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ABSTRACT *The central place of transhipment in rail transport solutions and the lack of successful innovations is the focus in this paper. Based on a questionnaire and interviews, several conclusions can be drawn. First, the respondents value the product characteristics of the different innovations as neutral. However, there appear to be a number of ways to make the innovations more attractive (e.g. reduce uncertainty/risks, increase the compatibility and decrease the complexity). Second, the respondents value the user requirements of the innovations concerned as neutral. However, several different opportunities can be identified to make the innovations more attractive on the user requirements side (e.g. flexibility). Third, concerning the user requirements, the costs of the innovations are perceived as high. This probably is one of the major barriers to the successful adoption of the innovations in the rail transhipment market. In this market, costs are very important and cannot always be recovered through charging higher prices. A last conclusion is that user requirements can be analysed from two points of view: first, the user of the innovation is the terminal operator and the innovation must meet his criteria; and second, the actual user is the rail transport company (and ultimately the shipper of the freight). The innovations are then evaluated on their increase in performance for the total intermodal transport solution.*

Introduction

In Europe, the road transport sector is important measured in terms of the volume of transported goods. It represents around 75% of the total ton-km transported in the European Union. Whereas road transport in the period 1985–95 has grown by 163% (ton-km), the increase in rail transport has only been 20% (European Commission, 2001). Among others, 'closed' national systems, decreasing rail networks, improved road infrastructure, the liberalization of road haulage, and

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the unreliability of rail transport have caused customers to abandon rail transport for the past three decades in favour of road. Now the European Union is seeking to bring companies back to rail to transport their goods. By liberalizing rail freight services and opening them to competition, the European Union wants to cut greenhouse gas emissions and revitalize the rail market. Albeit slowly, freight transport by rail is changing. Changes have taken place in the freight, which is transported by rail (e.g. high-value and high-quality goods have been added to the service offered) and in the intermodal transport units (more standardized units, e.g. deep-sea containers, rail containers, swap bodies and grappled arm trailer). An important part of the intermodal transport solution (in terms of costs and quality) is formed by rail transhipment. This central place of transhipment in rail transport solutions is the focus of this paper. More particularly, the focus is on innovations that might enhance the performance of the transhipment terminal and of the intermodal rail transport solution as a whole. The problem definition of this paper is as follows:

> Why are the majority of innovations in rail terminal transhipment not adopted, and how can this be improved?

Currently, the focus of most rail freight transport companies is on efficiency increases and cost reductions. This already suggests two important conditions (efficiency increase and/or cost reduction) that rail terminal innovations must meet in order to qualify for adoption in the rail freight transport market. To answer the main research question, the success potential of innovations will be analysed. First, the paper will describe the rail freight transport and rail transhipment sector on a European level. Second, innovation management theory (product characteristics and user requirements) will be described. Third, innovations that aim to improve rail terminal transhipment will be evaluated. Finally, a number of conclusions will be drawn.

Rail Freight Transhipment Market

Market for Intermodal Rail Freight

Historically, most freight rail companies in Europe are owned nationally. This national focus reduces the railway companies' chances of offering fast, reliable and efficient international services at a European level. The problems are numerous: incompatible forms of train electrification, differing track gauges and lengthy border checks, to name but a few. Nijkamp (1995) observed 10 years ago that a drastic reorientation of the management of railways was required. However, in a recent report, the European Commission (2001, p. 29) found that the average speed of international freight services has fallen to 18 km/hour: "lower than an icebreaker opening up a shipping route through the Baltic Sea". Keaton (1991) shows that significant reductions in transit times require large increases in both the number of connections and the operating costs. Europe is hoping that the liberalization of rail freight will increase the average speed and reduce traffic congestion and pollution. Currently, only 9% of all the freight transported in Europe is moved by rail, down from 21% in 1970. Table 1 shows for almost all countries that the modal share of rail freight transport has dropped between 1970 and 2001. This decreasing market share is—among other things—due to faster growth of road transport in that period. In the USA, where most rail networks are private and transcontinental transportation is open to competition, railway companies maintain a 40% share of the overall freight market (European Commission, 2001). So far, the European rail freight transport sector has not been able to halt its market share decrease. Ferreira (1997) shows that the rail freight market share increases are closely related to the level of service offered, particularly in transit times and reliability of arrivals. Furthermore, improvements in network capability and capacity and a greater customer focus are needed to realize the market potential (Woodburn, 2004). However, in recent years, important changes in European rail transport have occurred: liberalization, containerization and shuttle trains (Logitech BV, 2003; Bouwknegt *et al.*, 2004). Furthermore, investments in research and development in the rail freight market are considerable. The rail supply industry invests €1 billion a year in research and development. The rail operators invest €250 million a year in research and development (Mynard, 2003).

