Urban Distribution: The Impacts of Different Governmental Time-Window Schemes

H.J. Quak and M.B.M. de Koster

ERIM REPORT SERIES *RESEARCH IN MANAGEMENT*	
ERIM Report Series reference number	ERS-2006-053-LIS
Publication	October 2006
Number of pages	19
Persistent paper URL	http://hdl.handle.net/1765/8020
Email address corresponding author	hquak@rsm.nl
Address	Erasmus Research Institute of Management (ERIM) RSM Erasmus University / Erasmus School of Economics Erasmus Universiteit Rotterdam P.O.Box 1738 3000 DR Rotterdam, The Netherlands Phone: + 31 10 408 1182 Fax: + 31 10 408 9640 Email: info@erim.eur.nl Internet: www.erim.eur.nl

Bibliographic data and classifications of all the ERIM reports are also available on the ERIM website: www.erim.eur.nl

ERASMUS RESEARCH INSTITUTE OF MANAGEMENT

REPORT SERIES

RESEARCH IN MANAGEMENT

ABSTRACT AND KEYWORDS	
Abstract	Local authorities increasingly use time-access regulations to improve social sustainability issues, such as the attractiveness of a city centre, the shopping climate, or to reduce the nuisance caused by urban freight transport. However, these time-windows increase delivery costs and the environmental burden. This paper evaluates five different time-window schemes on their social, environmental, and economic impacts. The first scheme examines the current time-window policy scheme. In the second scheme time-windows are harmonized between different cities. The third scheme moves all deliveries to the night. The fourth and fifth schemes evaluate the consequences of the proposal by the Dutch committee for urban distribution (committee Sakkers). The fourth scheme includes noise-legislation for delivering during the night, the fifth does not. This research includes interviews with several Dutch policy-making officials and is further based on a multiple-case study of fourteen large retail chains in different sectors and with different formulas. The results show that the current time-window scheme performs worst. The best time-window scheme would be a combination of the proposal of the committee Sakkers and the harmonization scenario.
Free Keywords	Urban Goods Movement, Time-Window Regulation, Retail Logistics, Sustainability, City Logistics
Availability	
Classifications	

Contents

Abstract

Local authorities increasingly use time-access regulations to improve social sustainability issues, such as the attractiveness of a city centre, the shopping climate, or to reduce the nuisance caused by urban freight transport. However, these time-windows increase delivery costs and the environmental burden. This paper evaluates five different time-window schemes on their social, environmental, and economic impacts. The first scheme examines the current time-window policy scheme. In the second scheme time-windows are harmonized between different cities. The third scheme moves all deliveries to the night. The fourth and fifth schemes evaluate the consequences of the proposal by the Dutch committee for urban distribution (committee Sakkers). The fourth scheme includes noise-legislation for delivering during the night, the fifth does not. This research includes interviews with several Dutch policy-making officials and is further based on a multiple-case study of fourteen large retail chains in different sectors and with different formulas. The results show that the current time-window scheme performs worst. The best time-window scheme would be a combination of the proposal of the committee Sakkers and the harmonization scenario.

Keywords

Urban goods movement, time-window regulation, retail logistics, sustainability, city logistics

1 Introduction

1.1 Urban goods distribution

Urban goods transport is crucial to maintain the current urbanized way of living. It is fundamental to the economic vitality of urban areas, to the liveability in these areas, and to trade and leisure activities (Anderson, *et al.*, 2005; Ogden, 1992). The availability of goods is essential to function as a centre in the first place. Rapid and reliable goods distribution supports urban lifestyles and is an important element of the urban economy in itself (Browne and Allen, 1999).

However, urban goods transport is also recognized for its less sustainable impacts. Urban goods distribution interferes with the quality of life in urban areas, and it adds to global warming and acidification through global pollutant emissions, injuries and deaths resulting from traffic accidents and the consequences of local emissions on public health. Furthermore, it is responsible for noise, visual intrusion, and vibration. Next to that urban freight transport also adds to the decrease of city accessibility and the increase of congestion on the highways to and from the urban areas (Banister, *et al.*, 2000; Browne and Allen, 1999; Van Binsbergen and Visser, 2001).

Local authorities' response to these negative effects often results in regulation that focuses on reducing the citizens' inconvenience as a result of urban freight transport. This usually means that urban freight transport is restricted (Allen, *et al.*, 2000). Time-access restrictions, or time-windows, are among the most-used policy restrictions. A survey among the 278 largest municipalities in the Netherlands shows that the number of municipalities that use time-window regulations increased from 41% in 1998 to 53% in 2002 (PSD, 2002). Among the top 100 largest municipalities 71 use time-windows and the largest 20 municipalities all use time-windows. The main objective to use time-windows is to improve social sustainability issues, such as improving the liveability in the city centre, improving the shopping climate by reducing negative impacts caused by large vehicles, e.g. noise, pollution, vibration, visual intrusion, etc. (Allen, *et al.*, 2004), as well as to separate the shopping public (coming by car to visit the centres) and the supplying vehicles (Munuzuri, *et al.*, 2005). Time-windows are widely used, but are particular popular in Western European countries (OECD, 2003).

1.2 Time-window policies

Interviews with city policy-making officials responsible for their municipality's time-window policy give insights in Dutch local authorities' objectives to use time-window policies in the Netherlands. Furthermore, the interview results show whether these Dutch objectives correspond with those in literature (see Allen, *et al.*, 2004 and Munuzuri, *et al.*, 2005) The original sample for the interviews was the 50 largest Dutch cities; appendix A shows the final sample of 33 cities that cooperated in these interviews. Reasons for cities not to cooperate were that they did not use time-window policies (6), they did not have time to cooperate (2), or the person responsible for urban distribution policies left the municipality and there was no replacement yet (3). The remaining municipalities did not reply to the invitation for the interview and the following reminders. The interviews were conducted in early 2006, mainly by e-mail and telephone. We focused in these interviews on four elements:

1. main objective to use time-window policies
2. the effects of time-windows on this objective
3. the measurement of these effects
4. the official's opinion on the effects of time-windows on the:
    a. environment
    b. noise
    c. safety
    d. quality of shopping environment
    e. accessibility
    f. economic development.

