t-test and b) the likelihood-ratio test (or the likelihood-ratio indices $\rho^2$ and $\rho^2$ adjusted, respectively) [MAIER AND WEISS (1990), p. 176].

5.3.2.2 The Multinomial Logit Model

Based on experiences with earlier research in transport demand modelling (compare section 4.1) and recommendations in literature (e.g. [MAIER AND WEISS (1990)], [LOUVIERE ET AL. (2000)]), initial tests were made with a Multinomial Logit (MNL) model and utility functions with linear combination of its parameters (also referred to as “linear-in-parameters”). As explained in the following section, the Logit model family together with linear-in-parameters utility functions were also used for the final model.

In light of the wide range of available choice models the question arises why to start the modelling process with an MNL model. One reason is that the Logit model, which results from the assumption that error terms are independent and identically Gumbel distributed, is probably the most often used discrete choice model. The frequent use of this model family has its reason: in contrast to other models, such as the Probit model, the choice probabilities of the Logit model are available in an analytically closed form. In case of the Probit model their values must instead be approximated by e.g. numerical integration, Monte-Carlo-Simulation, or other comparable methods [MAIER AND WEISS (1990), p. 146]. Another reason are the comparably short solver runtimes for estimating Logit models compared to other types, which again is an advantage of the probabilities’ closed form.
When choosing the Logit model, one must keep in mind its underlying basic assumption of independent error terms, which leads to its characteristic independence from irrelevant alternatives (referred to as “IIA property” – see e.g. [LOUVIERE ET AL. (2000), p. 44]). This property is both a strength and a weakness of this model: its strength is the possibility to introduce and/or eliminate alternatives in choice sets without the need to re-estimated the model. The weakness lies in the restrictive model structure, which does not allow using the Logit model for all problems to solve, especially not for choice sets, where correlation between error terms must be assumed. Nevertheless, in practical application with such a restrictive model the risk is much lower to shift systematic effects into the random component, where they influence the parameters of the variance-covariance-matrix and thus cannot be clearly identified as such [MAIER AND WEISS (1990), p. 142]. Models with a less restrictive structure (such as the Probit model) are recommended in cases, if correlated error terms are to be expected based on theoretical considerations [MAIER AND WEISS (1990), p. 148]. A typical case of correlated error terms are nesting structures (i.e. multi-level choice decisions)\(^{40}\), but since we used unlabelled alternatives for the choice tasks, there is no reason for assuming a nested decision structure.

Based on the stated assumptions, a first model was built to test for significance of the main variables (without interaction terms except the influence of rail accessibility on rail transport choice). The main choice attributes price, on-time reliability, transit time, and GHG-emissions were included as generic variables, while transport mode was considered as two alternative-specific constants (one for rail-only and one for intermodal transport). The detailed results of this MNL model are listed in Appendix B.

### 5.3.2.3 The Mixed Logit Model\(^{41}\)

An important aspect of the applied survey design with 14 choice tasks per experiment is the problem of repeated measurements, i.e. during an interview 14 observations (or even 28 in case of two transport samples reported) were recorded from a single respondent. Each respondent has a specific background and way of dealing with choice tasks so that the model must be corrected for respondent-specific effects (also referred to as “unobserved heterogeneity”), which are not directly observable with the explanatory variables.

In order to account for this problem, a Mixed Logit (ML) model is generally applied. The ML model is a highly flexible model, which can approximate any random utility model. It obviates the three limitations of the MNL model by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time. The ML model is defined on the basis of the functional form for its choice probabilities. Any

\(^{40}\) For details on the Nested Logit model please refer to the according literature, e.g. [MAIER AND WEISS (1990)]; [LOUVIERE ET AL. (2000)].

\(^{41}\) This section draws mainly on [TRAIN (2003), p. 138-154] and [LOUVIERE ET AL. (2000), p. 199-205].
behavioural specification whose derived choice probabilities take this particular form is called an ML model.

ML probabilities are the integrals of standard logit probabilities over a density of parameters. Stated more explicitly, an ML model is any model whose choice probabilities for alternative \( i \) and individual \( n \) can be expressed in the form

\[
P_{ni} = \int L_{ni}(\beta) f(\beta) \, d\beta
\]

with \( L_{ni}(\beta) \) – logit probability evaluated at parameters \( \beta \): \( L_{ni}(\beta) = \frac{e^{V_{ni}(\beta)}}{\sum_{j=1}^{J} e^{V_{nj}(\beta)}} \); \( f(\beta) \) – density function; and \( V_{ni}(\beta) \) – the observed portion of the utility, which depends on the parameters \( \beta \).

If the utility is linear in \( \beta \), then

\[
V_{ni}(\beta) = \beta' x_{ni}
\]

with \( x_{ni} \) – observed variables relating to alternative \( i \) and decision maker \( n \).

In this case, the ML probability takes its usual form:

\[
P_{ni} = \int (\sum_{\xi} e^{\beta' x_{ni}}) f(\beta) d\beta
\]

The ML probability is a weighted average of the logit formula evaluated at different values of \( \beta \), with the weights given by the density \( f(\beta) \). It can be derived from utility-maximizing behaviour in several ways that are formally equivalent but provide different interpretations. The most straightforward derivation, and most widely used in recent applications, is based on random coefficients. The decision maker faces a choice among \( J \) alternatives. The utility of person \( n \) from alternative \( j \) is specified as

\[
U_{nj} = \beta'_n x_{nj} + \epsilon_{nj}
\]

with \( x_{nj} \) – observed variables relating to alternative \( j \) and decision maker \( n \);
\( \beta'_n \) – vector of coefficients of these variables for person \( n \) representing that person’s tastes;
\( \epsilon_{nj} \) – random term.

The coefficients vary over decision makers in the population with density \( f(\beta) \). This density is a function of parameters \( \theta \) that represent, for example, the mean and covariance of the \( \beta \)’s in the population. This specification is the same as for standard logit except that \( \beta \) varies over decision makers rather than being fixed.

Estimation of the ML model is normally done using simulation methods, since the multiple integral \( E = (C - 1) \times T \) does not exist in closed form \((C – \text{size of choice set}, \text{and} \ T – \text{number of choice sets}) \). It becomes particularly complex by the inter-alternative correlation of one or more of the error components. Since the number of operations...
increases with the power of $E$ (which determines the size of the covariance matrix), numerical integration is not computationally feasible.

Concerning the necessary minimum of random draws in simulation, LOUVIERE ET AL. (2000) suggest that 100 replications are sufficient for data sets with five alternatives, 1000 observations, and up to ten attributes. On the other hand, BIERLAIRE (2006) recommends a minimum number of draws of 1000 for ML estimation. Own tests of simulation runs with 100, 500, and 1000 draws showed that results differ significantly between 100 and 500 draws but do not change notably when comparing between 500 and 1000 draws. In order to keep run times for simulation at tolerable level, all further simulations were run with 500 draws.

5.3.2.4 Random Distributions for the Mixed Logit Model

One essential aspect to consider when using ML models is the assumption of how random coefficients are distributed. Basically, any random distribution can be applied, but some of them might either produce implausible model results or often lead to convergence problems during simulation.

Maybe the most intuitive and most often chosen distribution for ML is the Normal distribution, since it assumes that the shares of values smaller and larger than the estimated mean are equal. However, if the true distribution of observed values in the data set contains only negative values but with a mean close to zero (and a long tail into the negative space of numbers), the characteristic symmetry of the Normal distribution would produce an implausible share of positive values [HESS ET AL. (2005)]. When applying the Normal distribution, one therefore must decide, whether positive values are actually plausible (and to what degree) or whether they must be considered as artefacts of the assumed distribution.\footnote{Of course, the same can be said vice versa about a true distribution with only positive values.}

Alternatives to Normal distribution can be split into two main groups, according to HESS ET AL. (2005): distributions with fixed bounds and those with bounds, which are estimated during the model fitting process. Best-known example of the first group is the Lognormal distribution, the applicability of which is, however, limited due to its long tail on the unbounded side and occasional problems with convergence [HESS ET AL. (2005)]. Other fixed bound distributions listed in the referenced paper are the Gamma, Rayleigh, and Exponential distributions.

Nevertheless, “wrong” signed values are not necessarily implausible but could indeed be revealed by the data set (e.g. due to data impurities). HESS ET AL. (2005) consider it as bad practise to “simply constrain the model to only produce negative values […]” and therefore recommend the use of distributions with bounds on either side, which are directly estimated from the data set, such as the Triangular or Johnson’s $S_B$ distributions.
For the survey data in this research, one would assume a bounded distribution to be realistic, since for the random coefficients (price, on-time reliability, transit time, and GHG-emissions) values with “wrong” signs would basically not be expected (e.g. negative values for on-time reliability, etc.). But, since these tests were made with the total survey sample including a very heterogeneous mix of different commodities (each with different logistics requirements), it is likely that the data contains also “wrong” values. These could originate mostly from sample shipments, for which the respondent considered one or more attributes as irrelevant for the choice decision. From this viewpoint, a Triangular or \( S_B \) distribution would seem most appropriate. Nevertheless, the (unbounded) Normal distribution cannot be disqualified a priori, because its shape in the negative (or positive, respectively) space of numbers might be better able to approximate the shape of the observed (true) distribution [Hess et al. (2005)].

Based on the above considerations, different distributions were tested with the data set from the shipper survey including Normal, Lognormal, Triangular, and \( S_B \) distributions. For this purpose, the optimisation algorithm “CFSQP” [Lawrence et al. (1997)] was used, which is one of the available algorithms in Biogeme. Table 5-6 contains the results of the global models (i.e. using the complete data set) including the results from the simple MNL model for comparison.

<table>
<thead>
<tr>
<th></th>
<th>MNL Normal</th>
<th>MNL Triangular</th>
<th>MNL Lognormal</th>
<th>( S_B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC (Rail)</td>
<td>-2.15</td>
<td>-2.96</td>
<td>-2.94</td>
<td>-1.98</td>
</tr>
<tr>
<td>ASC (Intermodal)</td>
<td>-0.260</td>
<td>-0.374</td>
<td>-0.376</td>
<td>-0.245</td>
</tr>
<tr>
<td>( \log(Price) )</td>
<td>-5.40</td>
<td>-10.1</td>
<td>-5.79</td>
<td>-36.7(^*)\</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>-7.54</td>
<td>6.49</td>
<td>2.09(^*)</td>
<td>-1.35</td>
</tr>
<tr>
<td>On-time reliability</td>
<td>0.0923</td>
<td>0.148</td>
<td>0.0834</td>
<td>0.0800</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>0.137</td>
<td>0.116</td>
<td>0.0849</td>
<td>-0.0851</td>
</tr>
<tr>
<td>Transit time</td>
<td>-0.0101</td>
<td>-0.0217</td>
<td>-0.0120</td>
<td>-0.0141</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>-0.0350</td>
<td>-0.0282</td>
<td>0.0207</td>
<td>-0.0200</td>
</tr>
<tr>
<td>GHG-emissions</td>
<td>-0.297</td>
<td>-0.451</td>
<td>-0.245</td>
<td>-0.265</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>-0.479</td>
<td>-0.409</td>
<td>0.258</td>
<td>-0.264</td>
</tr>
</tbody>
</table>

\(^*)\ Value not statistically significant at the 5%-level

Biogeme calculates the Likelihood ratio test as:

\[-2 (L^0 - L^*) \]  \hspace{1cm} (5.6)

with \( L^0 \) - log-likelihood of the sample for a MNL model with all \( \beta \)-parameters = 0; \( L^* \) - log-likelihood of the sample for the estimated model.
Accordingly, the adjusted rho-squared is calculated as:

$$\rho^2 \text{adj.} = 1 - \frac{(L^* - K)}{L^0}$$

with  $K$ – number of estimated parameters.

Clearly, large differences exist in model quality: while the ML model with Normal and Triangular distributions shows values for $\rho^2 \text{adj.}$ of almost 0.40, the according values with Lognormal and $S_B$ distributions are even below the ones of the simple MNL model. This result is also supported by the results from the Likelihood ratio tests. Furthermore, the Lognormal and $S_B$ distributions revealed problems of convergence when extending the ML model by interaction terms with shipper- and commodity-specific characteristics. Therefore, this problem together with the low statistical fit led to disqualification of these two distributions.

The choice between Normal and Triangular distribution is less straightforward due to their similar model quality in terms of likelihood ratio test and $\rho^2 \text{adj}$. The main difference is the discrepancy between mean coefficients, which are almost twice as high for Normal distribution compared to Triangular, while differences in $\sigma$’s are less pronounced. This implies that the variance of the Triangular distribution is significantly higher, since the modulus of the ratios between standard deviation and mean are greater (and even larger than 1 for all four coefficients, while with the Normal distribution this occurs only in case of the emissions attribute). Furthermore, tests were run for calculating willingness-to-pay estimations from the Triangular distribution using random sampling. As expected, the results showed an unrealistically high share of values with “wrong” signs (e.g. for on-time reliability more than 50% of the 500 randomly generated means were negative). Corresponding results from the Normal distribution were much more resilient (see section 5.3.5).

Theses insights together with the above theoretical considerations determined the choice of the Mixed Logit model with Normal distribution. This model was then applied also to the commodity-specific subsets of the data. The following section explains the single coefficients of each model and the detailed results obtained.

### 5.3.3 Structure and Parameters of the Resulting Models

With the Mixed Logit modelling approach six different models were finally produced including a general model covering the complete survey data set plus five commodity-specific models. As mentioned in section 5.2, commodity groups 1 (Agricultural raw materials) and 3 (Chemical and mineral products) had to be merged into one model, since statistical significance of the group 1 model was insufficient due to its low number of observations. By comparing the logistics requirements of the single groups, the ones of group 1 appeared to be best comparable with the requirements of group 3.

The models presented in Table 5-7 are the detailed models including all interaction terms, which were statistically significant in at least one of the models. Basically, the models consist of the generic variables (i.e. the direct choice attributes price, on-time reliability,
transit time, and GHG-emissions, with mean values and standard deviations listed separately) plus two alternative specific constants (ASC) representing the transport mode attribute. The additional interaction terms reflect the influence of shipper or shipment characteristics on these variables/constants.

Shipper characteristics included are a) the availability of direct rail access (mostly via private rail siding) and b) the structure of transport chain organisation (labelled as “Choice LSP”). The latter considers the question, whether either the shipper or the logistics service provider (LSP) is mainly responsible for transport mode choice for a given shipment (compare section 5.1.4.2). The element “Choice shipper” does not appear in the table, because shippers’ responsibility of transport mode choice had no statistically significant influence on the preference of a specific mode.

Concerning shipment characteristics, the following aspects are included:

- Transport distance;
- Perishability of the goods; and
- Dangerousness (i.e. whether the goods are classified as dangerous cargo).

Note that figures in Table 5-7 are shown in italics, if the corresponding coefficient is significant only on a level below 97.5% (t-test below 1.96).

**Table 5-7: Overview of resulting models**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Global Model</th>
<th>Food/animal feed products</th>
<th>Chemical products; Agricultural raw materials</th>
<th>Iron/Metal products</th>
<th>Building materials</th>
<th>Manufactured goods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In (Price)</strong></td>
<td>Coeff.</td>
<td>-8.08</td>
<td>-8.59</td>
<td>-7.37</td>
<td>-17.3</td>
<td>-16.0</td>
</tr>
<tr>
<td>Mean</td>
<td>Std. err.</td>
<td>1.04</td>
<td>1.38</td>
<td>2.76</td>
<td>4.14</td>
<td>4.42</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>-7.79</td>
<td>-6.21</td>
<td>-2.67</td>
<td>-4.17</td>
<td>-3.61</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>Coeff.</td>
<td>7.48</td>
<td>-7.02</td>
<td>-9.14</td>
<td>17.1</td>
<td>-13.1</td>
</tr>
<tr>
<td></td>
<td>Std. err.</td>
<td>0.634</td>
<td>1.49</td>
<td>1.58</td>
<td>4.47</td>
<td>4.57</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>11.80</td>
<td>-4.71</td>
<td>-5.79</td>
<td>3.82</td>
<td>-2.87</td>
</tr>
<tr>
<td><strong>On-time reliability</strong></td>
<td>Coeff.</td>
<td>0.145</td>
<td>0.132</td>
<td>0.190</td>
<td>0.170</td>
<td>0.0845</td>
</tr>
<tr>
<td>Mean</td>
<td>Std. err.</td>
<td>0.0135</td>
<td>0.0381</td>
<td>0.0317</td>
<td>0.0527</td>
<td>0.0423</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>10.71</td>
<td>3.46</td>
<td>6.01</td>
<td>3.22</td>
<td>2.00</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>Coeff.</td>
<td>0.140</td>
<td>-0.142</td>
<td>-0.165</td>
<td>-0.162</td>
<td>-0.118</td>
</tr>
<tr>
<td></td>
<td>Std. err.</td>
<td>0.0120</td>
<td>0.0280</td>
<td>0.0297</td>
<td>0.0465</td>
<td>0.0366</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>11.59</td>
<td>-4.71</td>
<td>-5.79</td>
<td>-3.47</td>
<td>-3.23</td>
</tr>
<tr>
<td><strong>Transit time</strong></td>
<td>Coeff.</td>
<td>-0.0229</td>
<td>-0.0433</td>
<td>-0.0276</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mean</td>
<td>Std. err.</td>
<td>0.00608</td>
<td>0.0257</td>
<td>0.00917</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>-3.77</td>
<td>-1.69</td>
<td>-3.02</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>Coeff.</td>
<td>-0.0358</td>
<td>0.0448</td>
<td>0.0260</td>
<td>-</td>
<td>0.0454</td>
</tr>
<tr>
<td></td>
<td>Std. err.</td>
<td>0.00653</td>
<td>0.0262</td>
<td>0.0114</td>
<td>-</td>
<td>0.0097</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>-5.48</td>
<td>1.71</td>
<td>2.29</td>
<td>-</td>
<td>4.68</td>
</tr>
<tr>
<td><strong>GHG-emiss.</strong></td>
<td>Coeff.</td>
<td>-0.463</td>
<td>-0.812</td>
<td>-0.575</td>
<td>-0.463</td>
<td>-</td>
</tr>
<tr>
<td>Mean</td>
<td>Std. err.</td>
<td>0.0536</td>
<td>0.160</td>
<td>0.130</td>
<td>0.177</td>
<td>0.707</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>-8.64</td>
<td>-5.08</td>
<td>-4.42</td>
<td>-2.61</td>
<td>-</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>Coeff.</td>
<td>-0.498</td>
<td>-0.743</td>
<td>-0.618</td>
<td>0.302</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Std. err.</td>
<td>0.0625</td>
<td>0.150</td>
<td>0.139</td>
<td>0.190</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>-7.97</td>
<td>-4.94</td>
<td>-4.45</td>
<td>1.59</td>
<td>-</td>
</tr>
</tbody>
</table>

85
(Table 5-7 continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Global Model</th>
<th>Food/animal feed products</th>
<th>Chemical products; Agricultural raw materials</th>
<th>Iron/Metal products</th>
<th>Building materials</th>
<th>Manufactured goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail-only transport</td>
<td><strong>Coeff.</strong> &amp; -3.10 &amp; -2.70 &amp; -1.76 &amp; -4.02 &amp; -6.13 &amp; -3.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.161 &amp; 0.355 &amp; 0.358 &amp; 0.793 &amp; 1.10 &amp; 0.243</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail-only transport * Rail siding</td>
<td><strong>Coeff.</strong> &amp; 2.59 &amp; 2.70 &amp; 1.89 &amp; 1.79 &amp; 1.81 &amp; 3.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.177 &amp; 0.404 &amp; 0.391 &amp; 0.737 &amp; 0.778 &amp; 0.274</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>14.65 &amp; 6.69 &amp; 4.82 &amp; 2.43 &amp; 2.33 &amp; 11.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermodal transport</td>
<td><strong>Coeff.</strong> &amp; -0.814 &amp; - &amp; 0.461 &amp; -0.503 &amp; -0.954 &amp; -1.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.105 &amp; - &amp; 0.163 &amp; 0.252 &amp; 0.268 &amp; 0.169</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>-7.79 &amp; - &amp; 2.83 &amp; -2.00 &amp; -3.56 &amp; -7.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail-only transport * Dangerous goods</td>
<td><strong>Coeff.</strong> &amp; 1.59 &amp; - &amp; 0.616 &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.275 &amp; - &amp; 0.311 &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>5.80 &amp; - &amp; 1.98 &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermodal transport * Dangerous goods</td>
<td><strong>Coeff.</strong> &amp; 1.15 &amp; - &amp; - &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.260 &amp; - &amp; - &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>4.44 &amp; - &amp; - &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermodal transport * Choice LSP</td>
<td><strong>Coeff.</strong> &amp; 0.384 &amp; - &amp; - &amp; - &amp; - &amp; 0.807</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.136 &amp; - &amp; - &amp; - &amp; - &amp; 0.196</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>2.82 &amp; - &amp; - &amp; - &amp; - &amp; 4.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-time reliability * Perishable goods</td>
<td><strong>Coeff.</strong> &amp; 0.0700 &amp; 0.0990 &amp; - &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.0401 &amp; 0.0505 &amp; - &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>1.75 &amp; 1.96 &amp; - &amp; - &amp; - &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In (Price) * Distance</td>
<td><strong>Coeff.</strong> &amp; -0.00507 &amp; - &amp; -0.0078 &amp; - &amp; - &amp; -0.00519</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.00166 &amp; - &amp; 0.00389 &amp; - &amp; - &amp; 0.00244</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>-3.04 &amp; - &amp; -2.00 &amp; - &amp; - &amp; -2.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail-only transport * Distance</td>
<td><strong>Coeff.</strong> &amp; - &amp; - &amp; - &amp; 0.00117 &amp; 0.0196 &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>- &amp; - &amp; - &amp; 0.00065 &amp; 0.0048 &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>- &amp; - &amp; - &amp; 1.81 &amp; 4.09 &amp; -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermodal transport * Distance</td>
<td><strong>Coeff.</strong> &amp; 0.000556 &amp; - &amp; - &amp; - &amp; - &amp; 0.000768</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. error</td>
<td>0.000164 &amp; - &amp; - &amp; - &amp; - &amp; 0.000251</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>3.40 &amp; - &amp; - &amp; - &amp; - &amp; 3.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood ratio test</td>
<td>2442.774 &amp; 537.099 &amp; 522.170 &amp; 295.705 &amp; 195.767 &amp; 1023.993</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td>0.405 &amp; 0.430 &amp; 0.403 &amp; 0.491 &amp; 0.399 &amp; 0.392</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. observ.</td>
<td>2709 &amp; 545 &amp; 560 &amp; 252 &amp; 196 &amp; 1156</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
When looking at the indicators for overall model quality (log-likelihood and adjusted $\rho^2$), the statistical fit of the global model and all sub-models are good with $\rho^2_{\text{adj}}$ values of around 0.40.

