

LOADING BAY BOOKING AND CONTROL FOR URBAN FREIGHT

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Introduction

Drivers of delivery/collection and service vehicles operating in urban centres often encounter difficulties finding suitable places to stop their vehicles to load/unload goods, or to carry tools or equipment to the businesses being visited. This paper investigates the idea of a managed, bookable loading bay system, whereby advance bookings can be made by the users of the system and enforcement and control measures are used to ensure effective operation. The aims of such a system are to offer guaranteed loading and unloading places, and to discourage undesirable driver behaviour associated with unloading such as double parking, parking on the pavement and causing obstructions to pedestrians and other road users. Such a system could be facilitated through the use of the technology and concept proposed by the SmartFreight project (www.smartfreight.info) (wireless communications between freight vehicles, freight distribution centres and traffic control centres) whereby the city authority takes a more proactive approach in managing and controlling urban freight movements.

Literature review

Many different types of booking system applications can be found in the literature but few, if any, can be readily applied to the problem addressed here. The concept of over-booking, with the expectation of some bookings being subsequently cancelled or the customer not showing up, is seen in the airline industry, among other application areas. This requires a trade-off between the costs associated with not providing the service promised to some customers, if over-booked, and the costs associated with having unsold seats, where cancelled bookings are eligible for refunds (Feng and Xiao, 2006). In principle, this concept could be applied to the loading bay booking system under discussion here, if the number of users of the system was high and cancellations a common feature, however this idea may be unnecessarily complicated and may create problems so was not considered in this study. Some authors have considered the idea of reserving time slots to use a particular road, typically a motorway, with the objectives of providing reliable journey times and more efficient use of the road space (Wong, 1997; de Feijter et al, 2004; Edara and Teodorovic, 2008). The concept of highway reservation is similar to the research presented here, namely: (i) reservations are made in advance (whether days, hours or minutes in advance); and (ii) some control procedures are warranted to cater for vehicles not arriving at their booked times. The highway reservation problem is more difficult than the one under study here as the highway may be used by many more vehicles and vehicles can enter and exit the highway from different points (motorway junctions). Consequently, the algorithms that have been developed are not suitable.

Description of the problem

The objectives of this research were to evaluate what benefits might accrue from using bookable loading bays in urban areas for the use of delivery and service vehicles. These bays were assumed to be able to accommodate either one or two vehicles at a time, depending on the scenario being considered. In practice, these 'bays' could correspond to either on-street (Figure 1) or off-street (Figure 2) unloading areas.



Figure 1: On-street unloading area



Figure 2: Off-street loading bay

The case study area

The modelled loading bays were based on the existing freight unloading points in and around Winchester High Street (Figure 3). These unloading points were determined from a number of on-street observations that were made of freight unloading behaviour in Winchester. A part of Winchester High Street is fully pedestrianised (the hatched area of Figure 3 between points 1 and 2) and there is also a vehicle ban (buses excepted) between 10:00 and 16:00 hours on either side of the pedestrianised section. Two bookable loading bays were modelled, located at either end of the pedestrianised area (numbered 1 and 2 in Figure 1), but within the currently restricted area. These loading bays were assumed to operate from 06:00 to 16:00 hours which meant that users of the bookable loading bays, assumed here to be both delivery and service vehicles, had better access to the High Street and, particularly, to the currently restricted area. In reality, Winchester City Council would have to decide whether allowing such access would be acceptable or not.

