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Better use of delivery spaces in Oslo

Bjørn Gjerde Johansen[a,*], Jardar Andersen[a], Tomas Levin[b]

[a]*Institute of Transport Economics, Gaustadalleen 21, 0349 Oslo, Norway*
[b]*SINTEF, S.P. Andersens vei 5, 7465 Trondheim, Norway*

Abstract

The lack of space in urban areas is an important barrier to efficient freight deliveries. Available space in urban city centres has to be shared between different activities and actors, including public transport operators, private car users, taxis, cyclists and pedestrians in addition to freight operators. The lack of access to appropriate freight delivery spaces increases the time needed for deliveries and the distances truck drivers have to walk between their vehicles and the receivers of goods.
This lack of space is one of the issues that the ongoing project Green Urban Distribution (GUD) deals with. The project is set to develop environmental friendly and efficient solutions for urban freight distribution in Oslo, the capital of Norway, by (1) better use of road spaces, (2) better use of day and week time and (3) to demonstrate usage of environmentally friendly and energy efficient vehicles for unmanned deliveries.
One of the tasks in the GUD project has been to study delivery spaces on a street in the centre of Oslo and to analyse whether the delivery spaces could be better utilised. This work included 6 days of observations of vehicles using delivery spaces in two separate locations, as well as interviews with stakeholders, including drivers, shop workers and shop owners. The collected data have been used to analyse potential effects from giving designated vehicles exclusive right to use the delivery spaces at certain times.
The aim of this paper is twofold. Firstly, it gives an understanding on how delivery spaces intended for freight loading and unloading are used by different actors with different tasks and functions. Secondly, the paper presents alternative prioritization schemes for freight vehicles for these delivery spaces and outlines some of the costs and benefits. The analyses will give decision makers an increased understanding of the potential effects of such access restrictions.

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1 Introduction

Freight deliveries in Oslo and other city areas involve a wide variety of challenges. Congestion, narrow areas for freight delivery and a large number of stakeholders on a limited area contributes to reducing logistics' efficiency. At the same time, freight deliveries contribute to a series of environmental problems, like poor air quality, noise and the emission of greenhouse gasses. The project Green Urban Distribution (GUD) is set to develop environmental friendly and efficient solutions for urban freight distribution in Oslo, the capital of Norway, by (1) better use of road spaces, (2) better use of day and week time and (3) demonstrated usage of environmentally friendly and energy efficient vehicles for unmanned deliveries. One of the tasks in the GUD project has been to study delivery spaces on a street in the centre of Oslo and to analyse whether the delivery spaces could be better utilised (Johansen et al., forthcoming). Delivery spaces have been chosen on the basis of a preliminary recommendation of measures that are considered to be relevant and supported by a major group of urban freight stakeholders in Oslo (Nordtømme et al., 2013).

* Corresponding author. Tel.: +47-930-67-974;
E-mail address: bgj@toi.no

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The work has consisted of two parts. The first part is an extensive data gathering period, where manual registration of vehicles utilizing the urban delivery space has been conducted for six whole days. Interviews have been carried out with freight vehicle drivers and freight receivers and GPS data from transport companies have been gathered. The second part is the analysis of the results. In the project report (Johansen et al, forthcoming), the focus is on a prioritization scheme for trucks. In this article, some of the findings from that process will be highlighted. However, here, the focus will be on the observed use of the delivery spaces and how this information may be utilized to evaluate the effect of different prioritization measures. We argue that extensive data gathering prior to the implementation of such measures not only is important; it is vital for decision makers who want to achieve the desired results. Hence, this article provides added value for two reasons; it shows how such data may be gathered and utilized, and it provides an example of the use of delivery spaces for the case of Oslo. The two delivery spaces considered in the GUD project are shown in Figure 1.

