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DOI

[10.1080/01441647.2017.1297867](https://doi.org/10.1080/01441647.2017.1297867)

Publication date

2018

Document Version

Final published version

Published in

Transport Reviews: a transnational, transdisciplinary journal

Citation (APA)

Wiegmans, B., & Behdani, B. (2018). A review and analysis of the investment in, and cost structure of, intermodal rail terminals. *Transport Reviews: a transnational, transdisciplinary journal*, 38(1), 33-51. <https://doi.org/10.1080/01441647.2017.1297867>

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To cite this article: Bart Wiegmans & Behzad Behdani (2017): A review and analysis of the investment in, and cost structure of, intermodal rail terminals, Transport Reviews, DOI: [10.1080/01441647.2017.1297867](https://doi.org/10.1080/01441647.2017.1297867)

To link to this article: <http://dx.doi.org/10.1080/01441647.2017.1297867>



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Published online: 03 Mar 2017.



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A review and analysis of the investment in, and cost structure of, intermodal rail terminals

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ABSTRACT

The results presented in this article identify the role of costs in the scientific and grey freight terminal handling literature and analyses the handling costs of different terminal sizes. The literature review shows that handling costs only play a marginal role in the scientific research in intermodal rail freight terminals (IRT). This is remarkable given the large role costs occupy in decision-making in freight transport. Furthermore, the used cost levels show a wide range of proposed amounts and terminal sizes or handling technologies are seldom addressed. Finally, many of the scientific papers do not make it clear whether the average transshipment cost or market price is referred to. Next, the analysis of the investment in, and cost structure of, IRTs shows that IRT investments are very capital-intensive leading to relatively high average costs per handling. However, given the cost characteristics of IRTs, the average cost per handling represents the underlying cost structure and are – in this sense – representative. The cost analysis demonstrates that extra-large IRTs actually have the lowest average handling costs, followed by small IRTs.

ARTICLE HISTORY

Received 4 February 2014

Accepted 9 February 2017

KEYWORDS

Intermodal rail terminals;
handling costs; investment

Introduction

Intermodal rail freight transport is important for hinterland transport to and from ports (mainly containers) and also for continental transport of intermodal load units (ILUs) (trailers and continental load units) (e.g. Zhang, Wiegmans, & Tavasszy, 2009). “Standard” intermodal freight transport (IFT) usually consists of pre-haulage, terminal handling, main transport by rail, terminal handling, and end-haulage. Intermodal rail freight terminals (IRTs) are important to intermodal rail freight transport because of costs, operations, and quality interactions. An increasing body of scientific literature focuses on intermodal terminals (Limbourg & Jourquin, 2009; Macharis & Pekin, 2009; Nierat, 1997; Roso, Woxenius, & Lumsden, 2009). Not much is known, however, about the role of investment in, and exploitation of IRTs in relation to the operational characteristics and occupancy rates of IRTs. Intermodal rail transport costs are thought to increase considerably at the IRT

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(Bowersox, Closs, & Helferich, 1986). However, little is known about the exact cost characteristics of differently sized IRTs and their usage in the scientific literature. Therefore, the role of IRT costs in the scientific literature is reviewed. In addition, investment costs (such as land, cranes, and rails) must be reviewed and analysed in more detail so that the resulting average handling costs (fixed plus variable costs divided by the number of handled ILUs) for differently sized IRTs can be determined. The operating characteristics of the rail terminal, such as operating hours, number of shifts, number of trains, arrival schedules, and the resulting impact on costs/handling further complicate terminal operations. The cost analysis contributes to suggestions for cost reductions and/or quality improvements at the IRTs in order to increase the performance of intermodal rail transport.

In the review and analysis, the focus is on the core service of the intermodal terminal, terminal handling. Given this background, the problem addressed in this paper is as follows: are the cost characteristics for handling at IRTs representative and how is it possible to optimise the investment and exploitation of differently sized IRTs in Europe? The literature review answers the first part of the problem and the analysis answers the second part of the problem. In Section 2, different types of European IRTs are analysed and their general characteristics are provided. In Section 3, the approach towards the literature review and the literature itself is discussed. Theories about investment and exploitation of terminals are presented and related to the cost analysis in Section 4. Furthermore, investment and exploitation models for the different terminal sizes, and the analyses and the results are presented and compared. Finally, Section 5 presents the conclusions and indicates further research directions. This review and analysis will focus on the theories used to approach costs in freight transport and on the methodologies used to calculate costs and determine cost functions. The added value of the review lies in outlining the advantages and disadvantages of the theories and methodologies used, and in the identification of research gaps.

Different classifications for intermodal rail terminals

The central service provided by the intermodal terminal is the handling of freight and/or ILUs. This service includes (un)loading and temporary storage of freight/ILUs or direct transshipment (i.e. the direct exchange of freight/ILUs). Currently, IRTs can be characterised as follows. They are typically located within or near an urban area, they are land intensive, and the “reach” of the terminal is limited to 25–50 km (Nierat, 1997). Existing IRTs can be viewed in several different perspectives including: (1) rail terminal function in the rail network, (2) rail terminal operations, (3) other available transport modes at rail terminals, (4) type of freight handled at the rail terminal, (5) train types handled at the terminal, and (6) handled volume at the IRTs. The *first terminal classification* assumes that every IRT has a certain function in the rail network. A rail terminal can be an origin/destination terminal, a line terminal, a hub terminal, and a C-D terminal (for an overview, see Figure 1).