### 5.3.4 Interpretation of Results

Generally, in terms of the signs of the estimated coefficients, the modelling results are plausible and support the hypotheses from section 5.1.4.3: concerning the generic variables, price, transit time, and emissions have negative coefficients, i.e. with an increase of one of these attributes the probability decreases that the corresponding alternative is chosen. By contrast, an increase in on-time reliability would raise the attractiveness of the corresponding alternative (which is indicated by the positive coefficients for this attribute).

#### 5.3.4.1 Generic Variables and ASC’s

##### 5.3.4.1.1 Overview

In order to compare the relevance of the direct choice attributes relative to each other, their influence on the odds of choosing a given alternative in a choice task were calculated based on the coefficients in Table 5-7 using the odds-ratio approach. Table 5-8 illustrates the resulting changes in odds subject to a change in level of the corresponding attributes.

**Table 5-8: Influence of generic variables on choice probability**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Change</th>
<th>Global Model</th>
<th>Food/animal feed products</th>
<th>Chemical products; Agricultural raw materials</th>
<th>Iron/Metal products</th>
<th>Building materials</th>
<th>Manufact. goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>In (Price)</td>
<td>+10%</td>
<td>-53.7</td>
<td>-55.9</td>
<td>-50.5</td>
<td>-80.8</td>
<td>-78.2</td>
<td>-43.2</td>
</tr>
<tr>
<td>On-time reliability</td>
<td>+1%</td>
<td>15.6</td>
<td>14.1</td>
<td>20.9</td>
<td>18.5</td>
<td>8.8</td>
<td>15.1</td>
</tr>
<tr>
<td>Transit time</td>
<td>+1h</td>
<td>-2.3</td>
<td>-4.2</td>
<td>-2.7</td>
<td>-</td>
<td>-</td>
<td>-2.0</td>
</tr>
<tr>
<td>GHG-emissions</td>
<td>+10%</td>
<td>-8.8</td>
<td>-15.0</td>
<td>-10.9</td>
<td>-8.8</td>
<td>-</td>
<td>-6.8</td>
</tr>
<tr>
<td>Rail transport</td>
<td>No → Yes</td>
<td>-95.5</td>
<td>-93.3</td>
<td>-82.8</td>
<td>-98.2</td>
<td>-99.8</td>
<td>-96.9</td>
</tr>
<tr>
<td>Intermodal transport</td>
<td>No → Yes</td>
<td>-55.7</td>
<td>-58.6</td>
<td>-39.5</td>
<td>-61.5</td>
<td>-70.5</td>
<td></td>
</tr>
</tbody>
</table>

If, for example, the price offered for a certain transport alternative would be raised by 10% (with constant prices for the other alternatives), with the global model the odds of choosing this alternative would decrease by 53.7%. Accordingly, if rail or intermodal transport were offered, the odds of choosing this alternative would decrease by 95.5% or 55.7%, respectively, as compared to the road-only alternative.
5.3.4.1.2 *Generic Variables*

When comparing the price, reliability, and emissions variables, the figures show a clear order in relevance of the three attributes. A 10% increase in price would reduce the odds by between 43% (Manufactured goods) and 81% (Iron & metal products), which indicates that shippers of low-value commodities are more price-sensitive than those of high-value commodities. An increase in on-time reliability by only 1%-point would, however, increase the odds already by 16% (global model). This corresponds with an increase in the odds by more than 300% when improving reliability by 10%.

Transit time is not directly comparable, since it is measured in hours instead of percentage values. However, when assuming an average international overnight transport of 13 hours, the 1-hour increase indicated in Table 5-8 would correspond to a relative increase by almost 8%. The given odds changes therefore suggest that generally transit time is even less important to shippers than GHG-emissions and not at all significant in the Iron & metal products and the Building materials groups. This can be reasoned by the fact that these two groups contain mainly raw material shipments, which are usually not integrated in time-sensitive production concepts. The highest value of -4.2% in the Food & animal feed products group is probably due to its high share of perishable shipments.

A 10% raise in GHG-emissions would decrease the odds of choosing an alternative by 9% in case of the global model (and up to 15% for food & animal feed products). Nevertheless, it seems plausible that this attribute is not significant in the Building materials group: most of these shippers are positioned far away from the end-consumer in the value creation chain and therefore have few incentives to consider environmental aspects in transport logistics. Furthermore, the high share of transport costs in total costs (due to the low commodity values in this group) forces the shipper to optimise its transports logistics in terms of costs. Generally, the high coefficient for commodity group 2 (Food & animal feed products) supports the hypothesis that shippers, which are in direct touch with end-consumers (e.g. retailers or nutrition producers), are more sensitive to environmental concerns than others (compare section 5.1.4.3).

From these results we conclude that the relevance of the choice attributes included in the Stated Choice experiments can be ranked in the following order:

1. On-time reliability;
2. Price;
3. GHG-emissions; and
4. Transit time.

Comparable conclusions can be drawn when analysing the answers given to the ranking question asked in each interview before coming to the choice experiments (compare

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43 Unfortunately, this interaction between price and commodity value could not be included explicitly in the models, because data on commodity value is not available for all sample shipments.
section 5.1.4.1). The cumulative ranking of all respondents (one per transport sample) on a five-point Likert scale is illustrated in Figure 5-10. Note that this question additionally included the attributes “damage rate” and “flexibility”, which were left out in the Stated Choice experiments as explained in section 5.1.4.2.7.

**Figure 5-10: Shippers’ perceived relevance of demand criteria**

<table>
<thead>
<tr>
<th>Ranking (1 = completely irrelevant; 5 = highly relevant)</th>
<th>On-time reliability</th>
<th>Price</th>
<th>Damage rate</th>
<th>Transit time</th>
<th>Flexibility</th>
<th>GHG-emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>9</td>
<td>14</td>
<td>21</td>
<td>24</td>
<td>46</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>39</td>
<td>14</td>
<td>23</td>
<td>58</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>14</td>
<td>44</td>
<td>24</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>14</td>
<td>58</td>
<td>46</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>14</td>
<td>55</td>
<td>63</td>
<td>85</td>
<td>86</td>
</tr>
</tbody>
</table>

On-time reliability and price both got an average ranking of around 4.2, followed by damage rate and flexibility with 3.9 and 3.79, respectively. GHG-emissions received the lowest ranking (3.11), even below the one for transit time (3.31). This might be an indication that the coefficients for GHG-emissions are slightly over-estimated.

A comparison of the above results with data from literature is given at the end of this chapter in section 5.3.5.
5.3.4.1.3 Alternative-Specific Constants (Transport Mode)

Last but not least, a striking result of the choice probability analysis in Table 5-8 is the influence of transport mode: the use of rail-only or intermodal transport both have a strongly negative impact on the choice of the corresponding alternative. While in the global model intermodal transport brings down the odds by 56%, rail transport decreases the odds by more than 95%. As hypothesised in section 5.1.4.3, differences exist between commodity groups, but the range of the coefficients is nevertheless surprising. It means that, generally speaking, rail-only transport is hardly accepted at all by shippers, independent of the commodity group.

The reason for this surprising result lies mainly in shippers’ infrastructure and rolling stock restrictions: if for example rail transport is not possible due to missing rail access either on the sender or on the receiver side, the alternative offering rail transport would not be a valid option for the shipment used in the experiment. Since this is the case for a large number of sample shipments, the coefficients for rail transport show strongly negative values. The same can be said about intermodal transport, the variable of which has negative coefficients in the global model as well as in the Building materials, Iron & metal products and Manufactured goods groups. These three groups are more deprecative towards intermodal transport than the other ones, since in the Building materials group often specially equipped vehicles are required (e.g. for loading or unloading at construction sites), while the Iron & metal products and Manufactured goods groups contain several LTL shipments, for which an intermodal transport unit would be too large and inflexible (e.g. in case of round trips). The only exception with a positive coefficient for intermodal transport is the group of Chemical products & Agricultural raw materials. Here the characteristics of intermodal transport (i.e. full truckloads over medium and long distances) correspond well with shippers’ logistics requirements. For chemical products the safety aspect of the main haulage by rail (or waterway) additionally plays in favour of intermodal transport.

Also when comparing with literature results, coefficients appear not out of range at all: PATTERSON (2007) for example reports a coefficient for the intermodal constant of -0.81, which equals a decrease in odds of 55% (values for rail-only transport are not available). These figures match perfectly with the ones from the global model in this research.

As a conclusion for the final cost-benefit-analysis in chapter 1 we must keep in mind that a further modal shift from road to rail or intermodal transport is not impossible but often restricted by external constraints, which often need high investments to be eliminated.

5.3.4.2 Interaction terms

For the analysis of interaction terms we must differ between discrete and continuous variable interaction terms: discrete variable interaction terms reflect correlations between
the generic variables discussed above and discrete shipper or shipment characteristics. The following characteristics belong to this group:

- Perishableness (i.e. whether goods are classified as perishable);
- Availability of direct rail access (via rail siding);
- Dangerousness (i.e. whether goods are classified as dangerous); and
- “Choice LSP” (i.e. the case that the LSP is responsible for transport mode choice).

The only relevant continuous shipment characteristic in this case is transport distance.

5.3.4.2.1 Discrete variable interaction terms

Similar to the above analysis the influence of the interaction terms on the odds of choosing a given alternative in a choice task were calculated based on the coefficients in Table 5-7 using the odds-ratio approach. For this purpose combined coefficients must be calculated by summing the coefficient of the interaction term with the one of the corresponding generic variable or ASC. The influences of the discrete variable interaction terms on the odds changes are given in Table 5-9. For comparison the odds changes for the according generic variables and ASC’s from Table 5-8 are repeated in this table.

Table 5-9: Influence of discrete variable interaction terms on choice probability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Change in odds of choosing the according alternative (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Global Model</td>
</tr>
<tr>
<td>On-time reliability</td>
<td>+1%</td>
</tr>
<tr>
<td>Reliability * Perishable goods</td>
<td>24.0</td>
</tr>
<tr>
<td>Rail transport</td>
<td>No → Yes</td>
</tr>
<tr>
<td>Rail transp. * Rail siding</td>
<td>-40.0</td>
</tr>
<tr>
<td>Rail transp. * Dangerous goods</td>
<td>-77.9</td>
</tr>
<tr>
<td>Intermodal transport</td>
<td>No → Yes</td>
</tr>
<tr>
<td>Intermodal * Dangerous goods</td>
<td>39.9</td>
</tr>
<tr>
<td>Intermodal * Choice LSP</td>
<td>-34.9</td>
</tr>
</tbody>
</table>

Note that the list includes only those shipper and shipments characteristics, which are statistically significant in one of the interaction terms.

---

44 Note that the list includes only those shipper and shipments characteristics, which are statistically significant in one of the interaction terms.
These results indicate that shippers of perishable goods are more sensitive to on-time reliability than others. This effect is especially significant in the Food & animal feed products model, which appears plausible, since the share of perishable products in the food sector is higher than in other commodity groups. However, our hypothesis from section 5.1.4.3 that perishable goods would increase shipper transit time sensitivity cannot be sustained. This might (at least partly) be due to the generally low influence of transit time as a direct choice attribute.

The strongly negative impact of rail transport is (as hypothesised) partly relaxed by shippers’ rail access availability; but this does not guarantee a positive attitude towards the use of rail transport (in the global model the odds with available rail siding are still reduced by 40%). Here it is important to keep in mind that for the rail transport option always both ends of the transport chain (and not only one) must be equipped with direct rail access. Shippers with rail siding might therefore still be forced to disregard rail transport as an adequate alternative. Furthermore, as discussed above, additional constraints can impede the use of rail transport. Increasing odds can be observed only in the Chemical products & agricultural raw materials model, since a great number of respondents in this group are already using rail transport.

The data also supports the hypothesis that shippers of dangerous goods have a minor aversion against rail and intermodal transport. Although this is statistically significant only in the global model, in case of dangerous cargo the use of intermodal transport increases the odds of choosing the according alternative by 40%. On the other hand, the drawbacks of rail-only transport seem too large to let shippers of dangerous goods prefer rail compared to road or intermodal transport.

Finally, the results suggest that, especially in the Manufactured goods group, the probability to reject the intermodal transport alternative decreases, if the LSP (instead of the shipper) is responsible for transport mode choice. This is not totally surprising, since LSP’s normally possess the necessary information to compare between different transport modes, while the shipper would rather choose its habitual road carrier. This phenomenon has already been discussed in section 2.2.3.2.

5.3.4.2.2 Continuous variable interaction terms

The coefficients of the distance interaction terms are estimated per unit of distance, i.e. km. In order to calculate the distance impact on direct choice attributes, the coefficients are multiplied with three representative transport distances (100, 300, and 700 km) and then summed with the coefficients of the direct choice attribute. The resulting odds changes for the distance interaction terms are given in Table 5-10.

The results support the hypothesis that increasing transport distances raise shipper sensitivity to price changes (although this is not statistically significant in all sub-models). While in the global model a 10% higher transport price brings down the odds of the
corresponding alternative by 54%, the same price increase leads to a reduction in the odds of 60% for a distance of 300 km (and of 67% for a distance of 700 km).

On the other hand, increasing transport distance has a positive impact on the acceptance of rail and intermodal transport. In the global model and the one for Manufactured goods the probability decline is clearly less pronounced for longer transport distances. This is congruent with the common trend that rail-bound transport becomes more attractive with increasing transport distance due to its decreasing cost per tonne-km (compare e.g. [Wichser et al. (2006)]).

Table 5-10: Influence of continuous variable interaction terms on choice probability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Global Model</th>
<th>Food/animal feed products</th>
<th>Chemical products; Agricultural raw materials</th>
<th>Iron/Metal products</th>
<th>Building materials</th>
<th>Manufact. goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln (Price)</td>
<td>+10%</td>
<td>-53.7</td>
<td>-65.9</td>
<td>-80.8</td>
<td>-78.2</td>
<td>-43.2</td>
</tr>
<tr>
<td>ln (Price) * Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 km</td>
<td>-55.9</td>
<td>-54.0</td>
<td></td>
<td>-80.8</td>
<td>-65.0</td>
<td>-46.0</td>
</tr>
<tr>
<td>300 km</td>
<td>-60.0</td>
<td>-60.4</td>
<td></td>
<td></td>
<td></td>
<td>-51.1</td>
</tr>
<tr>
<td>700 km</td>
<td>-67.0</td>
<td>-70.6</td>
<td></td>
<td></td>
<td></td>
<td>-60.0</td>
</tr>
<tr>
<td>Rail transport</td>
<td>No → Yes</td>
<td>-95.5</td>
<td>-93.3</td>
<td>-98.2</td>
<td>-99.8</td>
<td>-96.9</td>
</tr>
<tr>
<td>Rail transport * Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 km</td>
<td>-98.0</td>
<td>-98.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 km</td>
<td>-97.4</td>
<td>-22.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700 km</td>
<td>-95.9</td>
<td>2.0E+5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermodal transport</td>
<td>No → Yes</td>
<td>-55.7</td>
<td>58.6</td>
<td>-39.5</td>
<td>-61.5</td>
<td>-70.5</td>
</tr>
<tr>
<td>Intermodal transport * Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 km</td>
<td>-53.2</td>
<td>-68.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 km</td>
<td>-47.6</td>
<td>-62.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700 km</td>
<td>-34.6</td>
<td>-49.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is, however, unclear, why the influence of distance on the attractiveness of rail-only and intermodal transport becomes statistically significant in different models. Furthermore, the coefficient for the Rail transport * Distance interaction term in the Building materials model (0.0196) seems too high: first, all other distance interaction terms have coefficients, which are by factor 10 or more lower, and, second, its impact on rail transport attractiveness is unrealistically high. It may be plausible that at a certain distance a break-even point is reached turning rail transport impact from negative to positive; but the calculated odds change would mean that the probability of choosing the corresponding alternative would be 100%. Therefore, the estimated impact of transport distance on the acceptance of rail transport should be taken with a pinch of salt, especially since in the global model (and the remaining four sub-models) no significant impact can be observed.
5.3.5 Willingness-to-Pay Estimations

Within the scope of this research the most relevant interpretation of the modelling results is the estimation of shipper willingness-to-pay (WTP) for the different quality criteria considered, i.e. on-time reliability, transit time, and GHG-emissions. WTP stands for an estimation of monetary values of non-monetary attributes.

When using random coefficients models, such as the Mixed Logit model in this case, there are two ways of deriving WTP estimations from the resulting coefficients. The straightforward approach is to estimate the marginal utility per unit increase of the sought-after attribute (e.g. emissions) by equalising the according utility functions and using simply the mean coefficients for the $\beta$-parameter:

$$U_0 = \beta_{\text{Price}} \cdot \ln(\text{Price}) + \beta_{\text{Emissions}} \cdot \text{Emissions}$$

$$U_1 = \beta_{\text{Price}} \cdot \ln(\text{Price} + \Delta\text{Price}) + \beta_{\text{Emissions}} \cdot (\text{Emissions} - \Delta\text{Emissions})$$

$\rightarrow$ set $U_0 = U_1$ and solve for $\Delta\text{Price}$

The drawback of this approach is that only the means of the random coefficients are considered. In order to also include the corresponding standard deviations, the second approach applies random sampling of mean coefficients, which are then used to calculate marginal utilities as described above.