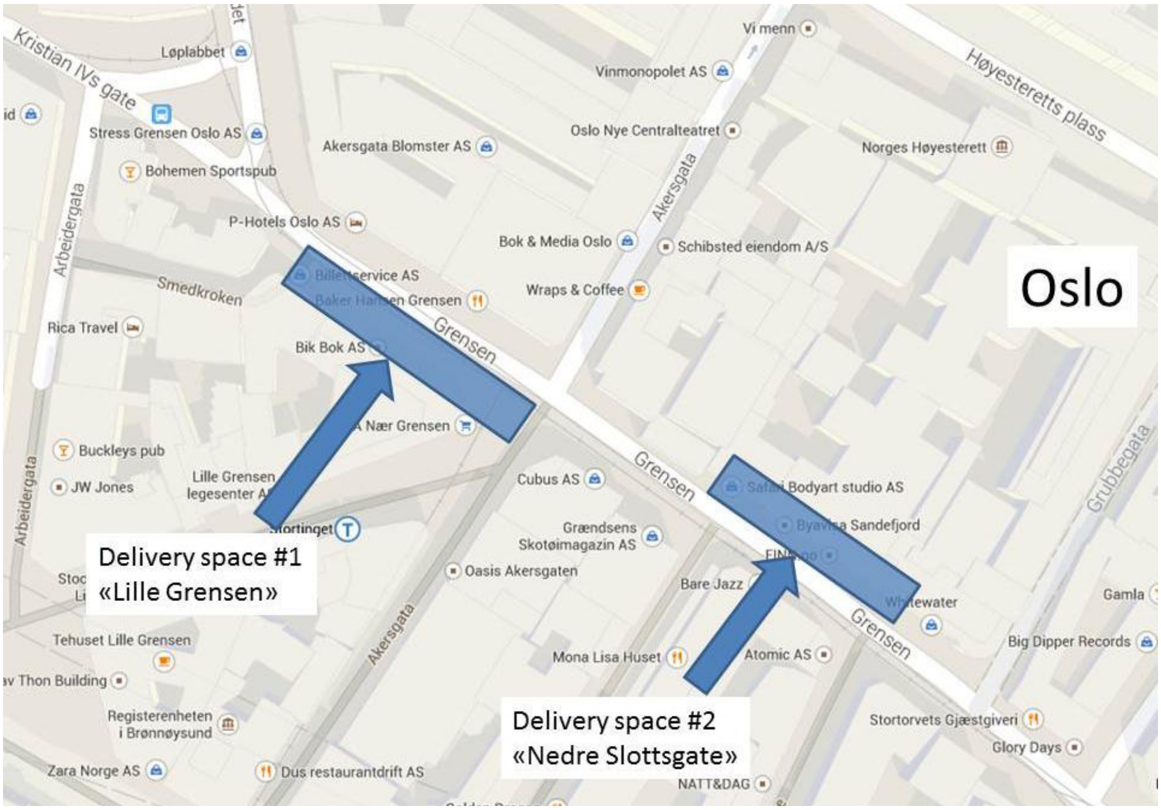

Figure 1. Location of the delivery spaces studied within the center of Oslo.

In Norway, such delivery spaces have signs which states that parking is prohibited. However, it is allowed to stop there. This means that not only freight vehicles can use these areas for unloading; also craftsmen, taxis and citizens are allowed to use the areas for short stops. While this is positive for high capacity delivery spaces where overcrowding is not a problem, it results in conflicts in areas with high traffic flows and low spare capacity. Therefore, enhanced regulations when it comes to delivery space permissions will reduce the negative effects of overcrowding.

The rest of the paper is structured as follows: section 2 describes the data gathering process and the gathered data. Section 3 gives an overview of the current situation for the two delivery spaces shown in Figure 1 with respect to the users of the delivery spaces and the spare capacity. Section 4 outlines various prioritization schemes that were considered within the GUD project. Section 5 briefly describes the main costs and benefits for various stakeholders after implementing prioritization schemes. Finally, section 6 concludes.

2 Method and data

In this section, the data gathering method and the resulting data are described. This data arise from three main sources; registration of vehicles, GPS data from transport operators and interviews with main stakeholders. Not all data described here is utilized in this paper; however, a complete overview of the gathered data will be beneficial for decision makers in other cities wanting to follow a similar process.

2.1 Registration of vehicles at the urban spaces

To map the current situation at the urban delivery spaces, vehicle data was registered. This was done manually for two delivery spaces on three separate days each (this totals to six registration days). Vehicle registrations were conducted between 8:00 and 16:00 all six days. The dates for the registrations correspond to the dates for which GPS data is available (see section 2.2), so that there is accordance between the different data sources. The registrations contain information regarding 445 vehicles altogether. The most important data collected concerned:

- Time of arrival at the delivery space;
- Time of departure at the delivery space;
- Spare capacity at the delivery space at the time of arrival;
- Purpose (passenger transport, taxi operations, craftsman operations or freight deliveries);
- Type of vehicle;
- If freight deliveries, name of transport operator; and
- If freight deliveries, description of unloading operations.

By utilizing the above information, inference can be drawn regarding the use of these urban delivery spaces.

2.2 GPS data

Most transport operators have IT systems that govern and document all steps of the transport conducted. Such data is very useful to highlight how actual transport operations take place. There are large differences between these IT systems. Some transport operators track the vehicles, while other transport operators track individual shipments. To analyze traffic flows, data on a vehicle level is preferable. To analyze the spatial distribution of deliveries however, data on shipment level is preferable. For this project, both vehicle and shipment data for one month (October, 2013) were gathered. The gathered data contains about 290,000 shipments and about 83,000 registrations of vehicles. These data specifically contributed to map:

- Delivery times;
- Driving routes;
- Driving pattern while looking for available delivery spaces; and
- Accuracy when it comes to finding delivery spaces for shipments with the same receiver.