This terminal classification is adequate, but it is theoretical and not fully reliable because IRTs have different functions in different rail service networks and in these cases, it is nearly impossible to determine the type of IRT. This terminal classification contributes *to the analysis*; however, it will not be used in this paper. The *second classification* focuses on operations in the terminal, particularly handling operations (see Wiegmans, Hekkert, & Langstraat, 2007). The core function of an IRT is handling freight and/or ILUs. This can

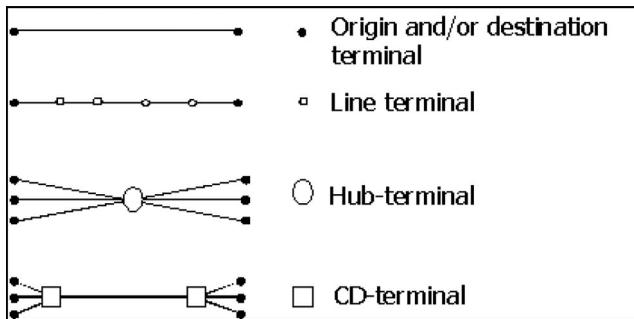


Figure 1. Overview of possible intermodal rail terminal functions in a rail network. Source: Based on Bontekoning (2006).

be carried out in two ways (1) horizontal handling or (2) vertical handling. *Horizontal handling* of freight or ILUs is handling without lifting the ILU. Horizontal handling typically requires dedicated wagons to enable the handling, which leads to high investments. The advantages of horizontal handling are that handling may take place under an overhead line, and there is limited/no need for additional handling cranes. Horizontal handling often addresses “trailers on trains” concepts. Other forms of horizontal handling include flat shunting yards and hump shunting yards. A shunting yard contains an arrival yard, a shunting hill area in the case of the hump shunting yard, a sorting yard, and a departure yard. Large yards may have installed automated equipment between the tracks of the sorting yard for train assembly. Arrival yards and sorting/departure yards are equipped with one or several locomotives. *Vertical handling* is the handling technique most commonly used at IRTs (involving cranes, reach stackers, and forklift trucks). This second classification provides a better understanding of the IRT market and core terminal handling processes; however, it has the disadvantage of not being distinctive enough. The *third classification* is based upon the available transport modes at the IRT (besides rail). Categories that can be distinguished are rail-road, rail-barge-road, rail-road-sea, and rail-road-barge-sea. In Europe, the largest category is the rail-road, followed by rail-road-sea. The advantage of this classification is that it is clear. The disadvantage is that it merely describes the characteristics of IRTs. The *fourth classification* focuses on the type of freight handled at the IRT. The types of freight that can be handled at the IRT include dry bulk (e.g. gravel, sand, coal, detritus, wood, and agrarian products), liquid bulk (mainly chemicals and fuels), ILUs (containers, swap-bodies, and trailers), and wagon loads (mainly large parts and semi-manufactured articles, e.g. steel, paper, cars, and agriculture machines). In the terminal analysis, the ILU portion of the IRT takes centre stage. In the *fifth classification*, the IRTs can be distinguished according to the type of trains that are handled at the terminal. In general, three types of services can be distinguished (De Wit & Van Gent, 2001): (1) shuttle trains that transport mainly maritime containers, (2) mixed trains that transport mainly continental containers, trailers (on trains), and package freight (fresh products, agrarian products, bulk, and cars), and (3) charter trains or block trains that transport chemicals, oil, ore, and coal, or other dry bulk and heavy loads. This type of terminal classification is closely linked to the type of freight that is handled by the IRTs. In this classification, there might be an overlap between the terminals that handle shuttle trains and mixed trains. If this is the case, then it will be difficult to

determine the exact terminal type unambiguously. Therefore, this classification is not used as the basis for the research in this article. The *sixth and last classification* of IRTs occurs according to handled volume (depicted in twenty feet equivalent units (TEUs) and/or ILUs). From the joint perspectives of handled volume and initial capacity, five characteristic types of IRTs are identified (see Table 1).

This last classification is the most “neutral” for distinguishing the different terminal types. Therefore, this classification is used to distinguish the different terminal types in XX analysis. The disadvantage is that the terminal volumes can vary and that the terminal types are, thus, ambiguous (Table 2).

Literature review: cost considerations in intermodal rail terminals

The purpose of the literature review is to critically analyse the current cost levels and cost usage in the scientific literature for IRTs. Therefore, the main focus of the problem in this paper is on the empirical question concerning cost in IRTs and this question is answered by reviewing the scientific and grey literature (this section) and by analysing cost data for five different terminal sizes (Section 4).

The scope of the review is quite specific and is primarily focused on the IRT. The first stage of the review started with a search on www.scopus.com. Journal papers with “cost intermodal rail terminal” in the paper title have been searched. This did not result in any papers found through Scopus. Next “intermodal rail terminal” resulted in approximately 15 papers for the review. In addition, the term “intermodal rail terminal location” was searched for and resulted in two scientific papers. Extending the literature search with the key words “cost AND rail AND terminal” and “intermodal AND rail AND terminal AND freight” has added 55 more papers to the list. Also the website of the journal “Transport Reviews” was used and papers with “rail freight” in the title have been included in the literature review. Finally, websites of European projects provided grey literature for the review. We merged all these publications and removed duplicates. Subsequently, we read all the abstracts, and selected 18 potentially relevant publications to be analysed in full. Furthermore, the snowballing method (Wohlin, 2014) was employed (by looking for references in recent publications and citation to old relevant papers) and 13 more publications were added to the list, forming the list of 31 publications in total. The findings in our literature review and the role of cost are discussed in two main lines of research. A first line of research is focused on the methods to determine the IRT location. In general, these methods can be classified into two groups. First, several mathematical modelling approaches are presented to determine the optimal location of a rail terminal. The second group of research is using qualitative or semi-quantitative methods to study the

Table 1. Intermodal rail terminal types distinguished according to volume.

Name	TEU/ILU volume
1. XXL-terminal	>500,000
2. XL-terminal	100,000–500,000
3. L-terminal	30,000–100,000
4. M-terminal	10,000–30,000
5. S-terminal	<10,000

Source: Adapted from Wiegmans et al. (1999).

Table 2. Overview of terminal characteristics.

Characteristics	Small 10,000	Small 20,000	Medium 50,000	Large 100,000	XL 500,000
Area	4 ha	4 ha	6 ha	10 ha	40 ha
Rail track(s)	1 (700 m)	2 (700 m)	3 (700 m)	6 (700 m)	12 (700 m)
Realisation cost	Total infra, pavement				
Crane	0	0	1	2	2
Reach stackers	2	3	3	6	6
Rail connection	1	1	1	1	1
Fence	1000 m	1200 m	1500 m	2500 m	3000 m
IT systems	Fixed amount				
Office	Shed, 200 m ²	Shed, 200 m ²	Shed, 400 m ²	Shed, 750 m ²	Shed, 750 m ²
Lighting poles	4	4	4	20	50
Prorail fee	Rail access				
Employees	3 fte	6 fte	10 fte	18 fte	25 fte
Manager	0.4 fte	1.0 fte	1.0 fte	2.0 fte	3.0 fte
Electricity	kWh	kWh	kWh	kWh	kWh
Fuel	Diesel (hl)				
Guards	2 persons				
Interest	4% of total assets				
Licenses	Fixed amount				
Insurance	Staff + cargo				
Administration costs	Fixed amount				
Taxes	Fixed amount				
Maintenance	5% of assets				

Sources: www.funda.nl and [Huiskamp \(2011\)](#).

trade-off of different factors that influence the location from different viewpoints of inter-modal actors.

