The Impacts of Time Access Restrictions and Vehicle Weight Restrictions on Food Retailers and the Environment

Hans Quak and René de Koster
RSM Erasmus University
Rotterdam
The Netherlands
e-mail: hquak@rsm.nl

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Urban freight transport has many sustainable aspects. It contributes to economic vitality and the competitiveness of a region. However, the less socially and environmentally friendly effects such as noise, pollutant emissions, and nuisance, are usually the central theme in designing urban freight transport policies. Restricting policies as time access restrictions and vehicle restrictions gain popularity among Dutch local authorities. More than half of the municipalities uses time access restrictions. In spite of the popularity of these policy measures, the effects on the distribution of retailers, the environment and the transport costs are not known yet. In this paper we present three case studies of food retailers, in order to examine the effects of time access restrictions and vehicle weight restrictions. We discuss the impacts on the transport costs and the distribution processes (on the retailer's side) and the environmental impacts. To find these effects we design five scenarios, in which we vary the length of time access restrictions, the allowed weight of the weight restriction and the number of cities in which these regulations are used. In these scenarios we adapt, based on the likely reaction of the involved food retailers, the distribution activities to fit the regulations. The results show that the vehicle weight restriction as well as the time access restrictions have a negative impact on the retailers' transport costs. In most cases we see that the policy measures also cause an increase in the pollutant CO_2 emissions that are emitted during the distribution of the goods. The time access restrictions cause a cost-increase that develops more or less convexly, as more stores are affected by this policy measure. The turning point is around 45% of the stores affected. The weight restriction causes linear cost-increase as more stores are affected. Both policy measures affect especially the roundtrips that combine multiple less than truckload orders for different stores. The policy measures have a different effect on different retailers.

Keywords: Urban goods movement, local policy, transport costs, environmental effects.

1. Introduction

1.1 Urban goods movement and city logistics

The interest in the field of urban goods movement has increased over the last years. The accessibility of many cities is pressurized, and the congestion levels have increased considerable over the last decades. Forwarders are demanded to provide higher levels of services at lower costs. Companies that perform urban distribution activities are becoming ever-more concerned about the efficiency, the reliability and the costs of distribution activities as the road traffic levels continue to grow and more stringent vehicle restrictions are imposed in towns and cities (Allen et al., 2003). Urban goods transport is one of the most significant sources of unsustainability in urban areas. On the other hand, freight transport and distribution activities are important factors in the sustainability of urban areas; they facilitate and support the economic life of and in an urban area (Allen et al., 2003). Furthermore, urban goods distribution has an important role to play in the context of urban life: it is fundamental to the economic vitality and competitiveness of industrial, trade and leisure activities that are essential to wealth generation (in these urban areas) (Ogden, 1992). However, the less socially and environmentally friendly effects of urban freight transport draw more attention to themselves. Contributing to road traffic, adding to congestion levels, pollutant emissions, noise, visual intrusion, the usage of fossil fuel and other negative impacts are frequently associated with urban goods transport (Allen et al., 2003; Banister et al., 2000; Browne, 1997; May et al., 2003). The environmental impact of freight transport on the global level, contributing to the climate change and the acidification of the atmosphere and on the local level, contributing to illness and premature death from local pollutants, are serious negative effects, and therefore considered in many policy reflections (Van Binsbergen and Visser, 2001).

Over the last decade the number of studies carried out to acquire better knowledge to aid decision-making in the field of urban goods movement has increased in industrialized countries (Ambrosini and Routhier, 2004). The major part of these studies deals with policy, in order to solve the problems that arise from urban goods movement. The full range of transport policy interventions (infrastructure management, regulation, information and pricing) are combined with land-use, environmental and wider social policy instruments to resist the less socially and environmentally friendly effects of urban goods transport (May et al., 2003). In spite of many studies dealing with urban transport policy and sustainable transport, such as (Feitelson, 2002; Ison and Rye, 2003), there is a serious lack of detailed understanding of the impact of many of these policy instruments and of their transferability to different contexts (May et al., 2003).

Next to these policy developments, we notice an increase in city logistics research. The city logistics objectives and policy objectives are to some extent the same. City logistics aims at globally optimizing logistics systems within urban areas by considering the costs and benefits of schemes to the public as well as to the private sector (Taniguchi et al., 2003). City logistics can be defined as the process for totally optimizing the logistics and transport activities by private companies with the support of advanced information systems in urban areas considering the traffic environment, its congestion, safety and energy savings within the framework of a market economy (Taniguchi et al., 2001). City logistics focuses on initiatives, such as, cooperative freight transport systems, public logistics terminals, load factor controls, underground freight transport systems and Intelligent Transport Systems (ITS) (Taniguchi et al., 2003; Taniguchi and Van Der Heijden, 2000).

1.2 Policies

Many local authorities do not have an extensive freight transport policy. And, partly caused by a lack of information, their freight policies tend to be based on a reaction to problems and negative impacts, rather than taking a proactive position. This results in a policy that tries to control and restrict urban freight transport as much as possible, rather than making the urban freight transport system more efficient (Allen et al., 2000). Local authorities tend to copy policy measures of other local authorities, rather than to look at the problems and the potential results of the policy measures. More and more, local authorities turn to taking measures such as prescribing delivery time access restrictions and vehicle restrictions (PSD, 2002). Policies that mainly focus on combating the negative impacts of urban goods movement often result in an increase of transport costs, in making the organization of transport more complex and are sometimes even counterproductive.

Crum and Vossen (2000) claim that especially vehicle restrictions are a major barrier to transporters. Vehicle restrictions can apply to the length, width, height, axle pressure, weight, environmental restrictions, and the degree of capacity utilization of the vehicle (PSD, 2002). The main reasons for vehicle restrictions are to protect (historic) buildings and infrastructure, and assure the livability, safety and environment in a city. Furthermore, vehicle restrictions are believed to reduce the impacts that are normally perceived to be caused by large vehicles, such as (local) pollution, safety concerns, vibration, noise and visual intrusion. However, transporters consider time access windows as the most urgent logistical bottleneck (Crum and Vossen, 2000). Coinciding time access restrictions in different cities, particularly if they are narrow, make it difficult to combine trips. This results in more trips at the same time and therefore an inefficient use of vehicles. Time access restrictions in the morning usually result in an increase of the congestion level that is already high, due to the morning rush-hour. Sometimes, access restrictions do not match the opening hours of stores, so that staff has to be available in extra hours to receive the goods. Nevertheless, more and more cities force deliveries to take place during a certain time access restriction period (PSD, 2002). This policy measure allows no large vehicles to enter a certain geographical area to supply or collect goods during large periods of the working day (Allen et al., 2003). The main objectives to establish time access windows are to separate the shopping public from the suppliers and to reduce the perceived impacts of trucks during certain periods of the day.

