INFRASTRUCTURE SOLUTIONS FOR INCREASED EFFICIENCY AND PRODUCTIVITY OF CONSTRUCTION MATERIAL TRANSPORTS IN CITIES


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Abstract
In many cities downtown areas there are restrictions on vehicle weight and length which often limits the load capacity of the vehicles that transports construction and excavated bulk materials, such as soil, gravel, stone, sand, concrete and asphalt. This means that a large amount of the transports cannot be performed effectively. To improve the efficiency of the transports one obstacle is the lack of places to reload or set of load units, which results in that vehicles usually run with limited cargo during the whole route despite that the restrictions only apply during a short section of the route. This study has, examined solutions for how these obstacles can be overcome with focus on changes in infrastructure and development of transport systems to enable efficient transports of construction and excavated bulk materials to increase the productivity and strengthen the competitiveness. The result indicates that a significant energy efficiency can be reached by establish shunting and/or transhipment sites where for instance full trailers can be set off before entering the downtown city areas.
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1. Introduction

Construction and excavated bulk material is the largest group of materials or products that is transported on the street and road network. Most of these transports consist of soil, sand, rock and other materials and are often carried out within short distances within urban areas, in Sweden less than 60 km. In Stockholm, transports of construction and excavated bulk materials also accounts for more than 50 % of the total amount of transported load weight (Trafikanalys, 2012). Construction and excavated bulk material in urban areas is also a resource-intensive and expensive activity with a large environmental impact.

Normally permitted length of solitary vehicles or vehicle combination on the public road network in Sweden is in general 24 m and 25.25 m for vehicle combinations according to the European Modular System (EMS). The permitted gross weight of the vehicles in Sweden is normally defined by the distance between the first and last axles of a solitary vehicle or in a vehicle combination.

The public roads in Sweden are normally divided into different classes of bearing capacity, called BK, see figure 1. The most common bearing capacity class is BK1 which covers 94 % of the public road network. BK4 is a recently introduced bearing capacity class which allows vehicle combinations to have a gross weight of maximum 74 tonnes only on a limited part of the road network. The maximum permitted gross weights for vehicle combinations are 74 tonnes at BK4, 64 tonnes at BK1, 51.4 tonnes at BK2 and 37 tonnes for BK3. For BK2 and BK3 the axle and bogie loads are also limited compared to BK1 and BK4.

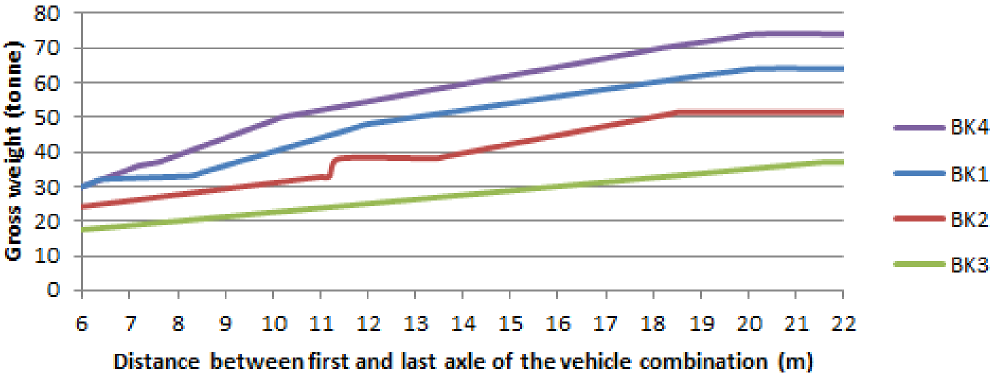

Figure 1 – Allowed gross weight of vehicles or vehicle combinations according to different bearing capacity classes and axle distances (Transportstyrelsen, 2017).

Within several major cities in Sweden there are local restrictions on the weight and length of solitary vehicles and vehicle combinations. A common restriction is a combination of bearing capacity class 2 (BK2) and a maximum permissible vehicle length of 12 m in inner cities or downtown areas. Due to these local restrictions, the load capacity of the vehicles carrying construction and excavated bulk materials is often limited. For a 3-axled single truck, see Figure 2, the load weight is limited by approximately 20 % at BK2 compared with the load weight of the same vehicle at the less restrictive and more common bearing class 1 (BK1).