2.3 Stakeholder interviews

To get a broader picture of the possibilities for adapting measures to fit the current situation, data that could not be derived from the information above had to be gathered. This mainly relates to more qualitative information, and hence semi-structured interviews were conducted with main stakeholders operating in the area. These stakeholders consist of shop owners, shop workers and drivers using the delivery spaces for unloading operations. Drivers of all kinds of delivery vehicles were interviewed.

The interviews gave increased knowledge about particular problems experiences by the stakeholders, how these stakeholders imagined that the problems may be solved in the future and also what problems the shops and the transport operators had solved on their own. About 1/3 of the approached stakeholders were willing to conduct an interview, and about 30 interviews were conducted altogether. In addition to highlighting specific problems, the interviews gave increased insight to more generic questions like:

- What drivers did when there was not enough spare capacity to stop at the urban delivery space, and how much additional time this took;
- At what time of the day the shops mainly receive their goods;
- At what time of day the shop workers would have preferred to receive the goods;
- To what degree the shops perceive delays in delivery time as problematic; and
- What aspects are most problematic with the current delivery situation.

3 The current situation for delivery spaces in Oslo

In this chapter the aforementioned data sources are used to draw a picture of the current situation in and around the logistics spaces. The first subsection concern the users of the delivery spaces, while the second subsection concern the capacity and to what extent the demand is met.

3.1 Users of the urban delivery spaces

The urban delivery spaces are used not only for freight deliveries, but also by taxis, private cars, craftsmen and other service vehicles. Figure 2 gives a picture of how the use varies between different stakeholders throughout the day. The bars in this figure corresponds to averages of both delivery spaces for all three days, i.e. a six day average. The stakeholder groups in Figure 2 are (from bottom to top):

- Green: freight deliveries (average share throughout the whole day: 53%);
- Orange: craftsmen (average share throughout the whole day: 4%);
- Yellow: private cars (average share throughout the whole day: 18%);
- Blue: taxis (average share throughout the whole day: 9%); and
- Red: other (mostly consisting of waste management vehicles; average share throughout the day: 17%).

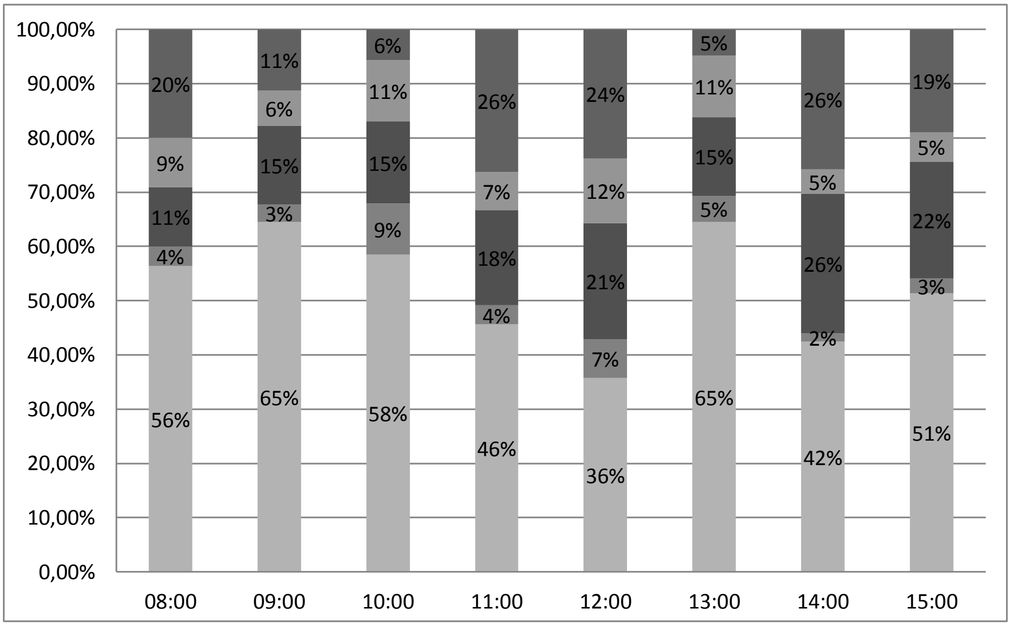

Figure 2. Users of the delivery spaces. Green: freight deliveries; orange: craftsmen; yellow: private cars; blue: taxi; and red: other.