The exact impacts on the environment and the social situation in urban areas, accessibility and economic development of different policy measures are not yet known, in spite of their popularity among local authorities. An example of this popularity is that 53% of the municipalities (with more than 15,000 inhabitants) in the Netherlands use time access restrictions. This percentage is even higher for the larger cities; 71% of the 100 largest and all municipalities in the top 20. Next to these time access restrictions almost 50% of these municipalities use at least one vehicle restriction. Different vehicle restrictions may result in the same effect. For example, a weight restriction can force the carrier to use a smaller vehicle, as can a length restriction.

1.3 Paper outline

In this paper we aim at finding the effects of two policy measures, time access restrictions and vehicle weight restrictions, on the transport costs and the vehicle activity of three different food retailers and on the environment. To do so we vary the length of the time access restrictions and the allowed truck weight of the vehicle restriction as well as the number of municipalities that is affected by the policy measures. In the next paragraph we state three research questions, followed by the research model we use in this study to answer these questions. Subsequently, we discuss the methods that we used and the data we gathered. We present the effects that the current policies in the Netherlands have on the three food retailers. Next, we present the effects of time access restrictions and vehicle weight restrictions on the transport costs and the vehicle activity of three food retailers that collaborated in this case study as well as on the environment. At the end we formulate conclusions.

2. Research questions, model and methods

2.1 Paper outline

The three research questions are:

- What are the impacts of time access windows and vehicle weight restrictions on the distribution processes of food retailers?
- What are the impacts of time access windows and vehicle weight restrictions on the environment?
- How do differences in distribution characteristics of different retailers influence these impacts?

Figure 1 shows the research model we use to answer these questions.

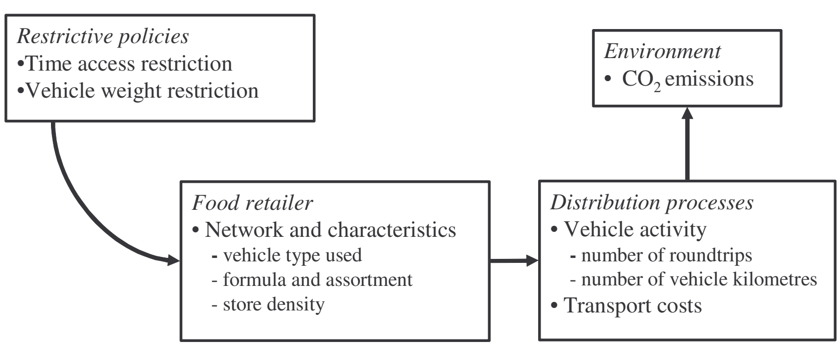


Figure 1. Research model

Time access restriction sizes and weight restrictions influence the distribution processes of food retailers (figure 1). We express these effects in the distribution processes: vehicle activities (expressed in the number of vehicle roundtrips and the number of vehicle kilometers) and the transport costs. The adjusted distribution changes the environmental weight of the distribution. The total CO_2 emissions express this. The characteristics that are expected to impact the change in the environmental emissions and distribution processes include vehicle types used, the store density and the formula and assortment (figure 1).

2.2 Research methods

Figure 2 gives an outline of the methods we used in this study to find the effects. We discuss the four steps in the following sections. In the next four paragraphs we explain the four steps that are denominated in figure 2.

Retailers involved

Food retailers in the Netherlands have a high number of deliveries per store. Stores are mostly located nearby or within a shopping centre. We selected three food retailers that differ from each other in some important characteristics (table 1). The retailers operations we consider take place in more or less the same geographical area (figure 4). Per retailer, we only consider the deliveries from one distribution centre to the stores and the corresponding return flows (empty roll containers, crates and waste). The retailer's characteristics in table 1 only apply to these deliveries, except for their market share, which applies to all stores and deliveries in the Netherlands.

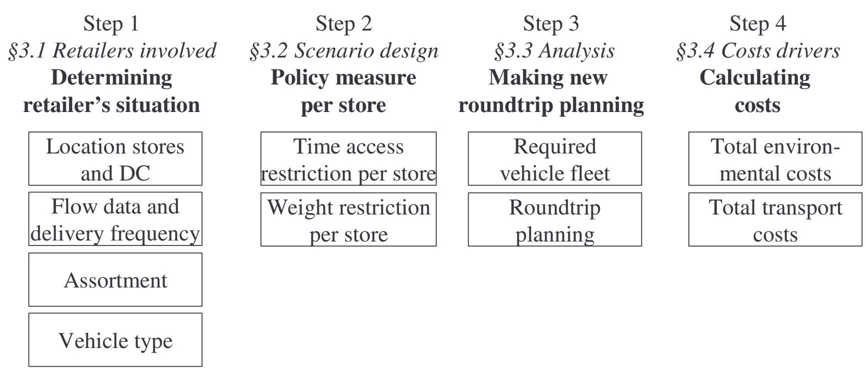


Figure 2. Outline of methods

Table 1. Retailers' characteristics

Characteristics	Food retailer 1	Food retailer 2	Food retailer 3
Formula	Soft discounter with a wide assortment	Full-service supermarkets and super-stores	Sharp prices and assortment
Market share (in the Netherlands)	2%	12.5%	7.5%
Number of stores (in considered region)	37	134	77
Orders (supplied from DC to stores; 1 week)	824	2165	263
Assortment	12,000 articles	12,000-18,000 articles (supermarkets) and 22,000 articles (superstores)	6,000-10,000 articles
Products handled by the DC (assortment)	Dry groceries, PVF*, other fresh goods and frozen products	Fast-moving dry groceries, fast-moving fresh products and PVF*	Dry groceries
Vehicles used	20 swap bodies and 10 trucks	25 fresh goods trucks and 40 dry groceries trucks (57 trailers, 6 city-trailers and 2 smaller trucks)	7 trailers and 1 city-trailer
Average distance DC to stores	32 km	42 km	71 km

* Potatoes, Vegetables and Fruits

Food retailer 1 (FR1) centralizes all logistics activities in one distribution centre; dry groceries, butchery activities, bakery activities, potatoes, vegetables and fruits (PVF), and other fresh and frozen goods. FR1 uses swap bodies for transporting the products from the distribution centre to the stores. A swap body is a detachable container that can be left on a specific location, after which the truck departs (see), so there are almost no combined trips. Picking up and putting down a swap body only takes five minutes. Every swap body has a cooling system so it can transport both dry groceries and fresh products. All products are transported in roll containers and frozen products in special closed roll containers (De Koster and Neuteboom, 2001; Geerards and De Vrij, 1999). The use of these swap bodies offers some significant advantages; the number of trucks can be limited (trucks do not have to wait during the loading and unloading), and it leads to more (un)loading flexibility (swap bodies can be loaded and unloaded in absence of a truck and they can be used for temporary storage) (De Koster and Neuteboom, 2001). However, some stores lack the space to park these swap bodies. This forces FR1 to use some additional trucks and therefore two transport systems are used at the same time (see table 1). FR1 owns its vehicles; extra capacity is hired if necessary.