Mathematical models for optimal location of intermodal terminals are somewhat dependent on the network configuration – as presented in [Figure 1](#). The most common configuration in the literature is a hub-and-spoke network configuration ([Limbourg & Jourquin, 2009](#); [SteadieSeifi, Dellaert, Nuijten, Van Woensel, & Raoufi, 2014](#)). We do not report details of hub location literature here for brevity. The details about single/multiple hub location (and allocation) models can be found in [Alumur and Kara \(2008\)](#), [Campbell and O’Kelly \(2012\)](#) and [Farahani, Hekmatfar, Arabani, and Nikbakhsh \(2013\)](#). In this paper, we especially look into the literature that applied such models for locating the inter-modal rail terminals. In order to identify the optimal terminal location, [Van Duin and Van Ham \(2001\)](#) discuss a three-step approach which includes a linear programming model, a costs analysis model and a simulation model. With their approach, they aim to address the terminal location from perspective of different actors (e.g. shippers, terminal operators, and carriers). [Arnold, Peeters, and Thomas \(2004\)](#) consider the problem of optimally locating rail-road terminals in a hub-and-spoke network. Intermodal terminals are defined as hubs in the network. They apply the model to the rail-road transportation system in the Iberian Peninsula. [Jourquin and Limbourg \(2007\)](#) studied the potential locations for rail-road terminals based on flows of commodities and their geographic distribution across the network. They further extend the model by proposing an iterative procedure based on both the p-hub median problem and the multi-modal assignment problem. In the extension, they focus on the effect of considering the flow dependent economies of scale on transshipment cost ([Limbourg & Jourquin, 2009](#)). The model is applied to find the location for seven European transfer terminals. They also use the hub-and-spoke model to study the market area for rail-road intermodal terminals, taking the network

structures, the operation costs and the location of terminals into account (Limbourg & Jourquin, 2010). Jeong, Lee, and Bookbinder (2007) present a hub-and-spoke network model for a rail-road freight system in which the goal is to find transport routes and frequency of service in addition to the terminal locations. In a similar approach, Ishfaq and Sox (2010, 2011) extend the p-hub median problem for locating rail-road terminals, by using an incapacitated hub location model that includes service time constraints. Dandotiya, Nath Banerjee, Ghodrati, and Parida (2011) present an optimisation model to determine the location of an IRT in an industrial region along with the optimum pricing policy, based on the usage levels of road and intermodal modes. They further apply the model to a case of Delhi–Mumbai freight corridor in India. To determine the optimal location of rail terminals in Sweden, Bergqvist and Tornberg (2008) present a geographical information system (GIS)-supported model. Meers and Macharis (2014) also discuss a GIS-based optimal location approach which is used to study the need and location of additional intermodal rail (and barge) terminals in Belgium, while avoiding competition with the existing terminals. Based on the p-hub location problem, Santos, Limbourg, and Carreira (2015) present a mixed integer-programming model to determine the location of rail-road intermodal terminals in the network and the allocation of freight flows between the modes. They also discuss the impact of different IFT promotion policies (e.g. subsidising intermodal transport or internalising external costs) on the optimum location of intermodal terminals.

In the majority of the aforementioned mathematical models, the objective is to minimise the total transportation cost (including pre-, main- and post-haulage) within the transport network to serve the given transport flows. Very few articles explicitly take the transshipment and handling cost into account. The exceptions are Van Duin and Van Ham (2001), Arnold et al. (2004), Jourquin and Limbourg (2007) and Limbourg and Jourquin (2009). In their modelling approach, Van Duin and Van Ham (2001) consider an average of €40 per handling. Arnold et al. (2004) assume that the relative cost of rail compared with road is €0.65 per km. They also assume that the transshipment cost is equivalent to 100 km. In theory, with a road price of €1/km, this leads to a transshipment cost of €65, which is a considerable amount. Furthermore, this relationship suggests a higher transshipment cost if road transport is more expensive and a lower transshipment cost if road transport is cheaper – which is not often the case. Furthermore, the paper does not make it clear whether this is the average transshipment cost of the terminal operator or the transshipment market price of the terminal customer. Jourquin and Limbourg (2007) and Limbourg and Jourquin (2009, 2010) consider an (un)loading cost of €1.297/ton in their model. With an average TEU weighing about 15–16 tons, this assumption results in a (un)loading cost of approximately €20 per TEU which is generally considered a low amount for handling cost. Additionally, in none of these papers, the relation between handling cost and terminal size or transshipment technology is explicitly addressed in the model (see also Table 3).

Besides optimisation models, a limited number of papers uses multi-criteria analysis methods to evaluate different influential factors (from the viewpoint of different actors) and find the appropriate location for an inland terminal. To examine potential terminal sites in Belgium, Macharis (2004) discusses a multi-actor multi-criteria analysis approach which involves multiple stakeholders (users, operators, investors and the community) in the decision process for terminal location. A similar approach is followed by Sirikijpanichkul and Ferreira (2005) and Sirikijpanichkul, van Dam, Ferreira, and Lukszo (2007).

Table 3. Overview of handling cost in the IRT literature.

Source	Handling cost in scientific papers
Newman and Yano (2000)	\$1–2 per container
Van Duin and Van Ham (2001)	Range: €14–68/TEU; average: €40/TEU
Arnold et al. (2004)	The relative cost of rail (compared with road) is assumed €0.65 per km and the transshipment cost is equivalent to 100 km
Bontekoning (2006)	€35 per ILU (average market price)
Jourquin and Limbourg (2007) and Limbourg and Jourquin (2009, 2010)	(Un)loading cost of €1.297/ton (an average TEU weighs about 15–16 tons)
Bhattacharya et al. (2014)	\$70–100 per container
Zhang and Facanha (2014)	\$40 per FEU
Source	Handling cost in grey literature
www.ectvenlo.nl (2001)	Transport (Rotterdam-Venlo) and container handling: '20 < 14.5 ton or empty €64 '20 > 14.5 ton €85 '30/40 full or empty €95 '45 full or empty €126
RECORDIT project (Black et al., 2002)	€36–60 per handling
REORIENT project (Vold, 2007)	€45 per handling
BELOGIC project (Bozuwa et al., 2011)	€40 per TEU
RIRDC (2007) reported from Victorian Department of Infrastructure (2003)	\$15 per lift

Note: FEU, forty feet equivalent unit.