This section briefly summarizes the main results of these interviews. The objective to use time-windows that was mentioned by the vast majority of the officials (over 90%) is to improve the shopping climate and the attractiveness of the centre. Reasons to improve the attractiveness and the shopping climate seem to be twofold: an attractive city centre increases the number of visitors and with that the local economic development. Next to that it is considered the task of local authorities to provide their residents with a centre that is attractive; it increases the 'quality of life' for city residents. Other objectives mentioned to use time-windows are:

- reduce the inconvenience (about 25% of the respondents, e.g. traffic blockades by unloading vehicles, noise, etc.)
- increase pedestrian safety (about 20% of respondents)
- reduce the noise nuisance in the early morning (about 10% of the responding officials).

Although most of the cities do not measure or examine the results, they argue that the attractiveness of the centre and the shopping climate improved due to the use of time-windows. Their main argument is that anyone can see that a city centre is more attractive without (large) vehicles. A similar argument also applies to the effects on the other objectives mentioned. In most cases there is no measurement of these effects, but officials argue that the effects can simply be observed by looking at the time-window area.

About 50% of the officials were of the opinion that the pedestrians' and cyclists' safety would increase due to the use of time-windows. There was no consensus between the respondents on the effects of time-windows on the environment. The amount of officials was more or less equally divided between thinking the use of time-windows would have positive environmental effects (about 25%), negative environmental effects (about 25%), no idea (10%) or no effect (40%). The officials all agreed on the effect of time-windows on noise nuisance; it would be worse during the time-window period, but better outside the time-window period. So, overall, they argue since there are less people in the area during the time-window period (during the morning hours it is usually not so crowded in the city centres), the nuisance decreases. Finally, an attractive centre is more likely to attract more visitors. This probably results in an increase in the total amount of sales. So, the main idea is that time-windows contribute positively to the economic development of a city centre.

Beside the positive effects on the local sustainability, time-window regulations cause numerous problems. Carriers that supply outlets in multiple urban areas experience reduced transportation efficiencies. Groothedde, *et al.* (2003) estimate the yearly cost-increase due to the current time-window policies in the Netherlands to be about 270 million euro. Next to this cost increase, current time-window policies increase global as well as local pollution (Quak and De Koster, 2006a). Since many of these time-windows force carriers to make their deliveries during the morning, it also

adds to the congestion on the highways during the morning rush hours and to a decrease in city accessibility. Carriers and transporters travel during these rush hours, to use as much of the time-window periods as possible to deliver outlets in the urban areas that are affected by time-windows.

The Dutch Minister of Transport asked Lemstra to give a clear image of the problems in urban distribution in February 2004. In the report that followed Lemstra's advice (2004) as regards to time-windows is that they could be harmonized in a region, and that the length of the actual delivery time-windows at the stores, depending on both the local authorities' time-windows and the retailers' self-implied time-windows should be large enough to supply the outlets, to profit from the positive sides of time-windows, and to reduce the negative impacts. Based on the Lemstra's (2004) advice, the Minister established the Committee for Urban Distribution in early 2005. This committee, currently known as the committee Sakkers, has as objective to promote the cooperation between public and private parties in the supply of urban areas. Furthermore, the committee is looking for measures that are most profitable for both the society and business (see http://www.stedelijkedistributie.nl). This last objective of the committee has lead to a reference model for urban distribution, which focuses on a directive for vehicle restrictions and a directive for time-windows. This last directive is discussed in more detail in paragraph 4.5.

This paper evaluates different time-window schemes, including two that are based on the Committee for Urban Distribution's (committee Sakkers) directive for time-windows, dated June 26, 2006, to see what the environmental and economical impacts are, considering the social sustainability issues as well.

2 Research question and model

Time-window policies have positive effects on the area in which they are enforced. Next to these positive effects, we also noticed the problems time-windows can cause for retailers, as well as the extra pollution that results from this policy. Therefore, the motivation for this study is to see how different time-window policy schemes can contribute to the attractiveness of city centres on the one hand, and reduce the negative effects on retailers' costs and the environment on the other hand. In other words, we consider the triple bottom line of sustainability: economic, environmental, and social sustainability (or triple P: people, profit, and planet) (Richardson, 2005). From this motivation the following research question follows:

> What are the effects of different time-window policy schemes on (i) retailers' costs, (ii) local and global pollution, considering time-window objectives, such as (iii) the centre's attractiveness and safety as well as the nuisance for residents?

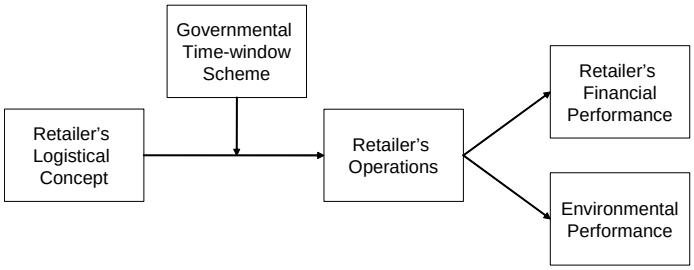

Figure 1 Research model

Figure 1 shows the research model that we use to find the effects of time-window policy schemes on retailers' costs and the environment, after that we argue, based on what we learned from the interviews with policy-making officials, what the effects are on the social sustainability issues.

3 Methodology

To answer the research question, we use a multiple case study (Eisenhardt, 1989; Yin, 2003). The case definition, similar to the unit of analysis, is defined as all deliveries from one retailer's warehouse to its stores during one week. We selected 14 cases, all large retail chains operating in the Netherlands, from four different lines of business; 4 food retailers, 5 fashion retailers, 4 department store retailers, and 1 drug store retailer. These lines of business are selected as these are mostly present in Dutch cities (see e.g. Boerkamps, 2001). The theoretical replication procedure to select the cases aims at selecting cases that are affected differently by similar time-window pressure (Voss *et al*. 2002; Yin, 2003). For example, retailers that combine few drops per delivery roundtrip are affected less by increasing time-window pressure (Quak and De Koster, 2006a). We selected large retail chains, because they are active in many cities and therefore they are confronted with many different local authorities' regulations. Although, the case sample consists of 14 retailer chains, this entire sample set includes over 2300 stores, which are delivered by over 320 vehicles per day, to make over 8200 deliveries per week. Our case sample includes a large variance of retailers e.g. varying from hard discounters to response or differentiation driven retail chains on the high end of the market.