The second food retailer (FR2) has several distribution centers, of which we only considered one. All products are transported in roll containers. FR2 owns its vehicle fleet and only hires extra capacity if necessary. Food retailer 3 (FR3) distributes different goods through different distribution centers; dry groceries from one DC, fresh goods (meat, cheese and desserts) and PVF from another, and slow moving dry grocery products from another (De Koster and

Neuteboom, 2001). In this study we only considered the dry groceries distribution centre. The transport between the distribution centre and the stores is completely contracted out. The products are transported on euro-pallets or roll containers.

Figure 3. Detachable swap body

Next to this retailer's characteristics we collected flow data, this consists of the number of roll containers transported between the DC and the stores per day, of one ordinary week: Monday June 16 until Saturday June 21 2003. The number of delivered roll containers per store is more or less the same per week, the products they carry are not. We are only interested in the transport of roll containers, therefore one week is sufficient. Flow data differs per retailer. Together with the distribution flows we collected information of all retailers on:

- The distribution centre - address and assortment.
- The stores - addresses and location specific information, such as delivery restrictions.
- The vehicles - the number of vehicles used, their capacity, the allowed working hours and the loading and unloading times. Information on the vehicle fleet contains the vehicle weight, capacity, age, number of axles and the engines' EURO-norm.

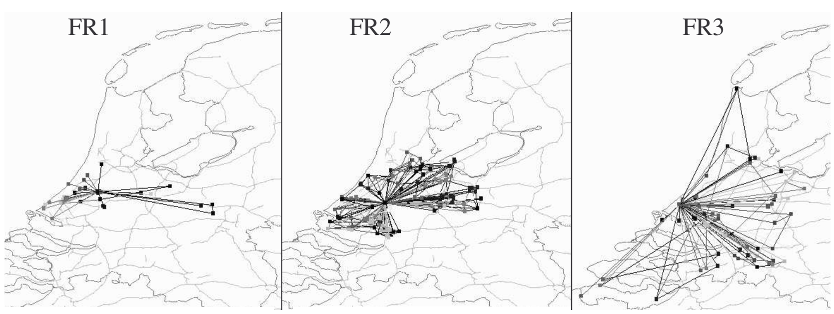


Figure 4. Store location

Scenario design

The second step in the research outline (figure 2) is determining the scenarios. We designed different scenarios to answer the research questions. All scenarios are based on the weekly orders that are used to supply all stores from the DC in the current situation (scenario 0a). In all other scenarios we introduce a restriction policy measure. We designed, in collaboration with the three food retailers and based on their likely reaction to the policy measure, a set of adapted orders per policy measure. In principle these orders are the same as in scenario 0a, but they have to meet the scenario's policy restriction. So an order's delivery time can change because of a time access restriction. And in case one order exceeds the vehicle's capacity, which is reduced because of the weight restriction, it is split up in multiple orders. Some stores have to deal with at least one policy measure in scenario 0a. Scenario 0b (no-restrictions scenario) is identical to scenario 0a, but it does not contain any delivery restrictions.

The average of all time access restrictions used at this moment in the Netherlands is from 6h53 to 11h18 (PSD, 2002). Scenario A equals more or less this average time access restriction. To find the effects of time access restrictions we varied the length of the time access restriction period. In scenario B and scenario C the time period is shortened (see table 2). At this moment scenario C is only reality in three municipalities in the Netherlands (PSD, 2002). Scenario D contains a weight restriction of 18 tons. The weight restriction is even more stringent in scenario E (table 2). The weight in these scenarios is based on the vehicle access matrix designed by the Dutch forum for physical distribution in urban areas (PSD, 2001) and on (Allen et al., 2003). All scenarios are divided in five sub scenarios, based on the number of cities in which the policy measure applies (see table 2). The choice for municipalities implies that the scenarios, because of the different locations of the stores of the three retailers, influence the three retailers differently (table 3). This makes direct comparison more difficult; the scenarios however are more realistic. Table 4 represents the vehicles types used in the scenarios.

Table 2. Scenarios defined

	Cities affected				
Restriction	*5 largest cities in the Netherlands*	*25 largest cities in the Netherlands*	*50 largest cities in the Netherlands*	*100 largest cities in the Netherlands*	*250 largest cities in the Netherlands*
Time Windows 7:00 -11:00	A1	A2	A3	A4	A5
Time Windows 7:00 -10:00	B1	B2	B3	B4	B5
Time Windows 7:00 -9:00	C1	C2	C3	C4	C5
Vehicle Weight < 18 tonnes	D1	D2	D3	D4	D5
Vehicle Weight <12 tonnes	E2	E4 (only for FR1)			
Vehicle Weight < 7.5 tonnes	E1	E3 (only for FR1)			

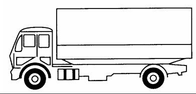
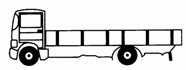
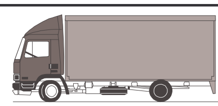
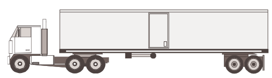
Table 3. Stores affected per scenario part and retailer

	Cities affected				
	5 largest cities in the Netherlands	*25 largest cities in the Netherlands*	*50 largest cities in the Netherlands*	*100 largest cities in the Netherlands*	*250 largest cities in the Netherlands*
Food retailer 1 stores affected	8%	21%	45%	61%	82%
Food retailer 2 stores affected	25%	40%	48%	66%	84%
Food retailer 3 stores affected	26%	38%	51%	69%	91%

In interviews with the retailer's distribution managers, we inventoried the likely reaction of the retailers to the policy measures. Their likely reaction on the time access window policy measure is to continue delivering during the day, even outside the window hours, sometimes because of dispensation from the municipality for food retailers or because of lack supervision by the authorities. If no dispensation is possible and if there is supervision, the likely reaction is to deliver and collect during the time access restriction period. They hire extra capacity, if necessary, in order to perform all activities within the permitted hours. So the likely reaction is a short-term reaction, because on the long term FR1 and FR2 would buy extra capacity. Not all extra hired vehicles can be loaded during (or just before) the time access restriction period, because of the limited number of dock doors in the DC's, so some are loaded in advance.

