Abstract Researchers emphasize that the ability of a freight consolidation centre (FCC) to function in an environment depends on more than only its technological or logistical design. The need for a design that contains more than only technological or logistical aspects is advised to increase chances on successful implementation of a FCC. What such a design should contain is however not mentioned. In this paper literature is studied to find aspects that were important for the functioning of various freight consolidation centres. With this literature study six critical design variables for the functioning of a freight consolidation centre were determined. The findings were validated in an expert interview. Designers of freight consolidation centres are advised to take at least these six variables into account when designing a FCC. Future research could be carried out to assess whether more design variables are critical for the functioning of a FCC and to determine the relative importance of the critical design variables.

Keywords: freight consolidation centre; design; functioning; implementation; critical design variables

1. Introduction

A freight consolidation centre (FCC) is a distribution centre serving a specific site at which smaller deliveries to the site and/or consignments from the site are brought together. A FCC is typically located at some distance from the site it services. As a result, more consolidated freight flows can enter and leave the site. Freight consolidation centres can serve various types of sites, such as harbours, shopping centres, construction sites or entire urban areas (Lewis, Fell, & Palmer, 2010). In literature different names are used for FCCs, such as urban consolidation centres (Allen, Browne, Woodburn, & Leonardi, 2012) and shared use freight terminals (Regan & Golob, 2005). However, they refer to the same concept.

Freight consolidation centres are developed for financial, environmental and logistical reasons. Objectives of FCCs include (Allen et al., 2012; Browne, Sweet, Woodburn, & Allen, 2005; Lewis et al., 2010; Marinov, Zunder, & Islam, 2008; Mok, 1994):

- To reduce freight traffic via the road in the area or at the site the FCC serves.
- To reduce the need for storage and other logistics facilities in the area or at the site it serves.
- To alter the type of road vehicles entering the specific area or site.
Worldwide thousands of freight consolidation centres have been designed over the past decades. Many of these designed consolidation centres have actually been constructed and have resulted in financial, environmental and logistical improvements. Others faced serious complexities during implementation or could not (yet) be implemented at all (Browne et al., 2005).

One of the main reasons mentioned in literature for FCCs facing difficulties during implementation is the lack of a complete design of such a facility. It has often happened that much emphasis was placed on designing a FCC technologically and logistically and that for example organizational and financial issues were not or insufficiently taken into account. Such issues (the non-technological or non-logistical issues) are also very important for the functioning and therefore for a successful implementation of projects/facilities in the transportation sector, such as FCCs (Konings, Kreutzberger, & Maraš, 2013; van Binsbergen, Konings, Tavasszy, & van Duin, 2013; Veenstra, Zuidwijk, & van Asperen, 2012).

Researchers emphasize the need for more than only a technological or logistical design, because not only technological and logistical aspects of a design are critical for the functioning of a FCC. Other design aspects, such as organizational and financial, also determine whether a FCC will be able to function within its environment and thereby whether a FCC is implementable (Zhou & Wang, 2014). Researchers however do not explicitly mention what the design of a freight consolidation centre exactly should contain so that a design fully describes how the facility will function in the environment.

The aim of this research is to define design variables of freight consolidation centres that have a critical influence on the total functioning of these facilities in their environment. With the total functioning more than only the technological or logistical functioning of the FCC in the environment is meant. By not missing on (at least) all these critical variables, a FCC can be designed in such a way that it will function in its environment and thereby will be implementable.

In this paper the methodology is explained in the second section. In the third section the scope of the literature study is explicated. Only literature about specific FCCs is studied for this research. In the fourth section a study is done towards urban consolidation centres. It is studied what aspects were important for the functioning of various urban consolidation centres. The same is done for sea freight consolidation centres in section five and for air cargo consolidation centres in section six. The findings of these literature studies are brought together and analyzed in the seventh section. Thereby the critical design variables for the functioning of a FCC are defined. Section eight explains how an expert validated the results. Section nine discusses the limitations to the research and the tenth section contains the conclusions and advices for future research.

2. Methodology

In literature it is not mentioned what design variables can be considered critical for the functioning of a FCC. However, in some researches towards the design of specific FCCs
or in evaluations of specific FCCs, lists of the important aspects in those specific cases can be found. A literature review is conducted to become known with as much as possible of those lists. The literature studied includes academic journals, research projects, case studies and trade press.