Table 1 Case characteristics

Retailer type	**Competitive strategy**	**Stores considered**	**Warehouses considered**	**Number of deliveries** (per week)	**Number of vehicles** (per day)	**Number of roundtrips** (per week)
Drug	Costs	498	1	515	20	96
Department store	Costs (discounter)	106	1	132	15	107
Department store	Costs	275	1	791	42	331
Department store	Differentiation	93	4	751	34	224
Department store	Differentiation	13	1	68	11	68
Fashion	Costs	108	1	510	22	121
Fashion	Costs (discounter)	475	1	952	28	105
Fashion	Response	180	1	900	23	109
Fashion	Response	122	1	244	8	34
Fashion	Response	133	1	266	7	26
Food (dry groceries)	Costs (discounter)	77	1	224	18	185
Food (dry groceries)	Differentiation	134	1	663	27	498
Food (dry groceries and fresh)	Costs (soft discounter)	38	1	820	30	782
Food (fresh)	Differentiation	134	1	1431	43	227
Total		**2386**	**17**	**8267**	**328**	**2913**

The contextual situation in Western-Europe is similar to that in the Netherlands (e.g. retail structure, transport-cost structure, and time-window policies, see OECD, 2003) therefore, we can base valid conclusions that can be generalized to the entire Western-European context. Table 1 presents the case characteristics of the cases in the sample. For all these cases we collected data using a research protocol to ensure external validity (see e.g. Voss, *et al.*, 2002). This means we gathered data for all cases in a similar way from several sources (interviews, questionnaires, company documents, site visits) including: retailer's distribution centre(s), stores, vehicle fleet, product carriers, transport planning, distribution strategies and experiences with time-windows. We recalculated the retailers' vehicle routing for their current situation and validated these outcomes with the actual transport planning and with the retailers.

We calculate how different time-window schemes, discussed in the next paragraph, affect the 14 cases (see Figure 1). We use the standard routing software SHORTREC 7.0, developed by Ortec, to calculate the vehicle routing for the cases (for all time-window schemes). The operational performance of the retailers follows from these vehicle routings. Indicators that measure the operational performance are: number of vehicles used, number of vehicle kilometres, total time, number of roundtrips, number of deliveries per roundtrip, vehicle utilization (during a 24-hour period), and vehicle load factor (when leaving the DC). Based on the retailers' operational performance we calculate both the financial performance and the environmental performance. The financial performance (per individual case) follows directly from the operational performance and is measured in weekly distribution costs (for all transport between the distribution centre and the stores and the unloading at the stores). The costs are mainly based on the costs per kilometre (e.g. fuel consumption) and cost per hour (e.g. driver's wage). The costs are based on cost information provided by retailers. The environmental performance for every retailer is based on a combination of emission tables (NERA, 2000), average vehicle speed, the number of kilometres (both following from the vehicle routing planning), and based on the actual retailer's vehicle fleet for which data was collected using a research protocol, the vehicle type (articulated or rigid) and engine type (EURO I, II, III or IV). The environmental performance is expressed in the weekly quantity of the global pollutant CO_2 emissions and the local pollutant emissions CO, NO_x, and PM10 (both from emissions as well as from tire and brake wear). We verified all results by the retailers' own results. Our results differed at most 5% with the costs, kilometres, and time used by the retailers in the current situation. Finally, we argue what the effects would be for the social sustainability performance. We use five indicators to rationalise the social sustainability performance: attractiveness city centres / shopping climate, inconvenience, noise nuisance (in the morning and night for residents), safety (pedestrians and cyclists), and the clarity for carriers and retailers. These indicators can vary on a seven-point scale between very positive (+++), no effect (0), and very negative (---).

4 Time-window schemes

In this study we use five scenarios to evaluate the impact of different kinds of time-window policy schemes. Table 2 summarizes the five scenarios and shows per scenario the average time-window length. The retailers' likely reaction on a time-window scheme is based on interviews with the retailers. This likely reaction simply means the way the retailers would plan their store-distribution in the case that the

time-window scheme would be real. For example, most retailers do not supply their stores during the night, or during the evenings, since there is no staff available to receive the goods. Next to that, it gives safety problems for the stores, the goods, and the drivers. This means that even in a time-window scheme in which the retailers are allowed to deliver during the evening, the majority does not use that opportunity, based on their likely reaction. So we use the likely retailer's reaction on each time-window scheme, which adds to the reality of the time-window schemes outcomes. Notice that the time-windows affect cities, and that the amount of stores affected per retailer might differ per scenario. Table 2 only shows that average percentage of stores affected per scenario for all fourteen cases. The design of the scenarios shown in Table 2 is discussed in more detail in the remaining parts of this paragraph.

Table 2 Scenario definitions and average time-window length

Scenario	***Time-window policy***	***Average time-window length and percentage stores affected by time-windows***
scenario 0	no time-windows	0 hours (0% stores affected)
scenario 1	current time-window policies	5 hours 20 minutes (43% stores affected)
scenario 2	harmonized time-windows	4 hours and 53 minutes (46% stores affected)
scenario 3	nightly time-windows	6 hours (46% stores affected)
scenario 4a	time-windows 'reference model committee urban distribution' (Peak)	10.5 hours (5 during the morning, and 5.5 during the evening The evening is hardly used by the retailers, so actual length is close to 5 hours) (43% stores affected)
scenario 4b	time-windows 'reference model committee urban distribution' (No Peak)	18.5 hours (5.5 hours are not used for deliveries; between noon-1730) (43% stores affected)

4.1 Scenario 0: no time-window policies

In the 0-scenario we remove all time-window policies. All other scenarios, in which there are different kinds of time-window policy schemes introduced, are evaluated by comparing the results with the 0-scenario. This evaluation shows what the effects are of the different time-window schemes. All retailers' characteristics are similar to the current situation in this scenario. This implies that we do not change e.g. the retailers' self-implied time-windows (based on the likely reaction), or the different vehicles types that are used at the moment, due to vehicle restrictions. Some retailers use self-implied time-windows to plan the loading and unloading at the stores, for example, to make sure extra staff is available. Other retailers supply their stores at times no staff is available at all - during the night or early morning. In order to deliver during the night, the drivers need a key to a store's depot or a store.