The reaction on the weight restriction differs for the three retailers. FR1 keeps using the swap bodies trucks. The time advantage and the fact that FR1 already possesses swap bodies makes it more cost efficient to keep using these vehicles rather than switching towards lighter vehicles. However, the empty weight of the vehicle and the swap body is already 11 tons. Assuming that the maximum average weight for a roll container is 350 kg (Klein Breteler, 2002), this limits the load capacity to 7 tons for roll containers in a swap body in scenario D. This leaves a capacity of 20 roll containers (instead of 30 roll containers in scenario 0a) for the 18 tons restriction. FR2 and FR3 and the stores of FR1 that are not supplied by swap bodies use smaller trucks with a capacity of 26 roll containers in scenario D. In scenario E all retailers use the same vehicle types; the capacity of the vehicles used in scenarios E2 and E4 is 20 roll containers. In scenario E1 and E3 the vehicle capacity decreases to 12 roll containers.

Table 4. Vehicle types used in scenario

Scenario E1			
Type: Truck		*Weight:* 3.5-7.5 ton *Wheelbase:* < 4.5 m *Length:* max. 7.5 m	*Width*: max. 2.3 m *Height*: max. 3.2 m
Scenarios D and E2			
Type: Truck		*Weight*: 7.5-18 ton *Wheelbase*: < 5.5 m *Length*: max. 10 m	*Width*: max. 2.55/2.6 m *Height*: max. 3.6 m
Current operations			
Type: Truck		*Weight*: > 18 ton *Wheelbase*: > 5.5 m *Length*: max. 12 m	*Width*: max. 2.55/2.6 m *Height*: max. 4 m
Type: Semi-trailer		*Weight*: < 40 ton *Wheelbase*: divers *Length*: max. 16.5 m	*Width*: max. 2.55/2.6 m *Height*: max. 4 m

For the vehicle weight restriction that only allows vehicles in the urban areas up to 12 tons (scenarios E2 and E4) and up to 7.5 tons (scenarios E1 and E3), the retailers reacted more or less equally; with the current distribution system it is not possible to supply a large part of their current locations with these small vehicles. The distribution concept would change too much to make an adequate prediction of the likely reaction. Therefore we decided to calculate for these weight restrictions only the scenario in which the restriction affects between 21% and 26% of the stores. The retailers could provide us with an adequate reaction for this percentage of affected stores. Based on this percentage we decided to use the results of scenario D2, E4 and E3 for FR1 and the results of scenario D1, E2 and E1 for FR2 and FR3, because these are easier to compare (see table 3).

Analysis

In this third step, we determine the vehicle types allowed based on the likely reaction per scenario and per retailer, and plan new roundtrips. We used a vehicle routing software program, SHORTREC, developed by Ortec Consultants BV, to do so with the adapted orders in different scenarios. To find these new roundtrips SHORTREC uses two algorithms; a construction algorithm, sequential insertion that provides a basic solution, and an iterative algorithm, the OPT algorithm, to improve this basic solution. We use this heuristic approximation to find the new roundtrips and with that the number of vehicle kilometers.

SHORTREC uses a greedy order-to-route assignment algorithm to generate initial rounds. This basic solution is further improved by changing the sequence of the orders in a roundtrip (optimization within a roundtrip) and by swapping orders between different roundtrips. After that the OPT algorithm, an 2OPT iterative improvement procedure, is used to improve the basic solution. These improvement procedures are:

1. Optimizing within a roundtrip
2. Moving of orders
3. Optimizing between roundtrips
4. Dividing of working hours
5. Choosing the cheapest possible vehicle (considering restrictions and load factor)
6. Changing of roundtrips

7. Changing of vehicle stops.

The final vehicle routing was found by performing all procedures at least three times. This vehicle routing is carried out for all orders, to minimize the necessary number of vehicles, considering the stores' demands, the time access restrictions (existing and scenario-determined), the opening hours of the DCs, the maximum driver working hours per day and the capacity of the used vehicles. The resulting roundtrips take the scenario restrictions in account. In case the arrival time at a store changed due to the time access restriction, we made sure that the order is delivered as close as possible to the original delivery time in scenario 0a. In these new roundtrips we also calculate the number of roundtrips and the number of vehicle kilometers (see figure 4).

Cost drivers

In this last step we calculate the costs. We distinguish two cost drivers: environmental and financial. Financial cost consists of transport cost only. Fixed costs per day (for example for hiring the vehicles), variable costs per kilometer (for example the fuel costs), variable costs per hour (for example the wage of the driver) and variable costs per hour working overtime determine the transport costs. These costs are based on costs indications per activity provided by the retailers and the DPP basic-model (ACNielsen, 2003). We used the same costs for the same activities for all three food retailers. This has two advantages: it makes a comparison between the retailers easier and it leads to better collaboration of the retailers in providing flow data, as they did not have to provide costs. The retailers consider the cost approximations rather closely.

For the environmental costs drivers we used emission rates in grams per kilometer for several different vehicle weights, for several different pollutants and for different vehicle speeds. The main source we used for vehicle emission data in this project is the NERA Report (NERA, 2000). This report contains emission factors for a range of pollutants for 33 types of vehicles over 3.5 tons gross vehicle weight driving at a range of speeds for all engines up to EURO IV. We used different pollutants in the project; emissions with a global impact (CO_2 and SO_2) and with more local effects (PM10). In this paper we only show the results for CO_2 emissions, unless other emissions show a substantially different pattern. We did not use indicators on the more social effects of the policy measures.

We went over these four steps (figure 2) for all scenarios. To compare the results of the different scenarios we calculated the percentage change of the costs and the vehicle activity of all scenarios in comparison with scenario 0a.