Table 5-11: WTP in CHF per ton-kilometre (detailed results)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Global Model</th>
<th>Food/animal feed products</th>
<th>Chemical products; Agricultural raw materials</th>
<th>Iron/Metal products</th>
<th>Building materials</th>
<th>Manufact. goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-time reliability (per % point increase)</td>
<td>Mean</td>
<td>5.70E-03</td>
<td>5.04E-03</td>
<td>4.32E-03</td>
<td>2.67E-03</td>
<td>1.64E-03</td>
</tr>
<tr>
<td></td>
<td>Std. dev.</td>
<td>1.25E-03</td>
<td>2.23E-03</td>
<td>4.08E-03</td>
<td>1.54E-03</td>
<td>1.35E-03</td>
</tr>
<tr>
<td></td>
<td>Min.</td>
<td>3.20E-03</td>
<td>8.93E-04</td>
<td>9.66E-04</td>
<td>3.11E-04</td>
<td>-2.20E-04</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>9.77E-03</td>
<td>1.29E-02</td>
<td>3.98E-02</td>
<td>9.40E-03</td>
<td>8.31E-03</td>
</tr>
<tr>
<td></td>
<td>Negative values</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Transit time (per hour decrease)</td>
<td>Mean</td>
<td>8.68E-04</td>
<td>1.49E-03</td>
<td>4.87E-04</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Std. dev.</td>
<td>1.19E-04</td>
<td>6.94E-04</td>
<td>4.22E-05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Min.</td>
<td>4.80E-04</td>
<td>-9.37E-04</td>
<td>4.50E-04</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>1.11E-03</td>
<td>2.79E-03</td>
<td>8.34E-04</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Negative values</td>
<td>0%</td>
<td>4.4%</td>
<td>0%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GHG-emissions (per % point decrease)</td>
<td>Mean</td>
<td>3.65E-04</td>
<td>6.24E-04</td>
<td>2.23E-04</td>
<td>1.28E-04</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Std. dev.</td>
<td>4.82E-06</td>
<td>9.34E-05</td>
<td>7.05E-05</td>
<td>2.19E-05</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Min.</td>
<td>3.55E-04</td>
<td>4.52E-04</td>
<td>1.65E-04</td>
<td>3.31E-05</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>3.81E-04</td>
<td>9.57E-04</td>
<td>8.31E-04</td>
<td>1.62E-04</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Negative values</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>-</td>
</tr>
</tbody>
</table>
In order to obtain more resilient WTP estimations, the simulation approach was applied in this research by generating random draws for the mean coefficients (β). For each β-coefficient in each model 500 random draws were generated based on a Normal distribution with mean and standard deviation as estimated with the ML model (see Table 5-7). For each set of random draws a WTP value was calculated, which produced the results listed in Table 5-11.

These results show a good statistical fit with almost no negative WTP values produced except in three cases. The maximum of negative values is 4.4% for value of time in the Food & animal feed products model. This is due to the low mean of 1.49E-03 and a comparably high standard deviation of 6.94E-04. This originates from a comparably high share of transport samples, for which respondents considered transit time as irrelevant for the choice decision.

Maybe more intuitive than estimating WTP per tonne-kilometre is the calculation of values per shipment or per tonne. Table 5-12 provides an overview of all three values for each attribute and each sub-model.

Table 5-12: Overview of WTP estimations (mean values only)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Global Model</th>
<th>Food/animal feed products</th>
<th>Chemical products; Agricultural raw materials</th>
<th>Iron/Metal products</th>
<th>Building materials</th>
<th>Manufact. goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-time reliability (per % increase)</td>
<td>CHF/shipment</td>
<td>19.8</td>
<td>12.5</td>
<td>61.2</td>
<td>14.1</td>
<td>5.43</td>
</tr>
<tr>
<td></td>
<td>CHF/t</td>
<td>2.03</td>
<td>0.88</td>
<td>2.89</td>
<td>1.18</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>CHF/tkm</td>
<td>0.00570</td>
<td>0.00504</td>
<td>0.00432</td>
<td>0.00267</td>
<td>0.00164</td>
</tr>
<tr>
<td>Transit time (per hour decrease)</td>
<td>CHF/shipment</td>
<td>3.02</td>
<td>3.70</td>
<td>6.90</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CHF/t</td>
<td>0.31</td>
<td>0.26</td>
<td>0.33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CHF/tkm</td>
<td>0.000868</td>
<td>0.001490</td>
<td>0.000487</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GHG-emissions (per % decrease)</td>
<td>CHF/shipment</td>
<td>1.27</td>
<td>1.55</td>
<td>3.17</td>
<td>0.68</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CHF/t</td>
<td>0.13</td>
<td>0.11</td>
<td>0.15</td>
<td>0.06</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CHF/tkm</td>
<td>0.000365</td>
<td>0.000624</td>
<td>0.000223</td>
<td>0.000128</td>
<td>-</td>
</tr>
</tbody>
</table>

The data show large differences in WTP between the single commodity-specific models, but basically the overall results appear plausible. As expected, a 1% increase in on-time reliability is clearly worth more to shippers than a 1-hour reduction of transit time or a 1% decrease of GHG-emissions. Rather astonishing, however, are the high values per shipment and per tonne for the Chemical products & Agricultural raw materials model. These are mainly due to the comparatively heavy shipments and long transport distances in this commodity group, since WTP values per tkm are well within the range of other commodity groups.
When comparing tkm-values, food & animal feed products and manufactured goods appear most sensitive to on-time reliability as well as to transit time. This makes sense, since these commodity groups have a great share of finished products, which are mostly of high value and often integrated into just-in-time or other comparable logistics concepts. WTP values per tkm for emissions reduction are also highest for the Food & animal feed products and the Manufactured goods model. This supports our hypothesis that shippers, which are in direct contact with end-consumers, are more sensitive to environmental concerns than others further back in the value creation chain (such as the building materials sector, for which no significant WTP for emissions reduction could be observed). Not directly supported by the survey data, however, is the hypothesis that shippers of dangerous goods (represented by the Chemical products group) are especially sensitive to environmental concerns (at least not in terms of WTP for reduction of GHG-emissions).

A comparison with results from other studies (see Table 5-13) suggests that WTP estimations from this research for higher on-time reliability are in a comparable order of magnitude, while the ones for transit time savings (VTTS) are lower than most of the published values. However, one must keep in mind that the estimates in this study are based on transport prices paid by a shipper to a contracted LSP. This means that the shipper (when comparing two alternatives with different transit time but identical price) does not consider the total transport cost but only the costs related to the cargo itself (e.g. capital costs of the shipment during transport). The operating costs are part of the transport price and thus only indirect costs to the shipper (which are at the responsibility of the LSP).

Since the values in Table 5-13 show a rather wide range of VTTS estimates, the values obtained in this research (though comparatively low) lie still within the order of magnitude of other studies, namely above the ones published by VELLAY AND DE JONG (2003). One explanation for the diverging VTTS could be the above-mentioned difference in cost components included in VTTS: a majority of the reviewed studies included only cargo-related costs in their estimation (i.e. their surveys focused on hire-and-reward shippers buying transport services from an LSP), while the one of BOUFFIOUX ET AL. (2006) had a high share of own-account shippers (thus including both operational and cargo-related costs in their estimates). This is underlined by the fact that their calculated value of reliability (VOR) is also more than twice as high compared to the others.

This dependence of VTTS/VOR estimates on the cost elements included is also pointed out by DE JONG (2008), who found in his review that studies indicating VTTS above 30 € per shipment all considered cargo-related as well as operational costs.
### Table 5-13: Comparison of WTP values from different studies

<table>
<thead>
<tr>
<th>Source</th>
<th>Country</th>
<th>Year of data</th>
<th>Value of on-time reliability per % point increase</th>
<th>Value of transit time per hour decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAPP TRANS AND IVT (2008)</td>
<td>CH</td>
<td>2007</td>
<td>0.0006-0.0050 CHF/tkm</td>
<td>0.0021-0.0099 CHF/tkm</td>
</tr>
<tr>
<td>PATTERSON (2007)</td>
<td>CA</td>
<td>2005</td>
<td>12.86-38.45 CAN$/smt.</td>
<td>-</td>
</tr>
<tr>
<td>BOUFFIOUX ET AL. (2006)</td>
<td>B</td>
<td>2004</td>
<td>0.0173 CHF/tkm</td>
<td>0.0077 CHF/tkm</td>
</tr>
<tr>
<td>VELLAY AND DE JONG (2003)</td>
<td>F</td>
<td>2000</td>
<td>n/a</td>
<td>0.95 - 4.28 CHF/smt.</td>
</tr>
<tr>
<td>This study</td>
<td>CH</td>
<td>2008</td>
<td>0.00164-0.01450 CHF/tkm</td>
<td>0.000487-0.001860 CHF/tkm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.43-61.2 CHF/smt.</td>
<td>3.02-6.90 CHF/smt.</td>
</tr>
</tbody>
</table>

Note: Values in other currencies converted to Swiss Francs (CHF); smt. – shipment

The WTP estimations for GHG-emissions cannot be compared with results from literature, but basically the values appear reasonable: a WTP of 1.27 CHF/shipment for a 1% emissions reduction (global model) seems not out of range when considering the qualitative estimations of CORDES (2008) and BME (2008), according to which 11 – 16% might be willing to pay higher prices for higher environmental performance. However, it is questionable, whether this WTP value follows a linear function with increasing emissions reduction (i.e. whether WTP for a reduction of 50% would really be in the range of 60 CHF/shipment).

The cost-benefit-analysis in chapter 1 shows, whether differences in operational costs for reducing GHG-emissions are in a realistic relationship to shipper potential WTP for this reduction. It is, however, promising that in all models (except the one for Building materials) a significant sensitivity for environmental concerns could be observed.
6 Environmental Benchmark for Freight Transport Chains

After having evaluated the demand for environmentally friendly freight transport, this chapter presents the setup and results from the environmental benchmark of selected freight transport chains. Its goal is to evaluate the differences in environmental performance between different transport modes for a selected shipment. The chapter starts with the model description, including boundaries and basic assumptions for the benchmark. It then explains the selection of transport chains from the survey sample and concludes with a presentation and discussion of the benchmark results.

6.1 The Life-Cycle Impact Assessment Model

As explained in section 4.2.4, the ReCiPe method [GOEDKOOP ET AL. (2009)] was chosen as general framework for the benchmark model. For the use in freight transport life-cycle assessment (LCA), the basic method had to be adapted to include all impact categories, which are relevant for transport operation processes. Section 6.1.1 explains the method developed to include damage from traffic accidents into the general model. Due to reasons mentioned in section 4.2.5.1, noise impacts could not be quantified and thus were omitted in the benchmark model. In the following we describe the resulting model including input data used for the environmental benchmark.

6.1.1 Model Extension by Integrating Accident Impacts

6.1.1.1 General Approach

The ReCiPe method was extended for this research by an additional impact category capturing damage from traffic accidents based on a comparable approach in the field of work safety on oil and gas rigs by PETTERSEN AND HERTWICH (2008). Their approach comes from a generic cause-consequence model as proposed e.g. by UDO DE HAES AND LINDEIJER (2002). This model defines a cause-consequence chain based on environmental risk assessment. For the application in traffic accidents analysis, this chain can be rewritten as:


\(^{45}\) “Disability-adjusted life years” – see definition in section 2.1
6.1.1.2 Impact Assessment

This method can only be applied to freight transport processes, if detailed statistical data on traffic accidents is available: while in most European countries figures for injuries and fatalities from traffic accidents are published, the main challenge in this context lies in filtering from the general statistics only data sets from those accidents, which were actually caused by freight transport vehicles. Freight transport operation cannot be accounted for damage from accidents, in which freight transport vehicles were only passively involved. Fortunately, the required data could be gathered for both, road and rail traffic in Switzerland.

For road traffic the Swiss Statistics online database “Superweb”\(^\text{46}\) provides data on a) the yearly total number of accidents in Switzerland, b) the number of accidents caused or impacted by goods vehicles\(^\text{47}\), and c) the number of damaged persons per year (differing between minor and major injuries and fatalities). From this we calculate the number of damaged persons of injury type \(i\) as

\[
V_{i,GV} = V_i \times \frac{A_{GV}}{A}
\]

(6.1)

with

- \(V_{i,GV}\) – Number of damaged persons of injury type \(i\) from accidents caused by goods vehicles
- \(V_i\) – Total number of damaged persons of injury type \(i\)
- \(A_{GV}\) – Number of accidents caused/impacted by goods vehicles
- \(A\) – Total number of accidents per year
- \(i\) – \{minor injuries; major injuries; fatalities\}

Since detailed data on rail traffic was available only for 2005, this was taken as reference year also for the road traffic data. The corresponding values are listed in Table 6-1.

**Table 6-1: Damaged persons from road traffic accidents in 2005**

<table>
<thead>
<tr>
<th>Total no. of accidents</th>
<th>Accidents caused by goods veh.</th>
<th>(i)</th>
<th>Damaged persons of type (i)</th>
<th>Damaged persons of type (i) from accidents caused by goods vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>22820</td>
<td>1550.5</td>
<td>Minor injuries</td>
<td>21695</td>
<td>1474</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Major injuries</td>
<td>5059</td>
<td>344</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatalities</td>
<td>409</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td>27163</td>
<td>1846</td>
</tr>
</tbody>
</table>

Source: BfS Superweb\(^\text{46}\); own calculations

For rail traffic the Superweb data is not as detailed as for road traffic. The only way to obtain comparable data was therefore to manually scan protocols from rail accidents,

\(^{46}\) http://www.bfs.admin.ch/bfs/portal/de/index/infothek/onlinedb/superweb.html

\(^{47}\) All classes included, i.e. heavy goods vehicles (HGV) and light goods vehicles (LGV) below 3.5 t.
which were provided by the Swiss Federal Office of Transport (BAV). These are standardised protocols prepared by the Federal Examination Office for Railway and Waterway Accidents (“Unfalluntersuchungsstelle Bahnen und Schiffe” – UUS), which report, among other things, the cause of the accident and damage to persons and technical equipment.

For the reference year 2005 (more recent data was not available) all rail accident protocols were scanned for such accidents, which a) were caused by freight vehicle movements, and b) involved injured persons and/or fatalities. In analogy to the approach for road transport, accidents, in which freight trains were only passively involved (e.g. a car passing a closed railway crossing), were not counted. Therefore, the only chargeable ones are almost exclusively accidents during manoeuvres in shunting yards or rail sidings with damage to shunting operators. The resulting figures are presented in Table 6-2.

Table 6-2: Damaged persons from rail traffic accidents in 2005

<table>
<thead>
<tr>
<th>Accidents caused by goods veh.</th>
<th>i</th>
<th>Damaged persons of type i from accidents caused by goods vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Minor injuries</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Major injuries</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Fatalities</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
</tr>
</tbody>
</table>

Source: BAV

### 6.1.1.3 Damage Assessment

In order to aggregate these results to the Human Health endpoint category of the ReCiPe method, the number of damaged persons per category from equation 6.1 must be weighted with weight and duration of the according damage type:

\[
DV_i = (V_{t,GV} / V_{t,GV}) * d_i * w_i
\]  

(6.2)

with

- \(DV_i\) – DALY per damaged person for damage of type \(i\)
- \(V_{t,GV}\) – Yearly total of damaged persons from accidents caused by goods vehicles
- \(d_i\) – Duration of damage of type \(i\)
- \(w_i\) – Weight of damage of type \(i\)

The sum of all \(DV_i\) represents the average damage to human health per damaged person. Since our basis of comparison is ton-kilometres, the values are converted as follows:

\[
D = \sum_i (DA_i * V_{t,GV} / TP_{GV})
\]  

(6.3)

with

- \(D\) – DALY per tkm
- \(TP_{GV}\) – Yearly freight transport performance in Switzerland (LGV + HGV), measured in tkm
As proposed by Pettersen and Hertwich (2008), weight and duration for injuries were taken from Murray and Lopez (1996): for major injuries values for the category “short term intracranial injuries” were used; for minor injuries the ones for “open wounds” were applied. By definition of the DALY unit, the corresponding weight for fatalities equals 1. The corresponding value for duration \( d \) in road traffic is the average remaining lifetime of the Swiss residential population. This value is calculated from its lifespan at birth minus average age:

\[
d_{\text{fatality}} = a - l
\]

with \( d_{\text{fatality}} \) – duration of damage due to fatal accident

\( a \) – Lifespan at birth of the Swiss residential population

\( l_{\text{road}} \) – Average age of the Swiss residential population

Note that the use of the lifespan at birth is a simplification of the actual (conditional) lifespan of the residential population. In other words, the older a person gets, the higher its actual life expectancy (i.e. the sum of the person’s age plus its remaining lifespan). However, a more precise calculation is difficult, because more detailed data would be required on accident victims. Furthermore, the sensitivity of the actual number of victims is considerably higher than the one of the applied simplification.

Since, as mentioned above, victims of accidents in rail freight traffic are mainly employees of railway companies, it is more precise in this case to replace the average age of the Swiss residential population \( l_{\text{road}} \) by the average age of the Swiss working population \( l_{\text{rail}} \). The values for \( l \) and \( a \) are listed in Table 6-3.

**Table 6-3: Parameters for the calculation of \( d_{\text{fatality}} \)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age of the Swiss residential population in 2005</td>
<td>( l_{\text{road}} ) = 40.6</td>
</tr>
<tr>
<td>Average age of the Swiss working population in 2005</td>
<td>( l_{\text{rail}} ) = 39.8</td>
</tr>
<tr>
<td>Lifespan at birth of the Swiss residential population in 2005</td>
<td>( a ) = 81.3</td>
</tr>
</tbody>
</table>

Source: BfS

An overview of parameters and the results from the damage assessment calculation are given in Table 6-4.

**Table 6-4: DALY for damages to human health from traffic accidents in Switzerland 2005**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Traffic</th>
<th>( TP ) [tkm/a]</th>
<th>( A ) [1/a]</th>
<th>( V_i ) [1/a]</th>
<th>( V_i/V ) [dim.less]</th>
<th>( d ) [a]</th>
<th>( w ) [dim.less]</th>
<th>( DV ) [DALY/victim]</th>
<th>( D ) [DALY/tkm]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road</strong></td>
<td></td>
<td>1.58E+10</td>
<td>1550.5</td>
<td>1846</td>
<td>1474</td>
<td>0.798</td>
<td>0.024</td>
<td>0.108</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>344</td>
<td>0.186</td>
<td>0.067</td>
<td>0.359</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td>0.015</td>
<td>40.700</td>
<td>1.000</td>
<td>0.617</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( \sum )</td>
<td>0.624</td>
<td>( \frac{1}{3} )</td>
</tr>
<tr>
<td><strong>Rail</strong></td>
<td></td>
<td>1.17E+10</td>
<td>12</td>
<td>14</td>
<td>9</td>
<td>0.643</td>
<td>0.024</td>
<td>0.108</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>0.357</td>
<td>0.067</td>
<td>0.359</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0.000</td>
<td>41.500</td>
<td>1.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( \sum )</td>
<td>0.010</td>
<td></td>
</tr>
</tbody>
</table>
It is important to note that these results represent mean values, which are subject to uncertainties. Main sources of uncertainty in this context are:

- Yearly number of accidents caused by goods vehicles;
- Number of damaged persons per accident; and
- The severity of injuries in the “minor” and “major” injuries categories.

Especially for rail traffic quantification of uncertainties is hardly feasible with maintainable effort, since accident protocols from several years would have to be scanned manually. Also for uncertainties of injury severity, more detailed data would be necessary for both road and rail traffic.

However, when compared with other impact categories contributing to human health damage from road and rail traffic, these results can be considered a fairly good approximation to include accident damage to transport LCA. Most important is the difference in magnitude between road and rail traffic: while for rail traffic accident damage is one of the least important impact categories, in case of road traffic it is the second largest contributor to the “Human Health” endpoint category. Details on the different impact categories are provided in section 6.2.2.5.

### 6.1.2 Model Description and Input Data

#### 6.1.2.1 Model Description

The benchmark model is based on an analysis of basic transport processes (also referred to as unit processes) as defined in the Ecoinvent database\(^{48}\). This database contains international life cycle inventory data on energy supply, resource extraction, material supply, transport services, etc. The two relevant processes for the transport modes considered in this research are “Transport, lorry” and “Transport, freight, rail”. For intermodal transport these two processes are combined. In Ecoinvent transport processes are measured in ton-kilometres. Therefore, emissions data is collected first on this basis and then multiplied by shipment size and length of the transport chain to be analysed. The principle is illustrated in Figure 6-1.