4.2 Scenario 1: current time-window policies

The current time-window policies are based on PSD (2002). In this study PSD (2002) listed all time-window policies of the 278 largest Dutch municipalities. In most municipalities the time-window restrictions only apply to stores in city centres, or even only to the pedestrian areas. We included this by applying the time-window

restrictions to stores that are located in the ZIP-code area of the city centre, as determined by Groothedde *et al.* (2003).

4.3 Scenario 2: harmonizing time-window policies

There are many ways to harmonize time-window policies in different municipalities (see e.g. PSD, 2001). Obviously, a carrier would like to see time-window harmonization in such a way that it could visit all neighbouring municipalities at that time it would suit its planned roundtrip. This is not possible in reality; the number of carriers is high, and their roundtrips differ, because of different depots they start from, different customer locations and so on, which means that they would all like different ways of harmonization. This cannot be realized in reality. A solution could be to determine which city centre benefits most from using strict time-windows, and which city centres would benefit least. The next step would then be to allow the centres that benefit most to use strict time windows. Unfortunately, most local authorities would argue that their centre benefits most and it is not this study's aim to evaluate all Dutch city centres. Therefore, we propose a straightforward way to harmonize time-window policies: based on city size (measured as the population). In this scenario the time-window policies of Dutch municipalities are harmonized as follows: the window size gradually decreases with the city size in this harmonization scenario. This means that the five largest Dutch municipalities use a time-window restriction of only three hours (from 7-10 a.m.) in this scenario, the sixth to the 25th largest Dutch municipalities use time-windows of 4.5 hours (from 6.30-11 a.m.), and the 26th to the 100th largest Dutch municipalities have a time-window of six hours (from 6 a.m. - noon). All smaller cities do not use time-window restrictions in this scenario.

4.4 Scenario 3: nightly time-windows policies

The main objective to use time-windows is to improve social sustainability issues. One extreme way to do this, is to have time-windows during the night. Although at this moment, night time deliveries to areas where people live are not allowed in several European countries, e.g. France, the Netherlands, and the United Kingdom (Browne, *et al.*, 2005). In the Netherlands the PEAK-norm (see e.g. www.Peak.org, Browne, *et al.*, 2005) restricts the maximum noise level between 11 p.m. and 7 a.m. to 60dB(A), which implies that normal distribution activities are not possible. The advantage of delivering during the night is that traffic congestion is considerably less than during the day, which could result in more reliable and faster journeys to the stores. It also contributes to the improvement of the shopping climate. The disadvantages are that it might be disturbing for people living nearby (or above) stores. Furthermore, from interviews with several retailers we learned that they fear for the safety of their drivers and cargo, in the case they are working alone in an abandoned centre. Next to that, the drivers' wages are higher during the night. Finally, since there is no staff available at the stores, the unloading times might increase, as the driver has to do this on its own. In this scenario the time-windows are set from midnight to 6 a.m. in the 100 largest Dutch municipalities (similar to scenario 2). This means exactly the same stores are affected by time-windows in this scenario as in scenario 2.

4.5 Scenario 4: time-windows policy according 'Referentiemodel commissie stedelijke distributie'[1]

The Dutch committee for urban distribution (committee Sakkers) that works for the Dutch Minister of Transport (see e.g. http://www.stedelijkedistributie.nl/) suggests in its concept for discussion (dated June 26, 2006) a directive for time-window policies in the Netherlands. This directive proposes:

- Before a municipality starts to use time-windows it should first show the necessity of it by a problem analysis.
- Time-windows are only to be used in core shopping centres that are pedestrian areas.
- Supplying vehicles are not allowed between noon and 5.30 p.m. and in case of late night shopping between noon and 9 p.m.
- The receivers should allow supplying vehicles during the time-window period for at least four hours in a row, so they cannot demand stricter time-windows for their stores than successive four hours. This might imply that they have to change their self-implied time-windows, or that staff has to be available before the actual opening hours of the store.
- Dispensation is possible for special products (e.g. fresh products).
- The retailers / entrepreneurs in the centre should make arrangements to improve the traffic flow (e.g. street furniture or commercial signs).

Scenario 4a implies that vehicles are not allowed between noon and 5.30 p.m. We apply these time-windows to all centres that use time-windows in the current situation (see scenario 1 and PSD, 2002). The retailer's self-implied time-windows have a minimum length during the morning of at least 4 hours. This was already the case for all retailers, except for one; for that fashion retailer we set the self-implied time-windows from 8 a.m. to noon (in stead of from 9 a.m.). We do not change the retailers' decisions based on their likely reaction, for example a retailer that decided not to deliver during the night, does not deliver during the night in this scenario. This results in a time-window length for these retailers, that is actually five hours, since most retailers (in the case sample) do not deliver their stores during the evening and the PEAK-norms do not allow deliveries between 11 p.m. and 7 a.m. (see scenario 3).

Scenario 4b is similar to scenario 4a; it is also based on the directive developed by the committee Sakkers, with this difference that we did not include the PEAK norms. This implies that the retailers can supply their stores at all times, except for the period between noon and 5.30 p.m. The period that can be used to supply the stores includes the night. Most retailers do not supply stores during the night though, so the difference between scenario 4a and 4b is mainly caused by the possibilities for retailers to supply the time-window affected stores also before 7 a.m. In the case sample this considerably broadens the time-window length for seven of the 14 retailers. The other retailers indicated that they would not supply (the majority of) theirs stores before 7 a.m.. Many retailers argued that they would not deliver during the evening hours, at times no staff is available to receive goods, or to open the stores' depots, as they do not want their drivers to open stores (or depots), because of the safety of the drivers, goods and the stores.