3. Results

3.1 Current operations and no restrictions

Table 5 contains information about the current operations of the retailers studied as calculated by SHORTREC (scenario 0a). We validated these outcomes with the three retailers. They affirmed that the differences with an ordinary week are negligible. The maximum inaccuracy in the number of kilometers as well as in the total time is 3% and in the costs no more than 5%. FR1 does not use a computer-based route planning program. A new master planning is designed every year, and FR1 adapts this master planning on a daily basis, depending on the goods to be moved from the DC to the stores. Because of the swap body system, there are almost no roundtrips that combine different stores. Therefore making a planning for FR1 is relatively easy. FR2 and FR3 use route planning packages, similar to SHORTREC to compute their master planning. On a daily basis, they adapt this planning to the actual amount of goods that has to be shipped between the stores and the DC. All other scenarios are compared with the scenario 0a.

Table 5. Current operations (scenario 0a)

	Food retailer 1	**Food retailer 2**	**Food retailer 3**
Rounds			
Total number of rounds (one week)	789	739	188
Average number of deliveries per round	1,04	2,85	1,22
Time			
Total time used for distribution (in hours for one week)	1360	3571	721
Distance			
Total number of kilometres (one week)	48845	61879	27043
Vehicle utilisation			
Number of vehicles used (one week)	180	412	72
Costs			
Total operations costs (in euros for one week)	69900	183158	63140
Emissions (transport)			
CO2 (in grams for one week)	3,8E+07	5,4E+07	2,3E+07

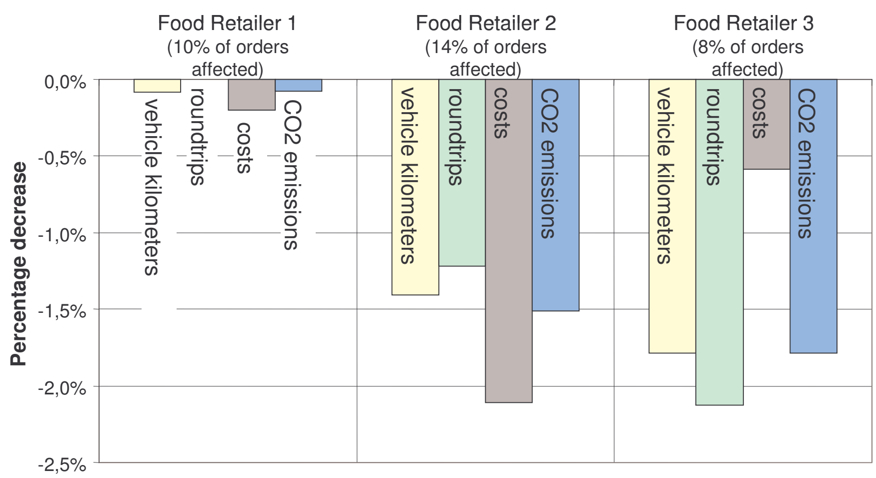


Figure 5. No restrictions (scenario 0b in comparison with scenario 0a)

FR1 differs from the other two retailers because of the use of the swap body system. Differences between FR2 and FR3 result from the differences in the assortment and the store density. FR2 combines especially fresh goods orders (these are usually less-than-truckload quantities) for different stores in one roundtrip; both FR2 and FR3 deliver dry groceries in full-truck loads per store.

Figure 5 shows the results of scenario 0b, in which we removed all external restrictions that were imposed on the distribution in scenario 0a. For FR1 the percentage of affected orders is 10%, for FR2 14% and for FR3 8%. All retailers had to deal with time access restrictions in scenario 0a, and FR2 and FR3 also with vehicle restrictions. This may explain the differences in the effects of removing all restrictions for FR1 and the other retailers. We see that especially FR2's transport costs decrease without restrictions, and that FR2's and FR3's CO_2 emissions are considerably lower in scenario 0b than they were in scenario 0a. The effects of the current policies are rather small for the food retailers, also in comparison with other research, see for example Groothedde et al. (2003). The reason for this might be that we calculated the difference between the current situation (scenario 0a) (based on the food retailers' flow data and restrictions) and the situation in which all restrictions are removed (scenario 0b). This scenario 0a is not based on the policy measures, as they are used by the municipalities see (PSD, 2002), but on the restrictions the retailers experience during their distribution. The regulations the retailers experience can differ from the restrictions as are imposed by the municipalities because of different reasons:

- dispensation regulations for food retailers;
- dispensation for loading and unloading at the back of stores (in other words, the restrictions only apply to the shopping streets);
- lack of supervision.

3.2 The impact of time access restrictions

In this section we describe the results of scenarios A, B and C for the retailers. The retailers have to use more vehicles, because of the narrower time period in which deliveries have to be carried out. The possibility of combining different orders in one roundtrip decreases. Therefore, the retailers use extra roundtrips to supply all stores. This may lead to an increase in the number of vehicle used. For the vehicle kilometers and the CO_2 emissions we expect an increase as well. Figure 6 presents the results of scenarios A, B and C for FR1. Figure 7 shows these results for FR2. Figure 8 shows the results of FR3.

We see for all three retailers an enormous increase in the transport costs if more than about 45% of the stores are affected. Before this point, vehicles supply the stores in the window area during the time access restriction periods and supply the other stores outside this time period. However, as more stores become affected this is no longer possible. The CO_2 emissions development is similar to that of the number of kilometers, because this is the only determining factor for the emissions in scenarios A, B and C.

FR1 (figure 6) delivers almost only full truck loads (swap bodies) between the DC and the stores. Therefore, initially, the number of vehicle kilometers, the number of roundtrips and the CO_2 emissions hardly change as more stores are affected by time access restrictions. The transport costs increase substantially if more than 45% of the stores are affected, for all time access restriction sizes. For the two-hour time access restriction this increase is considerably higher than for the other time access restriction sizes (figure 6).

FR2 can combine fewer orders in roundtrips due to the time access restrictions in scenario A (figure 7) and this causes an increase in the number of kilometers. Due to the time access restrictions, the delivering vehicles for the different goods (fresh products and dry groceries), arrive at the same time at the stores. FR2 considers multiple vehicles at the same time at one store as a problematic situation. There is staff available in the stores for receiving goods; however, this staff can handle only one truck at the time. So if there are two trucks at one store, extra staff has to be made available in the store, this leads to an increase in costs. FR2's reaction in scenario B and C is to hire extra vehicles that can transport fresh goods, and fill these vehicles up with dry-groceries orders. So instead of combining fresh goods orders (the same kind of goods) for different stores, FR2 starts to combine different kinds of goods for the same store. This has not yet happened in scenario A, because in that scenario FR2 did not need to hire that much extra capacity. Combining an affected store and a non-affected store in one roundtrip is still possible, because they have to be delivered at different times. As over 80% of the stores are affected in scenario C almost no combinations are possible (figure 7).