From the figure above, it is obvious that only about half of the vehicles that make use of the delivery spaces are doing freight deliveries. Whether the other half of the vehicles constitute a hindrance for the freight vehicles or not, depends on the capacity of the urban delivery spaces. This will be discussed in section 3.2. First, however, the situation for the freight vehicles will be slightly elaborated.

To discuss the situation for freight deliveries further, a separation has to be made between different kinds of vehicles used for freight operations. This is of particular importance when discussing the implementation of measures that may affect the different groups of freight vehicles differently. The categories of vehicles we will use are described in Table 1.

Table 1. Description of freight vehicle categories.

Vehicle category	Description and examples
Small vans	Mainly used by the service industry; however, also used for freight deliveries. In particular packages, or freight for small shops. E.g. Volkswagen Caddy, Citroen Berlingo, etc.
Vans	The main type of vehicle used for goods distribution within the center of Oslo. Used for all kinds of urban freight. E.g. Mercedes Sprinter, etc.
Trucks	Defined to only contain large goods vehicles, i.e. vehicles with a gross combination mass of over 3.5 tones. Most of the trucks used for urban distribution are also below 7.5 tones in gross combination mass, since narrow streets are problematic for larger vehicles.

The difference between these three groups when it comes to utilization of the urban delivery spaces are elaborated in the figures below (Figure 3-Figure 6).

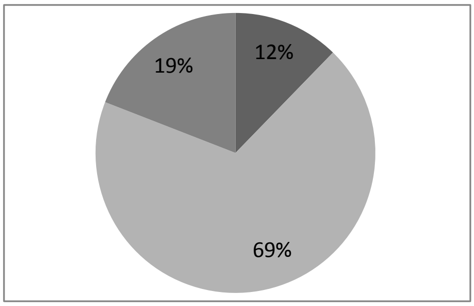

Figure 3. Distribution of vehicles for transport operators. Small van: 19%, van: 69% and truck: 12%.

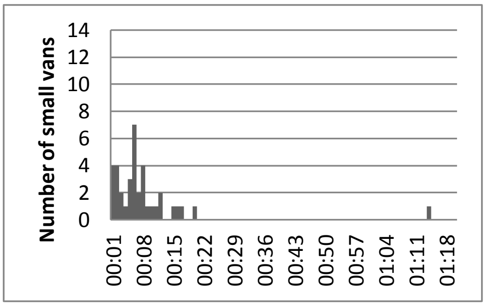

Figure 4. Distribution of number of minutes per stop for small vans.

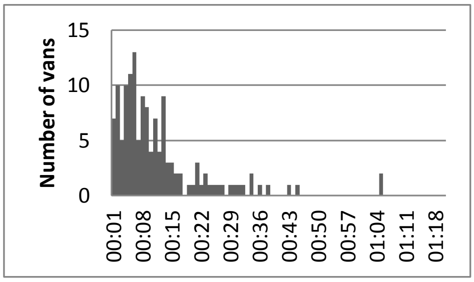

Figure 5. Distribution of number of minutes per stop for vans.

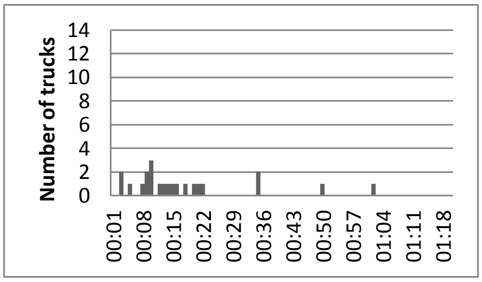

Figure 6. Distribution of number of minutes per stop for trucks.

Figure 3 shows the distribution between different types of goods vehicles. The number of trucks, which is the category that experiences the most problems when it comes to finding places to stop, is relatively low (on average 7 trucks per day per delivery space). This is obviously a result of the mixture of shops around the delivery spaces, but also reflects the difficult conditions under which trucks operate in larger city centres. Figures 4 to 6 show the observed distribution by the number of minutes used per stop for small vans, vans and trucks, respectively. From these figures, it is also apparent that the data for trucks and small vans is relatively more sparse than the data for vans.

On average, the truck drivers use 19 minutes per delivery, the van drivers use 11 minutes per delivery and the drivers of small van use 8 minutes per delivery. These averages are drawn upwards by asymmetrical distributions and a couple of large outliers. Hence, the maximum point of the distributions are somewhat lower (7 minutes for vans and small vans and 10 minutes for trucks). If these outliers are parked vehicles, increased law enforcement will have a positive effect on the overall capacity since it gives the parked vehicles incentives to drive somewhere else.