[1] Dutch: Reference model committee urban distribution

5 Evaluating different schemes

We evaluate the scenarios as follows: we calculate the difference in costs between the scenario and scenario 0 (no time-windows). This difference in total costs is divided by the number of time-window restricted stores; this results in the average cost difference per store due to a time-window restriction. At the end of this paragraph we evaluate performance of the scenarios individually. We include environmental, financial, and social sustainability performance in this evaluation.

Direct comparison between the different scenarios is possible. However, it is less straightforward because of differences in time-window pressure, which is constructed by the time-window length and number of stores affected by a time-window restriction. For example, in the harmonization and night scenario more stores are affected by a time-window than in scenario 1 and 4. This alone would result in extra costs for scenario 2 and 3. This is also the case for the time-window length (see Table 2). Therefore, we should be cautious by opting that one kind of scenario is better than the other from comparing the costs (or environmental) outcomes only. The scenario outcomes provide us with some clear insights in the effects of different time-window schemes, and what is causing these effects.

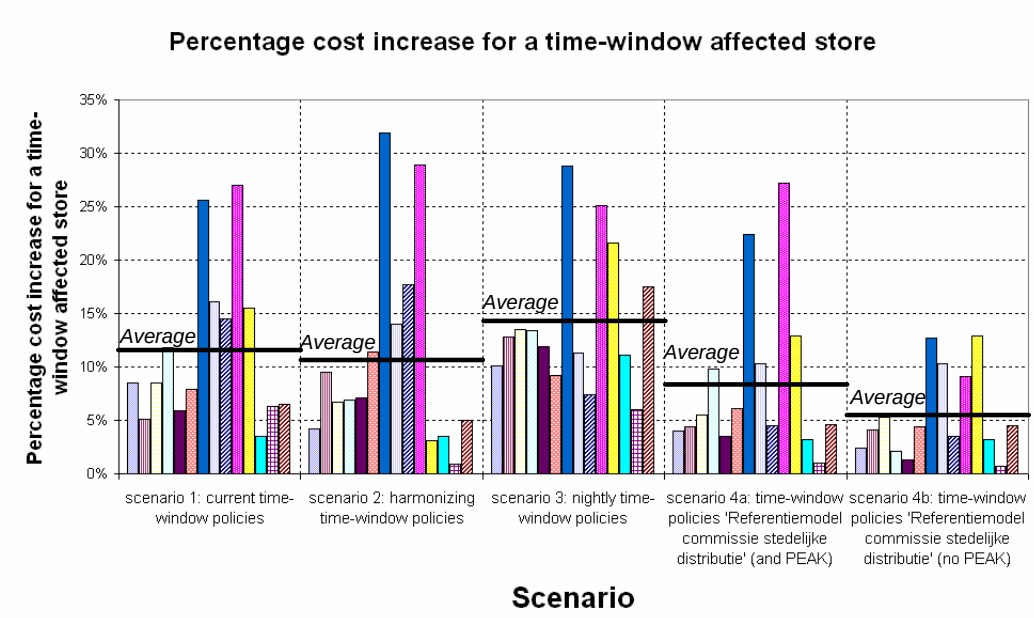

Figure 2 Cost increase per scenario for 14 different cases

Figure 2 shows the cost increase for all 14 cases individually for a store that is affected by a time-window restriction. This figure shows that on average the cost-increase is least for scenario 4 (reference model committee urban distribution). Scenario 4b performs even better than scenario 4a. In scenario 3, we see an increase in cost that exceeds all other scenarios. There is only a slight difference between scenario 1 and 2 in cost-increase for the retailers. Interpreting these results is only possible in combination with Table 2. This table shows time-window pressure is highest in scenario 2 (both in average time-window length and number of cities affected by time-windows). Previous research shows that an increase in time-window pressure leads to an increase in costs. So this suggests that the harmonization scenario

(scenario 2) performs better than scenario 1, than the difference in the average would suggest. Figure 2 shows that the cases are affected differently by the same scenario. It is outside this paper's scope to explain these differences in depth. Reasons for this variance in the way retailers are affected by time-window policies are for example the amount of stops per roundtrip (directly related to the drop size per delivery), the average distance between the stores and the retailer's distribution centre, the delivery frequency, differences in unloading times per product carrier, different self-implied time-windows, and of course the amount of stores affected by time-window restrictions. See for a more in depth analysis of retailers' sensitivity to time-windows and the relation between differences in time-window pressure and retailer's financial performance as well as the environmental performance Quak and De Koster (2006a).

Figure 3 shows the environmental impacts of the different time-window schemes. Global impacts are expressed in CO_2 emissions. The local impacts are expressed in the local pollutants NO_x, CO, and PM10. We have to be careful in interpreting the effects of local emissions, like PM10. These effects depend on many other factors; for example, the weather conditions and the physical shape of a shopping area, which may impact the time emissions are retained within the area. We assume the total amount of local emissions can be used as good indication for the local environmental impacts though. Previous research shows that if time-window pressure increases, the environmental impact increases as well. Noteworthy is at least that the scenario 4's schemes show by far the best environmental results for all indicators. Furthermore, the trend of all four environmental indictors is more or less similar. The current regulations (scenario 1) burdens the environment most, followed by the harmonized time-windows (scenario 2), although there is a slight discrepancy for the PM10 emissions in this trend, then the nightly time-windows, followed by scenario 4a, and finally by scenario 4b.