Rail freight transport almost always forms part of an intermodal transport solution. Intermodal freight transport is defined as "unitised freight transport by at least two transport modes" (European Commission, 2001, p. 18). An intermodal transport solution consists of at least five elements: pre-haulage (frequently road), transhipment, rail transport (or barge), transhipment and end-haulage (usually by road). The double transhipment means that intermodal transport competes with single-mode road transport in the market for shipments of 300 km and longer (Ministerie van Verkeer en Waterstaat, 1998). Sometimes, distances of 500 km and longer are quoted as being competitive with single-mode road transport. Overall, it can be stated that intermodal rail transport is competitive with single-mode road transport on relative longer distances. The exact distance depends on particular circumstances (e.g. transhipment costs, transported volume, transport frequency, etc.).

Markets can be divided according to product (service) or according to geography (De Vries *et al.*, 2001). The intermodal rail freight markets can be divided according to the way the freight (product) is transported (Elzinga, 1994; Lupo, 2003; Wiegmans, 2003):

- Dry bulk: this sector includes materials such as gravel, sand, coal, detritus, wood and agrarian products.
- Liquid bulk (or tanker transport): this sector consists mainly of chemicals and fuels.
- Intermodal transport unit (ITU): this sector is growing rapidly and consists of containers, swap-bodies and the rolling road. Different kinds of freight can be packed into one of these ITUs.
- Wagon loads: this sector mainly transports large parts and semi-manufactured articles (e.g. steel, paper, cars, agriculture machines).

Alternatively, the freight can be divided into freight groups based on percentage of ton-km (Figure 1). Another way to analyse the rail freight market is by looking at the services offered. In general, three types of services can be distinguished (De Wit and Van Gent, 2001):

- Shuttle trains transport mainly maritime containers. The transport takes place at regular intervals between the same origin–destination combinations. Usually maritime containers are transported, but other intermodal transport units are transported now and then as well (Konings and Kreutzberger, 2001).

Table 1. Modal share (%) (rail freight 1970–2000, per European Union Member State including non-EU member Switzerland)

	Austria	Belgium	Denmark	Germany	Greece	France	Ireland	Italy	Luxembourg	The Netherlands	Poland	Finland	Spain	Switzerland	UK	EU-15
1970	45.8	27.8	19.5	38.2	12.5	31.4	11.1	21.5	57.1	6.8	10.0	31.0	25.1	44.7	22.5	30.2
1980	37.0	24.8	12.4	34.1	9.9	24.6	10.7	12.5	43.8	5.4	9.1	29.0	18.1	43.1	14.9	24.2
1990	37.5	21.1	9.9	26.0	5.2	18.7	13.3	9.4	27.3	4.1	10.9	23.4	12.2	41.3	9.9	18.2
1991	36.1	20.0	10.9	20.5	4.7	18.4	12.5	9.4	26.1	4.0	13.2	22.8	11.0	41.9	9.8	16.5
1992	34.7	19.6	10.3	18.1	4.0	17.4	11.3	9.0	23.1	3.4	14.1	23.3	9.6	43.4	10.2	15.4
1993	33.3	17.4	10.2	16.9	3.7	16.3	12.8	8.7	22.2	3.4	14.2	26.5	8.2	41.2	8.6	14.5
1994	34.5	16.9	10.3	16.7	2.3	16.8	12.2	9.4	23.1	3.3	12.1	27.3	8.4	40.6	7.7	14.5
1995	35.6	14.9	10.1	16.2	2.0	15.9	9.8	9.6	18.5	3.6	14.7	28.7	9.4	39.0	7.2	14.2
1996	34.7	15.7	9.1	16.0	1.9	16.1	9.5	9.2	18.5	3.5	14.0	26.3	9.5	36.9	7.4	13.9
1997	35.0	15.2	9.8	16.1	1.8	16.8	8.1	9.5	20.7	3.6	14.8	27.6	10.1	36.0	9.1	14.4
1998	35.3	15.0	9.5	15.5	1.7	16.4	7.8	8.9	20.0	3.9	13.0	26.8	9.5	36.6	9.4	14.0
1999	35.6	14.2	8.2	14.5	1.7	15.6	7.6	8.1	19.4	3.5	13.5	26.6	9.2	36.2	9.7	13.4
2000	37.2	16.0	8.6	15.2	2.1	15.8	7.1	8.2	18.2	3.9	13.0	26.5	8.9	38.2	9.7	13.8
2001	30.8	12.6	8.6	14.7	2.0	14.3	6.7	8.1	17.1	4.0	12.8	25.9	7.5	39.5	10.3	13.1

