

SMART CONSTRUCTION LOGISTICS - THE CASE OF A DUTCH INNER CITY HOSPITAL AND UNIVERSITY

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Abstract

The construction Industry appears to be responsible for 25 to 30 % of all freight transport. Large scale construction works within a crowded inner city may therefore be a logistics challenge, especially in the case elaborated in this paper, where the involved hospital and university need to remain operational and accessible. HAN University of Applied Sciences was asked to provide advice on applying smart construction logistics.

First, a review of literature and case studies was carried out and experts (researchers, main contractors and project managers) were interviewed. This led to a long list of potentially effective concepts. Second, the logistics and organizational situation of the hospital / university and their construction project were analysed. Synthesis of the logistics concepts and local situation led to an advice why what concepts were expected to be most beneficial.

Due to the crowded inner city location, the need for a continued operation and reliable access, and positive prior results obtained elsewhere by using a construction consolidation centre (CCC), it was advised to use a CCC, added with other smart concepts like pre assembling, a ticketing system, a shuttle service for workers and integral planning. In this paper the proposal is argued step by step.

1. Introduction

Freight transport makes a major contribution to our prosperity, but also to traffic jams, congestion and pollution. Construction-related traffic is responsible for 25% of total traffic (UFEMAT, 2008). In addition, it is responsible for a large share of CO₂ emissions within urban logistics (CE Delft, 2016a), which accounts for 34% of all transport-related CO₂ emissions (CE Delft, 2016b).

In a large-scale construction project, the actual percentages locally will be higher rather than lower. If that project takes place in the centre of a busy urban area, this poses a challenge in terms of transport and logistics. Such a challenge will undoubtedly arise in Nijmegen, where both Radboud University and Radboud UMC (University Medical Centre) will be partly demolished and rebuilt. It will be essential to implement smart construction logistics, learn from success stories elsewhere, and integrate these insights into a new way of working. Because every city and every project is different, these lessons will need to be translated to the specific situation in Nijmegen.

KennisDC Logistiek Gelderland, the logistics research group at HAN University of Applied Sciences, was asked to explore the options and to advise Radboud in this area, supported by KennisDC Logistiek Amsterdam and the programme manager of construction logistics at Topsector Logistiek, an organization that promotes the competitiveness of the Dutch logistics sector. The main research question is:

What lessons from construction logistics may be relevant for the demolition and construction work at Radboud?

This report is structured as follows. Section 2 reviews the literature on construction logistics concepts, while section 3 describes several case studies that used these concepts. The literature review was complemented by interviews with experts, focusing on the conditions under which such concepts can be applied and the potential results. Section 4 describes the situation at Radboud with a view to identifying the local conditions. Section 5 identifies those construction logistics concepts that are applicable at Radboud and which can be expected to lead to the best results. Finally, a number of conclusions and recommendations are provided.

2. Overview of construction logistics concepts

Construction logistics encompasses all measures involved in ensuring that equipment, material and workers are transported, safely and for minimal cost, to the right place at the right time (Quak et al., 2011). According to Van Goor et al.'s (2003) integrated logistics concept, the following four elements need to be accounted for:

- infrastructure
- planning and control
- information

- organisation.

The effectiveness of this process can be measured by means of logistics performance indicators.

This section describes a number of construction logistics concepts for each of these elements. The concepts are based on the best practices identified by Van Merriënboer et al. (2013) and supplemented with concepts used in the recent Dinalog projects Amstelkwartier and De Trip (see next section for a description of these projects). Although some concepts are relevant for several elements, we describe them only under the most important one. All such construction logistics concepts can be described in a construction logistics plan; Lundesjö (2015) provides a checklist for this.

2.1 Infrastructure

2.1.1 Construction consolidation centre

A construction consolidation centre (CCC, sometimes also shortly referred to as “hub”) is a transshipment point that is both conveniently located for suppliers and minimises disturbance in the city centre. It provides temporary storage space for suppliers’ “push” deliveries and allows “pull” deliveries to be transported to the construction site in accordance with the construction schedule. Ludema (2015) describes such a hub as a place where goods can be packaged so as to increase the capacity of trucks headed to the city centre and to reduce the number of transports required. Supplies can also be transported using smaller (electrical) vehicles. As Figure 1 shows, delivery of goods via a construction consolidation centre calls for a different type of infrastructure.