Sirikijpanichkul and Ferreira (2005) propose a multi-objective evaluation approach to analyse the objectives and interest of different stakeholders including the terminal operators, infrastructure providers, terminal users and the community. Based on this analysis, an agent-based modelling approach is developed to allow for conflict management and negotiation between stakeholders involved (Sirikijpanichkul et al., 2007). They also discuss the application of this model for a case study of intermodal freight hub location decisions in South East Queensland of Australia. All these papers present a set of factors for terminal location evaluation but a precise cost value for handling is not discussed.

A second line of research on IRT is devoted to managing operations in an inland intermodal terminal. Considering the scope of this paper, we discuss the contributions to the operation of rail-road terminals (and especially on (un)loading optimisation of IRTs under conditions of service quality and cost). A comprehensive review of stacking, yard management, crane scheduling and terminal operation for (sea)ports can be found in Vis and De Koster (2003), Steenken, Voß, and Stahlbock (2004) and Stahlbock and Voß (2007). Newman and Yano (2000) developed a model to analyse train schedules with both direct and indirect (via a hub) trains. The goal is to minimise the total operating costs (which include a fixed charge for train shipment, and variable transportation and handling costs for each container together with yard storage costs), while achieving on-time delivery requirements. In their study, the handling cost is considered as \$1–2 per container, which is a very low value. Rizzoli, Fornara, and Gambardella (2002) present a discrete-event simulation model of the flow of intermodal terminal units (ITUs) among and within inland intermodal terminals. The intermodal terminals are interconnected by rail corridors. The simulation model helps to define the structure of the terminal and experiment with different train and truck arrival scenarios. Subsequently, various statistics can be gathered to assess the performance of the terminal equipment, the ITU residence time, and the terminal throughput. The operating cost of equipment (e.g. cranes) is defined as an input in the simulation but the specific value is not mentioned in the paper. Using a simulation approach, a dynamic analysis of operational conditions for different types of terminals is presented by Bontekoning (2006). A market price of about €35 per ILU is assumed in the simulation

model. Benna and Gronalt (2008) present a simulation study to support the design and operation of intermodal rail-road terminals. The input data includes both design parameters (like layout and infrastructure of the terminal) as well as operational parameters (like arrival patterns, and container characteristics). Using simulation, the impact of these parameters on the performance of the terminal can be analysed. A similar simulation study in ARENA is presented by Kozan (2006) in order to investigate the trade-off between operational performance (in terms of delay) and different service configurations for an inland terminal. The model has been applied to the case of the Acacia Ridge Terminal in Brisbane, Australia. Although relevant in their analysis, none of these two papers give a precise value for handling/transshipment cost that has been used in the analysis. Bhattacharya, Kumar, Tiwari, and Talluri (2014) discuss a two-step methodology to define the rail transport schedules in a network wide intermodal transport system. First, a traffic flow estimation model is used to define the expected traffic flow in definite time intervals. This information is used to develop scheduling plans by coordinating existing rail transport schedules with road-based freight systems. The objective is to optimise the trade-off between operational costs and the value of time cost incurred in the freight transit times. In calculation of operational cost, a handling cost of \$70–100 per container is considered in the model which appears to be a bit high. Zhang and Facanha (2014) present a model in order to analyse different strategies for empty container repositioning by shipping companies (using existing or new rail terminals). They consider a handling cost of \$40 per FEU in their analysis.

In conclusion, only in a limited literature (9 out of 31 analysed papers), the terminal handling cost is addressed explicitly in the modelling. In the papers that consider the handling cost, a wide range in cost levels is presented (see Table 3). Additionally, in the majority of this literature, it is not clear whether the presented value is the average transshipment cost (for a terminal operator) or the transshipment market price. Furthermore, the relation between handling cost and terminal size or transshipment technology is rarely addressed explicitly in the papers. Table 3 also presents the handling cost as found in the grey literature and the European/international projects. RECORDIT project defined a methodology for estimating the costs of IFT in Europe (Black et al., 2002). A range of handling costs is reported for different intermodal rail terminals in the EU. The REORIENT project examined the effects of the EU's legislation on rail interoperability on a trans-European transport corridor through 11 countries – called the REORIENT Corridor (Vold, 2007). In analysing the possible business models, a handling cost of €45 per container handling is considered in the calculations. BELOGIC (Benchmark Logistics for Co-modality) studied the performance indicators for pre-selected European inland terminals (Bozuwa et al., 2011). An average of €40 per TEU is reported for handling cost. To study the efficiency of Australian farm-to-port logistics chain, Rural Industries Research and Development Corporation (RIRDC) developed an Excel spreadsheet model (RIRDC, 2007). A handling cost of \$15 per lift (one loading/unloading) is considered in the analysis. The prices for container handling and transport between Rotterdam and Venlo by European combined terminals are also presented in Table 3. As can be seen, the grey literature also reports a wide range of handling cost and lacks a detailed analysis of terminal cost. In most cases, the distinction between handling cost and the market price is not clear. Moreover, the unit of analysis for presenting the handling cost is different for different sources which make the comparison of handling even more difficult.

In the existing literature, little attempt has been made to analyse the real handling costs of IRTs and take the handling/transshipment cost into account in developing the decision-making tools and this is the motivation for the next section.