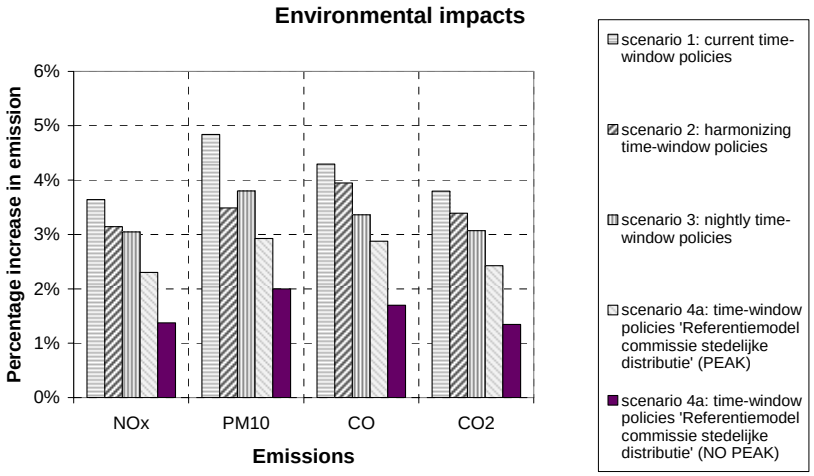

Figure 3 Local and global environmental impacts for different time-window schemes

Table 3 shows indications of the social performance for the different time-window schemes. These indications are all subjective. In this section we explain these results. In scenario 3 all deliveries are made during the night, which results in very positive effects during the day for all indictors. Only the noise nuisance during the night increases, which results in a very negative effect for the indicator noise. Time-window

policies in scenario 3 and 4 are clear for retailers; the time-window regulation is similar in all cities. Scenario 2 is less clear, since there are differences between cities (but these differences are based on criteria). In scenario 1 the retailer faces a chaos in which all local authorities design their own time-windows. The safety, noise, and inconvenience levels are corresponding for scenarios 1, 2, and 4a, although we can argue that the shorter the time-window period is, the longer the period is in which the positive effects are felt. So this would mean that scenario 2 scores slightly better than, scenario 1, that scores on its part slightly better than scenario 4a. Scenario 1 and 2 score better on the attractiveness indicator than scenario 4a and 4b as a result of the possibility to adapt the time-windows to the specific city situation (based on certain criteria), whereas this is not possible in scenario 4, as it was evaluated here. Scenarios 4a and 4b are similar, except for noise. Obviously, the noise nuisance is higher if the Peak-regulation is not included.

Table 3 Social performance indicators for different time-window schemes

	attractiveness city centre /shopping climate	*inconvenience*	*noise (residents)*	*safety (pedestrian / cyclist)*	*clarity (for carriers and retailers)*
scenario 1: current time-window policies	++	+	+	+	--
scenario 2: harmonizing time-window policies	++	+	+	+	+
scenario 3: nightly time-window policies	+++	+++	---	+++	+++
scenario 4a: time-window policies 'Referentiemodel commissie stedelijke distributie' Peak	+	+	+	+	+++
scenario 4b: time-window policies 'Referentiemodel commissie stedelijke distributie' no Peak	+	+	-	+	+++

5.1 Scenario 1: current time-window policies

Although the time-window pressure is not considerable higher than in the other scenarios, scenario 1 performs worst for its environmental impacts, and also quite bad for the retailers' costs. Since the average time-window length is relatively long, the nuisance caused by supplying vehicles for shopping public and residents is felt over a relative long period. From interviews with retailers we learned that they complain in this situation about the cluttered regulation. This makes it difficult for both planners and drivers to know exactly what applies in which city. Therefore, the overall judgement for scenario 1 is negative. The scheme of the current time-window policies, in which local authorities are free to decide on their time-window regulation, without considering other municipalities or conditions, scores low for all three performance indicators.

5.2 Scenario 2: harmonizing time-window policies

Scenario 2, in which the time-windows are harmonized between different cities, has the highest time-window pressure of all scenarios; the average time-window length is only 4.88 hours and the number of stores affected is the highest (on average 46%) of all four scenarios. In spite of this high pressure, this scheme scores third on the financial indicator (see Figure 2). For most environmental indictors this scenario is worst apart from the current situation. This was only to be expected, based on the high time-window pressure. This scenario scores better than a scenario with similar time-window pressure, but without harmonization (see Quak and De Koster, 2006b). Such a situation in which there are nationwide uniform and fully coinciding time-window policies, e.g. as proposed in scenario 4, would perform worse for both financial and environmental indicators. For the social performance we can only observe that is differs per municipality. The large municipalities, which supposedly have most shopping public and residents have tight time-windows (of only 3 hours) and see a reduction in inconvenience caused by supplying vehicles. This would imply that a limited number of cities have very positive social sustainability effects, whereas in this scenario smaller municipalities are confronted with a slight decrease in social performance. Of course, a harmonization scenario, that would come up with different criteria to allow municipalities to use strict, medium and wide time-windows, for example based on a problem analysis as suggested by the committee for urban distribution (see page 8), would have more or less similar results.

5.3 Scenario 3: nightly time-windows policies

Scenario 3, moving time-window restrictions from the morning to the night, appears to raise costs for most retailers. Although the driving time in scenario 3 is lower for all retailers, the total time needed for distribution retailers is higher for most retailers since the drivers now have to unload the vehicles on their own, rather than with the help of store staff. As a result, some retailers can even combine fewer deliveries in one vehicle than in the current situation, in which the time-window pressure was higher, because otherwise the total working time would exceed the permitted driver's working hours. The environmental impact is lower for this scenario than for most others. And this is probably an underestimation, since the large supplying vehicles are moved from the morning rush hours (and the corresponding congestion) to the calmer nights. The social impacts are two-sided for this scheme. On the one hand the shopping public is no longer hindered by the supplying vehicles at all, so from their perspective the social performance of this scenario is increased. The residents, on the other hand, are confronted with an increase of nuisance during the night. So from their perspective this scenario definitely decreases the social performance. A last remark is that many retailers do not really like the idea of night deliveries. Most retailers indicated that they were absolutely not willing to supply their stores during the night, for several reasons: criminality and safety concerns (the driver is alone and therefore an easy target especially for stores or vehicles with high-value products), disreputable characters hanging around in city centres during the night, no goods receipts increases vulnerability to fraud and many stores lack separate depots and the driver is not allowed to open a store during the night (for safety reasons).

