



Transport Research Arena (TRA) Conference

High capacity city transport with intelligent access - A Swedish case study of transporting excavated material

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Abstract

This project studies how the HCT-concept (High Capacity Transport) can be applied in cities, by performing pilots in Varberg and Stockholm. The project will test the hypothesis that the HCT-concept will improve both productivity and transport efficiency and thereby reduce CO₂ by up to 40%. The pilots include tests of new optimized trucks and new concepts with connected trucks, road machines and bridges. Demonstration of digital access control including geofencing of speed and routes will be included. A system analysis on a societal level will be performed, with the target to incorporate HCT-city in the existing HCT roadmap. The results will be a foundation for a strategy including dispensations and regulatory changes on national roads and a recommendation how HCT-city can be designed to reach the highest possible productivity and transport efficiency.

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1. Background, earlier studies, and scope

The transformation to a transport efficient and fossil free society, at the same time as transport volumes keep increasing, is a huge challenge but also an opportunity. The development of heavier and longer vehicles along with improved road infrastructure have made it possible to increase the load capacity of vehicles for all modes of transport. This has resulted in lower energy and fuel consumption, improved labour and capital productivity which has resulted in lower cost and fewer vehicles needed for the same job. This trend has been most dramatic for sea and air transport, but considerable improvements have been seen also for rail and road transport. However, in road transport most roads and bridges can accommodate much longer and heavier trucks than allowed today for general access. E.g. in Australia, 200 ton gross weight is allowed on some roads, in Finland 76 ton on almost all roads, in Sweden 74 ton on some roads, and in most European countries 40 ton. The reason for still having less productive trucks in Europe is partly because of a lack of knowledge of the benefits with HCT, and a perceived risk of road freight taking market shares from rail transport. Most freight transport do not compete with rail as the routes are quite different. The research on High-Capacity Transport on roads (HCT), meaning reforms that allow the use of vehicles that are heavier and/or longer than allowed for general access, has so far mainly focused on long-haul transports in non-urban areas. Much indicates that there is a large potential to deploy HCT reforms also in urban areas for local and municipal transport.

1.1 Earlier studies

A desk top research (Treiber and Bark 2018) suggested that CO₂ emissions can be reduced by 40% and the number of truck trips can be reduced by 50% by introducing the HCT concept in urban areas. This was confirmed in a pre-study on urban construction transport in Stockholm using a five-axle truck (Segeberg, A. et al 2020) as shown in figure 1 below. An ordinary truck using weight restrictions according to local urban regulations, which is the current access regulation in most cities in Sweden (orange) with the five-axle vehicle in the pre-study using higher access regulation (yellow). The green area shows the expected results from this study when using a new city optimized HCT vehicle.

Vehicle	Average weight (metric ton)	No of trips to move 2 196 (mton)	Average load (mton)	Average axle load (mton)	l/100km	ABba (ml/tonkm)
Three axle boggi Volvo medium heavy (BK2)	23,5	172 (100%)	12,8	7,8	31,79	50 (100%)
Pre-study five axle, real results	37,8	111 (-35%)	19,3	7,6	43,29	45 (-10%)
Calculated results from project HCT City Stockholm	42	93 (-46%)	23,5	8,4		30 (-40%)

Fig. 1. Results from the pre-study comparing current best praxis (orange) with the five-axle vehicle in the pre-study using BK4 (yellow). The green area shows the expected results from this project.

The maximum allowed length is 12 meter in all three cases, which is the regulation in Stockholm and several other cities in Sweden. So called ABba (transports both ways) shows the measured diesel consumption per tonkm. The payload is roughly doubled compared to current best praxis which means half the number of trips and 50% less road space. The below figure 2 shows the possible reduction of trucks in the pre-study.