Modal share of land transport modes, excluding maritime transport.
Source: http://europa.eu.int/comm/transport/rail/market/freight_en.htm

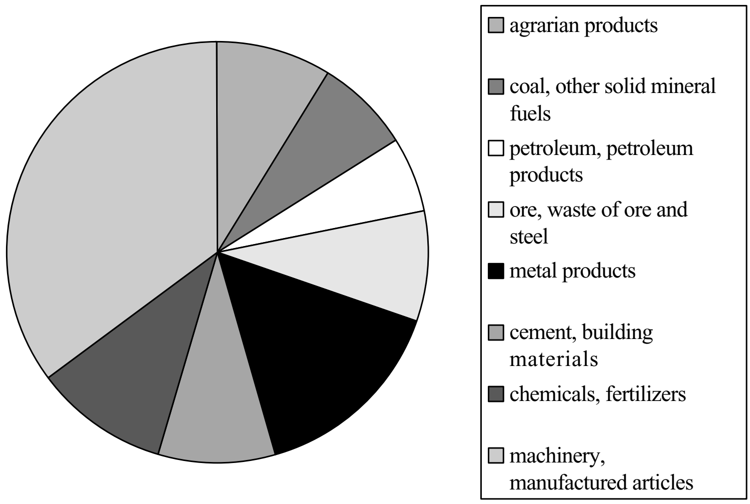

Figure 1. Importance of rail sub sectors in Europe. *Source:* Lupo (2003)

- Mixed trains transport mainly continental containers, trailers (on train), and package freight (fresh products, agrarian products, bulk and cars). Usually this type of train serves relatively smaller shipments that together form a train. Wagons are collected at the clients and formed into a train, together with other wagons at shunting yards. The train then travels to its destination and the wagons are distributed.
- Charter trains (or block trains) transport chemicals, oil, ore and coal, other dry bulk, and heavy loads. This type of train drives for one client with only its cargo on board. Usually the trains have a minimum length of 20 wagons (cost considerations) and drive at different times. Charter trains have the advantage of being faster because no shunting and/or transhipment is needed (Konings and Kreutzberger, 2001).

It is also possible to classify rail freight according to geographical markets. This is possible for countries or rail freight companies by looking at imports, exports and national freight by rail. Some rail freight transport companies make a distinction between national and international transport. For statistical purposes, this distinction is of less importance.

Market for Rail Transhipment

The former national railway companies in Europe (or their freight units) still own the majority of rail freight terminals. This suggests that the rail freight terminal market is an oligopoly or a monopoly (still nationally oriented). In rail transport in North America, the number of rail terminals in intermodal service fell from 1107 in 1976 to 199 in 1993 (Slack, 1998). A corresponding development is seen in the European rail freight market. The market area of railroad terminals is determined by the relative location of the customer relative to the terminal, by the direction of the rail transport and by the length of the rail transport (Nierat, 1997). The favourite location for a terminal is at the junctions of motorways and close to large cities

(Tanaguchi *et al.*, 1999). Inside the transhipment terminal unit loads are collected, exchanged, stored and/or distributed. Generally, the total real transportation costs increase markedly at the terminal point. This point of view is emphasized by Bowersox *et al.* (1986). They view handling as one of the most costly aspects of logistic channel performance. The logistic chain is here defined as the "integrated perception of production, transport and the market place" (Coyle *et al.*, 1994, p. 431). Terminal costs are incurred at exchange points, and that has always placed intermodal transport at a disadvantage compared with the single-mode road system. So far, there has been a tendency to use intermodal transport for trips where a transfer is unavoidable (Slack, 2001). Furthermore, at many transhipment terminals the number, type and quality of services is limited, and there appears to be no dominant transhipment technique (Van Andel, 2004). However, the use of standardized loading units has made it relatively easier for rail transport to form part of a successful transport solution (Bouwknegt *et al.*, 2004).