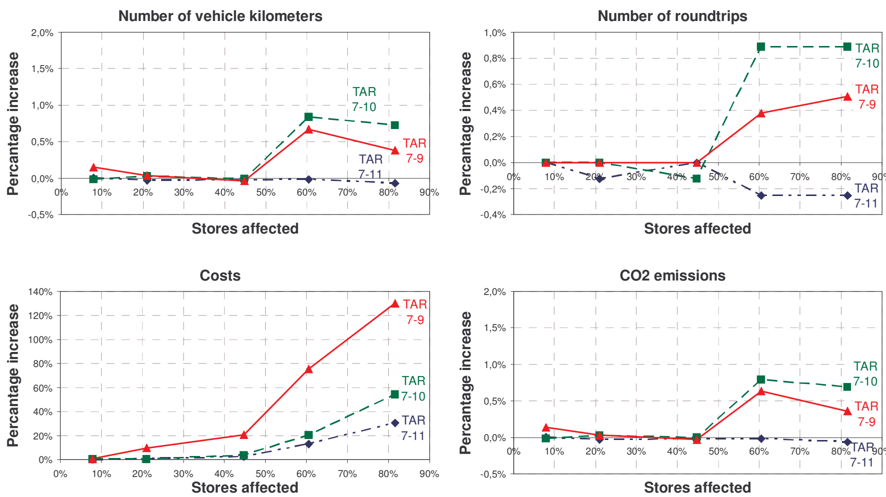


Figure 6. Values for FR1 and the time access restriction policy measure

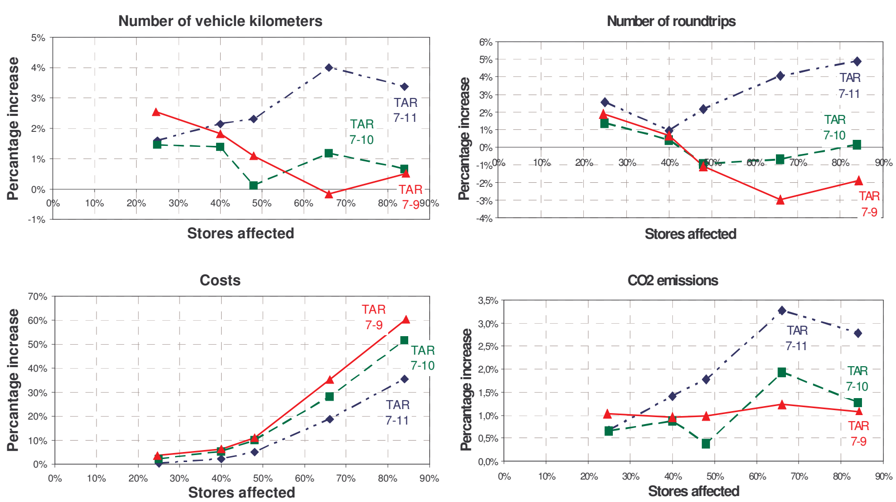


Figure 7. Values for FR2 and the time access restriction policy measure

FR3's number of vehicle kilometers and roundtrips show an increasing trend in scenario A (figure 8). When 50% of the stores are affected, extra truck capacity is hired, which results in a decrease in the number of kilometers. Although beyond this point even more capacity is hired, the stores that still were combined up to this point are now also affected. The number of roundtrips increases because the time access restriction is wide enough to make it possible for some vehicles to carry out two deliveries instead of combining two stores; during the time access restriction period all capacity is used to deliver affected stores, rather than to supply an unaffected store. It is cheaper to drive twice (and not combining orders), than to hire extra capacity. However, this leads to extra kilometers. The number of vehicle kilometers and the number of roundtrips decreases in scenarios B and C as more stores are affected because they can combine some affected stores in one roundtrip during the time access restriction period, that were not both affected earlier in these scenarios. The strange kink in the development of the number of roundtrips in scenario C around 50% of the vehicles affected (figure 8) is caused by an enormous increase in the extra capacity hired to fulfill the policy restriction as well as the delivering of all orders at this point (an increase of 40%). Because of the low store density it is almost impossible for one vehicle to perform more than one roundtrip per day in scenario C5; in scenario 0a a vehicle performed on average 2.6 roundtrips per day, in scenario C5 this was only 1.09.

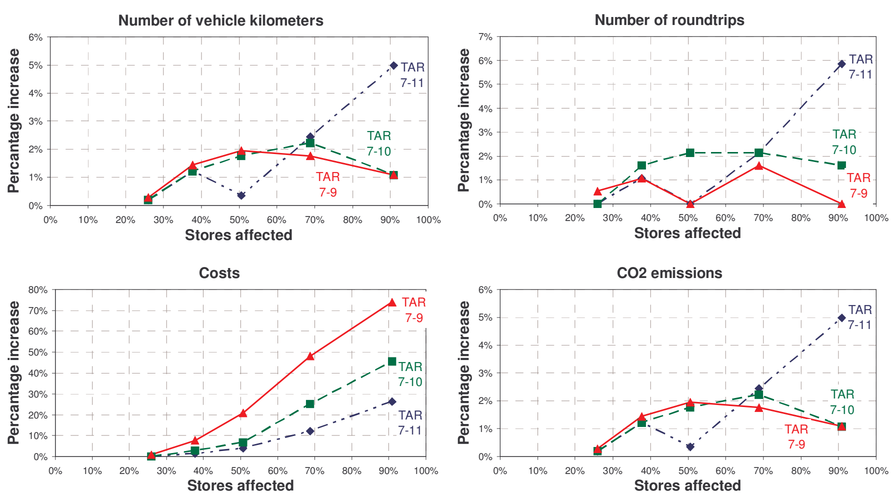


Figure 8. Values for FR3 and the time access restriction policy measure

3.3 The impact of vehicle weight restrictions

Figure 9 shows scenario D's results for the three retailers. The increase in the number of vehicle kilometers and the number of roundtrips, as the number of stores affected increases, is substantial and approximately linear. The extra vehicles (with a smaller capacity per vehicle) necessary to carry out the distribution are responsible for this. The transport costs increase linearly, due to the hiring of extra vehicles, to maintain the same capacity level, and extra costs for the extra kilometers. As long as the number of affected stores is less than half of the total, this cost increase exceeds the increase caused by time access restriction that we showed in the previous paragraph. The CO_2 emissions increase also substantially, as the number of affected stores increases. It is true that a smaller vehicle produces fewer emissions than a larger vehicle, but the total sum of CO_2 emissions of these small vehicles is higher.