The findings in literature about important (design) aspects of specific freight consolidation centres are brought together. An overall list is composed of unique aspects that were considered important for specific FCCs in the different case studies. Subsequently it is analyzed which of these aspects are actual design variables and which are other kind of aspects of design or implementation. With the design variables an influence diagram as described by Howard and Matheson (2005) is set up to find the mutual relations between all unique mentioned design variables. In such an influence diagram it becomes clear what design variables have an influence on the way other variables can be/will be designed. Based on the mutual influences that the variables have on each other, it is determined which variables are critical for the functioning of a freight consolidation centre. These are the variables that have the most influence on the design of other variables and are least influenced by other variables. Such variables are independent design variables with an influence on the rest of the design of a freight consolidation centre and thereby with a critical influence on the functioning of such a facility.

The conclusions that are drawn from the literature study and subsequent analyses are validated in an expert interview with dr. J.W. (Rob) Konings, senior researcher freight transport at the OTB department of the TU Delft (Konings, 2014).

3. Scoping of FCC literature studies

Characteristics of the environments (sites or areas) that freight consolidation centres serve differ. The organizations that are involved may differ, different regulation and legislation may be at place, etc. The environments that different FCCs serve may also differ from a logistical point of view. The amount of senders and receivers of freight can be different per environment, as well as the inter environment freight flows. For this research three different logistical environments were distinguished. These logistical environments are explicated in Figure 1.

From a logistical point of view the third possible environment of a FCC shown in Figure 1 is considered to be the most complex one. In this environment multiple senders and receivers are present and inter environment freight flows are carried out (freight flows between different senders or receivers of freight in the area or at the site the FCC serves). At a FCC that serves this type of environment vehicles will arrive from outside the environment to bring freight to multiple receivers in the environment and/or to pickup freight from multiple senders from within the environment. At a FCC that serves the first or second type of environment vehicles will arrive from outside the environment to bring freight to only receiver in the environment and/or to pickup freight from only one sender from within the environment. Splitting and consolidation of freight is expected to be
more complex in a FCC that serves the third type of environment than in a FCC that serves the first or second type of environment.

Figure 1: Possible logistical environments of FCCs before and after FCC implementation

<table>
<thead>
<tr>
<th>1: FCC ENVIRONMENT WITH ONE SENDER/RECEIVER AND NO INTER ENVIRONMENT FREIGHT FLOWS</th>
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<td><img src="image1.png" alt="Diagram" /></td>
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<tr>
<th>2: FCC ENVIRONMENT WITH MULTIPLE SENDERS/RECEIVERS AND NO INTER ENVIRONMENT FREIGHT FLOWS</th>
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<td><img src="image2.png" alt="Diagram" /></td>
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<tr>
<th>3: FCC ENVIRONMENT WITH MULTIPLE SENDERS/RECEIVERS AND INTER ENVIRONMENT FREIGHT FLOWS</th>
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<td><img src="image3.png" alt="Diagram" /></td>
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At least from a technological/logistical point of view freight consolidation centres that serve the third type of environment are considered most complex to design. Other aspects, such as organizational ones, could be more complex to design as well. In researches towards the design of FCCs serving the first or second type of environment or in evaluations of such designs, certain aspects of the facilities may not be classified as important that are important if the FCC would have served the third type of logistical environment. Vice versa this is not expected. To find design variables that can be considered critical for the functioning of any freight consolidation centre, literature is only studied about freight consolidation centres developed in or designed for the third possible logistical environment of Figure 1.

4. Important design aspects of urban consolidation centres

A first type of freight consolidation centre that serves the third type of logistical environment from Figure 1 is the urban consolidation centre (UCC). A UCC refers to a central pickup and drop-off location for goods. UCCs can serve specific sites, such as shopping centres, or entire urban areas such as large cities. The word urban implicates that a UCC does not serve dedicated freight hubs, such as airports or seaports. UCCs are located at some distance from the sites they serve and make sure that trucks do not have to visit the (often) congested urban sites or areas anymore. Trucks can deliver freight for multiple receivers at the UCC or pick up freight from multiple senders. Transportation of freight between the urban consolidation centre and the site or area it serves is carried out with vehicles that can realize high average vehicle loads because of the consolidation of freight in the UCC. Thereby the site gets visited with fewer trucks than before (Allen et al., 2012; BEST Urban Freight Solutions, 2008; Browne et al., 2005; Lewis et al., 2010).