**Figure 6-1: Principle of the benchmark model**

![Diagram of the benchmark model](http://www.ecoinvent.ch)

\(^{48}\) [http://www.ecoinvent.ch](http://www.ecoinvent.ch)
Although vehicle operation causes the greatest share of transport emissions, other aspects, i.e. mainly production and maintenance of vehicles and infrastructure, must not be neglected. Therefore, all relevant sub-processes with a direct link to the “Transport” processes, as defined in the Ecoinvent database, were included in the model. As an example, Figure 6-2 illustrates the process network for CO$_2$-emissions from road transport.

It is important to mention that not all environmental interventions covered by the ReCiPe method (e.g. land use) were used for the benchmark model but only those, which are directly relevant for the transport operation process (see following section). Other categories, which are related to the infrastructure only, are difficult to quantify in this model (at least only with high uncertainties) due to the problem that the infrastructure is normally used for both passenger and freight transport.

Since for the calculation of emissions from the transport operation processes disaggregate data is used (compare following section), it is not possible to simply multiply the data from the unit process by shipment size and transport distance of the transport chain to be analysed. For road transport, for example, the route used by the lorry must be split into several sections according to the type of road (e.g. motorway, inner-urban road, etc.) and emissions data calculated separately for each section before summing them up. For rail transport one must differ between main haulage and shunting processes.

**Figure 6-2: Relevant sub-processes for road transport CO$_2$-emissions**

After calculation of the emissions for the entire transport chain the results are converted into endpoint values of the according endpoint categories using conversion factors provided by the ReCiPe method. While accident damage contributes only to the “Human health” category, all three endpoint categories (i.e. “Human health”, “Ecosystems”, and

---

49 SimaPro is a widely used LCA software tool by PRé Consultants (www.pre.nl).
“Resources cost”) must be considered for calculating the overall environmental impact of freight transport. For each of them, the ReCiPe method provides specific conversion factors for all substances contributing to one or several endpoint categories. The resulting endpoint values finally serve as the benchmark criteria for the comparison of different transport chain alternatives.

In this project it was decided to replace the category “Resources Cost” by a separate calculation of the cumulative energy consumption of the analysed transport chains. The “Resources Cost” category used in the ReCiPe method bases on the geological distribution of mineral and fossil resources and is meant to quantify how the use of these resources causes marginal changes in the effort to extract future resources (i.e. a marginal cost increase due to the extraction of a defined quantity of a resource) [GOEDKOOP ET AL. (2009)]. The problem about this monetary valuation is that it depends a) on an assumption about the average discount rate of the dollar during a certain time period and b) on existing exploitation technologies (i.e. not taking into account future technological development).

In order to avoid this monetary valuation, resource consumption is instead accounted for by calculating the total energy consumption of a transport chain including all relevant sub-processes. For the calculation of the sub-processes the “Cumulative Energy Demand” (CED) method was applied [JUNGBLUTH AND FRISCHKNECHT (2004)]. This method aims to investigate the energy use throughout the life cycle of a good or a service. It includes the direct use as well as the indirect or grey consumption of energy due to the use of for example construction materials or raw materials. Five types of energy sources are distinguished: a) fossil and nuclear fuels as non-renewable resources, and b) biomass, wind, sun, geothermal energy and water as renewable resources.

### 6.1.2.2 Input Data

Data from Ecoinvent were used in the calculation for all sub-processes other than the “Operation” process due to a lack of more detailed emissions data. For the “Operation” process, however, more precise data was drawn from external data sources, since Ecoinvent is not a specialised transport-related database.

#### 6.1.2.2.1 Road Transport

The most relevant source for road transport emissions in Switzerland, Germany, and Austria is the Handbook of Emission Factors – HABEFA [INFRAF ET AL. (2004)]: a database of highly disaggregated emissions data on the operation of road vehicles, which originate from test series. For these test series different real-world traffic scenarios (e.g. free floating motorway traffic or dense intra-urban traffic) with different vehicle types are simulated. Emissions are measured for the following substances:

- Fuel consumption;
- Carbon monoxide (CO);
- Carbon dioxide (CO$_2$);
- Hydrocarbons (HC);
6 – Environmental Benchmark for Freight Transport Chains

- Methane (CH₄);
- Non-methane hydrocarbons (NMHC);
- Nitrogen oxides (NOₓ);
- Di-nitrogen oxides (N₂O);
- Ammonia (NH₃);
- Lead (Pb); and
- Particles (PM<10).

This list (plus accident damage) was also used for the benchmark model and all transport modes to ensure comparability of the results. An overview of emission factors of heavy goods vehicles (HGV) for different road types is given in Appendix C.

Since HABEFA covers only the operation process, emissions of relevant sub-processes were added using data from the Ecoinvent database. The following sub-processes are considered (Ecoinvent process names in brackets):

- Fuel production (“Diesel, at regional storage/CH U”);
- Vehicle production (“Lorry 40t/RER/I U”);
- Vehicle maintenance (“Maintenance, lorry 40t/CH/I U”);
- Road construction (“Road/CH/I U”); and
- Road maintenance (“Operation, maintenance, road/CH/I U”).

6.1.2.2.2 Rail Transport

For rail transport in Europe a uniform emissions database is missing; therefore data had to be collected from different data sources: notably from EcoTransIT [IFEU (2008)] and a 2007 update of Ecoinvent data [PSI AND ESU (2007)].

Energy consumption is calculated based on the equations used in EcoTransIT. IFEU (2008) differentiates first between electric and diesel traction, and second between “flat”, “hilly”, and “mountainous” territory:

\[ EC = \alpha \times GW^{0.5} / LF \]

with

- \( EC \) – Energy consumption [Wh/tkm or g/tkm]
- \( \alpha \) – Dimensionless parameter (see Table 6-5)
- \( GW \) – Gross weight of train [t]
- \( LF \) – Load factor (relation net weight to gross weight)

EcoTransIT (www.ecotransit.org) is a publicly available online calculation tool operated by several European railways for comparing the environmental performance of different transport modes in freight transportation. Although it provides quite detailed emission data, it could not be directly applied in this research, since it is limited to operational processes only (i.e. leaving out of consideration the lifecycle perspective) and does not allow for integrating damage to human health by traffic accidents.

Energy consumption for electric traction is measured in Wh/tkm, for diesel traction in g/tkm diesel.
Table 6-5: Values of parameter $\alpha$ in equation 6.5

<table>
<thead>
<tr>
<th>Type of territory</th>
<th>Mountainous</th>
<th>Hilly</th>
<th>Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric traction</td>
<td>810</td>
<td>675</td>
<td>540</td>
</tr>
<tr>
<td>Diesel traction</td>
<td>183.69</td>
<td>153.07</td>
<td>122.46</td>
</tr>
</tbody>
</table>

Source: [IFEU (2008)]

We assume that for rail main haulage in Switzerland (including border-crossing traffic) electric traction is used, while diesel traction comes into play only for shunting operations. Therefore, direct emissions from main haulage are limited to particulate emissions due to abrasion, for which PSI and ESU (2007) report a specific emissions factor of 0.0163 g/tkm (PM10 only).

All further emissions are related to energy production and other sub-processes, the data for which is taken directly from Ecoinvent. Relevant sub-processes for rail transport in Switzerland are (Ecoinvent process names in brackets):

- Electricity production (“Electricity, high voltage, SBB, at grid/CH U”);
- Diesel production (“Diesel, at regional storage/CH U”);
- Locomotive production and maintenance (“Locomotive/RER/I U”);
- Production of goods wagon (“Goods wagon/RER/I U”);
- Maintenance of goods wagon (“Maintenance, goods wagon/RER/I U”);
- Track construction (“Railway track/CH/I U”);
- Track operation/maintenance (“Operation, maintenance, railway track/CH/I U”);
- Disposal of track (“Disposal, railway track/CH/I U”).

Since emission data on energy production varies significantly between different countries, for international transport chains the part outside Switzerland must be valued separately using the following sub-processes:

- “Electricity, high voltage, production UCTE, at grid/UCTE U”
- “Diesel, at regional storage/RER U”

For diesel powered shunting operations direct emissions of the combustion process must be added. Since a comparison of different studies on diesel emissions [PSI and ESU (2007), p. 104] shows a fairly wide range of values, we furthermore compared these with the ones of [IFEU (2008), p. 25] and chose the values with the best match between all considered sources. The applied values are listed in Table 6-6.

Table 6-6: Applied emission factors for diesel traction

<table>
<thead>
<tr>
<th>(in g/kg diesel)</th>
<th>CO</th>
<th>NOx</th>
<th>PM&lt;10</th>
<th>CO₂</th>
<th>CH₄</th>
<th>NMHC</th>
<th>Pb</th>
<th>SO₂</th>
<th>N₂O</th>
<th>NH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15.80</td>
<td>55.00</td>
<td>1.39</td>
<td>3170.00</td>
<td>0.10</td>
<td>4.90</td>
<td>0.00</td>
<td>0.70</td>
<td>0.10</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Source: [PSI and ESU (2007)], [IFEU (2008)], [IFEU (2003)]
6.1.2.2.3 Intermodal Transport

As mentioned above, for intermodal transport chains each leg is calculated separately using the data of the according transport mode (i.e. main haulage by rail, pre- and post-haulage by road) before summing up the results. In order to take into account also the transhipment process between road and rail, energy consumption was assumed as in EcoTransIT, which calculates with 4.4 kWh per transhipment process [IFEU (2008)]. Since this is electric energy, emissions calculation is similar to the one for electric trains, as described above.

6.1.2.2.4 Endpoint Conversion Factors

In addition to the input data on emission factors and routing information, conversion factors are required to convert the emissions to endpoint values. These are provided by the ReCiPe method, which defines for all considered substances a quantitative relationship to the corresponding endpoint category (only “Human Health” and “Ecosystems”, since energy consumption was calculated separately, as described above). For the substances considered in the benchmark model conversion factors are listed in Table 6-7 together with the endpoint factors for traffic accidents from section 6.1.1.3.

Table 6-7: Endpoint conversion factors

<table>
<thead>
<tr>
<th>Substance</th>
<th>Endpoint Factor Human Health</th>
<th>Unit</th>
<th>Endpoint Factor Ecosystems</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide, fossil (CO)</td>
<td>1.78E-09</td>
<td>[DALY/kg]</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nitrogen oxides (NOx)</td>
<td>5.72E-05</td>
<td>[DALY/kg]</td>
<td>3.25E-09</td>
<td>[species*a]</td>
</tr>
<tr>
<td>Particulates</td>
<td>2.60E-04</td>
<td>[DALY/kg]</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide, fossil (CO₂)</td>
<td>1.40E-06</td>
<td>[DALY/kg]</td>
<td>8.73E-09</td>
<td>[species*a]</td>
</tr>
<tr>
<td>Methane, fossil (CH₄)</td>
<td>3.50E-05</td>
<td>[DALY/kg]</td>
<td>2.18E-07</td>
<td>[species*a]</td>
</tr>
<tr>
<td>NMVOC, non-methane volatile organic comp., unspec. origin</td>
<td>3.90E-08</td>
<td>[DALY/kg]</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>6.04E-02</td>
<td>[DALY/kg]</td>
<td>3.89E-07</td>
<td>[species*a]</td>
</tr>
<tr>
<td>Sulfur dioxide (SO₂)</td>
<td>5.20E-05</td>
<td>[DALY/kg]</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Dinitrogen monoxide (N₂O)</td>
<td>4.17E-04</td>
<td>[DALY/kg]</td>
<td>2.60E-06</td>
<td>[species*a]</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>8.32E-05</td>
<td>[DALY/kg]</td>
<td>1.42E-08</td>
<td>[species*a]</td>
</tr>
<tr>
<td>Accidents Road CH</td>
<td>6.11E-08</td>
<td>[DALY/txkm]</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Accidents Rail CH</td>
<td>1.05E-11</td>
<td>[DALY/txkm]</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Energy, from oil</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: [GOEDKOOP ET AL. (2009)]; own calculations

Most of the included substances are emitted to air, but some of them also have an impact on ecosystems diversity. Note that units are not the same for both endpoint categories: damage to human health is measured in disability-adjusted life-years lost (DALY); damage to ecosystems is valuated in loss of species per year. This is why the endpoint categories must be interpreted and compared separately.
6.2 Benchmark Results

6.2.1 Case Studies Selection

The environmental benchmark could not be performed for all transport samples from the shipper survey, first because in several cases the transferability between transport modes is limited, and second since the effort and time necessary to collect the detailed routing data would have by far exceeded the resources of this project. Therefore, a selection of case studies was drawn from the survey data based on the following criteria:

- All relevant market sectors (internal transport, import, and export) should be represented;
- If possible, rail-only transport should also be a realistic alternative;
- Shipment sizes should be comparable (full truckload size due to the transferability requirement); and
- The range of transport distances should be as wide as possible.

In total, 13 case studies were benchmarked: 5 in internal transport and 4 each in import and export, respectively. The calculations are based on the following basic assumptions:

- Road Transport: 40t lorry, full load, emissions class EURO 3;
- Rail transport: 500 t / 1000 t train (depending on connection) with load factor 0.5;
- Intermodal transport: assumptions same as for road and rail transport, respectively.

The routing for each transport mode was made based on different data sources: for road transport the online routing planner ViaMichelin was used, the main haulage connection for intermodal transport was determined using the “SPIN-ALP Planner” [IVT AND PTV (2009)], while for rail-only transport no dedicated routing tool exists. Instead, assumptions about which lines and classification yards used for which rail connection are based on the author’s experience. Uncertainties for Switzerland are low, but certain assumptions for international connections might be too optimistic.

6.2.2 Results of the Case Studies

6.2.2.1 Overview

The benchmark results are summarised in Table 6-8. For each sample the transport mode actually used (in most cases road) is marked grey. Data for rail-only transport is missing in certain cases, if it is not a realistic option (e.g. due to infrastructure restrictions). For all categories percentage values were added to analyse the gain or loss of environmental performance relative to the status quo. Results for energy demand are listed separately for energy from non-renewable and renewable sources based on the distinction made in the cumulative energy demand (CED) method (compare section 6.1.2.1). However, since resource consumption as an endpoint category was in this project replaced by energy demand, the comparison between transport modes was made on the basis of total energy demand, i.e. the sum of energy from renewable and non-renewable sources.
Table 6-8: Detailed benchmark results

<table>
<thead>
<tr>
<th>O/D</th>
<th>Transport Mode Distance</th>
<th>Human Health</th>
<th>Ecosystem</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-Renew.</td>
<td>Renewable</td>
<td>Total</td>
<td>Non-Renew.</td>
</tr>
<tr>
<td></td>
<td>Size [t]</td>
<td>[km]</td>
<td>[DALY]</td>
<td>[a]</td>
</tr>
<tr>
<td>Altstätten SG - Basel</td>
<td>20</td>
<td>Road</td>
<td>207</td>
<td>8.11E-04</td>
</tr>
<tr>
<td>Neuensberg (b. Olten)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Neuenegg - Wangen (b. Olten)</td>
<td>16</td>
<td>Road</td>
<td>77</td>
<td>2.91E-04</td>
</tr>
<tr>
<td>Sihlau - Rüschlikon</td>
<td>15</td>
<td>Road</td>
<td>71</td>
<td>2.60E-04</td>
</tr>
<tr>
<td>Givisiez - Regensdorf</td>
<td>18</td>
<td>Road</td>
<td>151</td>
<td>6.42E-04</td>
</tr>
<tr>
<td>Stabio - Neuendorf</td>
<td>18</td>
<td>Road</td>
<td>246</td>
<td>8.88E-04</td>
</tr>
<tr>
<td>Rorschach - Zutphen (NL)</td>
<td>18</td>
<td>Road</td>
<td>723</td>
<td>2.94E-03</td>
</tr>
<tr>
<td>Visp - Frankfurt (Main)</td>
<td>18</td>
<td>Road</td>
<td>617</td>
<td>2.26E-03</td>
</tr>
<tr>
<td>Monthey - Rotterdam Waalhaven</td>
<td>20</td>
<td>Road</td>
<td>932</td>
<td>3.64E-03</td>
</tr>
<tr>
<td>Rotterdam Waalhaven - Basel</td>
<td>18</td>
<td>Road</td>
<td>732</td>
<td>2.77E-03</td>
</tr>
<tr>
<td>Basle - Rotterdam Waalhaven</td>
<td>18</td>
<td>Road</td>
<td>732</td>
<td>2.77E-03</td>
</tr>
<tr>
<td>Antony - Zürich</td>
<td>18</td>
<td>Road</td>
<td>684</td>
<td>2.61E-03</td>
</tr>
<tr>
<td>Nancy - Landstabl</td>
<td>18</td>
<td>Road</td>
<td>740</td>
<td>7.87E-04</td>
</tr>
<tr>
<td>Trier - Dagmersellen</td>
<td>18</td>
<td>Road</td>
<td>388</td>
<td>1.49E-03</td>
</tr>
<tr>
<td>Nancy - Landstabl</td>
<td>18</td>
<td>Road</td>
<td>403</td>
<td>1.59E-03</td>
</tr>
<tr>
<td>Nancy - Landstabl</td>
<td>18</td>
<td>Road</td>
<td>403</td>
<td>1.59E-03</td>
</tr>
<tr>
<td>Nancy - Landstabl</td>
<td>18</td>
<td>Road</td>
<td>403</td>
<td>1.59E-03</td>
</tr>
<tr>
<td>Nancy - Landstabl</td>
<td>18</td>
<td>Road</td>
<td>403</td>
<td>1.59E-03</td>
</tr>
</tbody>
</table>
6.2.2.2 Comparison of Case Studies

For an easier interpretation of the different case studies Figure 6-3 provides for each of them a comparison of the available transport modes relative to the mode currently used by the shipper. This mode is always set to 100% and listed in first position in each legend. The first five figures are the internal transport samples, followed by the ones for export and import.

Figure 6-3: Overview of environmental impact per endpoint category and transport mode
A striking result is that in most cases (independent of sector and distance) road transport has the worst environmental performance (across all three endpoint categories), followed by intermodal transport and rail-only transport (if relevant). The differences between road and intermodal transport depend mainly on the margin between actual transport distances of the two modes, i.e. in several cases the distance in intermodal transport is much longer than the direct route taken by the lorry, if origin and/or destination are located far from the nearest suitable terminal (the suitability of a terminal depends on its available train connections).

In those cases, where intermodal transport performs worse than road transport, the necessary detour is especially long, such as in the Rorschach – Zutphen example: while the lorry can take the fastest and direct route, the shipment would take the train from Bregenz (Wolfurt) to Hamburg, change trains and go back to Herne (in Germany) before being carried to the final destination in the Netherlands by lorry.

Rail-only transport has the best environmental performance (or at least equal to intermodal transport), because it avoids long pre- and post-haulage by road and can normally take more direct routes than in case of intermodal transport. However, also in wagonload transport (which was assumed for this analysis – in contrast to complete trains on point-to-point connections) detours cannot be completely avoided because of the hub and spokes networks using central classification yards to establish connections between different trains. Longer transport distances in rail transport can be easily identified in the figures when focusing on energy consumption, which in such cases is comparable to the other modes (e.g. in the Givisiez – Regensdorf example). The impact of detours on Human Health and Ecosystems, however, is low, because in Switzerland and many other European countries mainly electric traction is used. Since (at least in Switzerland) electric energy is produced mainly from water and nuclear power, damaging emissions to air and soil are much lower than the ones of lorry operation (even if the transport distance is shorter).

In the Basel – Rotterdam example environmental performances of rail-only and intermodal transport are almost the same, because both origin and destination are located in direct proximity of two transhipment terminals, between which a direct train connection exists. In this context we underline that conditions for intermodal transport are generally good in case of seaport hinterland transports, because either origin or destination are necessarily located directly at a container terminal, which is almost always accessible also by rail thus avoiding the pre- or post-haulage leg of the transport chain.