Investment modelling and cost structure analysis

Broadly speaking, it is possible to identify seven characteristics of infrastructure investments (European Conference of Ministers of Transport, 1990), which might also have implications for terminal investments. *First*, the expected economic life of infrastructure is very long and may range from 20 years to more than a century. The payback period of infrastructure investments is also long, typically 15–30 years. In general, private investments must generate profits in a far more restricted time period (5–10 years), meaning that there will be no investment in IRTs without government involvement. *Second*, during the construction time, a large amount of capital is required. This large investment in IRTs leads to immediate costs, while the sales cannot yet be realised. *A third feature* of infrastructure investments is that the waiting period, prior to actual infrastructure construction can be very long due to the time involved in political decision-making. These formalities often lead to project changes that might influence the costs of IRT projects. In general, private companies are not willing to run these political risks, which is the reason for government intervention in IRT investment. *A fourth characteristic* is the irreversibility of the investment once the project has started. From the investor's point of view, the irreversibility of IRT investments is a fundamental obstacle, which increases the threshold of the minimum rate of return required. *The fifth feature* of infrastructure investment is the long construction period. This period may take two to seven years, depending on the scale of the project. During this period there are no revenues; however, there are already interest payments and other costs. *A sixth characteristic* is the uniqueness of each infrastructure project. This is likely to have an influence on cost estimates owing to lack of experience, low learning possibilities, and lack of comparability. Finally, *the seventh characteristic*, in many cases, is the relatively low level of operational (variable) costs. In such cases, setting prices according to marginal costs, which is economically optimal, does not allow for a satisfactory return on investment. This typically makes infrastructure investments (including IRTs) unattractive to the private investor. [Figure 2](#) exemplifies the infrastructure investment case (for simplicity, average variable and marginal costs are considered constant, which is a plausible assumption as long as capacity is sufficient). [Figure 2](#) depicts the typical investment situation of an investor in terminal infrastructure. In the figure, there is no price at which the terminal investment is profitable, assuming that prices cannot be raised (the average total cost curve is always above the demand line). It is now possible to operate the terminal infrastructure project at a profit, only if external government funds are available (e.g. subsidies and tax breaks). Such funds would help to lower the investor's ATC curve below A, thus enabling them to realise a profit.

Given the considerable investment in IRTs and the large part of fixed costs, Returns to Scale (RTS) might be expected. RTS exist if the total average cost per unit produced declines with the number or volume of units produced (which is the case for IRTs). RTS is a quantitative term typically measured by the cost per unit of the company's output. With a change of scale or size of the company, the inputs of all production factors change proportionally. The question is whether the outputs change accordingly. If the

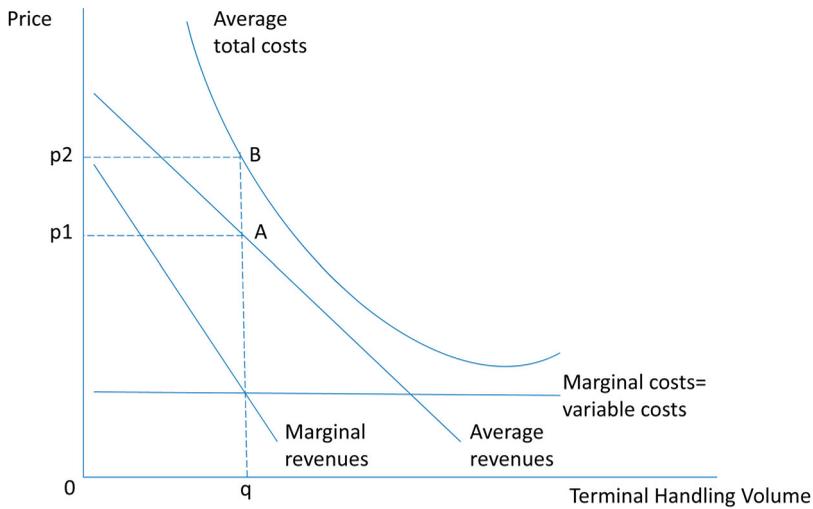


Figure 2. Cost structure for an investor in terminal infrastructure. Source: Adapted from Wiegmans, Masurel, and Nijkamp (1999).

scale increase leads to a relatively larger increase in production, then RTS exist. In this case, there are cost advantages and the average production of labour and capital increases (right section (c), Figure 3). The long-run average total cost curve is represented by the trace of the minimum short-run average total costs against a single class of output, which accounts for changes in input levels that are fixed in the short run. Constant RTS are depicted in the middle section (b) of Figure 3. Constant RTS exist if changing all inputs by a positive proportional factor increases outputs by exactly that factor. If the scale increase leads to a relatively lower increase in production, then negative RTS exist (left section (a), Figure 3). In this case, there are cost disadvantages (negative RTS) and the average production of labour and capital decreases (average total costs per unit increase as output grows).

Given the large part of fixed costs in IRTs, positive RTS might be expected (right section, Figure 3). In the next section, the impact of these characteristics on IRT investment modelling and cost structures is analysed.

Investments in IRTs are related to terminal assets, and thereby, linked to the required terminal performance. Investments in IRTs will only be made if the expected return on investment is sufficiently attractive to the terminal owner. This return on investment

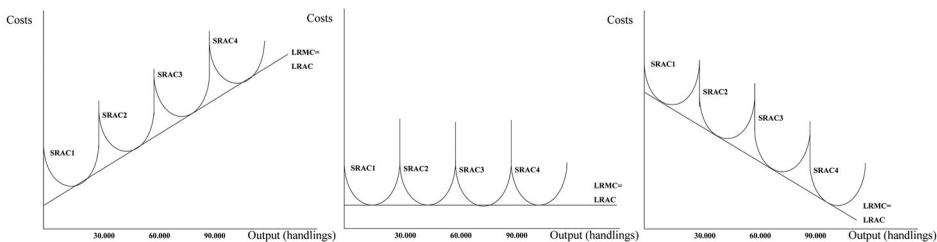


Figure 3. Decreasing, constant, and increasing RTS. Source: Adapted from Hensher and Brewer (2001).

must consist of profits raised by terminal exploitation. In order to analyse the investments in IRTs, it is necessary to identify the “cost drivers” for IRT investment and the corresponding cost structures. Cost drivers are mainly the valuable terminal assets, which relate to the “infrastructure” and “terminal area” and often lead to high levels of fixed costs (see Table 4).