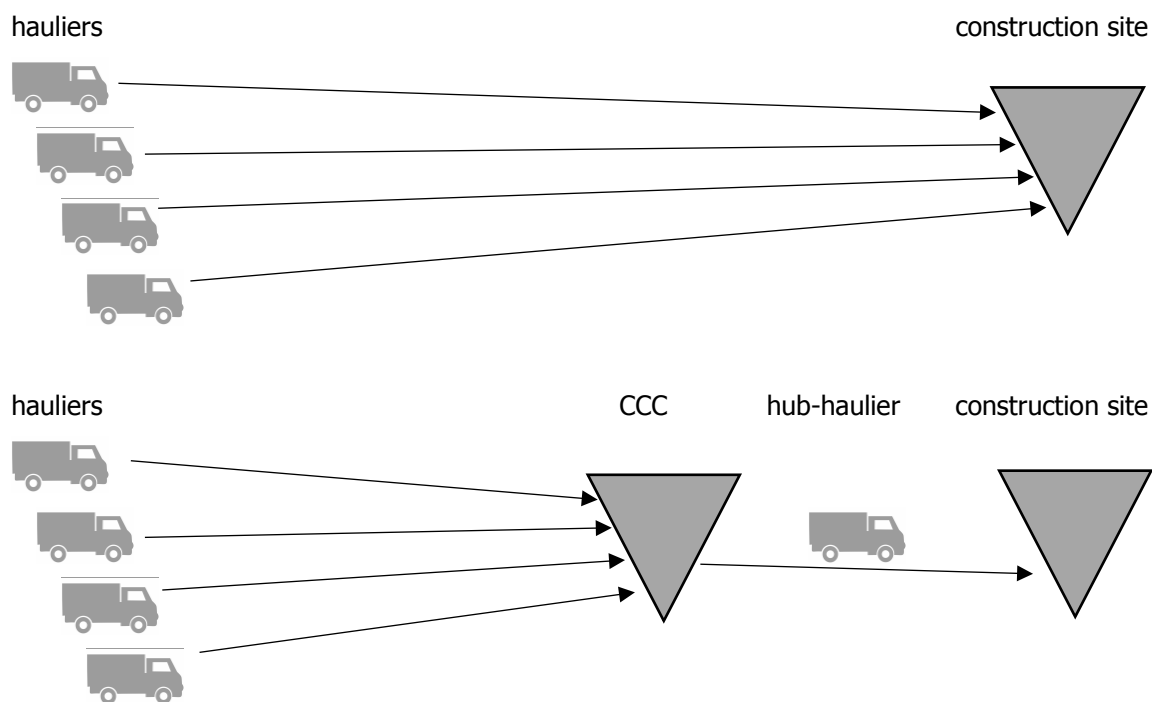


Figure 1: situation with and without CCC

This also results in a different cost structure. The transport costs can now be divided into a long haul to the hub and a short haul into the city. The hub is typically more accessible for trucks and remains open for deliveries longer than the construction site. Naturally, the hub itself gives rise to additional costs, consisting of overheads and operational costs. However, there are significant cost savings to be achieved, so the main challenge is in distributing these costs and benefits among the stakeholders.

In sum, the main requirements for establishing a hub are as follows:

- an accessible location both for suppliers and for trucks delivering to the construction site itself
- expertise in organising and managing a CCC (see 'Construction logistics coordinator')
- standardised information exchange, including construction schedule (see 'BIM')
- optional: space for prefabrication (see 'Prefabrication')
- compliance with obligation to supply through the CCC
- fair distribution of costs and benefits such that all stakeholders profit.

Such a CCC has the following effects (see case studies below):

- roughly 45% increase in productivity
- halving of inner city transport
- increased safety due to fewer transport movements
- increased delivery reliability
- 15% decrease in waste
- 25% reduction of CO₂ emissions in the city
- up to 0.8% lower total costs.

2.1.2 Prefabrication

Prefabrication (or prefab) refers to the prior construction or assembly of components to be transported to the construction site and installed later. This may involve anything from entire hotel rooms to kitchens which are put together elsewhere. VolkerWessels, a large contractor, increasingly makes use of prefabrication, both on order and by prefabricating things themselves at a construction consolidation centre. The latter reduces costs, waste, space and transport. Because inner-city construction sites often lack space and scheduling in construction projects is becoming ever tighter, it is important that work that can be done at the hub is actually done at the hub. Further, not all packaging materials need to be taken to the construction site only to be removed again afterwards, which saves additional time, freight and therefore money (TLN 2015).