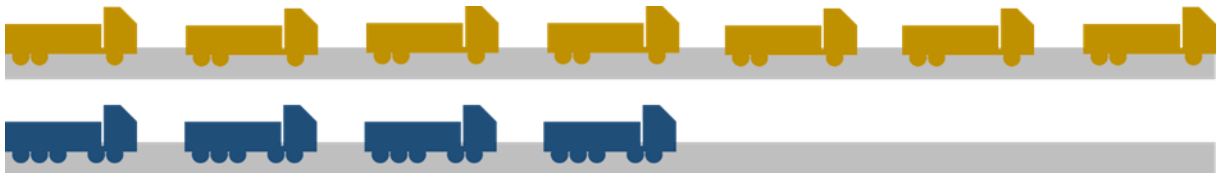


Figure 2. Illustration of how many less truck trips will be needed for the same job if using HCT-City vehicles.

1.2 Scope

The project has a budget of 2.4 million €, with 14 partners from industry, cities, universities, and research institutes and will run from April 2021 to March 2024. The project is unique as it concentrates on HCT for urban transport. So far, previous research has been focusing on long-haul highway transport (Asp and Wandel 2020). Only 8% of Swedish goods with high density is transported more than 300 kilometres according to statistics (Trafikanalys 2016). There is a large potential in optimising the transports in the construction sector to reduce CO₂. In Sweden 90% of the transport within construction is land transport. As much as 50%, calculated per weight, of all transports in urban areas relate to construction and mass transports in Sweden. (A. Fredriksson et al MIMIC 2021).

Vehicles with increased payload capacity are internationally called High-Capacity Vehicles (HCV) and an increasing number of countries are introducing them (ITF 2019, Asp/Wandel 2022). High-Capacity Transport's (HCT) schemes typically consist of these four parts: Dedicated roads, certified vehicles, operating requirements, and a legal, institutional, and digital framework for the three parts. In the project HCT-City all parts of the HCT-concept are included.

The Intelligent Access (IA) system is part of the digital framework. It supports the drivers and operators and monitors the compliance of regulations and access conditions. IA has been identified as a necessary component to get acceptance from the road owner and the operators of heavier trucks. Australia has twenty years of user experience from Intelligent Access that can benefit European partners according to Walker C et al 2021. We have established a close collaboration with responsible governmental agencies in Australia. During the project we will build, and test two city optimized trucks as well as several designs of digital support systems.

Previous research has mainly focused on the relation between the four parts in the HCT concept. This study extends the scope to also include the processes at the origin and destination of the transport. In this study, the whole production system is taken into consideration and not only optimization of the transports. Data is collected from several vehicles, infrastructure and construction equipment and this data is analysed to learn more about the system and how to make the whole system more efficient, se Figure 3.