This means that a large part of the current transports are performed with a lower efficiency than would be necessary.

Figure 2 – 3-axled truck (TFK)

Furthermore, restrictions imply that more vehicle movements are required to carry a certain amount of goods than would be the case if the vehicles could be loaded to maximum capacity or if larger vehicles or combinations of vehicles could be used. An example of a common vehicle combination in Sweden is a 3-axled truck and a 4-axled full trailer, see Figure 3.

Figure 3 – 3-axled truck and 4-axled full trailer (TFK)

One problem that arises from the restrictions is that energy consumption per transported mass or cargo unit becomes higher when the share of payload decreases in relation to the vehicle's own weight. A larger proportion of the consumed energy will therefore be used to move the vehicle instead of moving its load, which contributes to a greater environmental impact and an increased congestion.

A possible solution for the transports of construction and excavated bulk material to be more effective is to establish sites for shunting and transhipment and/or reloading where for instance trailers can be set off before entering the downtown city areas. This is to adjust the size of the vehicle combination to the applicable local restrictions on gross weight, usually BK2, and vehicle length limitations, such as 12 m in maximum allowed vehicle length. Furthermore, load units can be reloaded or refilled to increase the payload and increase the vehicle's load factor, e.g. the ratio between payload and gross weight, at the part of the transport that is performed outside the downtown city areas or outside other areas within restrictions applies. However, in today's situation, due to lack of shunting and transhipment sites, the vehicles often continue to run with a limited load at a certain transport chain or assignment (or route), according to BK2, throughout the current journey distance, although only a short section has a restriction to BK2.

1.1 Objectives

The aim of the study was to provide an overall picture of how the infrastructure and transport systems should be transformed and developed in order to increase the efficiency of transports of construction and excavated bulk materials in urban areas and cities throughout the transport chain. The study has included an investigation and analysis of the design and location of shunting and transhipment sites as well as nodes and paths for transport of construction and excavated bulk materials in big cities in general and especially in city downtown areas with restrictions on weights and length limits.

Furthermore, the study aims to increase understanding of the importance of including transports of construction and excavated bulk materials in society and infrastructure planning. The purpose of such a development is to create more efficient transports of construction and excavated bulk materials in short and long term and to develop solutions for more efficient planning of these transports.

1.2 Research approach

An investigation and analysis of the design and location of shunting and transhipment sites as well as nodes and paths for construction and excavated bulk materials in cities and urban areas have been carried out. Case studies were conducted on the basis of real transport assignments. Analyses have been made regarding the effects of new infrastructure solutions and transport systems for transport of construction and excavated bulk materials in cities, from different perspectives such as environmental aspects, energy consumption, congestions and costs. A workshop was conducted with stakeholders, politicians and other decision makers.

2. Consolidation centres

One method of increasing efficiency and reducing energy consumption from construction transports is to establish consolidation or logistics centres. This method has been tested in several places, but has primarily been used as logistics centres for building and construction materials. That means for instance building elements and pipes and not for construction and excavated bulk materials such as soil, sand and rock etc. Consolidations centres have so far been established in places with considerable congestion and where traffic noise and vibrations is likely to disturb citizens.

A demonstration of a consolidation centre has been achieved in the London area in UK. The centre was located in South Bermondsey in southern London and was conducted for two years starting in 2005. The consolidation centre was used for building materials for 4 major construction sites in London. The consolidation centre handled building materials in various shapes, but no bulk cargo such as gravel, stone and soil etc. The purpose of the demonstration was to reduce the number of vehicle movements to construction sites and thereby reducing congestion and emissions (Transport for London, 2008).

During the demonstration it was found that the number of vehicle movements that arrives to the construction sites could be reduced by 60-70 % for the material delivered via the consolidation centre. In total, carbon dioxide emissions are estimated to have been reduced by 70-80 % due to a reduced number of vehicle movements. During the demonstration, time savings could also be identified. On average, the delivery time could be reduced by 2 hours including loading and unloading time, because the vehicles did not have to drive into central London (Transport for London, 2008).

Consolidation centres have so far been used primarily for building and construction materials and not bulk cargo. For a consolidation centre that also will handle bulk cargo, larger areas are required. The handling of bulk cargo also gives rise to dust and noise which may result in that the consolidation centres have to be located further out from the city centres to minimize disturbance. It is therefore interesting to investigate other alternatives, such as shunting and/or transhipment sites for bulk cargo.