Requirements for prefabrication:

- a suitable location/hub where prefabrication can take place
- work activities and components that are suitable for prefabrication.

Effects of prefabrication (see case studies below):

- reduced costs
- fewer transport movements and less waste
- more efficient use of working hours
- more space on the construction site.

2.1.3 Transportation of workers

A new trend in construction is the use of public transport or shuttle buses to take workers to and from the construction site. TNO (2012) highlights the benefits of employees travelling to the site by public transport. However, depending on accessibility, capacity and efficiency, not all construction projects are suited to the use of public transport. An alternative option is to organise a private shuttle bus for workers.

Requirements for the use of public transport / a shuttle service for workers:

- public transport network with adequate capacity and parking space
- financial and operational feasibility of shuttle service.

Effects of public transport / a shuttle service:

- more space on the construction site as fewer employee parking spots are needed
- less traffic in the city centre
- lower CO₂ emissions in the city centre.

2.2 Planning and control

2.2.1 Construction logistics ticket

A construction logistics ticket gives the supplier access to the construction site to deliver goods under the principle "no ticket, no access". The aim is to retain control of the onsite logistical process, provide clarity for suppliers and create a safe work environment (Segeren 2010).

Requirements for establishing a ticketing system:

- capacity to monitor compliance
- a contact point for users (see 'Construction logistics coordinator')
- integration in the IT systems of contractors and subcontractors.

Effects of a ticketing system:

- control of the logistical process to and from the construction site
- clarity for suppliers and hauliers
- less stationary or parked construction traffic in the city centre
- lower CO₂ and fine-particle emissions in the city centre.

2.2.2 Logistics control tower

A logistics control tower is a control centre from which various logistical chains can be coordinated. Its aim is to ensure that the respective parts of the construction logistics chain are geared to one another, focusing on a select number of projects or pilot projects. Key issues with a control tower are willingness to work together, coordination of ICT facilities and identification of the logistics coordinator (De Vries et al. 2015).

Requirements for establishing a control tower:

- willingness to share data
- willingness to work together
- synchronisation of IT systems
- a logistics coordinator (see 'Construction logistics coordinator').

Effects of a control tower:

- ability to manage, coordinate and predict flows of goods
- ability to provide systematic feedback to the companies involved
- less congestion in the city centre.

2.2.3 Construction logistics coordinator

A construction logistics coordinator, or LC, coordinates all construction logistics to the construction site, with or without the involvement of a hub. Specifically, the LC manages, monitors and sends all required materials to the construction site in accordance with the construction schedule (potentially making use of a BIM system). Kolkman et al. (2008) outline the benefits of the use of an LC in the business case TOP-Bouw, showing that total costs can be cut by up to 2.5%. Of this, 85% consisted in savings for the contractor, who was able to work more efficiently, while the remaining 15% involved savings for the supplier, for example, because of fewer incorrect shipments.

Requirements for installing a construction logistics coordinator:

- a candidate with knowledge and experience in both construction and logistics
- stakeholders who are willing to cooperate
- a system within which the LC can work.

Effects of installing a construction logistics coordinator:

- possible cost savings of 2.5%
- a more structured construction logistics process
- increased safety due to control of inner city transport movements
- option to add other concepts, such as a construction logistics ticketing system, a control tower or a construction hub.

2.3 Information: BIM / planning tool

A Building Information Model, or BIM, is "a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle" (National BIM standard 2007). This "virtual construction" depicts the project as a 3D model, to which relevant, non-geometric project data such as scheduling information and logistics plans can also be added. This enables all parties involved in the chain of design, construction and management to share information via open standards, thus improving coordination and preventing errors. Lundesjö (2015) provides a comprehensive overview of the pitfalls in construction logistics and the solutions offered by BIMs and data management.

Not all parties in the chain plan their activities by means of IT systems, and even when they do, linking all these systems to one another or to the BIM is not always easy. But in a supply chain involving many parties, having accurate, linkable IT systems is essential for reliable and modifiable scheduling. An online planning tool can also help in this regard.

Requirements for using a BIM:

- integration of contractor's, subcontractors' and suppliers' IT systems
- knowledge of/experience with the system
- willingness of stakeholders to work with it.

Effects of a BIM:

- oversight for all stakeholders
- ability to systematically monitor the construction process
- fewer errors on the construction site and in the construction process
- ability to predict logistical flows.