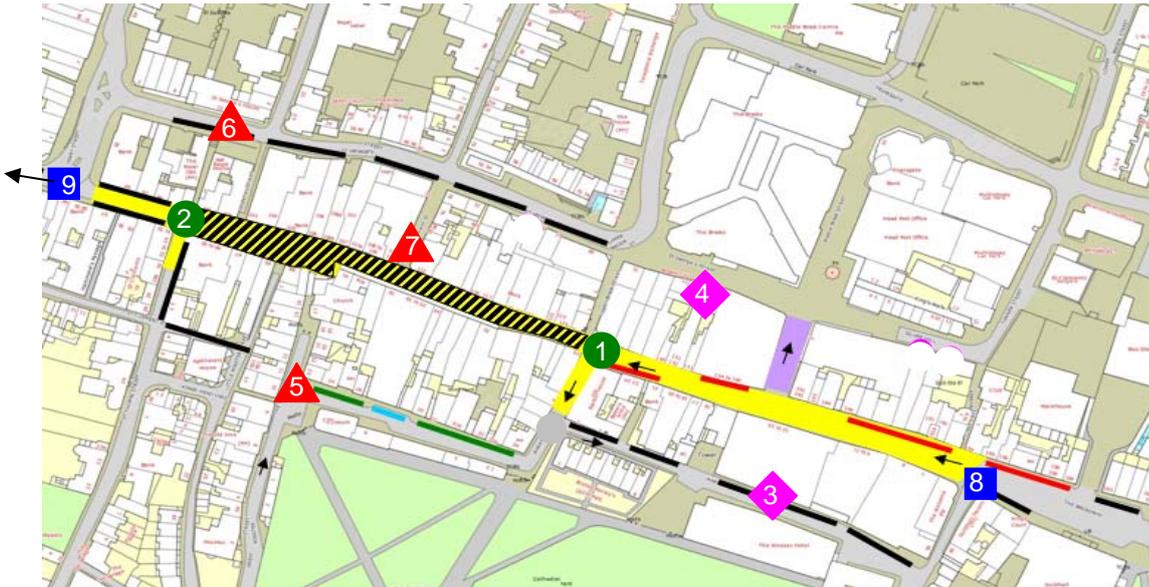


Figure 3 - Freight unloading points in Winchester

Key

- Bookable loading bays at “top end” and “bottom end” of the High Street.
- ◆ Private loading bays used before and after; not bookable.
- ▲ Freight unloading points used in the before case but banned from use in the after case, as they were considered to be undesirable from the viewpoint of pedestrians and traffic.
- Other freight unloading points that may be used in the before and after cases, particularly during the restricted time period (1000-1600). Note: point no. 9 is some 75m or so off the map.

The bookable loading bay system modelled here comprised two parts:

1. An advance booking system, which permitted users to book loading bay time slots ahead of their arrival in the city (e.g. some days or hours ahead; last minute bookings were not considered here).
2. A control system, which dealt with the day-to-day operational issues (e.g. vehicles arriving early or late).

Methodology

The advance booking and control system models were programmed in Fortran, based on the rules and assumptions described below:

Advance booking system

The advance booking system method used was relatively straightforward and involved:

1. Bookable time slots of 15 minutes duration (e.g. 09:00-09:15).
2. An input list of vehicles, in booking order, with each vehicle requesting their preferred entry time to the loading bay and the number of time slots required.
3. Allocation of time slots to each vehicle in turn. If the requested slots were not available then the nearest ones available, if any, would be allocated instead.

It should be noted that, with these rules, vehicles higher up the list would tend to receive their desired bookings whereas vehicles lower down the list would not necessarily be able to do so due to earlier bookings. In practice, the order in which vehicles book slots could be left entirely open, that is, a first-come, first-served system, or some form of priority booking could be used with certain groups of vehicle, or operator, being given the opportunity to book slots ahead of others. For example, in the results presented here rigid-bodied heavy goods vehicles undertaking deliveries (and/or collections), subsequently referred to in this paper as 'rigids', were allowed to book before vans undertaking deliveries (and/or collections) (e.g. couriers) who, in turn, were allowed to book before service vehicles. Whether priority booking would be desirable or not would depend on the individual city/scheme and its objectives.

For simplicity, it was assumed here that all allocated bookings would be accepted for use. In practice, though, some time slots offered by the allocation system would likely be rejected as being too early or too late and the driver (or freight distribution manager) would decide to make alternative arrangements, such as unloading elsewhere. The likely effect would be a slight reduction in the use of the bookable loading bays with corresponding increased use of other freight unloading points. It was also assumed that, for users of the bookable loading bays, an advance booking was mandatory, that is, it was not possible to book at the last minute.

Control system

The control system method involved a set of rules for dealing with the day-to-day situations that would likely occur in practice. These rules are summarised here, including some discussion of their implications:

- Users of the system were detected on the outskirts of the city centre (in practice this would need communications infrastructure on all of the main approach roads in two-way communication with freight vehicles).
- The vehicle bookings were checked to determine whether the vehicle was on time, early or late for its booking. This required estimates of the times needed to travel from the detection points to the loading bays.
- Vehicles arriving early for their booking could proceed immediately to the bay if it was expected to be available or they were instructed to wait in a designated holding area until the bay was expected to be available. The phrase 'expected to be available' is used rather than 'available' as there is a time difference between the time of detection and the time of arrival at the loading bay. If this time difference is significant (more than 5 minutes, say) then the prediction of the loading bay availability is needed to avoid the delays that would occur if vehicles had to wait at the holding area until the bay was actually free. The loading bay availability was not assumed to be determined by the vehicle bookings, but by the actual usage of the bays and an expected dwell time parameter value which was specified for each vehicle. In practice, this would require communications infrastructure at the loading bays to monitor entry and exit times. In addition, the system could require the users to provide expected dwell time data or such data could be recorded by the system over time. Naturally, any prediction is subject to error. The implications of errors in predicting the availability of the bay are that either:
 - (i) A vehicle could arrive at the bay before it is available - in this case, congestion problems may arise.
 - (ii) A vehicle may be delayed for longer than necessary in gaining access to the bay.
- Vehicles arriving late for their booking were allowed to use any remaining time left on the booking subject to a minimum use requirement which was specified as the larger of 25% of the expected dwell time or five minutes. Otherwise, an alternative freight unloading point had to be used. Late vehicles also had the opportunity to extend the booking if succeeding time slots were available. If

the booking could not be extended but there was some time remaining on the booking then it was assumed that the vehicle partly unloaded from the booked bay but then had to move to an alternative freight unloading point to complete the delivery and a 5-minute 'moving delay' was modelled.

- A 'strict enforcement' policy was assumed whereby it was assumed that the bay would not be used by non-users of the system (e.g. private cars) and users of the bays were not allowed to overrun their original or extended booking.
- Once a vehicle exited the loading bay, its booking was cancelled to allow following vehicles, particularly early vehicles, to gain access to the bay early. Another situation where such a system might consider cancelling a booking is when it recognises that a vehicle is too late to use its booking. This would provide some additional loading bay availability in the case of a "no show". This option was not modelled here however.

Input data

Three types of input data were required by the control system model: road network data, vehicle data and booking data.

Road network data

The free-flow travel time from each network entry point to each bookable loading bay was specified. These were obtained from an AIMSUN traffic simulation model of Winchester.

Vehicle data

A total of 69 freight vehicles were estimated to serve Winchester High Street during the time period 06:00-16:00, where this number was estimated from field survey data. Of these, 49 vehicles (12 rigid, 17 vans and 20 service vehicles) were modelled as being potential users of the bookable loading bays, with the other 20 vehicles modelled as using other freight unloading points. For each vehicle, the following data were supplied:

- Vehicle type (e.g. rigid (delivery), van (delivery), service vehicle)
- Entry point to the network, that is, one of the 8 approach roads to Winchester, used in determining the travel time from the entry point to the loading bay.
- Entry time to the network. Entry times were sampled at random and were modified between scenarios to assess the effects of vehicles arriving early or late.
- Desired loading bay and an alternative freight unloading point in case it was not available.
- Expected dwell time at the desired loading bay and at a preferred alternative. The dwell times at each freight unloading point were assumed to vary according to the vehicle type and the walking distances from each point to the central part of the High Street (Table 1), with the times at the bookable loading bays (numbered 1 and 2) being the shortest as they were the most conveniently located. These times were based on previous surveys, undertaken in Winchester as part of the Green Logistics project (www.greenlogistics.org), that had indicated that the average times spent at a freight unloading point were around 10 minutes for courier vans, 20 minutes for rigid lorries and 35 minutes for service vehicles.
- The number of 15-minute time slots required by the vehicle at the bookable loading bay. These were assumed to be one, two and three, respectively, for rigid, vans and service vehicles.

	Freight unloading point (ref. no.)								
	1	2	3	4	5	6	7	8	9
rigid	16	16	20	20	24	24	20	30	30
van	8	8	10	10	12	12	10	15	15
service	28	28	35	35	42	42	35	53	53

Table 1 - Assumed dwell times (minutes) by vehicle type and freight unloading point
Note: The reference numbers correspond to those used in Figure 1.

Booking data

The booking data for each bookable loading bay was output from the advance booking system model and comprised a list of vehicle identification numbers associated with the time slots. An example is shown for a loading bay accommodating two vehicles at a time (

Table 2).

start time	...	0800	0815	0830	0845	0900	0915	0930	0945	...
1 st vehicle identification no.		12	12	14	15	15	17	17	17	
2 nd vehicle identification no.		-	13	13	13	16	18	-	19	

Table 2. Example time slot bookings (vehicle identification numbers)

Performance criteria

Adherence to schedule

The advance booking system may have an impact on the times at which freight vehicles enter the network. If the number of unloading spaces during the peak unloading period (0900-1200) is less than the existing demand for spaces then some peak spreading may occur. This depends, of course, on the desirability of the bookable loading bays and on the availability of other options for unloading. The differences in entry times between the 'before' case, which was assumed to represent the 'desired entry time', and the time that was booked in the 'after' case' was measured and used as an indicator of the impact of the booking system on entry times. These differences in entry times may have an effect on a freight operator's ability to keep a vehicle on schedule, however, it is difficult to quantify the effect, as it may depend on other work to be done outside Winchester, on how the Winchester deliveries fit into the schedule and the scope for redesigning schedules.

