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## The academic literature on intermodal freight transport

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### Abstract

It is widely accepted that non-road freight transport is less energy intensive than freight transport by road. The use of other transport modes than truck for long haul freight transport can therefore contribute to more energy efficient transportation systems. As a result, the successful promotion of intermodal transport, using rail or sea on the long haul part, has been identified as the most critical action to achieve a sustainable transport sector. The aim of this paper is twofold. First, we examine the historical development of academic research on intermodal freight transport. Second, we identify the seminal works on the topic. In our analysis we identify and classify the academic literature on intermodal freight transport. This approach has also previously been used to aggregate knowledge about particular fields of research and it aims to be as unbiased as possible by being auditable and repeatable. A timeline on the evolution of the academic literature on intermodal freight transport is presented and the development in publication frequency and topics are commented on in relation to keywords, journals, author affiliations and countries. Publishing frequencies are measured, and reported, both in terms of absolute and relative values. Finally, what is likely the most important and influential papers on intermodal freight transport are identified, using citation frequency.

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### 1. Introduction

Intermodal freight transport is the movement of goods in a single loading unit or vehicle that successively uses two or more modes of transport without handling the goods themselves in changing modes (UN/ECE, 2001). The main idea behind intermodal transport is to utilize the strengths of different transport modes in one integrated

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transport chain (Flodén, 2007), thereby improving the economic performance (Rodrigue et al., 2009). It has been argued that economic performance is improved because the most suitable transport mode is used on each part of a trip (OECD, 2001).

The main advantage of intermodal transport solutions is their comparatively low external costs (Hanssen and Mathisen, 2011). According to Forkenbrock (2001), the external cost of an intermodal train per tonne-km is only 28 % of the external cost of a general freight truck. However, the difference in external cost might be even greater than this as the cost of congestion was not included in the calculations (Hanssen and Mathisen, 2011).

Because intermodal freight transport is less energy intensive than freight transport by road (Woodburn et al., 2007), it is considered to be an important contribution to achieve a sustainable European transport sector (European Commission, 2009). Intermodal freight transport has therefore been promoted by policymakers on all levels (Macharis et al., 2011). However, the market share of intermodal freight transport has not developed as positively as expected (Janic, 2007). In order to continue the development of intermodal freight transport from the academic point of view, it is important to know the history and to identify the status of the current body of research. In this way it can be revealed where resources are lacking and also empirical cases of best practice can be identified and draw attention to success stories for other researchers to follow.

The aim of this article is twofold. First, we will review the literature on intermodal freight transport to identify (i) how the publication frequency of articles in the field has evolved, (ii) their focus and (iii) identify the journals, research institutions and countries which have been most active in the debate. This review will illustrate the involvement of research on intermodal freight transport. Second, we will identify the seminal works on intermodal freight and rank these based on how often they have been cited. It has been argued that the most cited articles in a field are the articles which have had the highest impact on that particular field (Ibrahim et al., 2012). Thus, this will be a list of classic articles that provide insight into what have been the most important topics for researchers addressing intermodal freight transport.

The remainder of this article is structured as follows. In Section 2, we describe the methodology used and the data sources applied. Then, in Section 3, the historical development of academic research intermodal freight transport is presented before the seminal works on intermodal freight transport are presented in Section 4. Finally, conclusions and implications are presented in Section 5.

## 2. Methodology

Transportation journals first emerged in the late 1960's with the *Journal of Transport Economics and Policy*, followed by the *International Journal of Transport Economics* (Button, 2006). However, the number of journals has developed significantly and by 2013 about 80 journals publishing articles related to transport and logistics were ranked by the Institute of Transport and Logistics Studies at the University of Sydney (2013).