An extensive literature review and field study about urban consolidation centres was conducted by Browne et al. (2005). In total 67 urban consolidation centres, built between 1970 and 2005 in Canada, Europe, Japan and the United States were analyzed. Among other aspects Browne et al. (2005) analyzed the differences in design between different urban consolidation and the influence of these design differences on the functioning of the UCCs. To point out the differences in design between different urban consolidation centres, Browne et al. (2005, p. 4) listed the design aspects that came forward in their research as most characterizing the nature of an urban consolidation centre. These design aspects are listed below.

- Objectives of a UCC
- Distance from UCC to delivery area
- Spatial coverage
- Range and type of products handled
- Transport modes utilized
- Range of services provided
- Flexibility of operations (for example fixed delivery schedules or on demand)
- Ownership and operation of UCC
- Finance issues, particularly the nature of any financial support
- Responsibility for transport operations
- Degree of permanency of the centre and its operations
- Role of local authorities and other public sector bodies
- Compulsory or voluntary for users of the UCC
- Freestanding initiative or incorporated into the wider policy or regulatory framework of an urban area or region

Other extensive researches towards urban consolidation centres were carried out by BEST Urban Freight Solutions (2005, 2008), a sort of European think tank for urban freight problems. In these studies (the designs of) multiple European UCCs were studied. In one of these studies of BEST Urban Freight Solutions (2008) the main design issues when planning to develop an urban consolidation centre (in Europe) were mentioned. These main design issues are listed below (BEST Urban Freight Solutions, 2008, pp. 72-73).

- Participation of interested parties
- Proximity of the urban consolidation centre from the delivery area
- Management structure
- Products handled
- The operation of the UCC
- Funding

Except for these lists of important design aspects by Browne et al. (2005, p. 4) and BEST Urban Freight Solutions (2008, pp. 72-73) other researches towards UCCs do not explicitly specify what aspects of design are important for the functioning of such a facility.

5. Important design aspects of sea freight consolidation centres

In various seaports in the world deep sea vessels carrying containerized freight arrive at and depart from multiple container handling terminals. In the harbour of Rotterdam there are for example approximately 30 of such terminals that all serve different deep sea vessel carriers (Notteboom & Konings, 2004). Hinterland transportation from and to these terminals takes place via road, rail and inland waterways (Roso & Lumsden, 2009).

Because of the growing worldwide sea freight volumes over the past decades especially the large seaports are increasingly facing two problems:

1. The creation of more capacity has become difficult because of space shortage (and other physical and non-physical limitations to site expansion) (Rosa & Roscelli, 2009; Roso & Lumsden, 2009; Slack, 1999).
2. Congestion in these seaports has grown for the vehicles carrying out the hinterland transportation (Konings et al., 2013; Roso & Lumsden, 2009; Roso, Woxenius, & Lumsden, 2009).
To solve the above-mentioned problems in (large) seaports, different freight consolidation centres have been initiated, of which some have been developed. Examples are satellite terminals (Slack, 1999), extended gates (Veenstra et al., 2012), barge hub terminals (Pielage, Konings, Rijsenbrij, & van Schuylenburg, 2007) and dry ports (Roso & Lumsden, 2009).

When trucks or trains carry out the hinterland transportation from and to large seaports, they generally only visit one container handling terminal (van Der Horst & de Langen, 2008). No inter seaport freight flows occur by truck or train. Consolidation centres serving seaports for trucks and trains therefore serve the first or second type of logistical environment as shown in Figure 1. Literature written about these consolidation centres is hence not studied.

Consolidation centres for inland barges on the other hand do serve the third type of logistical environment from Figure 1. Inland barges often need to visit multiple container handling terminals when pickup up or delivering freight at a seaport, such as in the harbour of Rotterdam (Konings, 2007, pp. 444-445). From a visualization by Konings et al. (2013) it becomes clear that freight consolidation centres at seaports for inland barges need to deal with multiple is and receivers of freight and inter seaport freight flows (see Figure 2). Literature is studied about consolidation centres for inland barges serving (large) seaports.