A better understanding of the terminal market starts with the classification and the characteristics of freight terminals in the European Union. A thorough investigation of the literature (Konings, 1996; Transport Research APAS Strategic Transport, 1996, 1997; Kreutzberger, 1997; Cardebring *et al.*, 1999; Emolite, 2001; Slack, 2001; Tsamboulas, 2001; Ballis and Golias, 2002) leads to several options to classify rail terminals:

- Product-oriented: the freight terminals can be classified according to the type of freight handled by the terminal (dry bulk, liquid bulk, wagon loads and intermodal units). See Figure 2 for an overview.
- Service-oriented: the terminals could be divided into terminals that mainly handle shuttle trains, mixed trains and charter trains. The shuttle train terminals tranship large volumes, focus on containers, and are located in large ports and

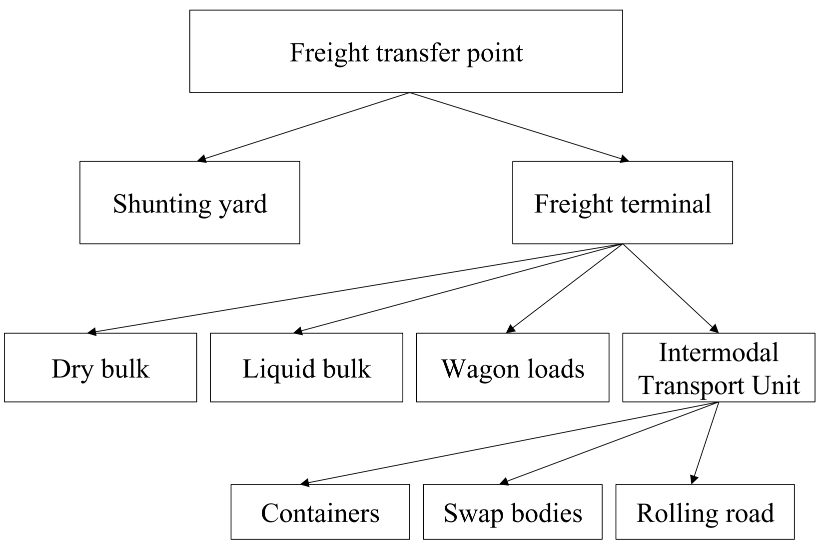

Figure 2. Product-oriented types of freight terminals. *Sources:* based on Wiegmans *et al.* (1999a, b), Konings and Kreutzberger (2001), Ballis and Golias (2002), Logitech BV (2003)

inland. Mixed terminals focus on the handling of intermodal transport units, and charter terminals are mainly concerned with dry and liquid bulk.
- Geographical market-oriented: this division seems difficult to identify in practice as most terminals focus on products and/or services.

In this paper, the focus will be on the product-oriented classification, because at the shunting yard the focus is on repositioning complete trains. More specifically, the focus is on wagonloads and intermodal units as dry- and liquid bulk are usually transhipped on private in-company terminals. Furthermore, a reliable classification of terminals into service or geography seems to be impossible. The central service provided at the transhipment terminal is the movement of freight (Wiegmans *et al.*, 2001). This service is the (un)loading and temporary storage of freight, or direct transhipment (the direct exchange of freight between the same transport mode). Direct transhipment includes shunting (the direct repositioning of complete rail wagons). The switching service is the direct exchange of freight from one transport mode to another—different—transport mode. At the intermodal terminal, several transhipment techniques are used. Depending on of the quantity of ITUs to be transhipped, a choice is made between a forklift truck, reach stacker, high stacker and/or gantry crane. Wagonloads are usually transhipped with the forklift truck. The forklift truck can also be used to (un)load containers. The other equipment (reach stacker, high stacker and gantry crane) is used for the transhipment of containers and swap-bodies. The transhipment for the rolling road can also be done by crane or reach stacker.