2.4 Organisation

2.4.1 Construction logistics cooperation

The benefits of working together in a chain would seem to be obvious, but it rarely occurs in reality. Cooperation means spreading the risks, but also the costs. It also requires an initial time investment – but suboptimal cooperation will end up costing even more. According to Dijkmans (2014), successful

cooperation in construction logistics chains in Amsterdam results in fewer transport movements and greater sustainability.

Our interviews with experts, too, showed that there is room for improvement when it comes to cooperation. Just as with a construction logistics hub, stakeholder interests need to be acknowledged and solutions sought that benefit everyone collectively as well as individually. In a role play with students, Macharis et al. (2015) used the MAMCA method to highlight the interests of different stakeholders in urban construction and thus facilitate dialogue.

2.4.2 BLVC approach

The Accessibility, Livability, Safety and Communication plan (in Dutch *Bereikbaarheid, Leefbaarheid, Veiligheid en Communicatie*, hence BLVC plan) is a systematic plan to safeguard these four components during the construction logistics operation. For each component, the plan has a number of checklists that can be used to analyse the project and compose the plan (Het BLVC-uitvoeringsplan, n.d.). Quak (2011) emphasises the importance of a BLVC plan in the preparatory phase, suggesting that a central point of contact be installed to monitor the implementation of the plan during the construction phase. An example can be seen in the form of the City of Amsterdam's BLVC plan (2008).

Requirements for working with a BLVC plan:

- manageable and verifiable standards for the four components
- an individual who can maintain control of the plan
- willingness of stakeholders to cooperate with the plan.

Effects of working with a BLVC plan:

- upholding of relevant standards in an urban construction project
- safeguarding of accessibility, liveability, safety and communications throughout the project
- a well-informed environment during the project.

2.4.3 EMAT criteria

EMAT stands for Economically Most Advantageous Tender. During the tendering phase, clients can use EMAT criteria to score contractors' proposals on a range of different criteria, thus preventing tenders from being awarded solely on the basis of the lowest price. Van Amstel et al. (2015) show how the criterion "logistical quality" can be established on the basis of Van Goor et al.'s (2003) integrated logistics concept.

2.5 KPIs

Key Performance Indicators, or KPIs, are metrics that allow processes and projects to be compared with one another. As KPIs can vary, they can be difficult to compare across projects. The SCOR model provides

a set of tools for establishing comparable KPIs (although it does not take environment-related KPIs into account (Vrijhoef 2015)).

Requirements for working with KPIs:

- available and comparable KPIs
- knowledge of/experience with measuring KPIs
- personnel to do the measurements (e.g. students).

Effects of working with KPIs:

- insight into the effects of construction logistics
- increased commitment of stakeholders and higher chances of use in other construction projects
- ability to make modifications in a timely manner and reduce costs
- enhanced ability to evaluate and reflect on a construction project.

3. Results obtained in practice with construction logistics concepts

The previous section presented smart construction logistics concepts. This section presents a number of case studies, illustrating the results that can be achieved by applying smart construction logistics concepts.

3.1 Construction Consolidation Centre, London

Concepts used:

- permanent (construction) consolidation centre
- KPIs
- construction logistics coordinator
- prefabrication
- government measure: city closed to external construction logistics transport.

Lundesjö (2011) studied the results of a construction logistics hub in London, identifying three major advantages: 1. Reduced pressure on the local environment due to better use of truck capacity. 2. Reduced pressure on local infrastructure by avoiding the need for freight traffic in the city centre. 3. Optimal use of the construction site; materials were delivered to the construction site as needed, rather than taking up space on site. The study also highlighted three disadvantages of the hub: 1. Little experience in the use of such hubs in the UK. 2. Need for a central coordinator to manage transportation, supplies and delivery, which calls for effort on the part of the supplier, haulier and contractors. 3. Higher costs due to additional handling. The most striking effects of the use of the construction logistics hub were:

+ 95% delivery reliability

- + 25% safety
- + 47% productivity
- 68% transports to construction site
- 15% waste
- 75% CO₂ emissions

3.2 Linköping University Hospital, Sweden

Concepts used:

- construction consolidation centre
- logistics coordinator (third-party logistics service provider at construction hub)
- online planning tool
- construction ticketing system.