Delivery time

The delivery (or service) time was defined here to include:

- travel time from the network entry point to the loading bay, including any waiting time in a holding area (where an early vehicle has to wait to gain access to the bay)
- time needed to move goods from vehicle to store, which was calculated as a fixed, specified time for the individual vehicle plus any additional time needed as a result of having to park further away from the store than desired or as a result of having to move the vehicle from the bookable loading bay to an alternative freight unloading point.

Use of freight unloading points

The use of the different available freight unloading points were monitored in the before and after scenarios to provide an assessment of any improvements in the legality or desirability of the freight unloading points that were used. Some unloading points were classed as 'illegal and/or undesirable', on the basis that they caused obstructions to other road users and/or presented safety hazards.

General traffic delay

Where a lorry causes an obstruction, by parking on a double yellow line, for example, there can be delay to general traffic. Example scenarios of this were modelled, using the Winchester AIMSUN network, to illustrate the effects of illegal freight unloading behaviour. Significant delays to traffic were observed as a result of this activity (McLeod and Cherrett, 2009).

Results

Impact of advance booking system on adherence to schedule

The extent to which vehicles received their requested bookings, or bookings close to these, are shown in

Table 3 and Table 4 for the cases with one space and two spaces at each loading bay, respectively.

From

Table 3 it can be seen that rigid vehicles nearly always received their requested time, and, if not, the allocated time was close to the requested time. At loading bay one, only 3 out of 10 vans received their requested time but 6 others received a time within one hour of the requested time. More vans (5 out of 7) received their requested time at loading bay two as their was less demand for this loading bay, compared with loading bay one. After the rigid vehicles and vans had made their bookings, there were only a few 45-minute slots left available for service vehicles to book and often these were very early in the morning or late in the afternoon, which meant that any booking allocations made would not necessarily be acceptable or useful for the service vehicle driver.

Where the loading bay could accommodate two vehicles at a time (Table 4), rigid vehicles and vans nearly always received their requested time, and, if not, the allocated time was close to the requested

time. The additional spaces also made it possible for 4 out of 13 service vehicles at loading bay one and all 7 service vehicles at loading bay two to obtain time slots within one hour of their requested times.

	Difference between requested and allocated time slots							
	Loading bay 1				Loading bay 2			
	Zero	15-60 mins	> 60 mins	No slot allocated	Zero	15-60 mins	> 60 mins	No slot allocated
Rigid vehicle	6	1	0	0	5	0	0	0
Van	3	6	1	0	5	2	0	0
Service vehicle	0	1	2	10	0	2	3	2

Table 3. Number of vehicles obtaining booking slots with only one space available at each bay

	Difference between requested and allocated time slots							
	Loading bay 1				Loading bay 2			
	Zero	15-60 mins	> 60 mins	No slot allocated	Zero	15-60 mins	> 60 mins	No slot allocated
Rigid vehicle	7	0	0	0	5	0	0	0
Van	8	2	0	0	7	0	0	0
Service vehicle	1	3	0	9	4	3	0	0

Table 4. Number of vehicles obtaining booking slots with two spaces available at each bay

Delivery times

The impact of the booking and control system was investigated over a range of scenarios which varied the extent to which freight vehicles arrived early or late for their bookings. The scenarios were:

1. All vehicles arrive on time for their booking
2. Half of all vehicles arrive on time, half arrive 15 minutes late
3. Half of all vehicles arrive on time, half arrive 30 minutes late
4. Half of all vehicles arrive on time, half arrive 45 minutes late
5. Half of all vehicles arrive on time, half arrive 15 minutes early
6. Half of all vehicles arrive on time, half arrive 30 minutes early
7. Half of all vehicles arrive on time, half arrive 45 minutes early
8. The entry time of each vehicle was randomly chosen to be anywhere from 15 minutes early to 15 minutes late for its booking.
9. The entry time of each vehicle was randomly chosen to be anywhere from 30 minutes early to 30 minutes late for its booking.
10. The entry time of each vehicle was randomly chosen to be anywhere from 45 minutes early to 45 minutes late for its booking.
11. The entry time of each vehicle was randomly chosen to be anywhere from 60 minutes early to 60 minutes late for its booking.