The data presented in this article was gathered from Scopus, the world's largest abstract and citation database of peer-reviewed literature ([www.scopus.com](http://www.scopus.com)). The database was searched in order to obtain entries containing the term "intermodal transport" and at least one of the words "freight" or "goods". In order to be included these words had to appear either in the title, the abstract or in keywords defined either by the author or the database. The search was then restricted to journal articles written in English. The remaining number of entries was then 239 from the period from 1985-2013. Articles published in 2014 were omitted, since we are not able to obtain observations for the full year. An advantage of such a structured approach for the literature review is that it is easy to replicate which gives a high degree of reliability. This approach has been applied to study the body of literature within other topics, e.g. air transport (Ginieis et al., 2012).

Despite its extensive range of entries of journals within the transportation economics, the Scopus database does not give a complete picture of the body of literature. Hence, the selection of articles would be different if based on other sources. The data set was compared to a similar searching procedure by the ISI web of knowledge provided by Thomson Reuters (2014b). This database includes fewer journals and the number of observations was lower. However, the majority of articles found in the ISI search were present in the Scopus search, which indicates that the most important works are present in the data set applied in this paper. The use of a more extensive search engine, such as Google Scholar, would include many observations that are not peer reviewed and perhaps of lower scientific

quality. Additionally, meta data problems make these results unreliable (Jacsó, 2010). The different scopes of the databases also influence the citation counts.

A disadvantage of the Scopus database relates to poor availability of older articles. It is reported that the database is not complete for the years prior to 1995. Hence, the analyses carried out on data predating 1995 are highly uncertain and must be treated with caution. Still, the topic of intermodal transport is relatively new and the rapidly expanding body of literature over the last 20 years is covered at a satisfying level in this database. For a more extensive review of the older literature we refer to Bontekoning et al. (2004) which analysed articles published prior to 2000.

### 3. Academic research on intermodal freight transport

In this section we will present our findings with regard to the historical development of academic research on intermodal freight transport.

#### 3.1. Publishing frequency

A total of 239 articles were published during the period from 1985 to 2013. The distribution over time is illustrated in Figure 1 where the horizontal and vertical lines represent publication year and percentage of publications, respectively. It is evident from Figure 1 that the majority of articles have been published in the latter part of this period. In fact, one third (33%) of the articles relates to the three latest years from 2011 to 2013. Up to 1999, the annual publishing frequency was five papers or less. This supports the conclusion of Bontekoning et al. (2004) that the field did not expand until the mid-nineties.

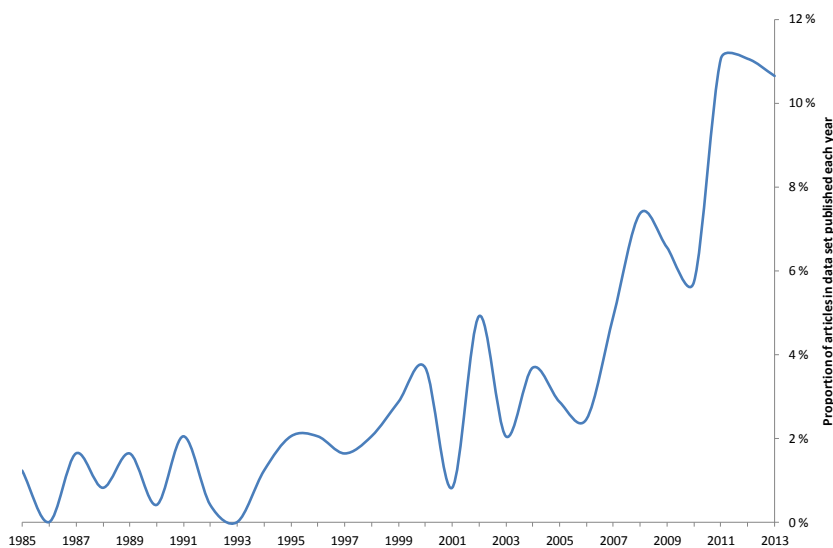


Figure 1. Proportion of articles published each year.