The weight restriction in scenario D has the same kind of effects for all three retailers (figure 9), in contrast with the time access restrictions effects in the previous paragraph. FR1 uses relatively light vehicles in comparison with FR2's and FR3's heavy trailers in scenario 0a. For example, FR2 is forced to use vehicles with a capacity of only 26 roll containers instead of 51 roll containers in scenario 0a. This explains why FR1's number of kilometers and roundtrips increases less than that of the other retailers. Because FR3 hires its vehicles, FR3's cost increase is lower than for the other two retailers.

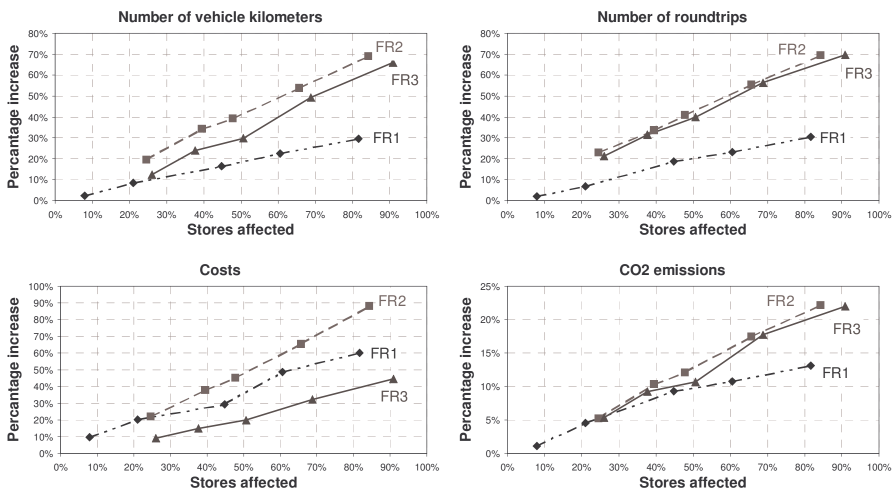


Figure 9. Values for all retailers and the 18 tons weight restriction

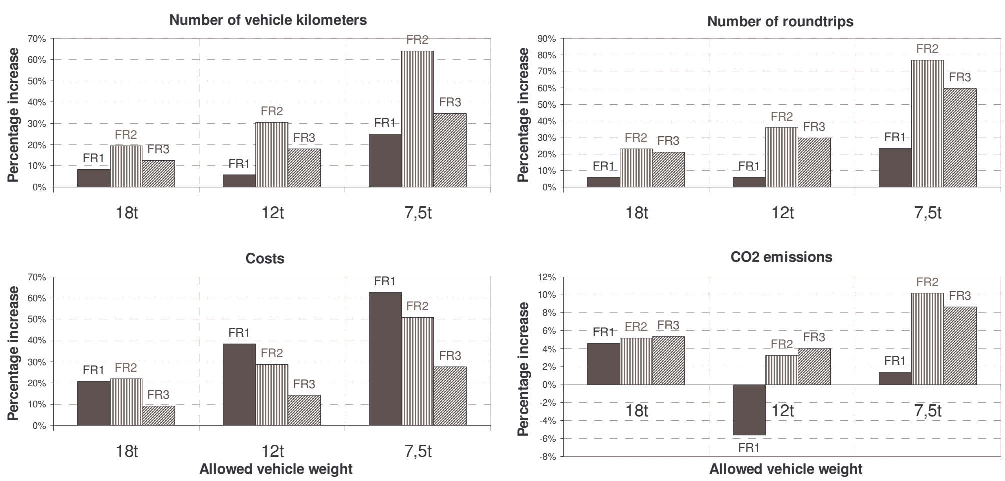


Figure 10. Values for all retailers and different weight restrictions

Figure 10 shows the effects of different weights in the weight restriction, with 21% of FR1's stores affected, 25% of FR2's and 26% of FR3's. Figure 10 shows scenarios D2, E2 and E1 for FR1 and for the other two retailers scenarios D2, E4 and E3 for FR1 and for the other two retailers scenarios D1, E2 and E1. The weight restrictions affect between 21 and 26% of all retailer stores. Figure 10 shows an increase in the number of vehicle kilometers, the number of roundtrips and the costs as the allowed weight gets less. FR1's switch from swap bodies

(18 tons restriction) to lighter trucks (with the same capacity for the 12 tons scenario) causes a decrease in number of vehicle kilometers, although there is still an increase in comparison with scenario 0a. The lighter vehicles can combine different stores, but loading and unloading takes more time, what results in a substantial cost increase.
The vehicle switch also leads to a striking reduction in CO_2 emissions for FR1[1]. Figure 10 shows also an improvement for FR2 and FR3 in the emissions if we compare the 12 tons restriction with the 18 tons restriction. However, compared to scenario 0a we see deterioration. The vehicles used in the 12 tons scenario produce considerably fewer emissions than the larger vehicles and still have a sufficient capacity. However, the 7.5 tons weight restriction causes an enormous increase in CO_2 emissions for all retailers. Although we did not investigate the effect explicitly, it is very likely that the emissions will grow even more strongly if more stores were affected by the vehicle weight restriction.

4. Conclusions and further research

4.1 Conclusions

Time access restrictions have a negative financial impact on food retailers and a negative impact on retailers vehicle activities. The transport costs increase as more stores are affected by this policy measure. This is particularly true when more than 45% of the stores are affected by the time access restriction. The costs development follows a more or less convex function. This can be used to develop a well-balanced policy framework for governments. The shortening of the time access restriction length also results in an increase in transport costs. Vehicle weight restrictions have a negative financial impact on food retailers and a negative impact on the retailer’s vehicle activities as well. The cost increase, caused by the weight restriction, is linear in the number of affected stores. Both time access windows and vehicle weight restrictions result in the use of extra vehicles. Time access restrictions only cause this increase during the time access restriction period, which is usually during the heavy traffic in the mornings, while the vehicle weight restriction adds extra vehicles to the traffic the entire day. Therefore, we believe that both policy measures do not relieve the traffic in and around urban areas.
The use of time access restrictions does not result in a decrease of pollutant CO_2 emissions, and in almost all cases it results in an increase of these emissions. The use of the vehicle weight restriction results in almost all cases in a considerable increase of pollutant CO_2 emissions. This increase develops linearly as the number of affected stores increases. However, if a weight restriction is considered, the 12 tons weight restriction has a better environmental impact than the 18 tons weight restriction and the 7.5 tons weight restriction.
In conclusion, there are some interesting discrepancies between the three food retailers. Fresh goods deliveries, which are supplied in less-than-truckloads, are affected most by the time access restriction policy measure. Narrow time access restrictions result in combining fresh goods and PFV orders with dry grocery orders in one vehicle, for the same destination, instead of combining fresh goods and PVF in one roundtrip for multiple stores. In general, we

[1] We have to mention here that PM10-emissions (local pollutant) increase enormously by the use of these smaller and lighter vehicles. So we cannot say that this policy measure has only good effects on the environment.

can say that time access restrictions hit less-than-truckload quantities for different stores that are combined in one vehicle most. Time access windows seem to affect the swap body concept less than the other concepts, because of the short (un)loading times. And finally, the weight restriction affects retailers that use heavy vehicles worst.