3.2 Capacity at the urban delivery spaces

Figure 7 shows how the spare capacity at the delivery space *Nedre Slottsgate* varies each minute throughout a random day (the first day of registration). The spare capacity is measured in private car lengths of available space at each point in time (a spare capacity of two means that there is available space for two private cars). However, this is not 100% accurate, since it also depends on the specific placement of each vehicle. Small vans and vans count as one private car length, while a truck counts as two private car lengths.

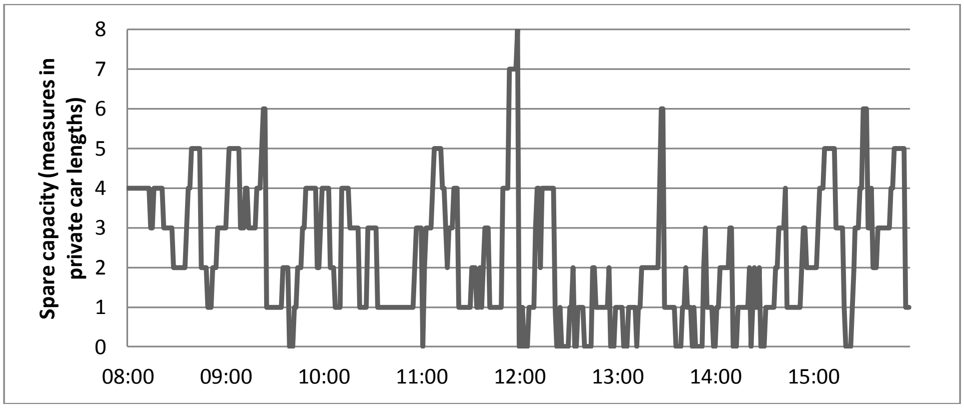

Figure 7. Spare capacity at *Nedre Slottsgate* the first day of registration in the period 8:00-16:00, measured in private car lengths.

The figure shows that the capacity is lowest between 12:00 and 14:30. The capacity is never zero for a long time interval; however, when there is spare capacity the delivery space is filled up again almost immediately. This suggests that a number of vehicles are circulating the area, looking for an opportunity to stop. This results in numerous negative externalities, including higher emissions and congestion. Figure 7 also shows the high degree of volatility when it comes to spare capacity. This illustrates a negative externality in itself, i.e. the uncertainty drivers face as to whether there will be spare capacity when they arrive at the delivery space or not.

This figure is useful since it gives an exact picture of the situation and shows that at certain times (1) too many users, (2) lack of available delivery space and (3) uncertainty contributes to more time-consuming deliveries. However, it is difficult to separate useful information from noise. Therefore, Figure 8 is included to give a more easy-to-understand picture. In this figure, red means *too little space* and is defined as 0-1 private car lengths, yellow means *some space* and is defined as 2-3 private car lengths while green means *enough space* and is defined as 4 or more private car lengths. The delivery spaces are seven and eight car lengths, respectively. There are two main reasons for these thresholds; firstly, it shows the variability throughout the day when it comes to spare capacity for all vehicles. Secondly, it gives a picture of the precise situation for trucks. When there are 0-1 private car lengths of spare capacity, there is no room for a truck; on the other hand, when there are 2-3 private car lengths of spare capacity there may or may not be room for a truck, depending on whether the private car lengths of spare capacity are next to each other or not.

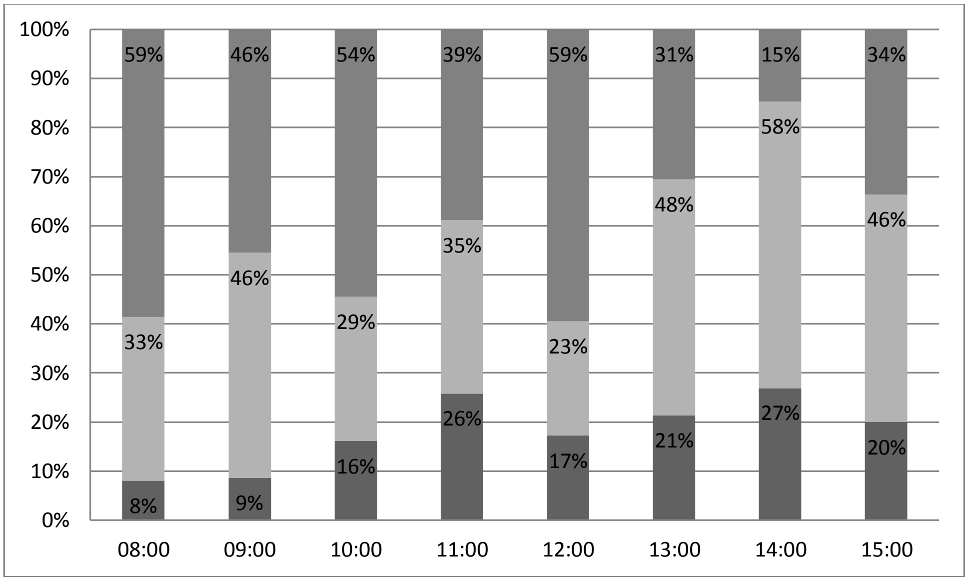

Figure 8. Average distribution of spare capacity throughout the day for both delivery spaces all six registration days. Red: too little space (0-1 private car lengths), yellow: some space (2-3 private car lengths) and green: enough space (4 or more private car lengths).