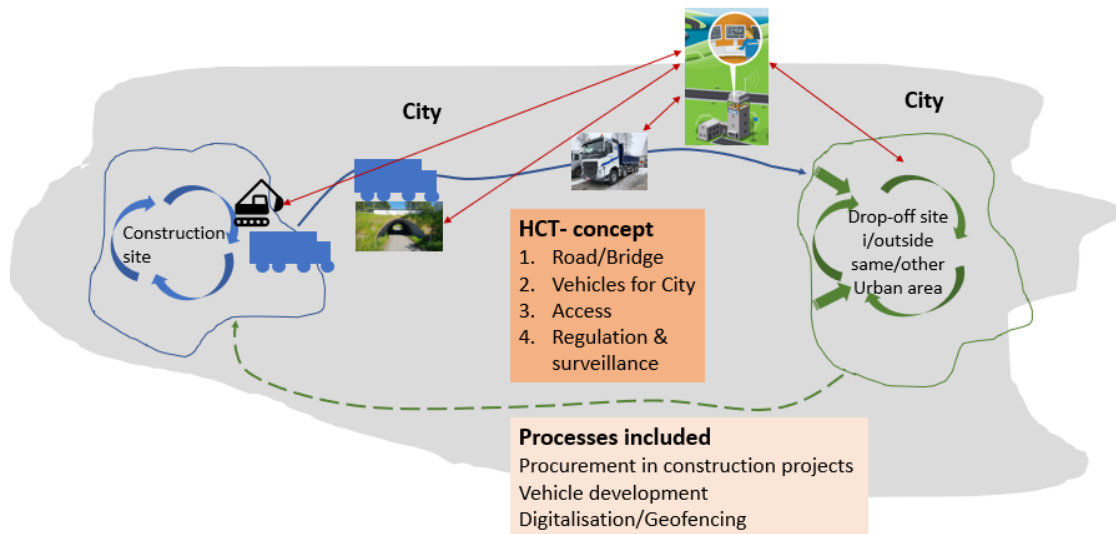


Fig. 3. Concept picture of the HCT system that is studied in the project HCT-City

However, there are also two system aspects that need to be addressed involving *compliance* and *integration*. The compliance considers the aspects of trust for policy and regulation fulfilment. Specific regulations may be applicable for HCT concerning dynamic aspects of routes, speed, weight, and time. The integration aspect considers the utilization of the vehicles in a larger system perspective.

In the construction domain, the transportation is part of a larger production process where flow is important. Heterogenous fleets or fleets considering unbalanced capabilities and capacity may influence the productivity of the operation negatively where the productivity and sustainability of a specific vehicle may well increase but the overall productivity might even decrease on a fleet level (Rylander 2021). Transport vehicles with shorter cycle time may need to wait and idle for activities in the production due to larger weight capacity vehicles up front with longer cycle times. This would decrease the overall productivity and increase carbon footprint. To address the compliance and ensure high productivity, the payload, vehicle gross weight, as well as axle weight distribution are important factors. The weight of the vehicles can either be proactively controlled in the loading sequence or by reactively measuring the actual load on the truck or by the infrastructure, for example by WIM-bridge measurements.

2. Purpose and research design

The purpose of the project is to perform field tests in ongoing construction projects and thereby obtain new knowledge for deploying HCT reforms for urban and local transport of excavation materiel and masses in urban areas. The field tests will be performed at the two test sites:

- Stockholm: Excavation to make room for a new residential area. Two new 5-axle heavy truck prototypes will be built and tested with gross weight capacity ranging from 38-42 tons with length under 12 meters, specially designed for urban construction sites and with a capacity twice the payload compared to today.
- Varberg: Blasting and excavating a 3.6 km railway tunnel under the city centre. Focus here is on the system perspective and the plan is to log vehicle data, both from standard and HCT-vehicles, both below and over 74 ton gross weight.

A hypothesis is that strictly controlled operations with Intelligent Access can open for more flexible permissions for the operation of heavier and more efficient transports. Tests will be performed with sensors on vehicle axles, in wheel loader buckets, on bridges, and in weight stations so that over- or under loading is avoided. GPS will monitor routes and position and active speed control will ensure reduction of the speed over extra sensible infrastructure (Hill and Greenow 2021). The two optimized vehicle prototypes for the Stockholm city conditions have more axles and improved traffic safety features such as steerable axles, improved telematic system, cameras, and speed control functions (Geofencing). The expected result is that the payload can be doubled. In the Stockholm test site, there is a length limitation of 12 meters, but in Varberg test site, vehicles are allowed to be up to 25.25 meters. Effects of optimizing both the loading process and vehicle combinations for the transports are investigated in the project. The impact of HCT on bridges, road wear and traffic safety will be analysed, using a combination of collected sensor data and model simulations. The results will be compared with regular, non-HCT vehicles, as a baseline.

3. Major work areas

The work in the project is divided into several work areas. The major ones are described below.