Rail Freight Transhipment Innovations

For the rail freight and terminal markets, innovations are important. So far, it has proven to be difficult to adopt innovations on freight terminals. In the European TERMINET project, 124 transhipment innovations have been identified (TERMINET, 1997a, b). Most innovations have been developed to improve speed, reliability, costs, labour usage and/or safety of the transhipment process. Among the transhipment innovations, three main categories can be recognized: 'new generation terminal' concepts, 'trailers on train' and transhipment techniques. The new-generation terminal concepts are completely new terminal designs for new or existing terminal locations (e.g. Tuchschmid compact terminal, A-IUT). Most concepts distinguish themselves from current equipment by extensive automation and a more space-intensive terminal area. Several innovative terminal concepts can be separated into a number of modules that can be applied separately at the terminal location. Most innovations can be characterized by fully automated transhipment techniques. Automation may reduce false handlings, labour costs, and/or transhipment time. The Tuchschmid Compact terminal exists of four modules: transhipment, storage, road and distribution. The transhipment module is the core of the concept and consists of a crane, an automated identification system for ITUs, trains and wagons, a (un)loading location and a buffer zone. The terminal can be built with fully automated, semi-automated or manual operation. The storage, road, and distribution module are optional and the capacity of the terminal can always be extended. The Austrian Innovative Transhipment and Terminal consists of three elements: the buffer/storage rack, the buffer/

storage rack transport system and the container crane. After arrival of the train, the crane unloads the ITUs and moves them to the sorting zone. The transport system transports them to their place in the buffer/storage system. Later, the ITUs are transported back to the sorting zone and be placed on a truck or train for further transport.

The second category of concepts is the 'trailers on trains' (e.g. TATRA, Cargo Speed). The trailers on trains concepts come in different forms, but they all have at least one thing in common: transporting trailers or swap-bodies on rail wagons. The concepts vary in automation, speed, complexity, and land use (TERMINET 1997a–c). The concepts range from an improvement in 'putting the trailer on the train' to complete new terminal layouts. Consequently, the resulting transhipment time and costs vary considerably. TATRA is a concept whereby the load-bed can be removed from the wagon. At the terminal, the load-bed is taken of the wagon by a crane. On the terminal, a trailer is driven on the load-bed by a truck (or tractor) after which the load-bed is placed back on the wagon. Cargo Speed is a roll on/roll off system that consists of a pop-up mechanism between the rails. The mechanism pops-up, thereby lifting the wagon load-bed. The mechanism also turns the load-bed about 35°, so as to enable trucks to drive onto the wagon load-bed directly of the terminal platform. Installing more pop-up mechanisms can easily increase the capacity of Cargospeed.

The third category is the transhipment techniques (e.g. Transmann, Krupp FHS). The transhipment techniques can be separated between horizontal and vertical. Currently, mainly vertical transhipment techniques (cranes, reach stackers, and forklift trucks) are used. The innovative vertical concepts in transhipment aim at the increased use of automation to supervise the transhipment material; improvement of the transhipment speed; increasing weight lifting capacities; transhipment in the presence of an electric overhead line; and a reduction in the used terminal surface. The Transmann crane works according to the same principle as a normal gantry crane. The Krupp FHS can be characterized by speed, low noise levels, space intensive operation and automation. When a train enters the terminal, the terminal system takes over the train traction. While the train drives slowly to the terminal, the ITUs are (un)loaded.

The horizontal transhipment innovations enable the transhipment without lifting the ITU. Most innovations propose changes to wagons so as to enable horizontal transhipment. Advantages are that transhipment may take place under an overhead line and limited need for additional transhipment cranes. Disadvantages are that wagon owners are required to invest considerable amounts, many concepts are relatively labour intensive, and the concepts are not faster than conventional transhipment techniques. Because of the disadvantages, it has been decided to leave the horizontal innovations out of the analysis. The next section will discuss the theory needed for the analysis.

Innovation Management Theory

Numerous terminal innovations have been identified (TERMINET, 1996, 1997a–c; Bontekoning, 2002). But, so far, only limited changes have taken place. In order to analyse this lack of success, several 'promising' transhipment innovations will be tested on product characteristics, rail terminal requirements, and to a lesser extent on rail freight transport requirements.

Adoption of Innovations: Product Characteristics

If an innovation is completed, it can be applied. If this is at another organization than the organization that has produced the innovation, this is called the adoption of an innovation. The implementation process of an innovation in the organization that has created the innovation differs from the implementation process of an organization that adopts an innovation. An adopting organization will not pass through all phases of the implementation, because it has not been actively involved in the innovation process. Several terminal innovations are ready for adoption. The adoption process of an adopting organization consists of a number of steps (Rogers, 1995):

- Awareness of the innovation possibilities.
- Creation of an attitude towards the possibilities of an innovation.
- Evaluation of the innovation potential.
- Decision to adoption of the innovation.
- Test of the adoption.
- Permanent adoption of innovation.