Looking at the figure, spare capacity is more or less evenly distributed throughout the day; however, the time period 13:00-15:00 seems to be slightly more occupied than previous intervals. The average spare capacity (the average of the columns from Figure 8) is displayed in Table 2.

Table 2. Distribution of spare capacity.

Spare capacity	Distribution
Too little space (0-1 private car lengths):	18%
Some space (2-3 private car lengths):	40%
Enough space (4 or more private car lengths):	42%
Sum:	100%

4 Alternative priority schemes for the delivery spaces

In close cooperation with the Municipality of Oslo, three alternative measures were outlined prior to the data gathering described in the previous section. The initial plan within the GUD project was to implement one of these solutions within the center of Oslo. The process of choosing the appropriate measure will be based on the data analysis conducted in Johansen et al. (forthcoming).

- *Prioritization of trucks within a certain time interval in combination with an urban consolidation center (UCC) (only trucks and vehicles designated by the UCC are allowed to use the delivery space between 08:00 and 14:00).* This is expected to have four main positive effects. Most importantly for trucks (1), the time and fuel costs related to low spare capacity will be reduced. This leads to an increase in efficiency for truck drivers and a decrease in negative externalities per transport unit, which contributes to (2) an increase in the total amount of goods delivered by truck compared to other vehicle categories. This moves the economy closer to a (sub-) optimal social equilibrium; in particular, because other negative externalities for trucks are proportional to the transport operators' internal costs (emissions are proportional to fuel costs). Hence, the transport operators already have the incentive to minimize fuel consumption per delivery given all the other constraints they face. Moreover (3), the negative effects for receivers and transport operators not using trucks (i.e. who lose delivery spots) will be partly mitigated by the UCC. In particular if the UCC operators can use environmentally friendly (electric) vehicles that also have access to the delivery spaces, this will (4) reduce the negative externalities related to emissions from vans and small vans, and help to optimize the operations due to economies of scale. The two main challenges are (1) to work out a viable financing scheme and (2) to be able to get enough stakeholder support so that the UCC will have enough deliveries per roundtrip to work efficiently.
- *Prioritization of trucks within a certain time interval (only trucks are allowed to use the delivery space between 08:00 and 14:00).* This alternative will have the same positive effects for transport operators and receivers using trucks for their deliveries; that is, the costs for trucks related to spare capacity will decrease and deliveries from trucks will become more reliable. It will also increase the number of deliveries made by truck, but in this case, the increase may exceed the optimal social equilibrium. This may happen if costs from delivering by truck decline to the extent that most empty trucks outcompete vans and small vans in terms of internal costs. Whether this measure is beneficial or not depends on the relative magnitudes of the changes in benefits for the truck operators and the costs for the van and small van operators. The changes in costs for vans and small vans consist of an increase in time and fuel consumption (and the external costs of increased emissions) as a result of having to find other areas for delivery or deliver to outside the time interval of the prioritization scheme. Negative effects for the receivers using operators with vans or small vans must also be taken into account. This measure should be considered if an UCC is not operationally feasible or economically viable in the current situation.
- *Prioritization of freight deliveries within a certain time interval (only vehicles delivering freight are allowed to use the delivery space between 08:00 and 14:00)*. This measure will not alter the balance between different freight vehicle categories. However, it will reduce both internal and external costs of logistics at the expense of other users of the delivery space, such as private cars, taxis, craftsmen and other service industries. This measure should be considered if UCC is not appropriate and if the share of vans and small vans is too large to justify the prioritization of trucks only. It is easy to combine this measure with incentives for e.g. electric private cars, by prioritizing these as well.

It has become clear lately that developing a UCC for this part of the center of Oslo is not possible within the timeframe of the project. However, the Municipality of Oslo is working on this concept in parallel to the GUD project. The municipality hope to have a functioning UCC in the near future if stakeholder cooperation is successful. Costs and benefits of the aforementioned prioritization schemes are outlined more in-depth in the section below based on the data from section 3.