52 The electricity mix for rail traction in Switzerland and the remaining countries were modelled separately according to the corresponding Ecoinvent processes as listed on page 106.
6.2.2.3 Influence of Transport Distance and Load Factor

In section 3.3 we formulated the hypothesis that road transport’s environmental performance is generally lower than the one of rail and intermodal transport. This hypothesis can be sustained based on the above case study analysis.

Furthermore, we assumed that road-only transport for full truckload shipments over up to 200 km might be the better alternative in terms of environmental performance. This can be verified by analysing total energy consumption of the three modes relative to the direct transport distance (i.e. the one of road transport) – see Figure 6-4. Note that results show no significant difference when instead analysing the Human Health or Ecosystems category.

**Figure 6-4: Influence of transport distance on total energy demand**

![Figure 6-4](image)

While in road transport energy consumption shows a linear dependence on transport distance, no clear correlation can be observed for rail and intermodal transport. This is again due to the large detours necessary on certain connections (as explained above). Consequently, it is generally independent of the door-to-door distance, whether intermodal transport has higher energy consumption than road transport or not.

However, when focussing on distances of up to 200 km, differences in environmental performance are less significant, i.e. it depends on the underlying assumptions which transport mode actually performs best. In order to test for the results’ sensitivity to
different train load factors (i.e. the ratio between net and gross weight), the initial value of 0.5 used for the above calculations was lowered to 0.3. The lorry load factor remained unchanged, since the analysed transport samples are all of full truckload size, which was also assumed for the calculation of the HABEFA emissions data [INFRAS ET AL. (2004)]. Figure 6-5 illustrates the changes in energy consumption as compared to Figure 6-4.

**Figure 6-5: Total energy demand with train load factor 0.3**

While differences are significant especially for longer distances (which is logical), road transport would now be the best alternative from the environmental point of view in the distance class below 200 km. On the other hand, a load factor of 0.3 appears realistic only in case of low-density cargo and bad capacity use of the wagon.

We conclude that these results do not allow a clear support or rejection of our above hypothesis. On the one hand, differences in environmental performance are lower for lower distances so that road transport can be the best alternative under certain assumptions; but on the other hand examples of road in the first position exist also for longer distances, while road can as well perform worst on shorter distances.

### 6.2.2.4 Influence of Lorry Emission Classes on Environmental Impact

A further assumption with potential influence on environmental performance is the emission class of lorry engines. The above calculations were made based on data for
lorries with engines complying with the Euro 3 emission class, because during the last 4 years this class had the highest share in the total heavy goods vehicles fleet in Switzerland (compare Figure 6-6). In the coming years the repartition will shift towards a higher share of Euro 4 and Euro 5 vehicles. Since in the current version of HABEFA data for Euro 5 lorries is not yet available, differences in environmental performance between Euro 3 and Euro 4 vehicles were analysed for the benchmarked case studies.

**Figure 6-6: Development of emission class shares in the Swiss heavy goods vehicles fleet**

[Image: Development of emission class shares in the Swiss heavy goods vehicles fleet]


The detailed results are listed in Appendix D. Since no big differences exist between the single cases, the figures for the Stabio – Neuendorf transport (see Figure 6-7) can be considered as representative for the whole sample. In the figure we differ between road and intermodal transport with Euro 3 and Euro 4 vehicles, respectively. Since in intermodal transport this concerns only the pre- and post-haulage part of the transport chain, engine technology has almost no impact on overall environmental performance.

Energy consumption, however, is higher with Euro 4 lorries (both in road-only and intermodal transport). This is a characteristic of the newer engine emission standards (Euro 4 and later): less NOx and particle emissions are bought with higher fuel consumption (and slightly higher CO2-emissions). In road transport an emissions reduction of almost 5% in the “Human Health” category is facing an increase in energy consumption by 1.3%. Interestingly, in road transport a similar increase can be observed for the “Ecosystem” category. This is due to the mentioned higher CO2-emissions of the Euro 4-equipped engines.

As compared to the differences in environmental performance between transport modes, these changes appear rather insignificant. However, the potential for optimisation in the
“Human Health” category might be an interesting aspect for shippers, which have difficulties choosing alternative transport modes for their shipment.

**Figure 6-7: Influence of lorry emission class on environmental performance**

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### 6.2.2.5 Impact of Important Environmental Interventions on Human Health and Ecosystems

Of particular interest concerning the proposed labelling system is the question of which data to be displayed on such a freight transport label. One possibility would be to use the endpoint categories of the ReCiPe method; but since these values are not easy to understand by practitioners, the direct use of the most relevant environmental interventions might be a suitable alternative.

In order to identify these categories, the ones with a share above 1% in at least one of the endpoints are illustrated in Figure 6-8 for the Stabio - Neuendorf example, which is representative also for the remaining case studies. With respect to the “Human Health” endpoint there is a big difference between road and rail: while in rail transport the share of damage from accidents (measured in DALY) is negligible (<1%), in road transport this share is between 20 % and 36% of the total damage to human health for the analysed case studies. On the other hand, in rail transport particle emissions reach a share of 26% in the Stabio - Neuendorf example, compared to only 4% in road transport. Concerning the remaining categories the differences are less significant (with a maximum of 4% between road and rail transport).
Interestingly, the share of CO$_2$-emissions is rather similar for both transport modes and both endpoints: for “Human Health” it is just above 50%, while reaching ca. 95% in case of the “Ecosystem” endpoint. This leads us to the observation that, independent of transport mode and endpoint, only four environmental interventions represent 90% and above of the overall environmental impact: these are CO$_2$, NO$_x$, particles, and accident damages (the latter being relevant only for impacts to human health by road transport). These four categories might therefore indeed be directly indicated on a freight transport label, instead of the aggregated endpoint values. This question is further discussed in section 8.3.

**Figure 6-8: Contribution of environmental interventions to the “Human Health” and “Ecosystem” endpoints**

Furthermore, these results underline that damage from traffic accidents has a significant impact on the outcomes of LCIAs including road transport processes and should therefore generally be accounted for in future applications (at least in Switzerland, where appropriate data sources are available). The illustrated results are comparable for the other case studies and can therefore be considered as generally representative for freight transport in Switzerland.
7 Analysis of Prices for Freight Transport Services

After the environmental benchmark of the case studies presented in the previous chapter, the second prerequisite for the cost-benefit-analysis is the price benchmark. This chapter deals with an analysis of transport prices including an estimation of prices for each transport mode for the specific case studies. As explained in section 4.3.1, the price analysis is based on operational cost models for each transport mode. For rail-only transport a price-based approach was tested additionally to obtain most realistic results.

7.1 Structure of the Cost Model and Assumptions

Since for every case study operational costs must be calculated separately for all transport modes involved (i.e. road-only, intermodal, and rail-only transport), no uniform cost model could be applied. Instead, the calculation setup for each mode consists of different cost elements. A basic difference is made between road-bound and rail-bound transport due to their specific operational processes. Intermodal transport, however, can be considered a mixture of both with rail operation for main haulage and road operation for pre- and post-haulage (PPH).

7.1.1 Road Transport

For road transport processes (including PPH in intermodal transport) one generally differs between fixed, i.e. time dependent cost elements and variable, i.e. distance-related cost elements, which are listed in Table 7-1.

<table>
<thead>
<tr>
<th>Fixed cost elements</th>
<th>Variable cost elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-related amortisation</td>
<td>Performance-related amortisation</td>
</tr>
<tr>
<td>Imputed interest</td>
<td>Fuel costs</td>
</tr>
<tr>
<td>Vehicle tax</td>
<td>Lubricant costs</td>
</tr>
<tr>
<td>Liability insurance</td>
<td>Tyre costs</td>
</tr>
<tr>
<td>Comprehensive insurance</td>
<td>Maintenance &amp; repair costs</td>
</tr>
<tr>
<td>Driver wage costs</td>
<td>Road tolls</td>
</tr>
<tr>
<td>Overhead/Margin</td>
<td></td>
</tr>
</tbody>
</table>
For calculating these cost elements, assumptions are needed concerning the underlying elementary cost and process data. In this research a difference is made between a) Switzerland and b) EU countries in Western Europe (including Germany, France, Benelux, and Italy). These countries are assumed to have comparable cost levels, while other European countries with lower cost levels are not concerned by the case studies. The elementary data including their assumed levels are listed in Table 7-2.

### Table 7-2: Elementary cost and performance data in road transport operation

<table>
<thead>
<tr>
<th>Cost elements</th>
<th>Switzerland</th>
<th>Source</th>
<th>EU countries</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price for tyre set (4 axles) [CHF]</td>
<td>8'525</td>
<td>EBP (2007)</td>
<td>9'375</td>
<td>VR</td>
</tr>
<tr>
<td>Fuel price [CHF/l]</td>
<td>2.03</td>
<td>ASTAG</td>
<td>2.00</td>
<td>BGL</td>
</tr>
<tr>
<td>Imputed interest</td>
<td>8.5%</td>
<td>VR</td>
<td>8.5%</td>
<td>VR</td>
</tr>
<tr>
<td>Ratio of time-related to performance-related amortisation</td>
<td>40:60</td>
<td>Average of EBP (2007) and VR</td>
<td>40:60</td>
<td>Average of EBP (2007) and VR</td>
</tr>
<tr>
<td>Vehicle tax [CHF/a]</td>
<td>1'039</td>
<td>VR</td>
<td>1'039</td>
<td>VR</td>
</tr>
<tr>
<td>Liability insurance [CHF/a]</td>
<td>7'031</td>
<td>VR</td>
<td>7'031</td>
<td>VR</td>
</tr>
<tr>
<td>Compreh. insur. [CHF/a]</td>
<td>5'642</td>
<td>VR</td>
<td>5'642</td>
<td>VR</td>
</tr>
<tr>
<td>Driver wage costs (1.3 drivers/lorry) [CHF/a]</td>
<td>109'057</td>
<td>EBP (2007)</td>
<td>87'141</td>
<td>DHL</td>
</tr>
<tr>
<td>Overhead/Margin</td>
<td>12% of fixed costs</td>
<td>Own assumption</td>
<td>12% of fixed costs</td>
<td>Own assumption</td>
</tr>
<tr>
<td>Performance elements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel consumpt’n [l/100km]</td>
<td>33.04</td>
<td>VR</td>
<td>33.04</td>
<td>VR</td>
</tr>
<tr>
<td>Operation time, lorry [h/a]</td>
<td>2'090</td>
<td>EBP (2007)</td>
<td>2'090</td>
<td>EBP (2007)</td>
</tr>
<tr>
<td>Capacity usage</td>
<td>80%</td>
<td>VR</td>
<td>80%</td>
<td>VR</td>
</tr>
<tr>
<td>Operational performance, lorry [km/a]</td>
<td>120'000</td>
<td>Own assumption</td>
<td>150'000</td>
<td>VR</td>
</tr>
<tr>
<td>Operational performance, tyres [km/a]</td>
<td>139'500</td>
<td>VR</td>
<td>139'500</td>
<td>VR</td>
</tr>
</tbody>
</table>

Notes: Conversion factor CHF/EUR = 1.5625
1) Germany, France, Benelux, Italy
2) Sample calculation for lorry operation provided by “VerkehrsRundschau” on http://www.verkehrsrundschau.de/fm/3576/Fahrzeugkostenrechnung_magnum.xls (accessed 03/MAR/2009)
3) Average diesel prices in Switzerland 2008 provided by the Swiss Trucking Association (ASTAG) on http://www.astag.ch/?rub=118 (accessed 03/MAR/2009)
4) Average diesel prices in Germany 2008 provided the German Association for Trucking, Logistics, and Recycling (BGL) on http://www.bgl-ev.de/web/initiativen/kosten_diesel.htm (accessed 02/APR/2009)
5) Data provided by DHL Freight – value calculated for Germany
Based on these values, road transport costs per kilometre were calculated by summing up the cost elements in Table 7-1. The (time-related) fixed cost elements were converted into distance-related elements by dividing them by the yearly operational performance of the lorry. In order to obtain the total costs for each case study, costs per kilometre were multiplied by the total transport distance. Finally, costs for road tolls were added by multiplying the distances covered in each country by the average toll costs as listed in Table 7-3. In analogy to the assumptions made for the environmental benchmark, toll values for the Euro 3 emissions class was used.

### Table 7-3: Average road tolls per country and emissions class

<table>
<thead>
<tr>
<th>Country</th>
<th>[CHF/km]</th>
<th>Emissions class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Euro 3</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1.0640</td>
<td>0.9040</td>
</tr>
<tr>
<td>Germany (&gt;3 axles)</td>
<td>0.3188</td>
<td>0.2859</td>
</tr>
<tr>
<td>France</td>
<td>0.3125</td>
<td>0.3125</td>
</tr>
<tr>
<td>Italy</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benelux (1-year vignette)</td>
<td>0.0130)</td>
<td>0.0130)</td>
</tr>
</tbody>
</table>

Notes: Conversion factor CHF/EUR = 1.5625
1) Price of vignette divided by yearly operational performance


### 7.1.2 Intermodal transport

#### 7.1.2.1 Rail Main Haulage

For the cost calculation of the rail main haulage in intermodal transport a cost model developed for the intermodal routing software “SPIN-ALP Planner” was used. The underlying cost and performance elements as assumed in IVT AND PTV (2009) are listed in Table 7-4.

Based on these values, total costs are first calculated on a full train basis for the rail traction provider (traction and train path costs plus 10% overhead) and the intermodal operator (rail car and transhipment costs plus 15% overhead). Costs per shipment are then derived by dividing train costs by the average number of shipments per train. The calculation is based on a typical 500 m-long intermodal shuttle train with a gross weight of 1000 tons. One shipment is assumed with a volume of 2 TEU thus resulting in a total train capacity of 0.5 * 60 TEU/train = 30 shipments/train. For a detailed description of the single calculation steps please refer to IVT AND PTV (2009).
Table 7-4: Cost and performance elements for intermodal transport

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Train Path Costs (excl. energy supply &amp; consumption)</strong></td>
<td></td>
<td><strong>Rail Car Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Train Path Factor (CH) [CHF/train-km]</td>
<td>0.95</td>
<td>Car Costs (6-axle car) [CHF/d]</td>
<td>43.75</td>
</tr>
<tr>
<td>Train Path Factor (DE) [CHF/train-km]</td>
<td>3.66</td>
<td>Overhead/Margin Intermodal Operator</td>
<td>15%</td>
</tr>
<tr>
<td>Train Path Factor (NL) [CHF/train-km]</td>
<td>2.45</td>
<td>Transhipment Costs</td>
<td></td>
</tr>
<tr>
<td>Train Path Factor (BE) [CHF/train-km]</td>
<td>1.92</td>
<td>Cost per Lift [CHF]</td>
<td>39.06</td>
</tr>
<tr>
<td>Train Path Factor (FR) [CHF/train-km]</td>
<td>1.22</td>
<td>Terminal Shunting Cost [CHF/train]</td>
<td>312.50</td>
</tr>
<tr>
<td>Train Path Factor (IT) [CHF/train-km]</td>
<td>3.14</td>
<td><strong>Train Properties</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Traction Costs</strong></td>
<td></td>
<td>Train Capacity [TEU/Train]</td>
<td>60</td>
</tr>
<tr>
<td>Factor Single Traction [CHF/train-km]</td>
<td>10.94</td>
<td>Train Load Factor</td>
<td>0.50</td>
</tr>
<tr>
<td>Factor Double Traction (CH, AT, I) [CHF/train-km]</td>
<td>15.63</td>
<td>No. of cars per Train (6-axle cars)</td>
<td>15</td>
</tr>
<tr>
<td>Overhead/Margin Traction Provider 1)</td>
<td>10%</td>
<td>Op. Performance per Car [km/a]</td>
<td>110'000</td>
</tr>
</tbody>
</table>

Note: Conversion factor CHF/EUR = 1.5625
1) The element “Distribution cost” included in the “SPIN-ALP Planner” was omitted.

Source: IVT AND PTV (2009)

The intermodal cost calculation is further complicated by subsidies in Switzerland paid to the rail traction provider, the intermodal operator, and the pre- and post-haulage (PPH) operator. While the discount on the train path factor in Switzerland is already included in the value given in Table 7-4, the remaining subsidies are partly calculated per train, partly per shipment and are therefore subtracted from the resulting total cost per shipment. Basically, the allowable amount of subsidies depends on a) the main haulage section of the transport (i.e. origin and destination region) and b) on the size of the transport container.

If the main haulage leg of the intermodal transport chain crosses the Alps on Swiss territory, an allowance of 45€ (70.31 CHF) is paid per shipment. Furthermore, each train is subsidised with 1100 € (1718.75 CHF) multiplied by a distance-related factor [BAV (2008)]. This factor decreases the further north the northern origin (or destination) terminal is located (i.e. highest for terminals in the German part of Switzerland and in Southern Germany, and lowest in the UK and Scandinavia). Subsidies for non-transalpine main haulage also consist of an allowance per shipment (depending on whether it is an internal or import/export transport) plus a distance-related component depending on the main haulage distance covered on Swiss territory. The accountable distance is limited to 110 km. An overview of the specific subsidy factors is given in Table 7-5.
Table 7-5: Subsidies for intermodal transport in Switzerland

<table>
<thead>
<tr>
<th>Transalpine main haulage</th>
<th>Value [CHF]</th>
<th>Non-transalpine main haulage</th>
<th>Value [CHF]</th>
<th>Pre-/Post-haulage</th>
<th>Value [CHF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per shipment</td>
<td>70.31</td>
<td>Per shipment (CH)</td>
<td>15.63</td>
<td>Per shipment (18'-20')</td>
<td>24.00</td>
</tr>
<tr>
<td>Per train (CH)</td>
<td>2148.44</td>
<td>Per shipment (import/export)</td>
<td>25.00</td>
<td>Per shipment (&gt;20')</td>
<td>37.00</td>
</tr>
<tr>
<td>Per train (DE central)</td>
<td>1632.81</td>
<td>Per km</td>
<td>0.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per train (DE north)</td>
<td>1546.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per train (NL)</td>
<td>515.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per train (BE)</td>
<td>1718.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Conversion factor CHF/EUR = 1.5625

Source: [BAV (2008)], SR 641.811

For each case study subsidies per shipment were calculated depending on the rail connection chosen for the main haulage. Train-related subsidies were converted to amounts per shipment. The resulting main haulage costs were finally obtained by subtracting the total subsidies per shipment from the (above calculated) costs per shipment.

For the four Swiss internal non-transalpine transport samples it was assumed that shipments use SBB Cargo’s “Cargo Domino” service, which integrates transports of 7.45m swap bodies on conventional railcars into the national wagonload network53. In these cases the main haulage process was modelled as for rail-only transport using the corresponding values in Table 7-6 in the following section. Subsidies were included as listed in Table 7-5 for “Non-transalpine main haulage” and “Pre-/Post-haulage”. Due to the use of the wagonload network, the “Cargo Domino” shipments cannot benefit from train path cost reduction (as in dedicated intermodal transport).

7.1.2.2 Road Pre- and Post Haulage (PPH)

For the PPH calculation the same basic elements as in road-only transport (compare section 7.1.1) were employed. One might argue that a lorry’s operational performance in PPH is lower due to the short distances and frequent stops including waiting times. However, lorries are often used for both PPH and longer distance door-to-door road transports so that it is justified to apply the same values as in the cost analysis for road-only transport.

PPH costs per shipment are calculated by multiplying the road distance on either end of the transport chain by the country-specific cost elements as listed in Table 7-2. Since in PPH it is rarely the case that the delivering lorry can immediately take another shipment

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53 http://www.sbbcargo.com/index/ang_produkte/ang_intps/ang_produkte_domino_downloads.htm (accessed 30/JUL/'09)
back to the terminal, total PPH costs per shipment are multiplied by 1.5 to account for the additional costs for driving either back to the terminal or to a nearby shipper to pick up the next outbound shipment.

As mentioned above, in Switzerland PPH operation is also subsidised. Of the heavy-duty vehicles charge (LSVA) paid by the PPH operator an allowance is reimbursed (24 CHF for swap bodies between 5.5 and 6.1 m long and ISO containers between 18’ and 20’, respectively; and 37 CHF for swap bodies longer than 6.1 m and ISO containers longer than 20’, respectively)\(^5\). These values are also included in Table 7-5.