The relative dwell time for each scenario, compared with the base case scenario in which freight vehicles entered the network and used their favoured, non-bookable, unloading points, is shown in Figures 4 and 5, alongside the associated waiting time and moving delay, as defined earlier. In Figure 4, it was assumed that the loading bays could accommodate only one vehicle at a time. It can be seen that, with the exception of scenario 4, the introduction of the bookable loading bays reduced the dwell time for users of the system as a result of the improved access to the restricted part of the High Street. In the scenarios where some vehicles arrived early for their bookings (scenarios 5 to 11), these dwell time savings were offset by having to wait at a holding area to gain access to the loading bay, so that, the overall delivery time was modelled to increase, particularly for scenarios 7 and 11 where some vehicles arrived 45 minutes early. This assumes that the driver waits at the holding area rather than looking for an alternative unloading point, which would likely not be the case for some drivers. In the scenarios where some vehicles arrived late (scenarios 1-4 and 8-11), the dwell time savings tended to reduce according to the number of vehicles and severity of the lateness and there was also a small amount of moving delay modelled, where the loading bays were used partially. In Figure 5 it was assumed that the loading bays could accommodate two vehicles at a time. In these results, the dwell time savings were considerably greater than before at around 400 minutes totalled over the 49 modelled vehicles (around 8 minutes per vehicle). This was due to the fact that, with two spaces

available at the bays, more vehicles could use the bookable loading bays, even if the vehicles were late. Similarly, the waiting times that were modelled were lower than in Figure 4, as vehicles were able to gain access to the bays quicker than before due to the additional spaces.

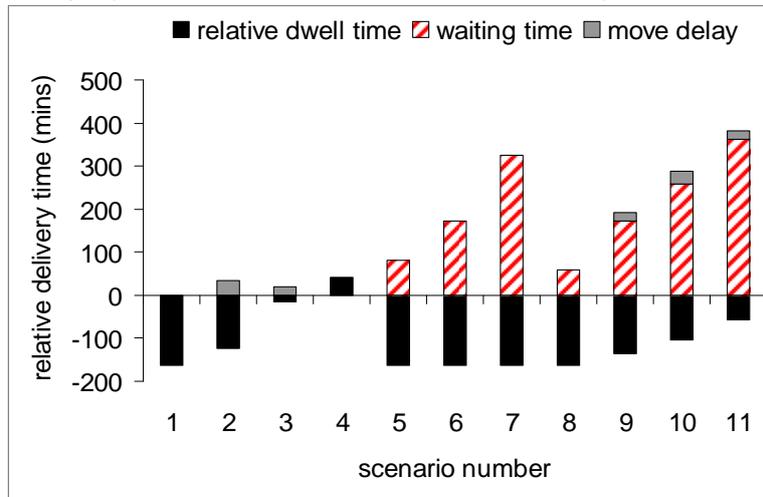


Figure 4 - Effect on delivery times (one space at bays)

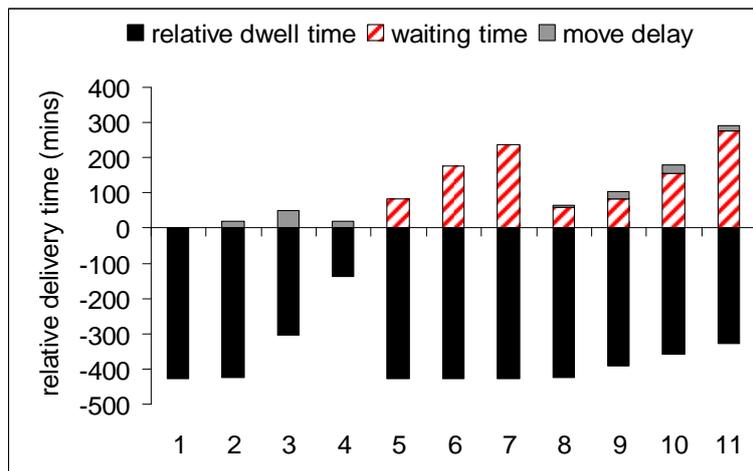


Figure 5 - Effect on delivery times (two spaces at bays)