The perception of the characterizations of an innovation that potential users have influences the decision to adopt the innovation and the further use after adoption. It proves that the perception of potential users concerning the innovation characterizations is a good method to measure the chance for adoption and continued usage (Tidd *et al.*, 2001). An innovation's chance of success correlates positively with the chance for adoption and continued usage. Tornatsky and Klein (1982) have identified compatibility and complexity as being statistically significant innovation characteristics. Rogers (1995) distinguishes five factors that influence the chances for adoption and continued usage of an innovation:

- Relative advantage.
- Compatibility.
- Complexity.
- Opportunities to observe.
- Try-out.

In addition to these factors, Nooteboom (1989) mentions uncertainty, user-friendliness, and risk as important subjects. On the basis of the literature, the following general criteria have been selected to evaluate the lack of successful innovations: relative advantage, compatibility, complexity, try-out, observability, trial ability, uncertainty, user friendliness, and risk. In the theoretical approach, user friendliness is combined with relative advantage. Furthermore, try-out also incorporates observability and trial ability. Finally, uncertainty and risk are combined into one product characteristic. For an overview, see the left part of Figure 3. These criteria will now be discussed in more detail. Relative advantage is the degree to which an innovation is expected to perform better then the existing product/service that it replaces (Rogers, 1995). User-friendliness is assumed to be one component of relative advantage. User-friendliness refers to the degree to which an innovation is used with relative ease. It is crucial to realize that relative advantage must be gained instead of being something that is inherent to an innovation. The value of the relative advantage (and/or its elements) itself depends on the innovation concerned. In addition, the character of the actor concerned may also influence

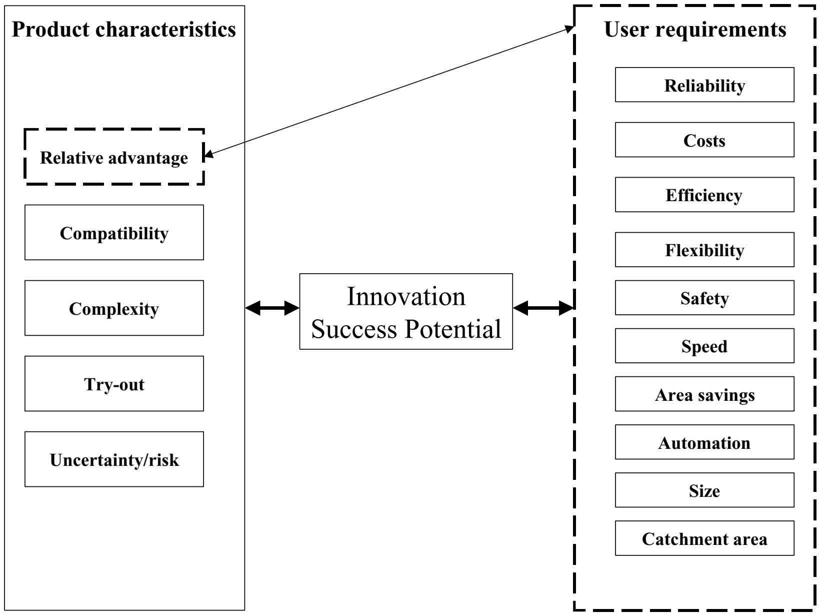

Figure 3. Success potential of rail transhipment innovations. *Sources:* based on Nooteboom (1989), Rogers (1995), Bergquist and Abeysekera (1996), Konings (1996), Kreutzberger (1997), Konings and Kreutzberger (2001), Tidd *et al.* (2001), Chan and Wu (2002) and Wiegmans (2003)

the relative advantage of an innovation. The relative advantage of an innovation, as observed by the actors involved, correlates positively with the degree of adoption of this innovation. Compatibility refers to the degree to which an innovation fits into existing infrastructure (either technological or social/organizational). It is the degree to which an innovation is observed as being consistent with existing values, experiences from the past, and the needs of potential users (Rogers, 1995). The degree of compatibility of an innovation, as observed by actors involved, correlates positively with the degree of adoption of this innovation. Complexity means the degree to which the innovation is more difficult to understand and use (either technological or social/organizational) than the current technology (Frambach and Schilleweart, 1999). Therefore, complexity is an aspect that is multidimensional. The degree of complexity of an innovation, as experienced by the actors involved, correlates negatively with the degree of adoption of this innovation. Try-out refers to the degree to which an innovation can be experienced (observe) and tested (trial ability) (Rogers, 1995). Try-out is an important property of an innovation, especially for early adopters. Some innovations have clear results, as a result of which users observe the usefulness of an innovation. When the usefulness is less perceptible, it may have an impact on the degree and speed of adoption. In later adoption stages, the influence of this property on the adoption decreases. The degree of try-out, as experienced by involved actors, correlates positively to the degree of adoption of this innovation.