Total costs per shipment for the entire intermodal transport chain are finally derived by summing up the resulting main haulage and PPH costs (both including the allowable subsidies).

### 7.1.3 Rail Transport

For the cost analysis in rail wagonload transport two different approaches were compared to obtain most realistic results. The first approach is the cost-based calculation (similar to the main haulage cost calculation in intermodal transport, but with partly different cost and performance elements – see Table 7-6). Other than in intermodal transport, twice the total distance was considered for the calculation, since in wagonload transport the probability to find suitable backload for the same rail car on the same connection is very low.

**Table 7-6: Cost and performance elements for rail transport**

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Train Path Costs (excl. energy supply &amp; consumption)</strong></td>
<td></td>
<td><strong>Rail Car Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Train Path Factor (CH) [CHF/train-km]</td>
<td>2.65</td>
<td>Car Costs (2-axle car Hbbillns) [CHF/d]</td>
<td>30.00</td>
</tr>
<tr>
<td>Train Path Factor (DE) [CHF/train-km]</td>
<td>3.66</td>
<td><strong>Shunting Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Train Path Factor (NL) [CHF/train-km]</td>
<td>2.45</td>
<td>Classification in Yard [CHF/car]</td>
<td>10.00</td>
</tr>
<tr>
<td>Train Path Factor (BE) [CHF/train-km]</td>
<td>1.92</td>
<td>Train Grouping [CHF/train]</td>
<td>100.00</td>
</tr>
<tr>
<td>Train Path Factor (FR) [CHF/train-km]</td>
<td>1.22</td>
<td><strong>Train Properties</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Traction Costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor Single Traction [CHF/train-km]</td>
<td>10.94</td>
<td>No. of cars per Train (2-axle cars)</td>
<td>20</td>
</tr>
<tr>
<td>Factor Double Traction (CH, AT, I) [CHF/train-km]</td>
<td>15.63</td>
<td>Op. Performance per Car [km/a]</td>
<td>60'000</td>
</tr>
<tr>
<td>Overhead/Margin</td>
<td>15%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Conversion factor CHF/EUR = 1.5625

---

As an alternative a price-based approach was tested: SBB Cargo publishes detailed price lists for internal and border-crossing transports to and from Switzerland\textsuperscript{55}, which were applied for the case studies assuming a 2-axle car for each shipment (including return of the empty wagon to the origin). The general problem about rail freight price lists is that the published prices are almost never charged without reductions, which strongly depend on the volumes shipped by a single customer and are specified in individual contracts. Therefore, to obtain realistic price estimates, suitable assumptions must be made concerning these reductions. Experts’ experiences show that a realistic range is between 30 and 50\%. A comparison of these two approaches is illustrated in Figure 7-1.

Figure 7-1: Rail price calculation (cost-based vs. price-based approach)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail - Cost-based</td>
<td>241.71</td>
<td>406.96</td>
<td>451.43</td>
<td>1622.60</td>
<td>595.57</td>
<td>102.03</td>
<td>686.33</td>
<td>731.36</td>
</tr>
<tr>
<td>Rail - Price-based</td>
<td>690.2</td>
<td>1330.00</td>
<td>935.90</td>
<td>2497.3</td>
<td>1446.8</td>
<td>2752.3</td>
<td>1865.7</td>
<td>2099.3</td>
</tr>
<tr>
<td>Actual Price Rail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road</td>
<td>269</td>
<td>528</td>
<td>861</td>
<td>1565</td>
<td>1712</td>
<td>2211</td>
<td>1509</td>
<td>1456</td>
</tr>
</tbody>
</table>

The decision, which approach is more realistic, is not straightforward, because a benchmark with actual prices of the case studies is possible only for those two, where rail transport is the currently used mode (i.e. Monthey – Rotterdam and Trier – Dagmersellen). In case of the latter a good match could be reached with the price-based approach. Another argument against the cost-based approach is that the resulting values in all samples are more than 50\% lower than the ones of the price-based calculation and also lower than calculated prices for road transport. Lower prices for rail than for road transport also on shorter distances (such as the first two samples) seem not realistic due to the higher fixed costs in rail transport resulting in higher prices per km.

These considerations led to the decision to apply (for rail-only transport) the price-based approach in the following case study analysis. For road and intermodal transport, however, the described cost-based models were used.

\textsuperscript{55} Relevant for the case studies are: SBB Cargo – Tariff 800.000 (version 01/JAN/’09); Dutch/German – Swiss Rail Freight Tariff No. 7300.00/7301.00 (updated 01/JAN/’09); Wagonload Tariff 9506 – 00 for the corridor Netherlands/Belgium to/from Switzerland via France (version 01/JAN/’09) (all documents available at www.sbbcargo.com – accessed 17/JUL/’09).
7.1.4 Data Uncertainties

As mentioned above, in all three cost models assumptions were made for several cost elements due to a lack of reliable data sources. Assumptions per se always hold uncertainties, which must be accounted for by a sensitivity analysis. Furthermore, uncertainties are also brought into the model by sound data, which are subjected to variations over time.

Since some cost elements have a smaller impact on total costs than others, the result’s sensitivity to these uncertainties is lower than the one to variations in values of more important elements. Therefore, the sensitivity analysis was limited to a) the most relevant elements and b) elements with especially uncertain assumptions. A list of the considered elements (including lower and upper bounds) is given in Table 7-7.

### Table 7-7: Cost and performance elements considered in the sensitivity analysis

<table>
<thead>
<tr>
<th>Road Transport</th>
<th>Lower Bound</th>
<th>Assumed Value</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel price CH [CHF/l]</td>
<td>1.61</td>
<td>2.03</td>
<td>2.30</td>
</tr>
<tr>
<td>Fuel price EU [CHF/l]</td>
<td>1.58</td>
<td>2.00</td>
<td>2.62</td>
</tr>
<tr>
<td>Operational performance, lorry CH [km/a]</td>
<td>90’000</td>
<td>120’000</td>
<td>150’000</td>
</tr>
<tr>
<td>Operational performance, lorry EU [km/a]</td>
<td>120’000</td>
<td>150’000</td>
<td>170’000</td>
</tr>
<tr>
<td>Overhead/Margin</td>
<td>10% of fixed costs</td>
<td>12% of fixed costs</td>
<td>15% of fixed costs</td>
</tr>
</tbody>
</table>

| Intermodal Transport                    |             |               |             |
| Train load factor                       | 0.25        | 0.50          | 0.75        |

| Rail Transport                          |             |               |             |
| Reduction on list price CH              | 20%         | 50%           | 50%         |
| Reduction on list price import/export   | 20%         | 35%           | 50%         |

7.2 Price Analysis Results

Using the models introduced in the previous section, prices for all relevant transport modes were estimated for each case study (the price for rail was included only if this mode was a realistic alternative in the corresponding transport sample). The results are illustrated in Figure 7-2 including lower and upper bounds from the sensitivity analysis. For comparison, corresponding prices as reported by the respondents for the transport mode actually used are displayed as an additional column in the figure.

The case studies are grouped by internal transports (first five from the left), export and import (four samples each). For each connection distances in road transport are indicated. (Note that in specific cases calculated distances in rail and intermodal transport may exceed this value significantly.) Above each column for the actual price the transport mode currently used is indicated (together with the corresponding colour of the column).
7 – Analysis of Prices for Freight Transport Services

**Figure 7-2: Calculated and actual prices for the case studies**

![Graph showing calculated and actual prices for different case studies.](image)

The overall impression of the results is that the applied cost models have difficulties reproducing the prices actually paid for the sample shipments, although in some cases a good match is reached. The model results seem to be slightly better for longer distance transports than for short distance (internal) transports in Switzerland. However, no systematic error can be observed, because the prices are neither generally overestimated nor always too low. Thereof we conclude that it is generally hardly possible to estimate realistic prices for specific transports, because the influencing pricing factors are too manifold and too complex to be entirely included in a model.

This conclusion is supported by an analysis of prices of the complete survey sample. Figure 7-3 shows median prices per ton-kilometre aggregated to six distance classes, which were defined according to the number of samples per distance band (the minimum is 26).

Despite the oscillating lines for road and rail prices, a clear trend of decreasing prices per tkm over distance is visible. The rail transport value of 0.10 CHF/tkm for the distance class of 100-199 km can be considered an outlier, which is caused by a high share of whole train shipments with a tonnage of more than 1000 tons.
Comparing the specific prices for the analysed transport samples (represented by diamonds in the corresponding colour) with the median values, the match with the median of the total sample is reasonable in most cases, while the deviations from the mode-specific medians are even larger than the ones in Figure 7-2. This is furthermore underlined by the large bandwidth of values for each distance class (compare 25% and 75% percentile values in Table 7-8): even in the total sample the 75% percentile reaches up to 560% of the median value.

Table 7-8: Detailed price analysis of the survey sample

<table>
<thead>
<tr>
<th>CHF/tkm</th>
<th>&lt;100 km</th>
<th>100-199 km</th>
<th>200-399 km</th>
<th>400-699 km</th>
<th>700-799 km</th>
<th>&gt;=800 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2.48</td>
<td>2.68</td>
<td>1.26</td>
<td>0.86</td>
<td>0.22</td>
<td>0.31</td>
</tr>
<tr>
<td>Median</td>
<td>0.50</td>
<td>0.58</td>
<td>0.33</td>
<td>0.27</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>25% Percentile</td>
<td>0.29</td>
<td>0.24</td>
<td>0.18</td>
<td>0.14</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>75% Percentile</td>
<td>2.38</td>
<td>1.91</td>
<td>1.85</td>
<td>1.38</td>
<td>0.19</td>
<td>0.39</td>
</tr>
<tr>
<td>Road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2.30</td>
<td>3.29</td>
<td>1.14</td>
<td>1.18</td>
<td>0.23</td>
<td>0.36</td>
</tr>
<tr>
<td>Median</td>
<td>0.48</td>
<td>0.97</td>
<td>0.26</td>
<td>0.66</td>
<td>0.14</td>
<td>0.16</td>
</tr>
<tr>
<td>25% Percentile</td>
<td>0.29</td>
<td>0.33</td>
<td>0.19</td>
<td>0.26</td>
<td>0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>75% Percentile</td>
<td>2.35</td>
<td>2.25</td>
<td>0.57</td>
<td>2.43</td>
<td>0.20</td>
<td>0.40</td>
</tr>
<tr>
<td>Rail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>4.05</td>
<td>0.13</td>
<td>1.48</td>
<td>0.11</td>
<td>0.10</td>
<td>0.11</td>
</tr>
<tr>
<td>Median</td>
<td>1.19</td>
<td>0.10</td>
<td>0.72</td>
<td>0.11</td>
<td>0.09</td>
<td>0.11</td>
</tr>
<tr>
<td>25% Percentile</td>
<td>0.72</td>
<td>0.07</td>
<td>0.17</td>
<td>0.08</td>
<td>0.05</td>
<td>0.11</td>
</tr>
<tr>
<td>75% Percentile</td>
<td>5.95</td>
<td>0.17</td>
<td>1.14</td>
<td>0.14</td>
<td>0.14</td>
<td>0.11</td>
</tr>
<tr>
<td>Intermodal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.22</td>
<td>1.61</td>
<td>0.75</td>
<td>0.25</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>1.50</td>
<td>1.40</td>
<td>0.75</td>
<td>0.17</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>25% Percentile</td>
<td>1.03</td>
<td>0.27</td>
<td>0.42</td>
<td>0.13</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>75% Percentile</td>
<td>1.54</td>
<td>2.74</td>
<td>1.07</td>
<td>0.36</td>
<td>0.28</td>
<td></td>
</tr>
</tbody>
</table>

The above analysis clearly demonstrates that with either approach (cost-based as well as price-based) it is very difficult to approximate real prices for concrete transport services.
with given shipment sizes and transport distances. It is nevertheless necessary in this research to make assumptions about mode-specific prices for the analysed case studies in order to estimate the market potential of environmentally better performing freight transports based on a cost-benefit-analysis.

We therefore decided to apply the cost-based prices for road and intermodal transport in the cost-benefit-analysis (see following section), while for rail-only transport the cost-based approach was replaced by the price calculation based on price lists (as described in section 7.1.3). The decision concerning road and intermodal prices is based on a) the fact that the applied cost models have already been applied in similar analyses (the above mentioned “SPIN-ALP Planner”, for example, is a specialised tool for such comparisons [IVT AND PTV (2009)]) and b) the higher estimation quality of the cost-based approach when comparing the mean absolute percentage errors (MAPE), which is 0.06 vs. -1.65 for the price-based estimation. The absolute bias between estimated and real prices is of minor relevance for the cost-benefit-analysis, because this is based on relative differences between the mode-specific prices.
8 Potential of Environmentally Friendly Freight Transport

After the environmental benchmark and price analysis, this chapter presents the resulting cost-benefit-analysis of the case studies analysed by the environmental benchmark (section 8.1). In the following sections the results from the cost-benefit-analysis are interpreted in terms of sustainable freight transport’s economic potential and the potential effectiveness of the proposed labelling system.

8.1 Cost-Benefit-Analysis

8.1.1 Introduction

The cost-benefit-analysis was carried out to compare a potential gain in environmental performance with the related change in transport price. If for example a shipment currently carried by lorry would be transferred to rail, what would be the environmental gain in relation to the expected price increase?

To answer this question, for each available mode in each transport sample absolute changes in transport prices (for each mode not currently employed) were plotted against the relative environmental impact of this mode (see Figure 8-1). The x-axis (in logarithmic scale) represents the percentage change in environmental impact; differences in transport price (absolute values in CHF/shipment) are plotted on the y-axis. Each case study is represented by a different colour. Differences in brightness specify the available modes as listed in the legend (the brighter data points are framed with a line of the corresponding darker colour). The data sets consist of three values, each of which represents one environmental impact category: the diamond stands for the “Human Health” category, the square for the “Ecosystem” category, while the triangle indicates the “Total Energy Demand” (compare chapter 1).

56 The term “cost-benefit-analysis” is not employed literally (“price-benefit-analysis” might be more appropriate) but is nevertheless held, because it is a common term describing the general comparison of efforts vs. benefits for a certain object.
Figure 8-1: Results of the cost-benefit-analysis
As an example take the intermodal alternative of the Altstätten – Basel connection (in gray-blue): its calculated transport price would be about 120 CHF lower than for the currently used road alternative, while at the same time the impact of this shipment on human health would be reduced by 65%, on ecosystems by around 60%, and total energy demand would be almost 40% lower. For this sample no values for rail transport are available, because it is not a realistic alternative (i.e. shipper without rail access).

8.1.2 Results

The results are interpreted separately for each quadrant of the diagram starting with the upper right one and proceeding in clockwise direction.

8.1.2.1 The “Lose-Lose-Situation”

Transport options in the upper right quadrant combine higher transport prices with increased environmental impact (such as Stabio – Neuenburg by road or Nancy – Landquart by intermodal transport). Evidently, these are interesting neither for shippers nor for LSPs, because the willingness to pay higher prices for reduced benefit can be expected to be zero.

It is worth pointing out that not all values in this quadrant belong to road transport alternatives: the Nancy – Landquart (black), Rorschach – Zutphen (bright pink), and Neuenegg – Wangen (bright brown) results are for intermodal transport. The main reason for this is the longer transport distance in intermodal transport as compared to the road option, which leads primarily to a significant increase in energy demand (represented by the triangles) but influences also the impact on human health and ecosystems. The relative impact reduction in the “Human Health” category in the latter two cases (despite the longer transport distances) is mainly due to the strong influence of road traffic accidents on the road-only alternative, which is four to six times higher in road than in intermodal transport. In case of the Neuenegg – Wangen sample the difference in transport distance is less significant so that the lower specific CO₂-emissions in intermodal transport (due to electric rail traction) over-compensate the additional emissions from the distance surplus. This leads to a relative reduction of environmental impact also in the “Ecosystem” category.

These results underline that intermodal (and also rail-only) transport is not necessarily the better alternative from the environmental perspective, let alone in terms of prices.

8.1.2.2 The “Cost Optimisation” Option

The lower right quadrant contains cases with higher environmental impact but lower transport price. These samples might be interesting alternatives for shippers not attaching much importance to environmental aspects but rather optimising their transport logistics in terms of costs.
In particular the Trier – Dagmersellen connection by road or the Monthey – Rotterdam link by intermodal transport, both of which are currently operated by rail transport, hold high potential for cost optimisation. Especially the Monthey – Rotterdam intermodal option combines a potential price reduction by almost 800 CHF with a comparatively low emissions increase (between 31% for energy consumption and 77% for human health impact).

8.1.2.3 The “Win-Win-Situation”

Concerning the third quadrant, alternatives promising both lower price and reduced environmental impact are certainly most interesting for shippers as well as for LSPs. Especially the intermodal option for the Rotterdam – Basel hinterland connection would clearly be worth considering as a valuable alternative, because it combines a potential price reduction of ca. 550 CHF with an emissions decrease by up to 85% (for the Human Health impact category). However, since this example is a shipment of fresh foodstuff, transit time and on-time reliability play an important role, which are not considered in the cost-benefit-analysis.

In sum only three of the 13 case studies belong to this category of lower price combined with reduced environmental impact. Furthermore, the results of the Altstätten – Basel intermodal option include rather high uncertainties, since in this case the use of the “Cargo Domino” service was assumed (compare previous section), for which a reliable price estimation is especially difficult. On the other hand a higher share of samples in this quadrant would have been astonishing, because this would mean that many shippers would have difficulties optimising their shipments even in terms of transport price.

8.1.2.4 The “Environmental Optimisation” Option

Most interesting in the context of this research are the samples in the upper left quadrant (i.e. with higher prices but reduced environmental impact), because here shippers’ willingness-to-pay (WTP) for better environmental performance (as calculated in chapter 5) comes into play.

We recall that global WTP for the complete survey sample was 1.27 CHF/shipment for each percent-point increase in environmental performance (compare Table 5-12 on page 95). Assuming this WTP follows a linear function, it can be drawn as a straight line from the origin as plotted in Figure 8-2. It becomes clear that most data sets in this quadrant have a much stronger price increase than the margin, which could possibly be compensated by shippers’ additional WTP for the corresponding increase in environmental performance.

There are only two samples that are even close to this range, the first of which is the intermodal alternative for the Brüttisellen – Luzern connection (brown). This offers, however, no significant gain in environmental performance so that the shipper would hardly be ready to pay 64 CHF more per shipment.
The second case is the intermodal option for the Givisiez – Regensdorf connection (green). The environmental benchmark for this sample resulted in quite different values for the three impact categories so that we must take a closer look at which of them is most relevant to the shipper. Since in the interviews environmental performance was represented by the attribute “Greenhouse-gas emissions”, the “Human health” impact category is probably most relevant for the WTP comparison, because GHG-emissions mainly affect this category. Since in this case the gain in environmental performance is highest in the “Human health” category (impact reduction by ca. 50%), the Givisiez – Regensdorf sample looks like it could be a realistic case, in which the shipper might accept the price difference of 65 CHF/shipment for reducing environmental impact.

**Figure 8-2: Detailed view of the upper left quadrant in Figure 8-1**

Nevertheless, two arguments are opposed to this hypothesis: one is that this case study is a shipment of metal products, which belongs to commodity group 4 (“Iron & metal products). Since, according to the modelling results in Table 5-12, shippers in this group are willing to pay only about 0.68 CHF/shipment per percent-point decrease in
environmental impact (thus half as much as the WTP of the global model), the 65 CHF price increase for a 50% reduction seems hardly acceptable. The second point is that the assumption of linearity in WTP may not hold. We might expect it to be the case that the WTP function is not linear but flattens at higher reduction rates. Supposing this would be true, this fact would further reduce shippers’ WTP for a 50% reduction.

8.2 Economic Potential for Logistics Providers

From the above evaluation we conclude that, although a WTP for reducing freight transport’s environmental impact can be observed, the acceptable price margins are generally too small to find examples of shipments, for which this WTP could be the driving force for transferring a shipment to a more environmentally friendly transport mode.