3.1 Development and test of prototype vehicles

In this project, two new vehicles will be developed by Volvo, designed specifically for urban, Swedish vehicle certification requirements, and for some alternative access policies. Special focus for the design of these new vehicles will be on:

- More axles to reduce road damage
- Longer distance between first and last axle
- More steerable axles for better manoeuvrability
- More liftable axles for less need of fuel when empty
- More driving axles to balance traction, fuel consumption and weight
- Specially designed tip body to balance sturdiness and weight
- Devices to improve safety of vulnerable road users

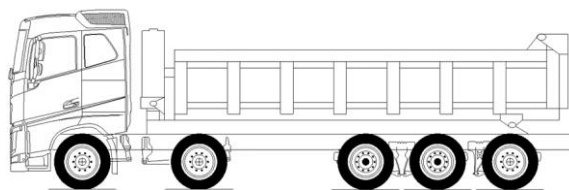


Fig. 4 shows the idea of a 5-axle HCT vehicle optimized for Swedish urban conditions.

Results so far is that we have chosen the following specification for the first vehicle: 5 axels of which 2 are liftable, 3 steerable and 2 driving, and certified gross vehicle weight of up to 47 ton. The specification the second vehicle will depend on the operating use case and the outcome of the tests of the first vehicle. Reference vehicles will be driven in parallel to get reliable comparisons. Important parameters to monitor are fuel, load, routes, user-friendliness, traffic safety, as well as manoeuvrability.

3.2 Impact on infrastructure and traffic safety

This work area addresses the effects on the life of bridges, roads, and streets as well as on traffic safety and vulnerable road users. The impact of different vehicle combinations on bridges is simulated and compared with

linear elastic calculation programs (ERA-pave). The program PEDRO will be used to study impact on the bitumen layer. Real data is collected from operation of real vehicle combinations to calibrate the models for each use case. This knowledge will be used as base for the upcoming changes in the regulations.

3.3 Collection of research data

In contrast to most previous research on HCT, the impact on the performance and productivity for the larger construction process is studied here, not only on moving masses from A to B. One hypothesis we will test is that implementing HCT, together with digitalization, will improve the synchronization between the different operations in a construction site, ranging from production processes to transportation schemes. In this project, data will be collected from several sources, experiments with different vehicles and digitalization will be performed, and then data will be analyzed.

For data collection, the project utilizes a combination of systems including infrastructure sensors such as weight in motion (WIM) mounted on a bridge, vehicle sensors and wheel loader sensors. The WIM-bridge system is a stationary system mounted on a suitable bridge, providing accurate data about the vehicle configuration, number of axles, individual axle weights and axle distances for every vehicle crossing over that bridge. The vehicle system utilized include continuous logging of vehicle positions, weight, speed, and fuel consumption from relevant vehicle combinations that are utilized in the construction operation of the study. The wheel loaders are equipped with weight sensors and a graphical user interface that enables the use of assisted weighing of load for the vehicles.

The results from the WIM-bridge measurements so far show unexpected high variations in gross weight around the weight allowed. More detailed analyses of the loading process indicated that there are improvement possibilities in using weight sensors in the loader and communication between the loader and the vehicle.

3.4 Development of a digital framework and Intelligent Access for urban HCT

Intelligent Access is a technology that utilize positioning and tracking systems together with wireless communication technologies to monitor and control where, when, and how heavy vehicles operate (Australia 2012). A hypothesis is that Intelligent access technologies can support both to ensure compliance and integration of high capacity vehicles in the earth material transportation and construction domain.

Further assessments of the available protocols and standards including the r-FMS (remote Fleet Management System) for data exchange in-between actors are performed for fulfillment of the needs identified, see Fig 5. A hypothesis of the work is that efficient utilization of the intelligent systems combined with data exchange in between relevant actors can address both the compliance and integration challenges identified.

The project does not only consider the functional aspects of data exchange but also non-functional aspects of the weight data accuracy and availability as well as GDPR compliance issues in the addressed dynamic multi actor and stakeholder environment.