3. Case-studies

Three real transport assignments in downtown Stockholm have been studied and data collection has been made. These three transport assignments are as follows:

- Contaminated excavated material: Slussen (Stockholm city) – Högbytorp
- Concrete: Farsta – Regeringsgatan (Stockholm city)
- Asphalt: Arlanda – Klarastrandsleden (Stockholm city)

For these transport assignments, calculations have been made to investigate how different infrastructure changes affect the efficiency of the transports.

The contaminated excavated material was transported with a 3-axled truck. The load weight was 10 tonnes and the transportation started where there are local restrictions according to bearing capacity class 2 (BK2) and 12 m maximum vehicle length. The journey from the worksite Slussen to the waste facility Högbytorp and back again was 96 km long and took 110 min including loading and unloading. The transport was performed with limited load throughout the whole journey, although the restrictions on BK2 and 12 m only apply for a few kilometres.

If the transport is performed with a 3-axled truck and 4-axled full trailer (se Figure 3) instead, that sets off the trailer on a shunting area before entering the restricted downtown area, the energy consumption can be reduced by 44 % and the number of vehicle movements outside the restricted area can be reduced by almost 70 %. If the truck and trailer gets additional load at the transhipment and shunting area after the truck has been in the restricted area to collect load in order to achieve the maximum allowed load weight according to the higher bearing capacity class 1 (BK1), the energy consumption can be reduced by 53 % and the number of vehicle movements outside the restricted area can be reduced by 72 %.

For the transport of concrete, the last part of the route had restrictions according to bearing capacity class 2 (BK2) and maximum 12 m vehicle length. This transport was performed with a 3-axled concrete mixer truck, see Figure 4. The journey to the worksite and back to the concrete factory was 25 km long and took about 66 min. In order to make this transport more efficient, it is necessary to allow vehicles longer than 12 m or to allow BK1. By allowing vehicles longer than 12 m, a concrete mixer tractor and a trailer vehicle combination can be used instead which can reduce the energy consumption for this transport by 35 %.

Figure 4 – Concrete mixer truck at Regeringsgatan, Stockholm (TFK)

For the asphalt transport, a new innovative vehicle combination was used that is optimized according to the local restrictions BK2 and 12 m maximum vehicle length. The vehicle combination consists of a 3-axled tractor and two identical so-called links that consisted of semi-trailers with sliding bogies, see Figure 5. When travelling in areas with restrictions on BK2 and a maximum vehicle length of 12 m, the rear link can be disconnected and the bogie is pulled in to cover the length limitation.

Figure 5 – 3-axled tractor and two links with sliding bogie (TFK)

By using this innovative vehicle combination, the energy consumption can be reduced by more than 40 %, and the number of vehicle movements can be reduced by more than 20 % in cities or downtown areas and by 60 % outside cities or downtown areas compared to transports that are achieved by 3-axled single trucks with load restrictions according to BK2.

4. Results

By shunting and/or transhipment activities, energy consumption can be reduced significantly in a transport chain or assignment. The case studies indicated that a 40 % reduction in energy consumption was possible compared with today's transport solution. It also means that fewer vehicle movements are required to transport a certain amount of material which reduces congestion and increases road safety. With fewer vehicle movements, the total transport time also decreases, which in turn can reduce the total scheduled time to accomplish a construction assignment. Lower fuel consumption and shorter transport time also provide cost savings.

For the case with transport of contaminated excavated material from Slussen to Högbytorp, the transport was compared with 4 other transport alternatives, see table 1.

Table 1 – Index for energy consumption and vehicle movements for different transport alternatives compared to the transport in the case study at Slussen

Transport alternative	Reference	Shunting	Shunting and additional load	No shunting	
Restriction	BK2 and 12 m	BK1/BK2 and 12 m		BK2 and 15 m	BK1 and 12 m
Vehicle	 3-axled truck	 3-axled truck + full trailer		 2-axled tractor + semi-trailer	 4-axled truck
Energy consumption (l/tonne)	100	56	47	56	61
Vehicle movements in city	100	100	100	48	56
Vehicle movements outside city	100	33	28	48	56