The hypothesis in chapter 3.4 (claiming that in most cases the economic potential of labelled transport chains is expected to be low) can therefore be accepted: LSPs cannot generally expect realising positive price margins from offering alternative transport modes as environmentally friendly transport options, because the differences in operational costs exceed the realistic margins. This, however, concerns only the cases with an increase in transport price: for the samples with both reduced environmental impact and lower operational costs (the ones in the lower left quadrant of Figure 8-1) LSPs might indeed be able to realise additional price margins.

Furthermore, the second part of the hypothesis (according to which eco-labelled transport services might be an interesting field for niche players in specific commodity groups) cannot be directly supported. Although the analysed case studies, which represent all relevant commodity groups, show large differences in environmental potential and price, only three of them offer a sufficient cost-benefit-ratio for successful modal shift. Since these three samples belong to three different commodity groups and different transport sectors, a specific niche cannot be identified.

However, the generalisation that environmentally better performing transport alternatives are always too expensive to be accepted by a shipper is not justified. One must keep in mind that the price calculation is based on single shipments of a given size; a more comprehensive reorganisation of the transport chain (including an adaptation of shipment sizes, frequencies, etc.) might bring down the resulting price per shipment to an acceptable level and thus a better cost-benefit-ratio.

Furthermore, other measures to increase environmental performance exist, such as using lorries with higher emission classes. As evaluated in section 6.2.2.4, such vehicles allow reductions of emissions with damage to human health of up to 5% (when comparing between the Euro 3 and Euro 4 emission classes) and more (with Euro 5 engines). Although these vehicles consume slightly more fuel (the difference between Euro 3 and 4 is in average 0.3 litres per 100 km [INFRAS ET AL. (2004)]), road toll systems in several European countries (e.g. in Switzerland and Germany) abet lorries with higher emission
classes so that additional fuel costs are more than compensated, which results all-in-all in lower operational costs. Other measures (such as driver training for fuel-efficient driving) aim at reducing fuel consumption, which results in both higher environmental performance and cost reductions.

These examples (although they are not as effective as a change of transport mode) show that emissions reductions are not necessarily linked to a cost increase: this could be beneficial to the LSP as well as to the shipper (if price reductions can be realised).

Eventually, we cannot give a clear recommendation for LSPs to actively expand the market segment of environmentally friendly transport services. “Green” transport offers hold indeed a certain market potential but should always include a careful consideration of a shipment’s specific constraints.

8.3 The Potential of Environmental Information as a Steering Instrument

In the context of the previous considerations an environmental labelling system (as proposed in this section) could be a useful decision aid for the shipper by informing about the environmental improvement potential of different transport service offers.

8.3.1 Labelling Concept

One of the reasons for examining the applicability of a labelling system for freight transport services is the innovative idea of using “soft” steering instruments to improve freight transports’ environmental performance (compare section 2.5.2 on page 22). Labels are able to facilitate the comparison of alternatives based on standardised information (such as energy consumption, CO₂-emissions, etc.) and the classification of alternatives according to specified criteria.

When thinking about a label on freight transport services one must differ between two “target groups”, as illustrated in Figure 8-3: the first group consists of logistics managers, which buy transport services from external providers; the second group are the end-consumers buying a product, which (or parts of which) was previously transported by a labelled freight transport. Designing a label, which satisfies the needs of both groups, is difficult due to their different backgrounds and information requirements.

8.3.1.1 Requirements of the Logistics Manager

When ordering a transport service, a logistics manager first collects offers from different service providers and compares them before placing the definite order. If environmental aspects are relevant for the comparison, according information is necessary on all offers. In order to guarantee comparability of the data, the label could be used to define a standardised set of indicators (green icons in Figure 8-3).
One possibility would be to use the endpoint categories of the ReCiPe method (i.e. “Human Health”, “Ecosystem”, and “Resource Consumption” or “Energy Demand”, respectively). However, as evaluated in section 6.2.2.5, the sum of only four single environmental interventions (CO₂, NOₓ, particles, and traffic accident damages) represents 90% and more of the total damage to human health and ecosystems. Therefore, a suitable alternative could be to use these categories plus total energy consumption as indicators to be directly displayed on the label. Although five indicators might be considered a fairly large number for a simple comparison, the clear advantage is that they are less abstract than the aggregated ones and avoid the weighting problem: logistics managers could decide themselves, which indicator might be most relevant for their evaluation of transport service offers. Based on these advantages we recommend the use of the five disaggregate environmental interventions.

8.3.1.2 Requirements of the End-Consumer

The second “target group”, i.e. the end-consumer, is less interested in such details but wants to know simply, which product has the best overall environmental performance. For the purpose of such simple comparisons, the proposed label could be adapted from the existing Swiss energy label “Energieetikette”, which is implemented so far in the automobile, household appliance and lighting sectors. As illustrated in Figure 8-4, this labelling system consists of seven categories (A-G) with category D corresponding to the
average environmental impact. The categories are readjusted regularly to have always one-seventh of all certified transport solutions ranked in category A (best value). This guarantees that the entire bandwidth of the labelling system is used and that potential remains for further improvement in environmental efficiency.

Figure 8-4: Example of the “Energieetikette”

Source: http://www.energieetikette.ch

Unfortunately, this concept has two major problems: the first one is the difficulty to define an average environmental impact of freight transport services, and the second problem is the risk to induce additional production costs and rather confuse the end-consumer by introducing another label (in addition to the already large number of existing ones), as mentioned in section 2.5.2 on page 22.

The first problem could possibly be overcome by replacing the average environmental impact by the one of a reference group, as applied e.g. for the “Climatop”CO₂-label⁵⁷. For freight transport a number of reference transports could be defined differing between e.g. transport mode, weight and size of shipment, vehicle load factor, share of empty return

⁵⁷ http://www.climatop.ch
The necessary level of detail would have to be evaluated in a more detailed analysis.

The second problem could be solved by integrating the freight transport label into existing product labels. This would not be a problem for products with mandatory labelling schemes, such as the above-mentioned “Energieetikette”. For products with voluntary schemes, however, this would be more complex, since for non-labelled products their transport-related environmental impact could not be communicated to the end-consumer.

In these cases it might be justified to introduce a separate label on freight transport on the final product. However, the effect and validity of such kind of label can be questioned. A mandatory scheme with quantitative information would hardly be accepted by manufacturers and retailers due to cost increases and unrealistic organisational effort. Furthermore, it would provide the end-consumer with no information about the overall environmental impact of a product, and often production-related emissions by far exceed the ones caused by transport processes.

Therefore, the only realistic and useful approach could be to introduce a mandatory air transport label. Although air freight transport is not covered by this research, it is generally the transport mode with highest emissions per ton-kilometre [IFEU (2008)]. An air transport label could encourage the end-consumer to avoid products transported by air. On the other hand it could conflict with already existing air transport labels, such as the “By-air” label\(^58\) by the retailer “Coop”, since this indicates air transport with compensated CO\(_2\)-emissions.

### 8.3.2 Potential of Label Information to Influence Shipper Demand

#### 8.3.2.1 Impact of Label Information

In order to estimate the potential effectiveness of a freight transport label from the logistics manager’s perspective, we come back to the modelling results presented in Table 5-8 on page 87: the results for “GHG-emissions” suggest that, given a 10% increase in greenhouse-gas emissions (while keeping all other attributes constant), the odds of choosing the corresponding alternative would decrease by 0 – 15% depending on the commodity group (with only the Building materials group showing no sensitivity to GHG-emissions). This matches well with the survey results by CORDES (2008), who reported that only 17% of the interviewed shippers would be indifferent to changing emissions levels.

These results suggest that, if standardised environmental information could be, shippers would indeed consider this information in their transport logistics planning.

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\(^58\) http://www.coop.ch/by-air
The problem in this context, however, is illustrated by the results of the cost-benefit-analysis in section 8.1: in certain cases an increase in environmental performance is not gratis (at least when comparing between different transport mode alternatives), and the price differences are often much greater than the margins, which could be compensated by shippers’ additional willingness-to-pay (at least for the case studies analysed in this project). This would clearly conflict with the effectiveness of the proposed labelling system. A possible solution could be a combination of the label with a bonus-malus-system.

### 8.3.2.2 Combination of Labels with a Bonus-Malus-System

A bonus-malus-system is a financial incentive scheme to achieve defined political goals (such as emissions reductions) by punishing those actors not complying with this goal and abetting the ones actively supporting it. An example in this context is the CO₂-charge on fossil fuels\(^{59}\), which is currently applied only to combustibles for non-transport applications. The levels of this charge are linked to the achievement of predefined reduction goals for CO₂-emissions in Switzerland. Since these goals were not reached since its introduction in January 2008, the charge will be increased in January 2010 to 36 CHF/t CO₂, which equals to 0.09 CHF per litre heating oil.

The CO₂-charge could also be applied to fuel consumption in transportation. Assuming the updated level of 0.09 CHF/l, its application to the benchmarked case studies shows that the resulting price margin would not exceed 28.50 CHF per shipment. Compared to the calculated price differences between transport modes, this amount could hardly influence a shipper to choose an environmentally better performing transport solution.

The legitimate upper limit of the CO₂-charge is 210 CHF/t CO₂ (0.50 CHF/l). This would increase the road transport price in the Rotterdam – Basel example (the one with the greatest difference in energy demand) by around 159 CHF. However, the energy saving potential is lower in case of the critical samples in the upper-left quadrant of Figure 8-1 (as discussed in section 8.1): in the Brüttisellen – Luzern example intermodal transport’s energy demand is just 5% below the one of the road alternative, which would result in a price increase for road of only 1.08 CHF when calculating with the maximum level of 0.50 CHF/l diesel.

On the other hand more pronounced charge rates would make no economic sense. It is due to the large price differences between transport modes that such a bonus-malus-system cannot effectively approximate the prices of the mode-specific alternatives in a way that environmental criteria could (indirectly) become the key factor for transport mode choice.

We therefore conclude that the initial hypothesis from section 3.5 assuming a measurable impact of environmental information on shippers’ demand can be maintained based on the

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\(^{59}\) This is based on the Swiss act on CO₂-charges no. SR 641.712 from June 8, 2007.
modelling results from section 5.3.4.1. However, when comparing different transport mode options for a given shipment, price differences are mostly too large (with a positive sign) to be able to provoke a modal shift based on the label information (even when combining the label with a bonus-malus-system). The label could be more effective when comparing transport offers with only slightly higher (or even lower) prices but certain improvement potential in environmental performance, such as the examples discussed in section 8.2 (higher lorry emission classes, driver training, etc.).

### 8.3.3 Recommendation

From the above considerations we conclude that it is not straightforward to implement a label on freight transport services, which can be a useful decision aid for logistics managers as well as for end-consumers.

Clearly, standardised information on freight transports’ environmental performance (be it in form of a label or otherwise) could ensure transparency for shippers and facilitate the comparison of different transport options in terms of environmental performance. This could help including the environmental aspects in the evaluation of available transport offers. For this purpose, the indication of the most important environmental interventions (i.e. CO$_2$, NO$_x$, particles, and traffic accident damages) is probably easier to understand than aggregated endpoint indicators.

On the other hand, product labelling for the information of end-consumers cannot be recommended without reservation, because the risk to overload product packaging with (sometimes not directly relevant) label information and induce unjustified increases in production costs is high. In order to gain more precise information on positive and negative effects of such a freight transport label, a first attempt might be to integrate information on transport emissions into the existing “Energieetikette” and limit the trial to products already covered by this labelling scheme. This might be done using the existing label categories and defining appropriate reference transports as a benchmark for ranking the according transport chains, as proposed in section 8.3.1.2.
9 Concluding Remarks and Perspectives for Further Research

This concluding chapter contains a summary of the key results obtained from each work package, concluding remarks on the project as a whole, and finally a short outlook concerning future research in the field of environmental aspects in freight transportation.

9.1 Summary of Key Results

At the beginning of this report we have asked the question of what impact information about transport’s environmental performance has on shippers’ freight transport mode choice as compared to other demand factors and what is the perceived value of higher environmental performance in comparison to other demand criteria. In the following we summarise the answers to the detailed questions derived from this consideration.

Do shippers consider environmental aspects in transport mode decisions, and how does it vary between specific types of commodities? What is shippers’ willingness to pay for environmentally friendly transport solutions?

A general willingness-to-pay exists among Swiss shippers for reducing greenhouse-gas emissions in freight transport. The value lies in the region of 1.27 CHF per shipment for each percent-point decrease in environmental impact. Shippers of finished products, which are in direct contact with end-consumers, (namely firms in the manufactured goods and food/animal feed commodity sectors) show a higher sensitivity to environmental concerns (ca. 1.50 CHF/%-point per shipment) than the ones of raw materials and other lower value products (0 – 0.70 CHF/%-point per shipment). In other words, the higher the specific value of the cargo and the higher the position of a product in the value creation chain, the more a shipper can be expected to be willing to pay for a reduction of its freight transport’s GHG-emissions. This result appears plausible, since first it is mainly the end-consumer deciding to buy environmentally friendly products, and second the higher the product value, the lower the share of transport costs in total production costs: a marginal increase in transport costs is therefore much easier accepted in case of high value products.

What is shippers’ perceived value of reducing environmental impacts compared to the value of “conventional” aspects (e.g. on-time reliability, transit time, etc.)?
The modelling results in chapter 5.3.4 allow a clear ranking of the analysed demand criteria: on-time reliability is generally most relevant, followed by transport price, while GHG-emissions and transit time are at a comparable level.

When comparing willingness-to-pay (WTP) values per ton-kilometre (tkm), food/animal feed products and manufactured goods appear most sensitive to on-time reliability as well as to transit time. This makes sense, since these commodity groups have a great share of finished products, which are mostly of high value and often integrated into just-in-time or other comparable logistics concepts.

WTP values per tkm for emissions reduction are also highest for these goods. This underlines that shippers, which are in direct contact with end-consumers, are more sensitive to environmental concerns than others further back in the value creation chain (such as the building materials sector, for which no significant WTP for emissions reduction could be observed). Not directly supported by the survey data, however, is the hypothesis that shippers of dangerous goods are especially sensitive to environmental concerns.

What criteria can be used for measuring the environmental impact of transport chains?

In this research the use of life-cycle assessment (LCA) proved to be a suitable approach for measuring a shipment’s environmental impact. The applied “ReCiPe” method distinguishes between three impact categories: damage to human health (caused e.g. by greenhouse-gas-emissions), to ecosystems (i.e. pollution of soil and water), and resource consumption. The method was extended by impacts from traffic accidents to better comply with the particularities of (freight) transportation.

The hypothesis in chapter 3.3 was that road transport’s environmental performance is generally lower than the one of rail and intermodal transport. This hypothesis can be sustained based on the environmental benchmark of selected case study in chapter 6.2.2. In most cases, independent of sector and distance, road transport has the worst environmental performance across all three environmental impact categories, followed by intermodal transport and rail-only transport. The differences between road and intermodal transport depend mainly on the margin between actual transport distances of the two modes, i.e. in several cases the distance in intermodal transport is much longer than the direct route taken by the lorry.

Is the market segment of environmentally friendly transport services a field worth being expanded from a logistics service provider’s perspective?

Logistics service providers cannot generally expect realising positive price margins from offering alternative transport modes as environmentally friendly transport options, because the differences in operational costs generally exceed the margins, which could possibly be compensated by shippers’ WTP. On the other hand the cost-benefit-analysis has revealed certain cases where a modal shift could provoke both, a cost reduction and a decrease in environmental impact. Therefore, environmentally more efficient solutions are
not a priori uneconomical, but each transport should be analysed within the context of its specific constraints.

Furthermore, the hypothesis that eco-labelled transport services might be an interesting field for niche players in specific commodity groups, cannot be directly supported (but also not clearly rejected). Although the analysed case studies, which represent all relevant commodity groups, show large differences in environmental potential and price, only three of them offer a sufficient cost-benefit-ratio for successful modal shift. Since these three samples belong to three different commodity groups and different transport sectors, a specific niche cannot be identified. However, one must keep in mind the limited number of case studies for the cost-benefit-analysis. A higher number of samples per commodity group (including varying shipment sizes) might therefore reveal a different picture.

How great is the potential of a labelling system to contribute to the EU commission’s energy efficiency goals?

Basically, the potential of an eco-label for freight transport services to support the use of environmentally friendly transport modes is low. When comparing different transport mode options for a certain shipment, price differences are mostly too large to be able to provoke a modal shift based on the label information (even when combining the label with a bonus-malus-system). The label could rather be a useful aid for comparing similar transport offers with more or less the same price but differences in environmental performance (e.g. due to the use of enhanced vehicle technology in road transport).

9.2 Concluding Remarks

From the above results we conclude that nowadays environmental concerns play a role in strategic transport logistics planning. These findings match well with qualitative studies that the willingness to pay higher prices for increased environmental performance of a shipment is still low: 38 CHF per shipment for a 30%-point change is a negligible amount compared to absolute transport prices of full truckload shipments of more than 50 km distance.

However, the general WTP shows that shippers are not entirely indifferent to the environmental performance of their carriers. If price differences are small enough between alternatives, many of them can be expected to choose the solution with better environmental performance.

Sceptics might claim that the survey data for this research was recorded before the actual economic crisis and that the “greening of freight transport” is only a temporary phenomenon during high boom periods. This was recently disproved by a survey of the European Business School’s Supply Chain Management Institute (SMI), according to which 63% of the interviewed logistics managers stated that, despite the economic crisis, environmental performance in supply chain management remains a vital issue [VERKEHRSRUNDSCHAU (2009)]. The article reports good practise examples combining
environmental performance with operational cost reductions. These include short-term measures, such as driver training, but also strategic concepts, e.g. the use of lorries with higher emission standards or also a modal split optimisation (i.e. choosing the most appropriate transport mode for each shipment).

These examples show that the issue of this research is still up to date and certainly will be even more critical in the expected period of economic pick-up. The results represent only a snapshot of freight transport demand, and it is not unlikely that shippers’ WTP for environmental performance might increase significantly over the next years.

9.3 Perspectives for Further Research

The expected increase in shippers’ sensitivity for environmental concerns in freight transport might necessitate an update of the results of this research. It would be especially worthwhile to collect Revealed Preference (RP) data from shippers having contracted an LSP based on a comparison of offers with different operational performance. This data could be combined with Stated Preference (SP) data from Stated Choice experiments carried out (if possible) within the same survey. This would significantly reduce the uncertainties of the WTP results.

Furthermore, since this project is just a first attempt to quantify demand for the “greening” of freight transport in Switzerland, another question arising directly from these results is the shape of the WTP curve for reducing emissions: most likely the marginal utility decreases with increased reduction, i.e. the curve is unlikely to be a straight line. However, its exact shape would be an interesting aspect not only from a theoretical viewpoint, because for the LSP it has direct implications on the realisable price margins especially for shipments with a high potential for improving environmental performance.

Due to an especially high public awareness of environmental concerns in Switzerland, one might assume that WTP for environmental concerns in freight transport is higher than in other countries. Therefore, it would also be worthwhile to carry out comparable surveys in different countries as well as to extend the survey sample also to smaller shipment sizes and other transport modes, e.g. inland waterway and ocean shipping as well as air cargo. A comparison between the latter two modes might be of special interest for intercontinental transport chains, since, first, the ranking of demand criteria might be different and, second, the differences in transport prices and environmental performance are likely to be larger than for the land-based transport chains analysed in this project.

Concerning the environmental benchmark method, there is an urgent need to find a suitable approach for integrating also damage to human health from traffic noise into the existing life-cycle-assessment methods. Although sophisticated traffic noise models exist for road traffic [Althaus et al. (2009)], no methodologically sound method has been developed so far, which allows a comparison between different transport modes.
Last but not least, further research will be necessary until a labelling system on freight transport services, as proposed in this project, would be ready for implementation. Several open questions could only be discussed shortly and need more detailed analyses. The most important ones are:

- Would it be practically possible, and would it really make sense to create an integrated labelling system for both the communication between LSP and shipper as well as between shipper and end-consumer?
- Who, i.e. which organisation or which actor in the transport logistics network, should be responsible for the labelling scheme, including supervision and updating?
- When using a label with a ranking system (such as the “Energieetikette”), how many reference transport chains would have to be defined as a benchmark, and at which level of detail?
- With a ranking system, should the label categories be defined globally based on absolute emissions or rather separate for each transport mode?
- Should the label be extended from simple transport processes to an integrated supply chain perspective?