5.4 Scenario 4: time-windows policy according 'Referentiemodel commissie stedelijke distributie'

Scenario 4 scores best for both the environmental impacts and the retailers' costs. This is no surprise since the time-window pressure in this scheme is lower than in all other scenarios, both for the number of stores affected by time-windows as well as the time-window length. We already mentioned that a uniform time-window scheme of 5 hours in the morning (between 7 a.m. and noon), in which the time-window pressure is almost similar to scenario 2, performs worse than scenario 2. The nuisance, or the social performance, of this scenario would be worse than that in all other scenarios. The period in which both residents (especially in the evening) and the shopping public are exposed to consequences of large vehicles is longer than in the other scenarios. A positive comment on this proposal of the committee for urban distribution is that it would have better financial consequences for retailers and better environmental consequences than the current regulation. Besides, it would transform the chaos of different local regulations to a clear nationwide similar situation. The fact that this scheme forces retailers to have self-implied time-windows of at least 4 consecutive hours reduces transport cost for retailers as well as the environmental burden.

Scenario 4b scores even better for the retailers than scenario 4a, which is not surprising since the time-window pressure is lowest in this scenario. The lower cost increase and the lower environmental burden is especially (in comparison with scenario 4a) caused by extra time in the morning to supply the stores, since most of the retailers do not use the evenings and nights to supply their stores. For retailers that also supply during the nights (and / or evenings) the results of this scenario are far better than that of scenario 4a. Three out of the five cases that are affected most (see Figure 2) in scenario 4a, see their cost increase far less in scenario 4b than in all other scenarios. So these retailers are really better of in scenario 4b than in scenario 4a. Table 3 shows that the noise nuisance around the stores increases in this scenario in comparison with scenario 4a, which is not surprising since the difference between these two variants is that we removed the noise regulation (PEAK) in scenario 4b. The difference between scenarios 4a and 4b can therefore be used as an indicator for the cost caused by the PEAK-regulation, under the condition that retailers do not change their behaviour (e.g. their self-implied time-windows, their equipment, etc.).

6 Concluding remarks

The current time-window scheme, in which local authorities design their time-window policies autonomously from others, performs badly on financial, environmental, and social performance. In this paper we evaluated three different schemes that all improve some performance elements. Nightly delivery time-windows would stop the nuisance for shopping public, decrease congestion during the morning rush hours by using the infrastructure better over 24 hours. On the other hand, this would increase inconvenience for city residents, e.g. noise, and increase retailers' costs. The scenario in which time-window policies of different municipalities are harmonized shows that it is possible to have a select number of cities with really strict time-windows, without increasing retailers' cost and deteriorating global and local environment. As long as there are enough cities with larger time-window periods, it is possible to improve social performance for those city centres that have good reasons to do so, e.g. the city centre is crowded by people all day. Finally, the scheme as suggested by the committee for urban distribution (scenario 4) shows that by having a

clear policy that uses relatively large time-windows for the entire country, negative impacts on the environment and the retailers' cost could be relatively low, without letting slide the social performance (e.g. the nuisance for residents and shopping public), the attractiveness of a centre and the liveability in a centre.

Only in the case that the noise nuisance would be low, the safety of the goods and driver can be guaranteed better, and the unloading speed of the vehicles can be increased, it is a good idea to start thinking about moving the freight transport to outlets in urban areas to the night. For the moment, a combination of scenarios 2 and 4, harmonizing time-window policies, based on criteria following from, for example, an obliged problem analysis in combination with a nationwide time-window scheme would be the best compromise for all different performance indicators. Since the parties have different interests, it is not possible to find one scheme that is best for all involved actors. But the combination of scenarios 2 and 4 probably would lead to a 'best' solution. This solution would provide cities that really feel the necessity (based on still to be determined requirements) to have strict time-windows to have that, under the condition that the amount of cities with these strict time-windows is really limited. In that case, the combined effects are 'best' for the whole range of stakeholders. Essential is that the amount of cities using very strict time-windows is very strict, and that the majority of cities uses large time-windows. In this solution we are confronted with some cost increases for retailers, a slight increase in pollutant emissions, and people are hindered by supplying activities in comparison to the best situation for that one actor. But overall, considering all interests, the best solution would be in this direction.

References

Allen, J., S. Anderson, M. Browne and P. Jones (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., M. Browne, G. Tanner, S. Anderson, G. Chrisodoulou and P. Jones (2004) Analysing the Potential Impacts of Sustainable Distribution Measures in UK urban areas, in: E. Taniguchi and R.G. Thompson (eds.) *Logistics Systems for Sustainable Cities*, Elsevier, Amsterdam, 251-262

Anderson, S., J. Allen and M. Browne (2005) Urban logistics - how can it meet policy makers' sustainability objectives?, in: *Journal of Transport Geography*, 13, 1, 71-81

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

Boerkamps, J. (2001) State-of-the-art of city logistics in the Netherlands: research framework and research activities, in: *City Logistics II*, Institute of Systems Science Research, Kyoto, 241-254

Browne, M. and J. Allen (1999) The impact of sustainability policies on urban freight transport and logistics systems, in: H. Meermans, E. Van de Voorde and W. Winkelmans (eds.) *8th World Conference on Transport Research* (WCTR), Elsevier, Antwerp, 505-518

Browne, M., J. Allen, S. Anderson and A. Woodburn (2005) Night-time delivery restrictions: A review, in: E. Taniguchi and R.G. Thompson (eds.) *City Logistics IV*, Institute for City Logistics, Langkawi, Malaysia, 253-566

Eisenhardt, K.M. (1989) Building theory from case study research, in: *Academy of*

Management Review, 14, 4, 532-550

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

Lemstra, W. (2004) *Stedelijke distributie: Samen gaan voor resultaat*, Ministerie van Verkeer en Waterstaat, Den Haag

Munuzuri, J., J. Larraneta, L. Onieva and P. Cortes (2005) Solutions applicable by local administrations for urban logistics improvement, in: *Cities*, 22, 1, 15-28

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

OECD (2003) *Delivering the goods - 21st century challenges to urban goods transport*. OECD working group on urban freight logistics, Paris

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

PSD (2001) *Voorstel regionale afstemming venstertijden*, Platform Stedelijke Distributie, Den Haag