As described in Ekeskar and Rudberg (2016), the university hospital in Linköping, Sweden, is being renovated over the course of 10 years. A large section will be entirely new, with four buildings covering 66,000 m² of floor space being erected in the first phase. In this phase 40 to 45 deliveries are expected per day. The client has a third-party logistics service provider (3PL) to coordinate all logistics from the hub to the construction site. The relationships between the various parties are depicted in the Figure 2.

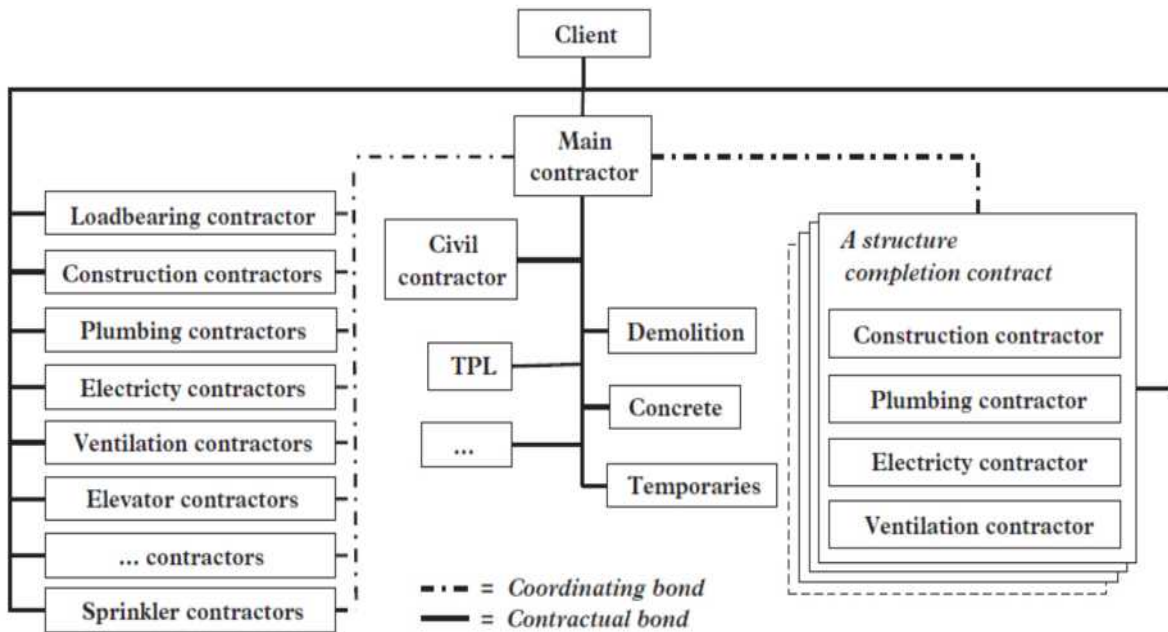


Figure 2: Relations between parties in the Linköping construction project (Ekeskar and Rudberg, 2016).

Figure 3 shows the organisation of logistics between supplier, construction hub and construction site. The contractor pays a certain sum per unit to the 3PL for unloading at the hub and transportation to the construction site. Additionally, the contractor pays a fine to the 3PL if the supply route or location is blocked.

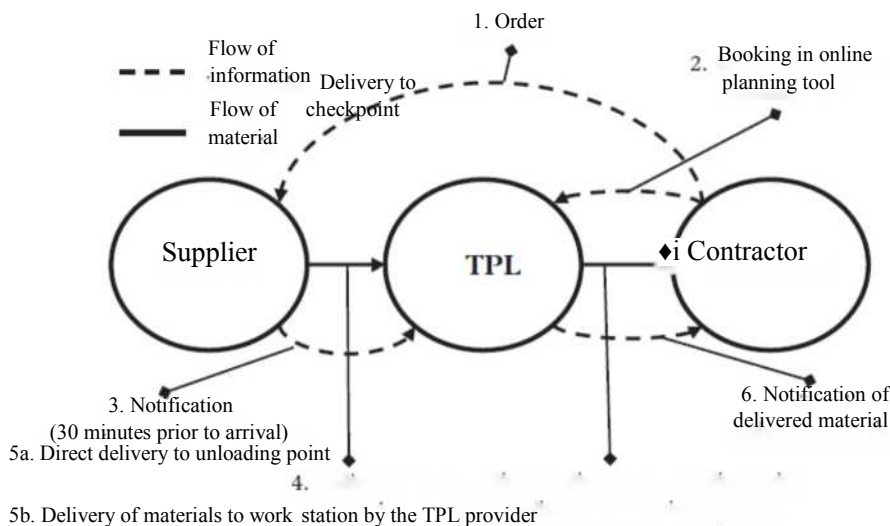


Figure 3: Flow of goods and information in Linköping construction project (Ekeskar and Rudberg, 2016)