There are certainly still more problems to be solved for a real-world implementation. However, for the next step in this direction it would certainly be necessary to cooperate with relevant partners, especially shippers and logistics service providers.
Appendices

Appendix A – Sample of the Questionnaire

Fragebogen zum Forschungsprojekt im Bereich Gütertransportnachfrage am Institut für Verkehrsplanung und Transportsysteme der ETH Zürich

Herzlich Willkommen!
Bitte geben Sie zunächst das Passwort ein, das Sie in der e-mail zusammen mit dem Link zu diesem Fragebogen erhalten haben.

Passwort: 
Weiter

Teil 1: Fragen zu den Logistikaktivitäten Ihres Unternehmens

Weiter

1. Name Ihres Unternehmens:

2. Welchem der folgenden Bereiche ist Ihr Unternehmen zuzuordnen?
   - Produktion/Handel
   - Spedition/Transportlogistik

3. Wie hoch ist Ihr jährliches Transportsaufkommen insgesamt (Wareneingang/-ausgang) in Tonnen?
1. Wie werden allgemein in Ihrem Unternehmen Warentransporte organisiert? (Mehrfachnennung möglich)

☐ Pauschale Vergabe an Logistikdienstleister (transportmittelunabhängig)
☐ Direktvergabe an Frachtführer im Strassentransport
☐ Durchführung mit eigenen Lkw
☐ Direktvergabe an Frachtführer im Bahntransport
☐ Durchführung mit eigenen Bahnwagen (Vergabe an Frachtführer im Bahntransport)
☐ Direktvergabe an Frachtführer im Kombinierten Verkehr

2. Haben Sie an Ihrem Unternehmensstandort die Möglichkeit, Bahntransport zu nutzen? (Dies betrifft nicht Transporte mit Wechselbehältern im Kombinierten Verkehr.)

☐ nein
☐ ja: Eigener Gleisanschluss auf dem Werksgelände vorhanden
☐ ja: Gleisanschluss eines benachbarten Unternehmens (im Umkreis von ca. 500 m) könnte mitgenutzt werden
☐ ja: Ware kann bei einer nahegelegenden Freiverladeanlage (bis ca. 5 km Entfernung) auf die Bahn verladen werden
☐ ja: Ware kann bei einem Railport (bis ca. 80 km Entfernung) auf die Bahn verladen werden

---

Nennen Sie bitte die mengenmäßig wichtigste Ware Ihres Unternehmens, bei der Sie für die Transportorganisation zuständig sind. Es kann sich dabei um einziehende oder ausziehende Ware handeln.

1. Warenbezeichnung: ________________________

2. geschätzter Warenwert (in CHF/t): ________________________

3. Handelt es sich um verderbliche Ware?

☐ ja ☐ nein

4. Ist die Ware als Gefahrgut einzustufen?

☐ ja ☐ nein

5. Durchschnittliches Sendungsgewicht (in Tonnen): ________________________

6. durchschnittliches Sendungsvolumen (falls bekannt): ________________________

[Bitte Einheit wählen]: ☐

Weiter:
Teil 1: Angaben zum Transportbeispiel

1. Wie ist die Ware normalerweise verpackt?
   - palettiert
   - lose
   - Schüttgut lose
   - Flüssigware im Tank
   - Gesärmte Ware im Tank

2. Wie wird die Ware mehrheitlich transportiert?
   - als Lkw-Teilladung zusammen mit weiteren Sendungen (Sammelverkehr)
   - als Komplettladung auf Lkw (Direktverkehr)
   - in Container/Wechselbehälter
   - im Bahnwagen
   - als Ganzzug

3. Wird die Sendung auf dem Weg zwischen Verlader und Empfänger kommissioniert?
   - nein
   - ja (bitte Anzahl Kommissionierungspunkte angeben)

Wählen Sie bitte eine typische Relation, auf der die beschriebene Ware häufig transportiert wird, und beschreiben Sie sie anhand folgender Punkte:

1. Abgangsort:

2. Land:

3. Zielort:

4. Land:

5. eingesetztes Transportmittel:
   - Lkw
   - Kombinierter Verkehr
   - Bahn
   - Sonstiges (bitte angeben)

6. Transportdistanz (km):

7. Durchschnittliche Transportdauer ohne Be- und Entladung (in Stunden):

8. Wie hoch liegen in etwa die durchschnittlichen Transportkosten für die angegebene Sendung auf dieser Relation (in CHF)?

9. Wie gross ist das Zeitfenster (in Stunden), innerhalb dessen die Sendung beim Empfänger einzutreffen hat?
Appendix

Teil 1 - Angaben zum Transportbeispiel

Wählen Sie bitte eine typische Relation, auf der die beschriebene Ware häufig transportiert wird, und beschreiben Sie sie anhand folgender Punkte:

1. Abgangsort:
2. Land:
3. Zielort:
4. Land:
5. eingesetztes Transportmittel:
   - Lkw
   - Kombinierter Verkehr
   - Bahn
   - Sonstiges (bitte angeben)
6. Transportdistanz (km):
7. Durchschnittliche Transportdauer ohne Beladung und Entladung (in Stunden):
8. Wie hoch liegen in etwa die durchschnittlichen Transportkosten für die angegebene Sendung auf dieser Relation (in CHF)?
9. Wie gross ist das Zeitfenster (in Stunden), innerhalb dessen die Sendung beim Empfänger eintrifft?

Teil 2: Bewertung konkreter Transportangebote

In diesem Teil präsentieren wir Ihnen einige Transportangebote entsprechend Ihrer Angaben aus Teil 1 und bitten Sie, diese zu vergleichen und zu bewerten.

Beachten Sie bitte, dass es sich um hypothetische Beispiele handelt, die nicht immer genau der heutigen Realität entsprechen!
The following page was shown 14 times (once for each choice task) with varying attribute values. This screenshot is based on a fictitious transport sample.

### Wenn Sie diese Alternativen hätten, für welches Angebot würden Sie sich am ehesten entscheiden?  

<table>
<thead>
<tr>
<th>Angebot</th>
<th>Angebot B</th>
<th>Angebot A</th>
<th>Angebot C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pünktlichkeit</td>
<td>85%</td>
<td>98%</td>
<td>92%</td>
</tr>
<tr>
<td>Transportdauer</td>
<td>24 h</td>
<td>17 h</td>
<td>29 h</td>
</tr>
<tr>
<td>Transportmittel</td>
<td>KV</td>
<td>Bahn</td>
<td>Strasse</td>
</tr>
<tr>
<td>Transportpreis</td>
<td>1320 CHF</td>
<td>1200 CHF</td>
<td>1080 CHF</td>
</tr>
<tr>
<td>Treibhausgas-Emissionen</td>
<td>Erhöhung um 50%</td>
<td>Reduktion um 50%</td>
<td>wie heute</td>
</tr>
</tbody>
</table>

Aufgabe 1 von 14

Weiter

### Hiermit ist auch das zweite Experiment abgeschlossen. Zum Schluss noch drei Fragen zum Thema Umwelt:

1. Betreibt Ihr Unternehmen ein Umweltmanagementsystem?
   - ISO 14001
   - Eco-Management and Audit Scheme (EMAS II)
   - Sonstige (bitte angeben):
   - kein Umweltmanagementsystem

2. Falls ja, werden darin die Gütertransporte Ihres Unternehmens berücksichtigt?
   - ja: Beschaffung und Distribution
   - ja: nur Beschaffung
   - ja: nur Distribution
   - nein, gar nicht

3. Kommen bei Ihren Produkten bzw. Dienstleistungen Verbraucher-Labels zum Einsatz?
   - nein
   - ja (bitte angeben):

Weiter
Appendix B - Results from the MNL Model

This table presents the results from the initial MNL model, which includes the generic variables, two alternative-specific constants representing the transport mode, and a dummy variable for shippers’ rail access availability. Note that values are given in italics, if the corresponding coefficient is significant only on a level below 97.5% (t-test below 1.96).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Global Model</th>
<th>Food/ animal feed products</th>
<th>Chemical products; Agricultural raw materials</th>
<th>Iron/ Metal products</th>
<th>Building materials</th>
<th>Manufact’d goods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ln (Price)</strong></td>
<td>Coeff. -5.40</td>
<td>-5.37</td>
<td>-6.58</td>
<td>-6.90</td>
<td>-4.97</td>
<td>-5.09</td>
</tr>
<tr>
<td></td>
<td>Std. err. 0.203</td>
<td>0.416</td>
<td>0.527</td>
<td>0.755</td>
<td>0.687</td>
<td>0.317</td>
</tr>
<tr>
<td></td>
<td>t-test -26.60</td>
<td>-12.92</td>
<td>-12.49</td>
<td>-9.15</td>
<td>-7.24</td>
<td>-16.05</td>
</tr>
<tr>
<td><strong>On-time reliability</strong></td>
<td>Coeff. 0.0923</td>
<td>0.106</td>
<td>0.101</td>
<td>0.0935</td>
<td>0.0619</td>
<td>0.0915</td>
</tr>
<tr>
<td></td>
<td>Std. err. 0.00472</td>
<td>0.0111</td>
<td>0.0105</td>
<td>0.0162</td>
<td>0.0169</td>
<td>0.00728</td>
</tr>
<tr>
<td></td>
<td>t-test 19.56</td>
<td>9.52</td>
<td>9.62</td>
<td>5.77</td>
<td>3.67</td>
<td>12.57</td>
</tr>
<tr>
<td><strong>Transit time</strong></td>
<td>Coeff. -0.0101</td>
<td>-0.0203</td>
<td>-0.0120</td>
<td>-</td>
<td>-</td>
<td>-0.00952</td>
</tr>
<tr>
<td></td>
<td>Std. err. 0.00274</td>
<td>0.0108</td>
<td>0.00442</td>
<td>-</td>
<td>-</td>
<td>0.00428</td>
</tr>
<tr>
<td></td>
<td>t-test -3.68</td>
<td>-1.88</td>
<td>-2.70</td>
<td>-</td>
<td>-</td>
<td>-2.22</td>
</tr>
<tr>
<td><strong>GHG-emiss.</strong></td>
<td>Coeff. -0.297</td>
<td>-0.487</td>
<td>-0.346</td>
<td>-0.203</td>
<td>-</td>
<td>-0.260</td>
</tr>
<tr>
<td></td>
<td>Std. err. 0.0290</td>
<td>0.0692</td>
<td>0.064</td>
<td>0.0988</td>
<td>-</td>
<td>0.0446</td>
</tr>
<tr>
<td></td>
<td>t-test -10.27</td>
<td>-7.04</td>
<td>-5.40</td>
<td>-2.05</td>
<td>-5.61</td>
<td>-5.84</td>
</tr>
<tr>
<td><strong>Rail-only transport</strong></td>
<td>Coeff. -2.15</td>
<td>-1.81</td>
<td>-1.18</td>
<td>-2.46</td>
<td>-2.13</td>
<td>-2.59</td>
</tr>
<tr>
<td></td>
<td>Std. err. 0.112</td>
<td>0.238</td>
<td>0.254</td>
<td>0.482</td>
<td>0.379</td>
<td>0.175</td>
</tr>
<tr>
<td></td>
<td>t-test -19.14</td>
<td>-7.62</td>
<td>-4.67</td>
<td>-5.11</td>
<td>-5.61</td>
<td>-14.79</td>
</tr>
<tr>
<td>**Rail-only transport *</td>
<td>Coeff. 1.92</td>
<td>1.68</td>
<td>1.47</td>
<td>1.78</td>
<td>1.07</td>
<td>2.32</td>
</tr>
<tr>
<td></td>
<td>Std. err. 0.127</td>
<td>0.273</td>
<td>0.276</td>
<td>0.515</td>
<td>0.450</td>
<td>0.203</td>
</tr>
<tr>
<td></td>
<td>t-test 15.13</td>
<td>6.14</td>
<td>5.32</td>
<td>3.46</td>
<td>2.37</td>
<td>11.47</td>
</tr>
<tr>
<td><strong>Intermodal transport</strong></td>
<td>Coeff. -0.260</td>
<td>-0.185</td>
<td>0.279</td>
<td>-</td>
<td>-0.520</td>
<td>-0.456</td>
</tr>
<tr>
<td></td>
<td>Std. err. 0.0518</td>
<td>0.121</td>
<td>0.122</td>
<td>-</td>
<td>0.185</td>
<td>0.078</td>
</tr>
<tr>
<td></td>
<td>t-test -5.03</td>
<td>-1.53</td>
<td>2.28</td>
<td>-</td>
<td>-2.80</td>
<td>-5.85</td>
</tr>
</tbody>
</table>

Final Log-Likelihood: -2085.152, -397.729, -436.262, -177.810, -156.636, -869.050
Likelihood ratio test: 1781.978, 402.029, 357.923, 198.080, 117.383, 801.892
Adj. $r^2$: 0.297, 0.324, 0.280, 0.332, 0.240, 0.31
No. observations: 2709, 545, 560, 252, 196, 1156
# Appendix C – Road Transport Emission Factors

This table is an extract of the HABEFA emissions database. Values are given for a vehicle with over 32 tons gross weight (fully loaded) and emission class Euro 3. Only those road categories and substances are listed, which were actually used for the emissions calculation.

“AB” stands for motorway, “AO_HVS” for main roads outside built-up areas, and “IO_HVS” for inner-urban main roads. The numbers represent different average speed levels.

<table>
<thead>
<tr>
<th>Road Category</th>
<th>Av. Speed [km/h]</th>
<th>CO [g/km]</th>
<th>NOx [g/km]</th>
<th>Fuel [g/km]</th>
<th>PM&lt;10 [g/km]</th>
<th>CO₂ [g/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB_120</td>
<td>86.21282196</td>
<td>1.348544598</td>
<td>6.76729393</td>
<td>259.7932434</td>
<td>0.144697905</td>
<td>818.3695068</td>
</tr>
<tr>
<td>AO_HVS1</td>
<td>72.64612579</td>
<td>1.801380038</td>
<td>8.94769669</td>
<td>270.6906738</td>
<td>0.165877789</td>
<td>852.6972656</td>
</tr>
<tr>
<td>AO_HVS2</td>
<td>66.05267334</td>
<td>2.062038898</td>
<td>8.573767662</td>
<td>287.7104797</td>
<td>0.173345491</td>
<td>906.3110352</td>
</tr>
<tr>
<td>AO_HVS3</td>
<td>59.76979446</td>
<td>2.168614149</td>
<td>9.115261078</td>
<td>303.3581543</td>
<td>0.188401759</td>
<td>955.602417</td>
</tr>
<tr>
<td>IO_HVS1</td>
<td>47.01276016</td>
<td>2.38499403</td>
<td>10.21465683</td>
<td>335.1276245</td>
<td>0.218970507</td>
<td>1055.678833</td>
</tr>
<tr>
<td>IO_HVS2</td>
<td>32.86322784</td>
<td>3.502935886</td>
<td>13.01547623</td>
<td>449.3356018</td>
<td>0.325757712</td>
<td>1415.443115</td>
</tr>
<tr>
<td>IO_HVS3</td>
<td>22.25107956</td>
<td>4.343192517</td>
<td>15.11609077</td>
<td>534.9915771</td>
<td>0.405848116</td>
<td>1685.266235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road Category</th>
<th>Av. Speed [km/h]</th>
<th>CH₄ [g/km]</th>
<th>NMHC [g/km]</th>
<th>Pb [g/km]</th>
<th>SO₂ [g/km]</th>
<th>N₂O [g/km]</th>
<th>NH₃ [g/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB_120</td>
<td>86.21282196</td>
<td>0.006915553</td>
<td>0.281232506</td>
<td>0</td>
<td>0.005195865</td>
<td>0.0059</td>
<td>0.005</td>
</tr>
<tr>
<td>AO_HVS1</td>
<td>72.64612579</td>
<td>0.006757839</td>
<td>0.274818778</td>
<td>0</td>
<td>0.005413814</td>
<td>0.0078</td>
<td>0.005</td>
</tr>
<tr>
<td>AO_HVS2</td>
<td>66.05267334</td>
<td>0.006711521</td>
<td>0.272935182</td>
<td>0</td>
<td>0.00575421</td>
<td>0.0078</td>
<td>0.005</td>
</tr>
<tr>
<td>AO_HVS3</td>
<td>59.76979446</td>
<td>0.007569852</td>
<td>0.307840645</td>
<td>0</td>
<td>0.006067163</td>
<td>0.0078</td>
<td>0.005</td>
</tr>
<tr>
<td>IO_HVS1</td>
<td>47.01276016</td>
<td>0.009312524</td>
<td>0.378709316</td>
<td>0</td>
<td>0.006702553</td>
<td>0.0084</td>
<td>0.005</td>
</tr>
<tr>
<td>IO_HVS2</td>
<td>32.86322784</td>
<td>0.01493707</td>
<td>0.607440889</td>
<td>0</td>
<td>0.008986712</td>
<td>0.0084</td>
<td>0.005</td>
</tr>
<tr>
<td>IO_HVS3</td>
<td>22.25107956</td>
<td>0.01915548</td>
<td>0.778989553</td>
<td>0</td>
<td>0.010699831</td>
<td>0.0084</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Appendix D – Benchmark Results for Emission Classes Euro 3 and Euro 4

In this table the benchmark results from the comparison between lorries with emission classes Euro 3 and Euro 4 are presented. Each sample is marked grey, representing the status quo. These lorries are subject to changes for all categories. The percentage values were added to analyse the gain or loss of environmental performance relative to the status quo.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabio - Neuendorf</td>
<td>15</td>
<td>Road 4</td>
<td>246</td>
<td>8.46E-03</td>
<td>95.35%</td>
<td>2.91E-06</td>
<td>101.19%</td>
<td>5662</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road 3</td>
<td>8.42E-04</td>
<td>100.00%</td>
<td>2.86E-06</td>
<td>100.00%</td>
<td>5640</td>
<td>99</td>
<td>5739</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermodal 4</td>
<td>3.16E-04</td>
<td>100.00%</td>
<td>1.05E-06</td>
<td>100.00%</td>
<td>2144</td>
<td>1301</td>
<td>3445</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermodal 3</td>
<td>2.12E-04</td>
<td>100.00%</td>
<td>8.52E-07</td>
<td>100.00%</td>
<td>1617</td>
<td>529</td>
<td>2146</td>
</tr>
<tr>
<td>Brüssel - Luzern</td>
<td>15.4</td>
<td>Road 4</td>
<td>71</td>
<td>2.28E-03</td>
<td>95.38%</td>
<td>2.91E-06</td>
<td>101.19%</td>
<td>5662</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road 3</td>
<td>2.60E-04</td>
<td>100.00%</td>
<td>8.42E-07</td>
<td>100.00%</td>
<td>5599</td>
<td>99</td>
<td>5698</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermodal 4</td>
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<tr>
<td>E. E. Ernst</td>
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<td>S. Fujii, T. Gärling, and R. Kitamura</td>
<td>Changes in drivers' perceptions and use of public transport during a freeway closure: Effects of temporary structural...</td>
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<td>Vlek and Michon (1992)</td>
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Curriculum Vitae

Hans Thomsen Nikolaus Fries

Born 30th April, 1979 in Göttingen
Citizen of Germany

Practical Experience

2005 – 2009
Research Assistant at the Institute for Transport Systems and Planning (IVT), ETH Zurich, Chair for Transport Systems

2004
Master Thesis at SNCF Paris - Direction de la Recherche et de la Technologie: "Etude pour l'amélioration du gestion de trafic dans le nœud ferroviaire de Nîmes"

2002 – 2003
Assistant at the Fraunhofer Institut for Transport and Infrastructure Systems in Dresden - Project RailML

2000 – 2003
Assistant at the Rail Operations Laboratory of Dresden University of Technology, Faculty of Transportation and Traffic Sciences – Software Development and Coaching

1998 – 1999
Military Service at the German Federal Navy

Higher Education

2003 – 2004
Courses in Transportation Sciences at the Ecole Nationale des Ponts et Chaussées Paris

1999 – 2003
Studies of Transport Engineering at Dresden University of Technology focussing on Telematics in Transport

1998
Abitur in Göttingen (D)