Uncertainty can be defined as the degree to which the expectations of the innovation will be met. Risk can be defined as the degree to which an innovation is not satisfying needs. The distinction between these two criteria is visible, but limited. Rogers (1995) distinguishes between financial and social market uncertainty/risk.

The degree of uncertainty/risk of an innovation, as experienced by involved actors, correlates negatively with the degree of adoption of this innovation.

Intermodal Rail Terminal: User Requirements

The intermodal rail transport solution consists of the main rail transport, two relatively expensive terminal handlings, and pre- and end-haulage (Figure 4). The notion of competitive forces is a useful framework when describing the rail terminal market (Wiegmans, 2003). The essence of this model is to link a company to its industry competitors and to its main stakeholders. This also helps to understand better the user requirements of the sectors that operate, use, supply, compete with, or regulate the rail terminal. Besides the industry competitors, the main stakeholders are buyers, suppliers, potential entrants, substitutes, and regulators. The industry competitor is the central actor in the rail transhipment market. The rail terminal must buy the innovations and implement them successfully at the terminal. Their main user requirements will be for more efficiency, lower costs, and/or more sales. The buyer of terminal services (the user) is a company, which arranges for containerized goods to be shipped (intermediary), the shipper himself, or a rail freight transport company. An intermediary can be: a company that is responsible for loading and unloading ships (stevedore); a person who buys and sells transport capacity for others (shipbroker); a representative who looks for door-to-door solutions that suit his customers (shipping agent); or a person/company who sends goods to someone (forwarder) (Wiegmans, 2003). Important customers of a terminal operator can be found among carriers of the containers and intermediate logistics companies. For the terminal customers, the innovations must result in cost reductions and/or quality increases.

Suppliers deliver container cranes, terminal area, terminal concepts, and buildings to terminal operators. Suppliers of, for example, container cranes usually have other businesses; their future prospects do not directly interfere with that of the buyers of their terminal facilities. The suppliers 'translate' user requirements of terminal operators into innovations. Their main goal is to sell their innovations to as many rail terminals as possible. So far, the suppliers have not been that successful in selling their transhipment innovations.

Potential entrants to the rail terminal market are newly constructed terminals. In general, newly established rail terminals start with relatively simple equipment to realize low costs. This suggests limited potential for transhipment innovations. In general, potential entrants are diverse companies, such as road transport companies, rail companies, or continental terminal operators. The potential entrant must ideally buy the transhipment innovations and implement them successfully at the terminal. Their main user requirements are for efficiency and low costs.

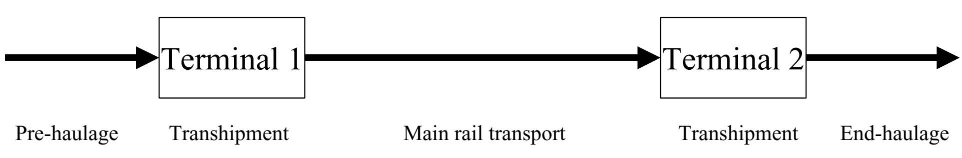

Figure 4. Intermodal rail transport including two transhipments. *Source:* based on Wiegmans (2003)

Substitutes decrease the potential profits of a sector by imposing a barrier on the prices that industry competitors in a sector can request. Especially, single-mode container road transport forces the rail terminal industry to be competitive. The substitutes are not directly involved in the transhipment innovations, but force the terminal operators and terminal users to become more efficient and to lower costs. The regulators include all governmental levels, ranging from the local to the European level, that influence the terminal market and the terminal operator in his daily operations. In Europe, important regulatory areas concern the promotion of intermodal transport and the corresponding issue of environmental safeguards. Regulators could promote transhipment innovations that improve these aspects.