#### 3.2. Publication channels

The articles addressing intermodal transport are published in 104 different scientific journals. These journals cover a wide a range of research traditions including engineering, computer, economics, statistics and statistics. Out of the 104 journals about two thirds are present only once in the data set. The journals most frequently publishing

articles on this topic can mainly be categorized as within the tradition of transportation economics. The 11 journals including five or more articles are presented in Table 1 by half-decade publishing frequency.

Table 1. Journals most frequently publishing articles on intermodal freight transport

Journal	Number of articles						Total
	85-89	90-94	95-99	00-04	05-09	10-13	
Transportation Research Part E - Logistics and Transportation Review	0	0	2	3	5	8	18
Transportation Planning and Technology	0	0	3	7	4	1	15
Railway Gazette International	4	7	2	0	0	0	13
Journal of Transport Geography	0	0	0	1	3	8	12
Transportation Research Part A - Policy and Practice	0	0	2	4	3	1	10
Transportation Research Part D - Transport and Environment	0	0	0	1	4	1	6
Research in Transportation Economics	0	0	0	0	0	5	5
Research in Transportation Business and Management	0	0	0	0	0	5	5
Rail International	3	0	1	1	0	0	5
Transportation Research Part B - Methodological	0	0	0	3	1	1	5
Transportation Quarterly	1	0	2	2	0	0	5
Total number of articles	8	7	12	22	20	30	99

It is evident that the most relevant journal for research on intermodal freight transport is Transportation Research Part E with 18 articles. This corresponds well with the aim of the journal to publish articles “... *across the spectrum of logistics and transportation research*”. This Elsevier journal has an impact factor of 2.272 and is highly regarded amongst transportation researchers (University of Sydney, 2013). A total of five journals have published 10 or more articles on this topic. Railway Gazette International and Rail International stand out as having most publications in the first part of the studied time period from 1985 to 1994.† In contrast, more recently established journals such as Research in Transportation Economics and Research in Transportation Business and Management have entries only in the last period starting in 2010. In general, the publication frequency in these journals has increased for each half-decade period.

### 3.3. Topics treated

Throughout the years, a number of topics have been addressed in relation to intermodal freight transport. Each article contains a number of keywords that can be related to broader categories. Based on the keywords of the authors and Scopus, Table 2 presents the categories most frequently used to describe the topic of the articles.

The most frequently used category comprises different combinations of the keywords “intermodal”, “freight” and “transport”. Since they can be included several times in the keywords section of a single article the total number of keywords on this topic exceeds the number of articles.

The second most frequent topic relates to the transport mode studied in the article. Transport related to “waterways” is most frequently addressed and makes about 30% of the keywords in this category, followed by “road” with 28% and “rail” by 26%. Transport by “air” is mentioned only for 1% of the articles. A study of the half-decade counts of keywords shows that “rail” was most commonly studied in the earlier period, while “waterways” and “roads” have become more frequently studied in the recent body of research. About 15% of the articles address several transport modes or modes in general.

† The Scopus coverage of Railway Gazette International and Rail International ended in 2007 and 2004, respectively. Also, Transportation Quarterly was covered until 2007. Oppositely, the Scopus coverage of a more recent journal such as Research in Transportation Economics started in 1994.

The third most used category relates to the geographical orientation of the article. This includes both countries and broader regions such as continents. The most commonly addressed regions are “Europe” and “United States” with 23% and 22% of the keywords, respectively.

Table 2. The most used topics in articles on intermodal freight transport

Topic/Category	Number of keywords
Intermodal freight transport	354
Transport mode (rail, water, road or air)	224
Geographical region (country or continent)	116
Policy and planning	100
Environment	83
Economics	64
Optimization and simulation	57
Competition and regulation	53
Network and infrastructure	50
Models and methodology	42
Containers	41
Terminals	32
Logistics	32
Innovation and technology	22
Traffic flow	20
Other topics (e.g. marketing, management)	38

The popularity of different topics has changed over the studied time period. While for example “rail” was relatively more frequently addressed in the older articles, “the environment” seems to be an increasingly important topic of interest for current researchers.