As can be seen in the summary below, the results were positive. But as Ekeskar and Rudberg (2016) explain, there was also room for improvement. The main issue concerns the positioning of the 3PL under the main contractor, which meant the 3PL had no direct control over the main contractor or subcontractors, let alone their suppliers. The main contractor regularly circumvented the 3PL, which signalled to the subcontractors that the agreements were unimportant. For optimal logistics, it is essential that contractors

and suppliers cooperate with the 3PL and stick to the agreed rules. The main contractor, however, found it difficult to explain the rules to his suppliers because he was unfamiliar with or did not understand their logistical underpinnings. Better direct contact between the 3PL and suppliers could have improved the use of bundling and temporary storage (which was not available at the hub!).

In addition, the 3PL's own focus on rules and agreements was not conducive to effectiveness. It would have been better if the 3PL had focused more on creating understanding and awareness and changing the attitude and culture of the other parties in the supply chain. For example, the subcontractors felt that the costs for the 3PL were high; greater insight into their own hidden logistical costs could have helped to change their attitude.

Finally, the client could have played a better role. After imposing the 3PL solution, the client left responsibility for it in the hands of the main contractor and avoided logistical tasks himself. More logistical expertise on the part of the project managers on the client's side could have improved the situation.

- + delivery reliability (1 to 2 of the 150 to 200 deliveries were not in the right location; most deliveries were on time; 70% within 15 minutes of the scheduled time)
- + working conditions (less stress, more focus on core tasks)
- + productivity (fewer workers needed than expected)
- + optimal use of equipment (cranes, lifts, etc.)
- + ambulance accessibility (only one delay caused by construction work)

3.3 Amstelkwartier and De Trip

Concepts used:

- construction consolidation centre
- logistics coordinator
- prefabrication
- KPIs
- shuttle bus for employees
- RFID
- BIM.

Contractor: VolkerWessels, a large international working Dutch contractor who develops smart construction logistics concepts company-wide

In collaboration with: TNO, HU University of Applied Sciences Utrecht, Rotterdam University of Applied Sciences and Delft University of Technology

Vrijhoef et al. (2015) compare two pilot projects (De Trip in Utrecht and the Amstelkwartier in Amsterdam) on the basis of the KPIs established for these projects. By using a construction hub in combination with a

logistics coordinator, deliveries could be scheduled according to the rhythms of the construction site. The hub provided space for prefabrication, which meant the work on the construction site could proceed faster. Further, the shuttle bus for workers ensured that the inner city construction sites were not overflowing with parked cars. Van Merriënboer (2016) indicates that despite early setbacks, once the hub was running at full capacity the De Trip project ran three months ahead of schedule.

A key lesson from this study is that it makes sense to reuse KPIs in different projects, which makes it easier to compare across projects. Results based on measured KPIs:

- + 45% productivity
- + 50% loading capacity
- 18% kilometres travelled
- 54% freight in city centre
- 23% CO₂ emissions
- 0.8% budget
- 40% delivery time.

4. Promising construction logistics concepts for Radboud

4.1 Construction logistics situation at Radboud

The demolition and construction work at Radboud will take place on the Heyendaal campus in Nijmegen. Both the university and the hospital will be renovated, each under its own project management team. The first construction projects have already been tendered. The tendering process will continue into 2018. The construction work is expected to last until 2020, and involves the following:

- renovation of the dentistry building
- addition of a new wing to the Gymnasium building
- refurbishment of the interior of the preclinical department
- renovation of the education building (expected completion: 2018). This is a complex project as the building is surrounded by a ring road and located near the main entrance to the hospital as well as the castle monument
- reconstruction of the area below the car park of the HAN sports halls (expected completion: September 2018)
- renovation of the monastery
- construction of a new social sciences building
- extension of the biology building
- construction of Building S: 45,000 m² surface area with high sustainability ambitions
- renovation of the Erasmus Building (around 2020)

- reconstruction of the Slotemaker de Bruïneweg – one of the potential supply routes – by the City of Nijmegen in 2017; this will need to be taken into account.