Cost drivers of a terminal relate to functional and exploitation requirements (investment costs are linked to the requested IRT production), but they can also depend on life cycle costs (integrated costs for realisation, maintenance, adaptation, and removal). For instance, the introduction of basic requirements that show the maximum level for realisation and maintenance costs may result in various, more cost effective alternative IRT designs. Also, specific requirements regarding flexibility may result in a design for an IRT that consists of components, which are easily replaced or repaired and reduce the cost of realisation or maintenance. The latter two requirement categories are often ignored in IRT studies, which thereby deny the potential for substantial cost savings in fixed IRT assets. In order to identify the total amount of investment needed for the IRT, first unit rates for the IRT assets need to be found. These unit rates are valid for supply and installation/realisation of the IRT (see Table 5). The variation in unit rates is considerable, especially for terminal assets that depend heavily on the size of the terminal (e.g. offices, staff, etc.) When the above-mentioned data plus equipment data from Tables 1 and 2 (Section 2) are used with the IRT types from Table 4, the following summary of costs per terminal type can be made.

Five different terminal types have been included in the analysis: a small IRT with a capacity of 10,000 ILU, a small IRT with a capacity of 20,000 ILUs, a medium IRT with a capacity of 30,000 ILUs, a large IRT with a capacity of 100,000 ILUs, and an extra-large IRT with a capacity of 500,000 ILUs. The TC are a function of {fixed costs and variable costs}. Fixed costs are land, rail track(s), realisation costs (total infra and pavement), cranes and/or reach stackers, rail connection to the network, the fence, the IT systems, the shed, and the lighting poles. Variable IRT costs include network fee for rail access, employees, management, energy, fuel, guards, interest, terminal licenses, insurance, administration and organisational costs, taxes, and maintenance.

Figure 4 depicts the handling costs per ILU for a terminal with a capacity of 10,000 ILUs. The handling costs range from €120 when 6000 ILUs a year are handled to about €80 when 10,000 ILUs are handled. Given the characteristics of this terminal, the handling costs represent the cost drivers, but, when compared with the market price at a terminal for handling an ILU (around €35–40 per ILU), the average handling costs are high. This means that it

Table 4. Intermodal rail terminal assets.

Cost drivers – assets rail terminal	Newly built/installed		Maintenance		Unit
	Supply lump sum	Labour	Supply p/annum	Labour	
Tracks (on shunting yard as well as handling area)	€500–700	N/A	€50–80	N/A	m
Handling area	€30–50	N/A	€10–15	N/A	m ²
Storage area	€30–50	N/A	€10–20	N/A	m ²
Handling equipment (L-terminal)	€2–3 million	N/A	€100–150k	N/A	Unit
Storing equipment (if applicable), L-terminal	€0.5–2 million	N/A	€50–100k	N/A	Unit
Terminal entrance (truck loading – unloading facilities)	€0.5–1.0 million	N/A	€50–80	N/A	m ²
Office and terminal staff (average rate)	N/A	€70	N/A	€45	€/h
Terminal management soft- and hardware	€200–500k	N/A		N/A	Unit

Source: www.funda.nl and Huiskamp (2011).

Note: N/A = not available. European prices, excluding VAT, index 2010 = 100.

Table 5. The cost per intermodal rail terminal type.

Name	TEU volume	Infrastructure	Terminal area	Equipment	Realisation costs (total infra, ground breaking and equipment) € million
1. XL	500,000	12 tracks	40 ha	23 million	138
2. L	100,000	6 tracks	10 ha	13 million	47
3. M	30,000	3 tracks	6 ha	3 million	9.5
4. S2	20,000	2 tracks	4 ha	1.5 million	5.5
5. S1	10,000	1 track	4 ha	1 million	3.5

Source: Wiegman et al. (1999) and Huiskamp (2011).

is not profitable to invest in and operate a small IRT. The terminal operator can aim for two options or a combination of both: (1) try to reduce the fixed and variable (vary with production volume) costs and (2) try to obtain a government subsidy. The first option can result in a lower average handling cost, but this will often be at the expense of quality of terminal handling (e.g. older material needs maintenance more often). The second option is to apply for a government subsidy. Woodburn (2007) showed that for the government the provision of subsidies also plays an important role in increasing or retaining rail freight flows. Often government subsidies are provided only for a certain period in the start-up phase of a terminal. As the handling cost analysis shows, this is not sufficient because the cost levels are structurally higher than the terminal handling market prices. Given the considerable difference between the average handling costs and the handling market price, it is difficult to operate a small IRT in an economically viable way. The same holds true for the small IRT with a capacity of 20,000 ILUs, although the average handling costs are lower and the difference between the handling costs €57–95 and the market-handling price €35–40 per ILU is smaller (although still considerable) (see also Figure 5).

For the handling cost of the medium IRT, a slight increase in the average cost per handling can be observed compared with the small 20,000 ILU terminal. This is mainly caused by the introduction of a larger expensive crane to handle the ILUs. On one hand, this is strange because a scale increase of the IRT would be expected to lead to lower handling costs. However, a medium IRT (30,000 ILUs) has different characteristics than the small

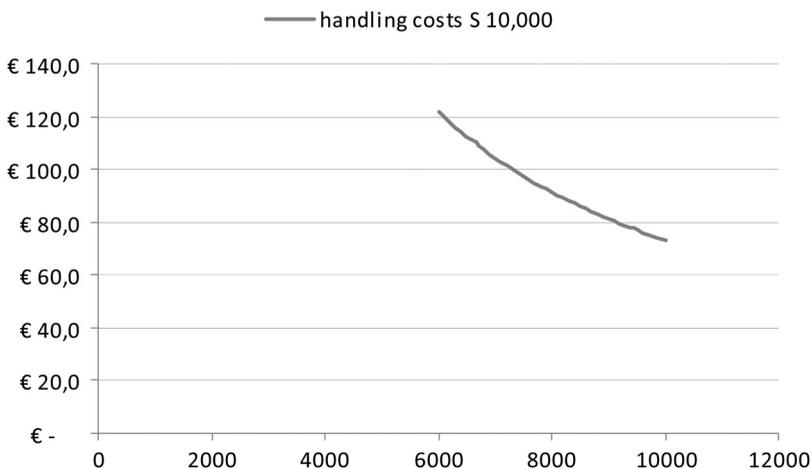


Figure 4. Handling costs of a small IRT with maximum capacity of 10,000 ILUs. Handling costs are depicted for handling 6000 (60% capacity filling) up to 10,000 (100% capacity filling) ILUs.