### 3.4. Countries

When studying the location of the authors of academic research on intermodal transport, some countries stand out. An author must be assigned to a country in Scopus in order to be included in Table 3. A total of 46 countries from all five continents are represented in the data set. The observations prior to 1995 are, probably due to the weakness of the database, rarely linked to specific countries and are omitted in Table 3. The proportion of articles in the last column to the right relates to the total number. Because one article can relate to more than one country, the total number of countries is higher than the number of articles in the data set.

It is evident from Table 3 that researchers in relatively few countries account for a big proportion of all research on intermodal freight transport; the United States and the Netherlands account for almost one-third of the articles on the topic. Moreover, with the exception of Japan, only countries in Europe and North America are represented on the list of the countries with most articles on intermodal freight transport. This could be due to the restriction to include only articles written in English.

Table 3. The countries with most articles on intermodal freight transport

Country	Number of articles					Proportion
	95-99	00-04	05-09	10-13	Total	
United States	4	14	10	21	49	19 %
Netherlands	4	7	11	11	33	13 %
United Kingdom	2	2	3	11	18	7 %
Belgium	2	2	4	9	17	6 %
Sweden	1	1	5	7	14	5 %
Italy	1	1	5	5	12	5 %
Germany	0	2	1	8	11	4 %
Canada	3	1	1	6	11	4 %
Japan	0	0	2	4	6	2 %
France	1	1	3	2	7	3 %
Total number of articles	18	31	45	84	178	67 %

### 3.5. Institutions

Using information about the authors' affiliation, the data set enable us to identify the institutions being most dedicated to research on intermodal transport. The eight institutions being the author affiliation for five or more articles are presented in Table 4.

Table 4. The academic affiliation of the authors of articles on intermodal freight transport

Affiliation	Number of articles					Proportion
	95-99	00-04	05-09	10-13	Total	
Delft University of Technology	2	4	9	5	20	7 %
Vrije Universiteit Brussel	0	1	2	4	7	3 %
Chalmers Tekniska Högskola	0	1	3	2	6	2 %
Vrije Universiteit Amsterdam	2	2	0	2	6	2 %
Universiteit Hasselt	1	0	1	4	6	2 %
UC Berkeley	0	0	0	6	6	2 %
Göteborgs Universitet	0	0	1	4	5	2 %
Napier University	0	0	1	4	5	2 %
Total number of articles	5	8	17	31	61	22 %

A total of 159 institutions are mentioned in the data set, of which 114 are included only once. Delft University of Technology (The Netherlands) is by far the most frequent affiliation for authors publishing articles on intermodal freight transport. Similar to Table 3, the column "Proportion" in Table 4 relates to the total number of institutions in the data set, which is higher than the number of articles.

The list of affiliations in Table 4 does not include the highest ranked universities worldwide. According to the Times Higher Education World University Rankings 2012-2013 (Thomson Reuters, 2014a), only TU Delft (77), VU Amsterdam (140) and UC Berkeley (9) are included on the top 200 list. Furthermore, VU Brussel and Chalmers are ranked between 200 and 400, while the remaining universities are not included on the list. Hence, it would seem that the most highly regarded universities are not leading the research on intermodal freight transport.

#### 4. Most cited articles on intermodal freight transport

The number of times an article has been cited is a reflection of its scientific impact (Gisvold, 1999). Hence, the most cited articles in a field can be considered the ones which have had the most scientific impact in that particular field. The most cited articles have been identified in several fields of research (e.g. Shapiro and Pearse, 2012, Ibrahim et al., 2012, Hodge et al., 2012). However, the most cited articles on intermodal freight transport, i.e. those which presumably have had the most scientific impact, have to the best of our knowledge not previously been identified.