Many of the researches towards potential freight consolidation centres for inland barges serving large seaports were conducted only from a logistical point of view. In these studies only logistical design aspects that are important for the functioning of these type of FCCs are mentioned. From a logistical point of view the following aspects were considered to be of high importance for a potential freight consolidation centre for inland barges serving the harbour of Rotterdam (Froeling, 2008; Konings et al., 2013; Pielage et al., 2007):

- The proximity of the consolidation centre to the container handling terminals
- The setup of the shuttle service
- The services offered in the consolidation centre

Pielage et al. (2007) also explicitly mention one non-logistical design variable that is important for the functioning and thereby the chances on successful implementation of a freight consolidation centre for inland barges serving a large seaport. This non-logistical design variable is the model of costs and gains sharing.
6. Important design aspects of air cargo consolidation centres

Hinterland transportation of air cargo to and from airports generally always takes place via road. Similarly to seaports and some urban areas, space shortages and truck congestion are also present at cargo airports (Mok, 1994; Waters, 2013). To solve these problems some airports make use of air cargo consolidation centres. An example of such an air cargo consolidation centre is the Baraki City Cargo Terminal, a FCC serving the international airport of Tokyo (Mok, 1994). At most airports there are multiple senders and receivers, because freight for/from different cargo airlines need to be delivered/picked up at different cargo ground handlers. Inter airport freight flows between the cargo ground handlers also takes place (Waters, 2013). An air cargo consolidation centre (generally) serves the third type of logistical environment from Figure 1.

The only available (design) study in literature towards an air cargo consolidation centre was conducted by Mok (1994). Two decades ago Mok (1994) did a study towards a potential air cargo consolidation centre for the Hong Kong International Airport, in which
he extensively analyzed the design and functioning of the Baraki City Cargo Terminal. The objectives of this air cargo consolidation centre were to reduce the need for space for freight facilities at the Hong Kong International Airport and to reduce truck movements at and around the airport (Mok, 1994). Mok (1994) composed a list of most important aspects for a conceptual design for an air cargo consolidation centre serving the Hong Kong International Airport. These aspects are listed below.

- The proximity of the facility to the Hong Kong International Airport
- The responsibility for the operations in the facility
- The activities performed in the consolidation centre
- The setup of the link between the facility and the airport via road transportation (for example: type of vehicles, frequency, etc.)
- The way in which documentation and charging is setup

No other (design) studies towards air cargo consolidation centres are available in literature.

7. Synthesis

Various researches towards specific freight consolidation centre(s) that all serve the third type of logistical environment from Figure 1 were studied. The studied researches include design studies and design evaluations of urban consolidation centres, consolidation centres for inland barges serving seaports and air cargo consolidation centres. In these researches different (design) aspects were named as being important for the functioning of the specific FCC(s). All these aspects are listed in Table 1. Aspects from the different researches studied that are similar or considered similar by the interpretation of the author of this paper are highlighted with the same colour. In total 19 unique important aspects for the functioning of a freight consolidation centre were mentioned in the studies pieces of literature.
Table 1: Overview of important design aspects mentioned in literature about relevant FCCs

<table>
<thead>
<tr>
<th>Type</th>
<th>Urban consolidation centres</th>
<th>Seaport consolidation centres for inland barges</th>
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<tbody>
<tr>
<td>Researcher(s)</td>
<td>Mok (1994)</td>
<td>BEST Urban Freight Solutions (2008)</td>
</tr>
<tr>
<td>Objectives of a UCC</td>
<td></td>
<td>Konings et al. (2013), Froeling (2008) and Pielage et al. (2007)</td>
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<tr>
<td>The proximity to site it serves</td>
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<td></td>
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<tr>
<td>Spatial coverage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range and type of products handled</td>
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<td></td>
</tr>
<tr>
<td>Transport modes utilized</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range of services offered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The setup of shuttle service</td>
<td></td>
<td></td>
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<tr>
<td>Ownership</td>
<td></td>
<td></td>
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<tr>
<td>Responsibility for the operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The setup of the shuttle service</td>
<td></td>
<td></td>
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<tr>
<td>The services offered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finance issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participation of interested parties</td>
<td></td>
<td>The proximity to site it serves</td>
</tr>
<tr>
<td>Degree of permanency</td>
<td></td>
<td>The setup of the shuttle service</td>
</tr>
<tr>
<td>Role of local authorities</td>
<td></td>
<td>The services offered</td>
</tr>
<tr>
<td>Compulsory or voluntary for users</td>
<td></td>
<td>The model of costs and gains sharing</td>
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<tr>
<td>Freestanding initiative or incorporated into wider policy</td>
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</table>