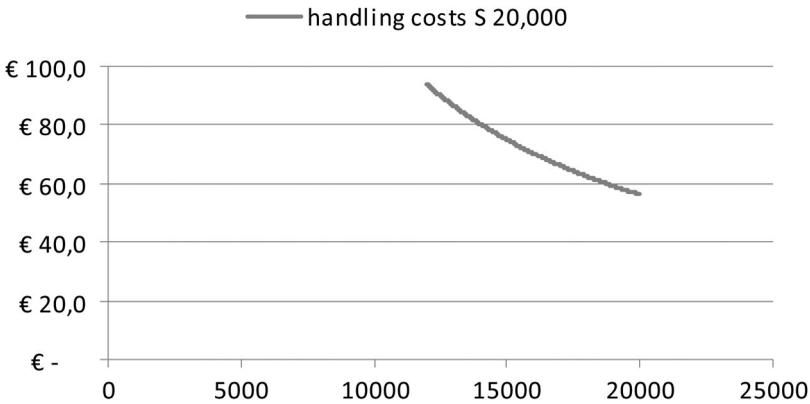


Figure 5. Handling costs of a small IRT with a maximum capacity of 20,000 ILUs. Handling costs are depicted for handling 12,000 (60% capacity filling) up to 20,000 (100% capacity filling) ILUs.

terminals, which might lead to cost increases. The handling costs range from €90 at 60% capacity to €60 when 100% of the capacity (30,000 ILUs) is used (see Figure 6).

The handling costs of a large terminal (100,000 ILUs) show a further increase in the average handling cost ranging from €105 (60,000 ILUs) to €65 (100,000 ILUs) (see Figure 7). With market-handling prices between €35 and €40, it is a considerable challenge to operate the IRT in an economically viable way. Costs could be brought down by reduced investments, but this might lead to decreases in quality. Another option would be to request that the government should also participate and ensure that handling costs reach market price levels in the long run. This would require the government to participate in the IRT for the long term.

The only IRT category capable of realising handling costs in the range of the market-handling price (€35–40) is the extra-large terminal (see Figure 8). The handling costs range from about €57 when 300,000 ILUs are handled to €33 when the terminal operates at full capacity (500,000 ILUs). This means that at a certain moment the handling cost

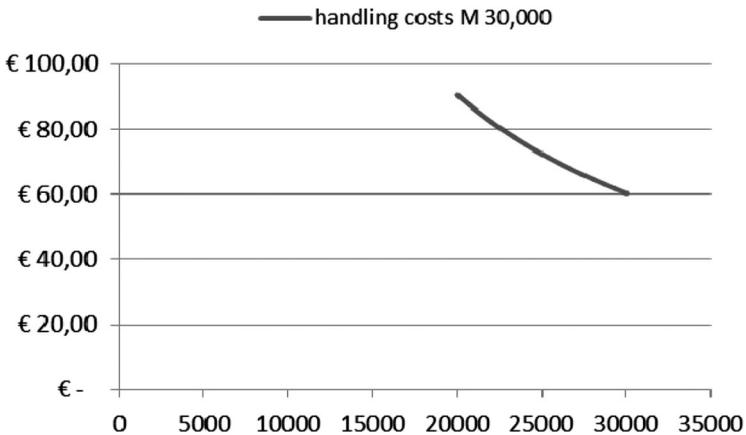


Figure 6. Handling costs of a medium IRT with a maximum capacity of 30,000 ILUs. Handling costs are depicted for handling 20,000 (67% capacity filling) up to 30,000 (100% capacity filling) ILUs.

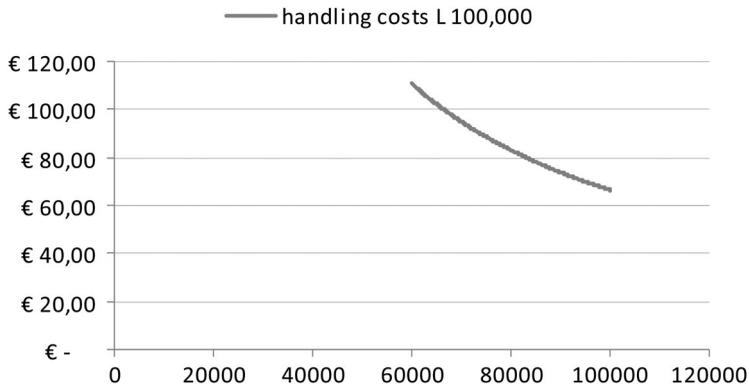


Figure 7. Handling costs of a large IRT with a maximum capacity of 100,000 ILUs. Handling costs are depicted for handling 60,000 (60% capacity filling) up to 100,000 (100% capacity filling) ILUs.

changes from increasing (for 100,000 ILUs) to decreasing (for 300,000 ILUs and above). This means that more IRTs must be analysed in this capacity range in order to determine the point or range where this change occurs. The average handling costs for this extra-large terminal are not high when compared with the market-handling price (€35–40 per ILU). The challenge for these types of terminals, with large volumes, is that the number of locations where these terminals can be developed is limited because large volumes will be limited to large port areas and to certain inland locations. Furthermore, especially in port areas, the coordination of railway and handling operations requires much attention because after the liberalisation of rail freight transport the resources are not optimally allocated from a port perspective (Van der Horst & Van der Lugt, 2014).

In Figure 9, all five terminal types and their average cost structures are depicted. Handling costs of small terminals with a capacity of 20,000 ILUs leads to the lowest handling cost per ILU. The lowest overall handling cost can only be realised with the extra-large IRT at capacity of 500,000 ILUs.

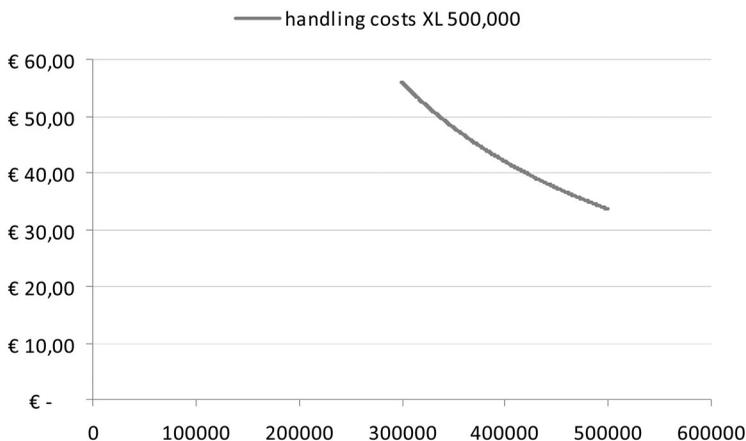


Figure 8. Handling costs of an XL IRT with a maximum capacity of 500,000 ILUs. Handling costs are depicted for handling 300,000 (60% capacity filling) up to 500,000 (100% capacity filling) ILUs.