Table 5. The 10 most cited articles on intermodal freight transport

Title	Author(s)	Journal	Citations (per year)
Storage space allocation in container terminals	Zhang et al. (2003)	Transportation Research Part B: Methodological	127 (12.7)
Is a new applied transportation research field emerging? – A review of intermodal rail-truck freight transport literature	Bontekoning et al. (2004)	Transportation Research Part A: Policy and Practice	111 (12.3)
Intermodal and international freight networking modeling	Southworth and Peterson (2000)	Transportation Research Part C: Emerging Technologies	76 (5.8)
Modeling the full costs of an intermodal and road freight transport network	Janic (2007)	Transportation Research Part D: Transport and Environment	63 (10.5)
The dry port concept: connecting container seaports with the hinterland	Roso et al. (2009)	Journal of Transport Geography	60 (15.0)
Towards collaborative, intermodal hub networks. A case study in the fast moving consumer goods market	Groothedde et al. (2005)	Transportation Research Part E: Logistics and Transportation Review	59 (7.4)
Optimal location of intermodal freight hubs	Racunica and Wynter (2005)	Transportation Research Part B: Methodological	59 (7.4)
Intermodal container flows in a port system network: Analysis of possible growths via simulation models	Parola and Sciomachen (2005)	International Journal of Production Economics	59 (7.4)
Modeling a rail/road intermodal transportation system	Arnold et al. (2004)	Transportation Research Part E: Logistics and Transportation Review	55 (6.1)
Local truckload pickup and delivery with hard time window constraints	Wang and Regan (2002)	Transportation Research Part B: Methodological	53 (4.8)

The 10 most cited articles on intermodal freight transport are listed in Table 5. The articles were cited between 127 and 53 times. These are relatively low numbers compared to many other fields (e.g. Ibrahim et al., 2012, Ponce and Lozano, 2010). The relatively few citations might be a result of the fact that research on intermodal freight transport only started to evolve in the early 1990s (Bontekoning et al., 2004). Consequently, there has been less time for citations to accumulate in this field, when compared to other fields of research which tend to have longer histories.

The articles in Table 5 are ranked according the accumulated number of citations received by each article. However, in terms of citations per year, the article by Roso et al. (2009) has the highest value, 15 per year on average. It should be noted that when calculating citations per year, we did not take into account their exact date of publication, i.e. whether an article was published early or late within the given year.

The most cited article on intermodal freight transport, with 127 citations, is a study of the space allocation problem in the storage yard of terminals (Zhang et al., 2003), followed by a review of 92 articles on intermodal freight transport published prior to 2001 (Bontekoning et al., 2004) and a description of the development of a

multimodal network (Southworth and Peterson, 2000). Information about the content of the most cited articles on intermodal freight transport is provided in Table 6.

Table 6. Information about the most cited articles on intermodal freight transport