Radboud UMC aims to keep all buildings as flexible and compact as possible. Due to the developments in healthcare and ICT, the number of patients treated at the hospital may decrease in the future. Because the exact developments cannot be foreseen, however, flexibility is important. Experiences from the construction of the Erasmus UMC showed that because medical developments can be extremely rapid, it is unwise to lock in construction plans too early. In some cases at Erasmus it turned out to be better to renovate buildings after completion rather than throw the plans into disarray during the building process (Limburgia 2014).

Discussions with both the city council and the Radboud project managers revealed a willingness to use smart construction logistics solutions. Questions arise as to what these solutions should involve, which stakeholder should take on which role, and how any costs and revenues should be shared such that all stakeholders benefit. The first question will be answered below; the others call for further study.

4.2 Possibilities for smart construction logistics

Table 1 outlines the relevant features of the construction project and their logistical consequences.

Table 1: Logistical features of Radboud renovation

Feature	Implications for construction logistics
In city centre	Little space on the construction site, busy traffic: smart construction logistics necessary
Many visitors (employees, patients, students)	Must remain (relatively) accessible and safe; separation of traffic flows (pedestrians/cyclists/cars): smart construction logistics necessary
Ambulance traffic	Must remain fully accessible: smart construction logistics necessary

Will take several years	Investment in good construction logistics possible; monitoring by means of KPIs will allow for interim improvements
Major financial investment	Investment in good construction logistics possible
Technology develops rapidly	Construction plans to remain flexible
Two project managers (university and hospital)	Coordination required
Available sites nearby	Construction logistics hub possible
Willingness to make use of smart construction logistics concepts	Investment in good construction logistics possible; support required in design of logistics and stakeholder management; follow-up research necessary

On the basis of these features and their logistical implications, the next section outlines the most promising construction logistics concepts for Radboud.

5. Conclusions and recommendations

Based on the foregoing analysis of construction logistics concepts, the construction logistics hub appears to offer the greatest benefits for Radboud. A construction logistics hub is a distribution centre on the outskirts of a city which is easily accessible for hauliers and from which the construction site can be efficiently supplied. The advantages have been demonstrated on several occasions. Moreover, such a hub facilitates the use of other smart concepts. The analysis of the situation at Radboud revealed that there is both a need and a willingness to use smart construction logistics concepts, and that the project managers already have ideas for a site for a hub.

The establishment of a construction logistics hub at Radboud is necessitated by the busy location of the construction site, limited space, high number of visitors and need for ongoing accessibility (especially for ambulances). It is recommended to establish the hub in combination with:

- prefabrication (to save time and space)
- a ticketing system (to regulate traffic to, from and on the construction site)
- a shuttle service for employees (to regulate traffic and save parking space)
- a construction logistics coordinator (to ensure that the above benefits are realised by means of smart planning)
- monitoring of the construction process by means of KPIs (to learn from and improve on previous experiences).

All this can only succeed if certain conditions are met. For instance, the cooperation of and collaboration between different stakeholders is essential, as clearly shown by the Linköping case study. Further, it is important for the stakeholders to realise that this may mean taking on additional roles. To illustrate:

- the municipality can play a role in providing a site for the hub, identifying preferred routes between the hub and the construction site, laying down requirements for vehicles in the building code, laying down conditions in the environmental permit, and so on
- the client can mandate the use of a hub in the tender and evaluate contractors' plans for the hub by means of EMAT criteria (in addition to other criteria)
- the main contractors can establish a logistical concept that is optimal for them, taking measures to involve their subcontractors and suppliers and to share the costs and benefits
- the subcontractors, suppliers and hauliers can actively choose to cooperate in the new way of working.

The latter is merely an illustration; the precise roles of all these parties remain to be addressed. In any event, it is essential to ensure that the costs and benefits are shared. Smart construction logistics have financial and other important benefits (peace and quiet, safety, sustainability, etc.). To engage all stakeholders in a new way of working, it is important for them to acknowledge these shared benefits in their attitudes and work culture. We look forward to addressing these aspects in follow-up research. Concretely, such follow-up research should focus on:

- developing the logistical concept of the construction hub for Radboud, including a detailed description of the roles of all directly involved stakeholders
- sharing the costs and benefits of the new logistical concept and fostering support among all stakeholders
- translating the above into concrete tendering procedures/EMAT criteria/contracts and conditions for environmental and other permits.

And above all: involving all stakeholders in the process, raising awareness and fostering support for the concepts and ideas to be developed collectively.

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