The aim of this research is to find out which of the 19 unique aspects from Table 1 are actual design variables and have a critical influence on the functioning of a freight consolidation centre. Therefore it is firstly evaluated which of the unique aspects from Table 1 are design variables and which are other type of aspects. Subsequently the mutual influences that the actual design variables have on each other are analyzed. The more a variable has influence on how other variables can be/will be designed and the less it is
influenced itself by how other variables are designed, the higher is its influence on the total FCC design and so on the total functioning of the FCC (within its environment).

To analyze the mutual influences that the variables have on each other an influence diagram is set up. An influence diagram can be made very complex and detailed with mathematical descriptions of the influences included, but is also useful to just give a formal representation of the mutual relations between variables (Howard & Matheson, 2005). Figure 3 shows the influence diagram. The influence diagram was set up in two steps.

1. Dependent on the nature of the 19 unique important aspects from Table 1, each aspect was categorized as design variable or policy consideration. An aspect was considered a design variable if the functioning of the FCC gets directly influenced by a different setup of the aspect. Otherwise an aspect was considered a policy consideration with no or indirect influence on the ability of a FCC to function in its environment.

2. The mutual influences that the design variables have on each other according to the author of this paper were assessed. It was recognized that many design variables influence the setup of other design variables. Many design variables also influence and get influenced by the same other variable. Only in case of a strong influence of one variable on another variable with a significantly weaker reverse influence, the influence was incorporated into the influence diagram. All incorporated influences are explained in Table 2.

By setting up the influence diagram in Figure 3 design variables with a critical influence on the functioning of a freight consolidation centre were found. These critical design variables are listed below.

- The model of costs and gains sharing of a FCC
- The ownership of the FCC
- The level of obligation or stimulus for usage of the FCC
- The responsibility for the operations in the FCC
- The proximity to the site the FCC serves
- The range of services offered in the FCC

The sketched influences between the different design variables are the estimations of the author of this paper and therefore these critical design variables are subject to the interpretation of the author. The results of the influence diagram (the six critical design variables that are listed above) are however considered to be robust against some adaptations in the influence diagram because of other interpretations by other researchers.
The participation of interested parties is an umbrella term that contains among other aspects how the management structure is set up.

A management structure must be set up in a way that the organization(s) becoming responsible for the operations agree(s) with.

The participation of interested parties is an umbrella term that contains among other aspects what organization(s) will become owner of the facility.

A management structure must be set up in a way that the future owner of the facility will agree with.

The way that new costs and gains that come with the development of a freight consolidation centre are shared determines how these costs can be charged.

The participation of interested parties is an umbrella term that contains among other aspects what
organization(s) will become responsible for the operations in the FCC.

7 If a FCC is made compulsory or stimulated in another way the amount of users will be larger. More users inside and outside the site/area the FCC serves will mean a higher spatial coverage.

8 If a FCC is made compulsory or stimulated in another way the amount of products that will flow through the facility from organizations inside and outside the site/area that the FCC serves will be larger.

9 Dependent on which organization(s) will become responsible for operating the facility, different organizations will be involved in the charges and documentation as a result of the FCC.

10 If different services get offered in the FCC, different services will need to get charged and documented.

11 If the FCC is located far away from the site it serves, the FCC may not be suitable for senders and receivers that are located closer to the specific site and so its spatial coverage may be lower.

12 When different services get offered in the FCC, different organizations may become interested in making use of it both inside and outside the area/site it serves.

13 Only services for specific types of products may be offered in the facility, making the FCC not suitable for some organizations inside and outside the site/area it serves.

14 The shuttle service will need to connect to the operations in the FCC that are carried out by the responsible organization(s).