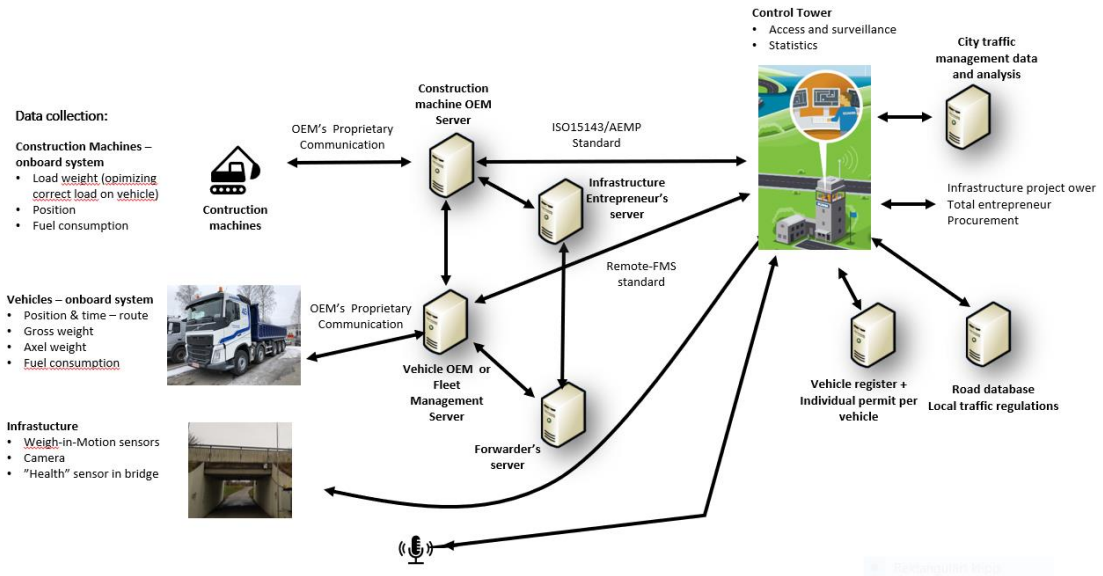


Fig. 5. IT-architecture of a construction site involving intelligent access control and HCT.

The construction operation often involves several enterprises with different roles. A future IT system needs to connect the different actors in the value chain to address the compliance and integration to ensure that the benefits of HCT are facilitated. In Fig 5, a conceptual system description is displayed, where the key actors, information flows and potential communication protocols are identified for the purpose. The HCT-City project will therefore address the compliance and integration challenges and evaluate system effects. A significant challenge is the system of system landscape that construction operate in. This landscape often involves several enterprises and complex business relations in several steps. A system solution must facilitate the communication with respect to integrity of both businesses and their personnel. A concrete problem example is that haulers can work for several construction entrepreneurs over the same shift. In this example the data connected to each entrepreneur and project must be protected resulting in a high complexity for how to track and collect data for an operation.

3.5 Recommendations regarding legal and institutional framework for urban HCT

- How to form a decision body on a national level to handle digital dispensation processes for regional and urban roads in Sweden and Europe (like TCA in Australia).
- Input and recommendations for new pilot sites and test arenas for urban construction projects with HCT-systems.

3.6. System analyses

The system analysis includes future potential, societal cost benefits, procurement and business model, and finally consolidation and conclusions. The model will be applied to construction projects in other cities.

4. Conclusion, road map, and future work

From the earlier pre-study performed in Stockholm 2020, we already have identified a potential in doubling the payload. Next step could be to digitalize the permit processes, and to adapt the HCT City transport concept with Intelligent Access reforms in other European cities, and in fast growing economies.

We will conclude with recommendations regarding procurement of transport and materials handling at construction sites, vehicle development, and for the legal, institutional, and digital framework for successful HCT reform deployment.

The main contribution of this paper is the description of the challenges and benefits of HCT for utilization within construction operations addressed in the HCT-City project. Construction operations are a large contributor of CO₂ emissions, where HCT can contribute with significant reductions.

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