5 Costs and benefits of priority schemes

In this section, the main costs and benefits related to the aforementioned measures will be described. In the first subsection, the internal costs and benefits for trucks, other freight vehicles and receivers will be outlined, respectively. The internal costs are important since they determine the viability of the measure. In the second subsection the external costs will be outlined. These must also be included in the evaluation to determine the net benefit for society.

5.1 Internal costs and benefits

In this section, the internal costs for various stakeholders will be briefly described. Costs and benefits for different vehicle categories are more thoroughly estimated in Johansen et al. (forthcoming). However, some of the main results will be replicated here. First, the economic benefit for transport operators using trucks if the capacity at the delivery space increases will be estimated. Second, the effect for transport operators using vans or small vans will be discussed. Third, the effect for receivers will be discussed. Effects for citizens will not be quantified, since they mainly relate to an increase or a reduction of the consumers' surplus.

The costs and benefits for trucks

To assess the effect for transport operators using trucks, four assumptions must be made:

- The number of trucks are evenly distributed throughout the day (supported by the data, although the data material for trucks is sparse);
- Hence, the numbers related to Figure 8 are representative ("too little space" 18% of the time, "some space" 40% of the time and "enough space" 42% of the time);
- A truck is able to find space 50% of the times when the capacity is "some space" (see Figure 8 and the discussion related to it);
- We assume that 50% of the trucks that cannot find space wait or drive around, and use the area for delivery later. Hence, they must not be counted twice.

The average number of trucks observed per day during the observation period was seven. Based on the assumptions above, 3.45 trucks per day between 8:00 and 14:00 are expected to find no space and will have to stop somewhere else. The extra cost for these vehicles are calculated as time costs plus distance costs. Interviews with drivers indicate that not finding space for a truck will increase the delivery time by 20 minutes. This is supported by the GPS data. Moreover, the GPS data indicate that about 10 of these minutes are used driving around looking for a space to stop, while the remaining 10 are used on increased time for unloading purposes. GPS data also shows that the average speed for trucks within the city center of Oslo is 12 km/h. This corresponds to a 2 km increase in driven distance for a 10-minute drive.

Grønland (2011) have mapped time specific and distance specific costs for various vehicle categories in Norway, and these are replicated in Table 3 for the appropriate trucks and vans used for city distribution. Figures are given in Norwegian Kroner (NOK), around 8 NOK correspond to 1 Euro. In this section the "truck" values are used. The "van" values are used in the next section and included here for the purpose of comparison. Distance specific costs include maintenance, fuel, car wash and tyres. Time specific costs include wages, capital expenditure, vehicle license fee, insurance and administration.

Table 3. Time and distance specific costs for trucks and vans (Grønland, 2011).

Vehicle category	Capacity	Distance specific costs	Time specific costs
Van	2.2 tones/vehicle	2.62 NOK/km	409 NOK/hour
Truck	5.7 tones/vehicle	3.17 NOK/km	420 NOK/hour

Using these cost coefficients, 3.45 trucks per day using 20 minutes and driving 2 km more will have a total increased cost of 508 NOK. This corresponds to 147 NOK per truck that cannot find a delivery space. On average, using the probability for finding a delivery space, the expected cost for transport operators as a result of limited access to the delivery space is 49 NOK per truck. This cost would be completely removed if a prioritization scheme existed in which trucks were prioritized for the delivery spaces.

The costs and benefits for vans and small vans

The costs vans and small vans will experience if a prioritization scheme for trucks was to be implemented are more difficult to estimate, since to a large extent they depend on how the drivers will adapt to the new situation. With a UCC, the costs should be reduced, since the vans no longer have to deliver to the core of the city. However, this depends on the financing scheme of the UCC. If the transport operators have to pay for it, their costs may increase. Without the UCC, there are three main options: (1) they can continue as before, by utilizing other nearby delivery spaces; (2) they can change the delivery time to outside the time interval for the prioritization scheme or (3) they can cooperate with other transport operators, utilizing trucks instead of vans.

Johansen et al. (forthcoming) describes different scenarios, utilizing similar procedures as for trucks but also taking into account the possibility to substitute away some of the costs by delivering at other times. The conclusion is that in certain scenarios, a prioritization scheme for trucks will give greater benefits than the costs that vans and small vans experience. However, these scenarios require a degree of substitution that is higher than one can confidently envisage due to the low number of trucks compared to vans.