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

Quak, H.J. and M.B.M. De Koster (2006a) Exploring retailers' sensitivity to local sustainability policies, in: *Journal of Operations Management*, (forthcoming)

Quak, H. and R. de Koster (2006b) Retailers' distribution and local time-window policies, in: E. Taniguchi and R.G. Thompson (eds.) *Recent advances in city logistics*, Elsevier, Amsterdam

Richardson, B.C. (2005) Sustainable transport: analysis frameworks. *Journal of Transport Geography*, 13, 1, 29-39

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

Voss, C., N. Tsikriktsis and M. Frohlich (2002) Case research in operations management, in: *International Journal of Operations and Production Management*, 22, 2, 195-219

Yin, R.K. (2003) *Case study research; design and methods*, SAGE Publications, Thousand Oaks

Appendix: List of cities of which we interviewed policy-making officials (responsible for time-window policies)

Alkmaar, Amersfoort, Amstelveen, Amsterdam, Apeldoorn, Arnhem, Bergen op Zoom, Breda, Deventer, Dordrecht, Ede, Eindhoven, Enschede, Gouda, Groningen, Haarlem, Helmond, Hengelo, Hilversum, Leeuwarden, Leiden, Leidschendam-Voorburg, Maastricht, Nijmegen, Oss, Roosendaal, Rotterdam, Sittard-Geleen, Utrecht, Veenendaal, Venlo, Zeist, and Zwolle.

Publications in the Report Series Research* in Management

ERIM Research Program: "Business Processes, Logistics and Information Systems"

2006

Smart Business Networks Design and Business Genetics
L-F Pau
ERS-2006-002-LIS
http://hdl.handle.net/1765/7319

Designing and Evaluating Sustainable Logistics Networks
J. Quariguasi Frota Neto, J.M. Bloemhof-Ruwaard, J.A.E.E. van Nunen and H.W.G.M. van Heck
ERS-2006-003-LIS
http://hdl.handle.net/1765/7320

Design and Control of Warehouse Order Picking: a literature review
René de Koster, Tho Le-Duc and Kees Jan Roodbergen
ERS-2006-005-LIS
http://hdl.handle.net/1765/7322

A Theoretical Analysis of Cooperative Behavior in Multi-Agent Q-learning
Ludo Waltman and Uzay Kaymak
ERS-2006-006-LIS
http://hdl.handle.net/1765/7323

Supply-Chain Culture Clashes in Europe. Pitfalls in Japanese Service Operations
M.B.M. de Koster and M. Shinohara
ERS-2006-007-LIS
http://hdl.handle.net/1765/7330

From Discrete-Time Models to Continuous-Time, Asynchronous Models of Financial Markets
Katalin Boer, Uzay Kaymak and Jaap Spiering
ERS-2006-009-LIS
http://hdl.handle.net/1765/7546

Mobile Payments in the Netherlands: Adoption Bottlenecks and Opportunities, or… Throw Out Your Wallets
Farhat Shaista Waris, Fatma Maqsoom Mubarik and L-F Pau
ERS-2006-012-LIS
http://hdl.handle.net/1765/7593

Hybrid Meta-Heuristics for Robust Scheduling
M. Surico, U. Kaymak, D. Naso and R. Dekker
ERS-2006-018-LIS
http://hdl.handle.net/1765/7644

VOS: A New Method for Visualizing Similarities between Objects
Nees Jan van Eck and Ludo Waltman
ERS-2006-020-LIS
http://hdl.handle.net/1765/7654

On Noncooperative Games, Minimax Theorems and Equilibrium Problems
J.B.G. Frenk and G. Kassay
ERS-2006-022-LIS
http://hdl.handle.net/1765/7809

An Integrated Approach to Single-Leg Airline Revenue Management: The Role of Robust Optimization
S. Ilker Birbil, J.B.G. Frenk, Joaquim A.S. Gromicho and Shuzhong Zhang
ERS-2006-023-LIS
http://hdl.handle.net/1765/7808

Optimal Storage Rack Design for a 3D Compact AS/RS with Full Turnover-Based Storage
Yu Yugang and M.B.M. de Koster
ERS-2006-026-LIS
http://hdl.handle.net/1765/7831

Optimal Storage Rack Design for a 3-dimensional Compact AS/RS
Tho Le-Duc, M.B.M. de Koster and Yu Yugang
ERS-2006-027-LIS
http://hdl.handle.net/1765/7839

E-Fulfillment and Multi-Channel Distribution – A Review
Niels Agatz, Moritz Fleischmann and Jo van Nunen
ERS-2006-042-LIS
http://hdl.handle.net/1765/7901

Leveraging Offshore IT Outsoutcing by SMEs through Online Marketplaces
Uladzimir Radkevitch, Eric van Heck and Otto Koppius
ERS-2006-045-LIS
http://hdl.handle.net/1765/7902

Buyer Commitment and Opportunism in the Online Market for IT Services
Uladzimir Radkevitch, Eric van Heck and Otto Koppius
ERS-2006-046-LIS
http://hdl.handle.net/1765/7903

Managing Supplier Involvement in New Product Development: A Multiple-Case Study
Ferrie E.A. van Echtelt, Finn Wynstra, Arjan J. van Weele and Geert Duysters
ERS-2006-047-LIS
http://hdl.handle.net/1765/7949

The Multi-Location Transshipment Problem with Positive Replenishment Lead Times
Yeming Gong and Enver Yucesan
ERS-2006-048-LIS
http://hdl.handle.net/1765/7947

Solving Lotsizing Problems on Parallel Identical Machines Using Symmetry Breaking Constraints
Raf Jans
ERS-2006-051-LIS
http://hdl.handle.net/1765/7985

Urban Distribution: The Impacts of Different Governmental Time-Window Schemes
H.J. Quak and M.B.M. de Koster
ERS-2006-053-LIS
http://hdl.handle.net/1765/8020

---

* A complete overview of the ERIM Report Series Research in Management:
https://ep.eur.nl/handle/1765/1

ERIM Research Programs:
LIS Business Processes, Logistics and Information Systems
ORG Organizing for Performance
MKT Marketing
F&A Finance and Accounting
STR Strategy and Entrepreneurship