Use of freight unloading points

The usage of the various freight unloading points was monitored for each scenario and are shown for the case where the loading bays could accommodate one vehicle at a time (Figure 6). In this figure, the freight unloading points (numbered 1 to 9 in Figure 1) were categorised as 'bookable' (1 and 2), 'undesirable/illegal' (5, 6 and 7) and 'other' (3,4,8,9). It was only in the 'before' case that the use of points 5, 6 and 7 was allowed. The greatest use of the bookable loading bays was seen in the scenarios where there were no late vehicles, as this meant that all of the vehicles with bookings could make full use of their slot. In those scenarios, the bookable loading bays were used for a total of 552 minutes. This usage represented only 46% of the total bookable time available (20 hours = 2 bays x 10hr booking period (0600-1600)). The reasons for this apparent low usage were that not all of the time slots could be booked (for example, a 30-minute gap could not be booked by a service vehicle needing a 45-minute slot) and that many vehicles were modelled to exit the loading bay before the end of the booking since rigid vehicles were modelled to require only 16 minutes of their 30-minute booking; vans 8 minutes of their 15-minute booking and service vehicles 28 minutes of their 45-minute booking. In the scenarios where there were late vehicles, the usage of the bookable loading bays reduced since these vehicles were liable to miss their booking entirely or to only be able to make partial use of their booking. The level of reduction in use of the bookable loading bays was dependent

on the number of late vehicles and on how late the vehicles were in relation to the length of the booking made.

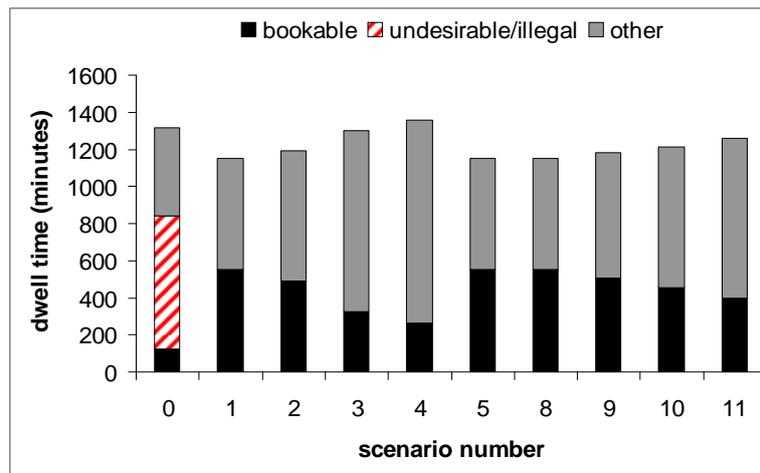


Figure 6 - Use of freight unloading points (one space at bays)

Discussion and conclusions

The concept of advance booking and control of freight loading bays in an urban environment has been modelled for the city of Winchester. The results very much depend on the assumptions made about the sizes and locations of the bookable loading bays and of the alternative freight unloading points and of the system rules. Benefits to users of the system, in terms of reduced delivery times were demonstrated, where these derived from improved access to the High Street. These benefits would not be available if the bookable loading bays did not improve upon existing delivery options.

A potential drawback to the usefulness and usability of pre-booked bays is the doubt about the ability of drivers to arrive in time for bookings. If the driver is early for a booking then he/she may have to wait in a holding area until the bay is free (or is predicted to become free) or may decide not to use the bookable loading bay at all. If a driver is late then the booking may only be partially utilized or the booking may be missed entirely. The worst case scenario would be where heavy congestion causes all vehicles to be late for bookings. In such a case, a more dynamic system, able to cope with perturbations, could possibly be more useful. An alternative approach would be to do away with advance bookings entirely and to provide access to the loading bays on a first-come, first-served basis, under the control of a SmartFreight type system. This latter approach would be well-suited to dealing with dynamic situations; however, it would not have the advantages of the advance booking system whereby the freight distribution manager (and/or driver) can plan the vehicle schedule in advance based on bookings received, and the driver has a guaranteed space and does not have to wait for other vehicles to complete their deliveries.

From the city perspective, such a system may improve freight delivery behaviour and may reduce problems associated with parking on kerbs and double parking. Such a system may also encourage spreading of the delivery peak (09:00-12:00 hours in Winchester). This may be desirable to limit the numbers of large vehicles in the city centre at the same time, however, some cities (e.g. Gothenburg) are adopting policies to try to keep large vehicles out of the city centre after a certain time (e.g. 10am) so peak spreading may not be desired by some cities.

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