In [Figure 9](#), it is assumed that all terminals are capable of operating efficiently up to their maximum capacity of 100%. In practice, however, problems often arise after operating at 80–85% of capacity because certain limits (crane capacity, reach stacker capacity, and personnel) are reached and this leads to cost increases. This means that, in practice, the average cost per handling starts to increase after 80–85% capacity use.

Discussion and concluding remarks

This paper focuses on the review and analysis of investment in, and cost structure of, IRTs. The review and analysis was performed to answer whether cost characteristics of handling at IRTs are representative and whether it is possible to optimise the investment and exploitation of differently sized intermodal freight terminals in Europe. The results obtained in this paper are presented as: (1) a literature review of the use of handling costs in scientific papers and grey literature, and (2) detailed analysis of the handling cost for different terminal sizes.

The literature review leads to several quite remarkable and interesting conclusions regarding the role of cost for intermodal rail terminals. First, the literature review shows that the detailed analysis of handling costs of IRTs is an under-researched topic. Furthermore, the studies that pay attention to the cost levels of terminal handling show a wide range of cost levels. Secondly, the literature review shows that very few articles explicitly take the transshipment and handling cost into account. The majority of papers does not pay any attention to the amounts needed for terminal handling, although cost is often one of the most important decision-making criterion. Thirdly, many of the scientific papers do not make it clear whether the average transshipment cost of the terminal

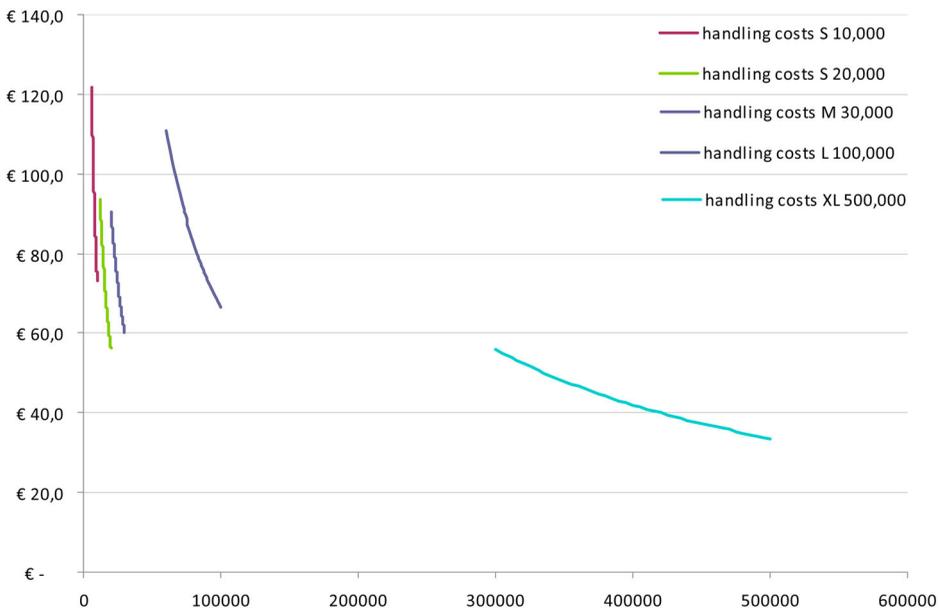


Figure 9. Handling costs of all five IRTs assuming 60–100% capacity. Handling costs are depicted for handling (60% capacity filling) to (100% capacity filling) ILUs.

operator or the transshipment market price of the terminal customer is referred to. Finally, the relation between handling cost and terminal size or transshipment technology is rarely addressed explicitly in the papers. All the more reason to analyse the cost levels of IRTs in more detail.

Given the analysis of the cost characteristics of IRTs, the average costs per handling are not high because only the necessary investments are made and in this sense the cost characteristics are representative. The analysis demonstrates that extra-large IRTs actually have the lowest handling costs, followed by small IRTs. The highest IRT handling costs occur at the medium and large terminals because these terminals require relatively large investments. When the real costs of IRT handling are calculated and compared to market prices, it reveals that the price for an IRT handling is, in fact, lower than the average handling cost, except for extra-large terminals operating near full capacity. This means that when comparing terminal handling costs with its price, the costs are not in all cases representative. Given the cost structure of IRTs, terminals have several options to cope with difficulties resulting from the cost characteristics: (1) reduce costs by changing the terminal design, (2) obtain subsidies, (3) offer extra services to generate extra sales that generate profits, and (4) reduce terminal service quality without harming the core handling activity. In practice, terminal operators use all of these options to improve financial performance. Reducing cost is realised by an IRT design optimised for low realisation and life cycle costs. This is done by lengthening write-off periods, using equipment for longer periods of time, and implementing other measures that result in lower average costs per handling. Obtaining subsidies is also important. This is particularly an issue when construction of a new terminal starts and/or when an existing terminal is enlarged. A third way for IRTs to cope with their difficult cost situation is to offer extra services to customers in order to generate more profits. These include services such as cleaning and/or repairing containers, inland waterway and/or rail transport, pre- and end-haulage, and logistics. In principle, this could be a good strategy to generate more sales, make more profits, and increase the quality of the terminal services. In the final strategy, the terminal operator might concentrate on reducing terminal service quality without harming the core activity of the terminal, the handling service. In this strategy, operating hours could be limited, the quality of the personnel (such as knowledge and responsiveness) could be reduced, and additional terminal services might be eliminated from the terminal service assortment. Ultimately, the main aim of an IRT should be to make handling costs equal to, or lower than, the market price of rail handling. In economic terms, there appears to be no way for IRT operators to become profitable without subsidies.

Several issues can be identified for further research. First, the literature review on costs could be broadened towards the full field of IFT. Secondly, the IRT costs could be analysed from the total supply chain perspective, including the terminal handling. Finally, cost models including multi-service characteristics for IRTs could be used in terminal location evaluation and terminal operations optimisation.

Acknowledgements

We want to thank two anonymous referees for their worthwhile comments and suggestions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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