As mentioned before, if the transport is performed with a 3-axled truck and full trailer, that sets off the trailer on a shunting area before entering the restricted area, the energy consumption can be reduced by 44 % and the number of vehicle movements outside the downtown area can be reduced by almost 70 %. If the truck and trailer gets additional load at the shunting area, after the truck have been in the restricted area to collect load, to get the maximum allowed load weight at BK1, the energy consumption can be reduced by 53 % and the number of vehicle movements outside the downtown area can be reduced by 72 %. If there are no shunting areas, but the allowed maximum vehicle length is increased from 12 m to 15 m, the energy consumption can be reduced by 44 % compared to the transport in the case study and the vehicle movements, both in and outside the city, can be reduced by 52 %. If the allowed vehicle gross weight is increased from BK2 to BK1, but the allowed maximum vehicle length still is 12 m, the energy consumption can be reduced by approximately 40 % compared to the transport in the case study. The amount of vehicle movements, both in and outside the city, can be reduced by 44 %.

This means that the shunting and/or transhipment areas do not reduce the amount of vehicle movements within the city if not special vehicles, adapted for transports in cities on short distances, are used. The shunting and/or transhipment areas can on the other hand result in reduced energy consumption for the total transport and reduced amount of vehicle movements outside the cities. The shunting areas also facilitate the use of electric vehicles for transports between the shunting areas and the sites in the city.

The shunting and transhipment sites need to have well-functioning route connections, preferably thoroughfare and the sites should be located so that they can be reached from roads classified to BK1 but close to areas with limitations of vehicle length and vehicle weights. The shunting and transhipment sites should also be located so that noise and dust from the sites do not interfere with residents. A location where the vehicles have to pass by on streets outside for instance day-care centres and schools should also be avoided.

In order to facilitate the truck drivers planning, it is desirable that it is easy to book a slot or a schedule time at a shunting and transhipment area and that it should be easy to see where there are vacancies. It should also be stated in procurement that there should be logistics solutions that enable efficient transports, for example, that there are areas for shunting and transhipment.

The shunting and transhipment sites can be located in connection with material handling areas in order to recycle materials near potential users. When transhipping different types of material, there must be containers or boundaries that ensure that the materials are not mixed or otherwise contaminated.

Depending on availability of available areas, shunting and transhipment sites can be designed and established as:

- Permanent sites: Permanent sites that are possible to use around the clock and that are located close to popular arterial roads.
- Dynamic sites: The sites are used daytime for transhipment and shunting and in evenings and nights for parking of mainly passenger cars. If the areas are used for shunting even at night, load units can be transported to the shunting and transhipments sites at night, and then be transported into the city at daytime.
- Temporary sites: Temporary sites can be established when needed, for example at large construction sites that last for longer periods of time. This can be done in parks or parking lots that are restored when the transhipment site no longer is needed.
- Microsites: Areas that today have no specific use, but where it today is prohibited to park trailers and other vehicles. These sites can be used as dynamic, temporary or permanent transhipment and shunting sites.

In order to further make the transports more efficient, the nodes, consisting of shunting and transhipment sites can be connected by streets and/or roads that allow longer and/or heavier vehicles and vehicle combinations. This is a way to minimize the distance the vehicles drive with limited capacity. Where it is possible, streets and roads can therefore be reclassified to a higher bearing capacity class, BK1, or allow longer vehicle length than 12 m.

5. Conclusions and discussion

By establishing shunting and transhipment sites close to areas with limitations of vehicle length and vehicle gross weights, transport of construction and excavated bulk materials can be significantly more energy and time efficient compared with today's transports.

However, there is a competition for areas in the urban areas. It is therefore important that shunting and transhipment sites are included in the infrastructure planning and that it also is required that shunting and transhipment areas will be established in connection to large buildings sites. One option is also to establish shunting and transhipment sites in connection to material handling sites, in order to facilitate the recycling of materials and to reduce the transport of materials that can be recycled without any processing.

A conclusion is that there is a great potential to make transports of construction and excavated bulk materials more effective in urban areas, especially downtown areas of big cities, by relatively simple means. Transport of construction and excavated bulk materials is, however, often a forgotten type of goods in discussions about goods transports, even though construction and excavated bulk materials account for the largest share of the freight transports. With more efficient transport systems for construction and excavated bulk materials, congestion can decrease while reducing the energy consumption and climate impact of these transports. There is therefore much to be gained from focusing more on transports of construction and excavated bulk materials.

6. References

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