15 A setup of a shuttle service includes among other aspects the responsibility for it.

16 A setup of a shuttle service includes among other aspects the transport modes utilized.

17 Some transport modes are better suitable for larger and others for smaller distances.

8. Expert validation

The six design variables that are considered critical for the functioning of a FCC in this research were validated with an expert. An expert interview was held with dr. J.W. (Rob) Konings, senior researcher freight transport at the OTB department of the TU Delft (Konings, 2014). According to Konings (2014), the six defined critical design variables can indeed be considered as being critical for functioning of a freight consolidation centre and thereby for the ability of a FCC to function in its environment.

9. Limitations of research

The results of this paper are only based on studies towards urban consolidation centres, sea freight consolidation centres for inland barges and air cargo consolidation centres. That is because these freight consolidation centres serve the third type of logistical environment as sketched in Figure 1. It is not assumed that the results of this paper would have been different if researches about freight consolidation centres serving the first and/or second type of logistical environment were studied. It is assumed that the same or fewer critical design variables would have been found if researches about freight consolidation centres serving the first and/or second type of logistical environment were studied. This is because FCCs serving the logistical environment that is most complex to function in (at least from a logistical point of view, but potentially also from organizational, financial and/or other points of view) were studied. For FCCs serving such a more complex logistical environment it is assumed that because of the complexity of the environment the same or more design variables are critical for its functioning than for FCCs serving less complex logistical environments.
However, only a limited amount of researches could be found about the design of FCCs serving the third type of environment and about the evaluation of the designs of these FCCs. Potentially if more (design) studies about such freight consolidation centres were available, the results of this paper would have been different/more extensive.

The results of this paper are subject to interpretations of the author. The author of this paper classified important aspects of (designs of) different freight consolidation centres that were mentioned in literature studies as either design variables or policy considerations. This categorization may be discussed. The mutual influences between the design variables as visualized in Figure 3 and explained in Table 2 are also the estimations of the author and hence may also be discussed. To limit the impact of personal interpretations of the author, the findings of this paper were successfully validated in an expert interview.

10. Conclusions and future research

The lack of a complete design of a freight consolidation centre is often referred to as a reason for difficulties during the implementation of such facilities. With a design that only contains technological and logistical aspects it is often not sure whether a freight consolidation centre will be able to function in its environment. As a result, many freight consolidation centres that were only designed from a technological and/or logistical point of view faced serious complexities during implementation. This research was therefore aimed at finding design variables that have a critical influence on the complete functioning of freight consolidation centres. By making sure that the design of a freight consolidation centre at least does not miss on the design of these variables, the FCC can be designed in such a way that its chances on successful implementation increase. It can also be better assessed before implementation whether a FCC will be able to function in its environment.

The design variables of a freight consolidation centre that are considered critical for the functioning of such a facility were found by studying and comparing literature towards various sorts of consolidation centres and conducting an expert interview. Six design variables are considered to be critical for the functioning of any freight consolidation centre.

- The model of costs and gains sharing of a FCC
- The ownership of the FCC
- The level of obligation or stimulus for usage of the FCC
- The responsibility for the operations in the FCC
- The proximity to the site the FCC serves
- The range of services offered in the FCC

Designers of freight consolidation centres are advised to take at least these variables into account when designing a FCC. The design of these variables reflects whether a FCC will be able to function in its environment. By adequately designing these variables the chances on successful implementation of a FCC can be increased.
The conclusions of this research are assumed to be applicable to all sorts of freight consolidation centres. Future research could however be carried out to:

1. Determine whether this list of critical design variables can be expanded with additional critical design variables.
2. Investigate whether there are differences in importance/criticality of the six critical design variables for the functioning of a freight consolidation centre.
3. Analyze whether the importance/criticality of the six critical design variables varies for different types of freight consolidation centres or different types of environments that a freight consolidation centre may serve.
References


Lewis, Alan;, Fell, Mark;, & Palmer, Derek. (2010). Freight consolidation centre study (pp. 107): Transport and travel research.

Marinov, Marin;, Zunder, Tom;, & Islam, Dewan;. (2008). Urban freight consolidation concepts: is there something missing (pp. 13). Newcastle: Rail Freight and Logistics Group, NewRail - Newcastle Centre for Railway Research - Newcastle University: Faculty of Science, Agriculture and Engineering.