4.2 Further research

With the addition of traffic information and road density in the modeling we think the results would give an even better insight in the effects of the policy measures.

Defining policies that concern urban freight transport is difficult. This paper shows some effects of only two policy measures. The effects on other actors, such as inhabitants, traffic participants, shopping public, are not considered in this study. Environmental effects could also be specified for the urban level, instead of the overall environmental effects. Finding these effects would be helpful to complete the picture of the policy measurement's effects.

In the Netherlands, municipalities are free to set their own time access restrictions. This paper shows that if more than 45% of all stores are affected with time access restrictions, a retailer is confronted with a considerable increase in costs. However, from a city perspective time access restrictions are believed to improve the shopping climate in that area. So, even if all cities are aware of the fact that the percentage of cities that use time access restrictions is too high, the question is which city should alleviate their time access restriction. Here is an opportunity for the higher government to propose an overall policy. How this overall policy should be designed is an interesting issue for further research.

Governments have multiple objectives in urban freight policies. Next to developing efficient and environmental urban freight systems, issues such as improving the shopping climate and the traffic safety are governmental objectives as well. The results of this study show that time access restrictions and vehicle weight restrictions do not improve efficiency and the environment. With these results governments should be able to rethink (parts of) their urban freight policies in the light of all their objectives. The effects of policy measures on, for example, noise and the way these vehicles influence the accessibility of cities are interesting to examine. It would be useful to find the effects on other retail sectors. The effects of other policy measures, such as pricing, the use of city terminals and more are to be found. After completing the picture of all policies' effects, as well as the effects of initiatives as co-operative freight transport systems, the governments should be able to define a deliberate urban freight policy. This is an interesting challenge for future research.

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References

ACNielsen (2003). Handleiding Uniform DPP (Direct Product Profitability)-model. Diemen.

Allen, J., Anderson, S., Browne, M. and Jones, P. (2000). A *framework for considering policies to encourage sustainable urban freight traffic and goods / service flows*. Summary report, Transport Studies Group, University of Westminster, London.

Allen, J., Tanner, G., Browne, M., Anderson, S., Chrisodoulou, G. and Jones, P. (2003). *Modelling policy measures and company initiatives for sustainable urban distribution*. Final Technical Report, Transport Studies Group, University of Westminster, London.

Ambrosini, C. and Routhier, J.L. (2004). Objectives, Methods and Results of Surveys Carried out in the Field of Urban Freight Transport: An International Comparison. *Transport Reviews*, vol. 2, no. 1, pp. 57-77.

Banister, D., Stead, D., Steen, P., Akerman, J., Dreborg, K., Nijkamp, P. and Schleicher-Tappeser, R. (2000). *European Transport Policy and Sustainable Mobility*. Spon Press, London.

Browne, M. (1997). *United Kingdom, in: Freight transport and the city*. Roundtable 109, OECD Publications Service, Paris.

Crum, B. and Vossen, M. (2000). *Knelpunten in de binnenstadsdistributie, inventarisatie van de beschikbare kennis en ervaringen*. Research voor Beleid (in opdracht van de MDW-werkgroep Binnenstadsdistributie), Leiden.

Feitelson, E. (2002). Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls. *Transportation Research part D*, vol. 7, no. 2, pp. 99-118.

Geerards, J. and Vrij, de, B. (1999). Kostenbesparing met wissellaadbakken in de distributie. In: *Praktijkboek Magazijnen en Distributiecentra*, Kluwer, Deventer, 3.5.E-01 – 3.5.E-16.

Groothedde, B., Rustenburg, M. and Uil, K. (2003). *De invloed van venstertijden en voertuigbeperkingen op de distributiekosten in de Nederlandse detailhandel*. TNO Inro, Delft.

Ison, S. and Rye, T. (2003). Lessons from travel planning and road user charging for policy-making: through imperfection to implementation. *Transport Policy*, vol. 10, no. 3, pp. 223-233.

Klein Breteler, A.J. (2002). *Stedelijke distributie in de retailketen*. Deelrapport 2: Functioneel ontwerp van de stadsbox, Connekt, Delft.

Koster, de, M.B.M. and Neuteboom, A.J. (2001). *The logistics of supermarket chains: a comparison of seven chains in the Netherlands*. Elsevier Business Information, Doetichem.

May, A.D., Jopson, A.F. and Matthews, B. (2003). Research challenges in urban transport policy. *Transport Policy*, vol. 10, no. 3, pp. 157-164.

NERA (2000). *Report on Lorry Track and Environmental Costs*. National Economic Research Associates, AEA Technology and The Transport Research Laboratory, London.

Ogden, K.W. (1992). *Urban Goods Movement: A Guide to Policy and Planning*. Ashgate, Aldershot.

PSD (2001). *PSD-voertuigenmatrix*. Platform Stedelijke Distributie, Den Haag.

PSD (2002). *Van B naar A*. Platform Stedelijke Distributie, Den Haag.

Taniguchi, E., Thompson, R.G. and Yamada, T. (2003). Predicting the effects of city logistics. *Transport Reviews*, vol. 23, no. 4, pp. 489-515.

Taniguchi, E., Thompson, R.G., Yamada T. and Duin, van, R. (2001). *City logistics: network modelling and intelligent transport systems*. Pergamon, Oxford.

Taniguchi, E. and Heijden, van der, R.E.C.M. (2000). An evaluation methodology for city logistics. *Transport Reviews*, vol. 20, no. 1, pp. 65-90.

Van Binsbergen, A. and Visser, J. (2001). *Innovation steps towards efficient goods distribution systems for urban areas.* DUP Science, Delft.