<i>Storage space allocation in container terminals</i> (Zhang et al., 2003) study the storage space allocation problem in storage yards of terminals. The authors decompose the problem into two levels and formulate each level as a mathematical programming model. The authors state that the method applied significantly reduces the workload imbalance in the yard, thereby avoiding bottlenecks in terminal operations.
<i>Is a new applied transportation research field emerging? – A review of intermodal rail-truck freight transport literature</i> (Bontekoning et al., 2004) is a review of 92 publications on intermodal freight transport. The authors argue that intermodal freight transportation research is in a pre-paradigmatic phase and they propose a list of nine research needs that they consider a precondition in order for intermodal research to evolve to a phase of normal science.
<i>Intermodal and international freight network modeling</i> (Southworth and Peterson, 2000) describes the development of a multimodal network, created and stored in digital form for use in the simulation of five million origin to destination freight shipments used in the 1997 United States Commodity Flow Survey.
<i>Modelling the full costs of an intermodal and road freight transport network</i> (Janic, 2007) develops a model in order to analyse internal and external costs of intermodal and road freight transport networks. The authors find that the full costs of both networks decrease more than proportionally as door-to-door distance increases; suggesting economies of scale. Moreover, they find that the full costs of intermodal transport decrease and those of road transport remain constant as the volume of loads increases; the break-even distance shortens at a decreasing rate.
<i>The dry port concept: connecting container seaports with the hinterland</i> (Roso et al., 2009) aims to extend the dry port concept and argues that the concept goes beyond the conventional use of rail to connect a seaport and its hinterland. Three dry port categories are defined and the authors argue that by combining them, a port and its surrounding city can be relieved of congestion and the logistics solutions for shippers might be improved.
<i>Towards collaborative, intermodal hub networks. A case study in the fast moving consumer goods market</i> (Groothedde et al., 2005) discusses the rationale behind collaborative hub networks, and argues that economies of scale and economies of scope in logistics can be achieved through collaboration in multi-modal networks.
<i>Optimal location of intermodal freight hubs</i> (Racunica and Wynter, 2005) proposes a model to locate the optimal configuration of intermodal freight transport hubs and obtaining their usage levels. To the model is added a representation of the economies of scale due to freight consolidation at hub terminals.
<i>Intermodal container flows in a port system network: Analysis of possible growths via simulation models</i> (Parola and Sciomachen, 2005) study how to face the impact on land infrastructures from the sea traffic growth. Three scenarios are evaluated with a particular focus on rail traffic share and percentage increase in road traffic.
<i>Modelling a rail/road intermodal transportation system</i> (Arnold et al., 2004) consider the problem of optimally locating rail/road terminals. The authors propose a model that relies on integer linear programming formulation. Applied to the Iberian peninsula, the model show that modal share of goods from the peninsula is very sensitive to variations in the relative cost of rail.
<i>Local truckload pickup and delivery with hard time window constraints</i> (Wang and Regan, 2002) describes a solution method for a multiple traveling salesman problem with time window constraints. The method presented by the authors is iterative, and at each iteration, they generate and solve an over-, and an under-constrained version of the problem. The two versions provide an upper, and lower, bound on the cost of the optimal solution.

The 10 most cited articles were published in seven different journals. Two journals have more than one article on the list. Three articles on the list were published in Transportation Research Part B, and two in Transportation Research Part E. Respectively, these two journals have published a total of 5 and 18 articles (see Table 1) addressing intermodal freight transport. Thus, the proportion of articles published in Transportation Research Part B included in the top 10 list (60 %) is more than 5 times as high as the proportion of the articles published in Transportation Research Part E (11 %). This suggests that the average scientific impact of articles on intermodal freight transport published in Transportation Research Part B is very high.

## 5. Conclusions and implications



Research on intermodal freight transport began to evolve as late as in the early 1990s. After a quarter of a century with continuously expanding research on the topic, this article has investigated how this field of research has evolved and has sought to identify those articles which have had the most influence on how the field has evolved.

Based on data from Scopus, the world's largest abstract and citation database of peer-reviewed literature, we find that despite fluctuations in publishing frequency it has, particularly after the year 2000, been a steady and strong growth in the yearly number of published articles addressing intermodal freight transport. It is not unreasonable to assume that this growth to a large extent is attributable to the strong political focus on intermodal freight transport as a mean to reduce the external cost of transport.

A closer study of the topics indicates that earlier studies on intermodal transport focused highly on rail transport, while current works to a higher degree includes waterways and roads. Moreover, topics of political concern such as the environment are increasingly popular. Terminals are an important part of the intermodal transport chain and have a strong influence on the competitiveness of intermodal freight alternatives. It is therefore somewhat surprising that terminals are a topic of relatively few articles. Particularly considering that the most cited article on intermodal freight transport is a study of the storage space allocation in storage yards of terminals. This might indicate that terminals are an under-researched topic that ought to be the focus on future research.

The list of the seminal works on intermodal freight transport, identified in this article, contains classic articles that; (1) researchers in the field should be familiar with; (2) could be a central part of the curriculum of courses in intermodal freight transport and (3) gives insight into what has mattered to intermodal freight transport researchers in the past quarter of a century.

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