The costs and benefits for receivers

A number of freight receivers in close proximity to the delivery spaces were interviewed following a semi-structured questionnaire. Based on these interviews, we believe that the effect for freight receivers is small. Shop workers repeatedly reported that their priority was to receive the goods before the afternoon (answers varied from 14:00 to 16:00), and that they did not care about the exact time of the freight delivery. This means that delays due to overcrowded delivery spaces will have an insignificant effect for the shops in most cases (most of the delays reported by drivers are less than 30 minutes). The only major negative impact for receivers is if a measure blocks their ability to receive freight, or significantly increases the costs of their logistics operation. The Municipality of Oslo has declared an objective for protecting the business environment for small niche shops, which mainly uses vans and small vans for deliveries, since these shops provide added value to the city center through a more varied business climate, increased diversity and a more specialized selection of commodities.

5.2 External costs and benefits

The main external costs of logistics relate to emissions and congestion. Noise is not a major issue, since there are practically no residents within the considered area of Oslo. The increased use of trucks as opposed to vans and small vans will reduce both emissions and congestion as long as commodities are consolidated. If the substitution from vans to trucks does not lead to a reduction in the number of vehicles, the external costs will increase. Prioritization of trucks will also reduce the amount of time trucks are driving on the roads, since it will be less problematic for trucks to find a delivery space. Since trucks use more fuel, this should result in a net benefit.

The largest reduction of external costs will be obtained with a successful implementation of a UCC, where the last leg is carried out by means of electric vehicles. This will reduce both the total distance driven by conventional fuelled vehicles and the distance driven in congested areas. A successful UCC should also reduce the total amount of kms driven, since economies of scale can be better utilized and roundtrips can be better optimized. Hence, the total amount of vehicles within the city center will also be reduced.

6 Conclusions and lessons learned

The aim of this paper is twofold. Firstly, it gives a better understanding on how delivery spaces are used by different actors with different tasks and functions. For the two particular delivery spaces in Oslo where data has been gathered, only half of the vehicles stopping are conducting freight deliveries. Furthermore, there is no spare capacity 18% of the day, and the spare capacity is a low 40% of the day. This illustrates a serious problem of overcrowding, and shows that if there is political will to prioritize freight deliveries, a number of serious negative externalities can be mitigated.

Secondly, the paper presents alternative prioritization schemes for freight vehicles for these delivery spaces and outlines some of the costs and benefits. It shows in particular that the number of trucks using the urban delivery spaces is too low to prioritize trucks only. This would result in too high costs for other freight delivery vehicles unless other measures are implemented simultaneously. The suggested measure is a UCC; however, the question of economic viability for such a concept for this particular part of Oslo is still not answered.

The main added value of this paper is to show how data may be gathered and utilized to evaluate the effect of prioritization schemes. We argue that extensive data gathering prior to implementation of such measures not only is important; it is vital for decision makers that want to achieve the desired results. In particular, the data analysis has concluded that implementing a prioritization scheme for trucks only will not be beneficial in this case.

On the basis of the analysis conducted we also provide some recommendations and lessons learned for how prioritization schemes may be implemented to suit today's situation better:

- For a prioritization scheme, a time interval is important. This allows stakeholders that are not prioritized to still use the delivery space after the time interval ends, which has the potential of mitigating some of the costs. In this evaluation, the time interval 8:00-14:00 is chosen. This is optimal from the receivers' point of view; without exception, the interviews indicate that receivers want to receive their shipments at the beginning of the day.
- The stakeholders that are not prioritized will have to bear the major costs of such measures. It is therefore vital that care is taken to identify and mitigate these costs. The suggested approach would be to implement a UCC for transport operators that are not included in the prioritization scheme. External costs may be further reduced if the vehicles designated by the UCC are environmental friendly (e.g. electric vehicles). However, this will often be infeasible in practice due to low stakeholder support or too small a client base. In situations where it is infeasible to compensate the losing stakeholders, it will often be better to prioritize all freight distribution.
- Trucks constitute a relatively low proportion of freight vehicles utilizing the considered delivery spaces (12%). However, only about half of the vehicles using the delivery spaces are freight vehicles in the first place. This aspect combined with the aspect of serious overcrowding shows that a prioritization measure where all freight vehicles are prioritized will result in a net benefit.
- Since receivers are dependent on a steady supply of goods, it is vital to analyze the conditions for each receiver that benefits from the delivery space before certain transport operators are refused access. The business environment for small niche shops (which mainly uses vans and small vans for deliveries) should be protected, since these shops provide added value to the city center through a more varied business climate, increased diversity and a more specialized selection of commodities. In some

cases, special permission could be granted. However, access restrictions should also be fair, so the aspect of fairness must be balanced against the effect of such special permission.

- Prioritization schemes for freight are ideal in combination with the prioritization of other environmentally friendly vehicles to promote sustainability. For instance, electric vehicles (private cars and freight vehicles) can be included in the group of vehicles that are prioritized. This must naturally be balanced against the possibility (and the effect) of overcrowding the delivery spaces with electric vehicles.

Acknowledgements

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