In this research, the focus is on the efficiency of transhipment, because most innovations aim to improve the transhipment of the freight at the terminal. Overall, it appears that the efficiency of terminals is quite good (Wiegmans, 2003). But, given the expectations for growth of freight transport, the capacity of rail freight terminals must be increased as well. The expectations are that part of the necessary capacity extensions can be realized through the introduction of innovative transhipment concepts. The main drivers of terminal operations are costs, reliability and speed of transhipment (Wiegmans, 2003). The implementation of innovative transhipment concepts probably strongly depends on improving these drivers. To evaluate the lack of success of terminal transhipment innovations, it is necessary to ascertain the user requirements. In this connection, Tsamboulas and Dimitropoulos (1999) have identified the nodal centre's size, its catchment area, and the level of political support for the investment as the main decisive factors for choosing the appraisal method and decision criteria for investments in rail terminals. To a certain extent, implementing an innovation (investment) can be compared with an investment in a terminal. Worrell *et al.* (1997) have mentioned fuel efficiency and costs as general criteria. Several other criteria can be found in terminal research (Konings, 1996; Intermodal Quality, 1997; Kreutzberger, 1997; Cardebring *et al.*, 1999; Konings and Kreutzberger, 2001; Wiegmans, 2003): reliability; costs; efficiency; flexibility; safety; speed; space saving; and automation. The criteria that result from terminal research have been selected to evaluate the lack of successful innovations. Furthermore, nodal centre size and catchment area are also included as criteria. Reliability is the degree to which the terminal operator meets the agreed service time. Innovation costs are the investment costs involved in purchasing the innovation and the exploitation costs incurred after purchase. Efficiency refers to the degree to which the terminal operator is able to perform the operations at the terminal right. Flexibility is the degree to which a terminal operator is capable of solving problems for customers when they arise. Safety refers to the chance that transhipments units are damaged during transhipment. Speed refers to the number of transhipments per hour. Space saving refers to the degree in which the innovation is able to use an existing terminal area more efficiently. Automation is the degree in which terminal personnel are replaced by machines. Nodal centre size refers to the number of transhipments per year. Catchment area of a terminal refers to the average distance of the pre- and end-haulage of that particular terminal.

To be able to evaluate the lack of success it is important to retrieve factors that influence the chance for success and to define what success comprises. Success is connected with the performance of the innovative product or service, but frequently also depends on external factors that influence the innovation process

(Tidd *et al.*, 2001). Two groups of factors that influence the chance of success can then be identified: first, external factors that determine the adoption of the innovation (technical product characteristics); and, second, factors that improve the transhipment technique (user requirements for performance). Technical product characteristics that determine the adoption of the innovation are: relative advantage; compatibility; complexity; opportunities to observe; try-out; uncertainty; user-friendliness; and risk. Performance (user) requirements of rail freight terminals (and rail terminal users) are: reliability; costs; efficiency; flexibility; safety; speed; space saving; automation; nodal centre size; and catchment area. The concept of Quality Function Deployment (QFD) appears to be a suitable framework to connect external factors with performance. QFD enables the 'translation' of customer requirements into product characteristics (Bergquist and Abeysekera, 1996; Tidd *et al.*, 2001; Chan and Wu, 2002). The resulting characteristics of QFD for innovative transhipment concepts must be optimized in order to increase the chance of success for an innovation. Figure 3 shows how QFD can be used to connect user requirements with product characteristics. In the next section, this framework will be used to analyse the lack of success of innovations in rail freight transhipment.

Evaluation of Rail Terminal Transhipment Innovations

In this section, the six selected transhipment innovations are evaluated in terms of product characteristics and user requirements through a survey among terminal operators, experts and terminal users. User requirements for intermodal rail transport (and thus also for rail transhipment innovations) can be analysed from two points of view: first, the user of the innovation is the terminal operator and the innovation must meet his criteria; and, second, the actual user is the rail transport company (and ultimately the shipper of the freight). The innovations are then evaluated with reference to their performance increase for the total intermodal transport solution. What does the innovation contribute to the total intermodal rail transport solution in terms of reliability, costs, capacity, efficiency, flexibility, safety, speed, etc?

The selection of the six innovations (out of 124) has been based on data availability, potential success, current status of the innovation, number of investors involved, complexity of the innovation, adoption in current terminal processes, useful for standard ITUs, flexibility in handling different types of ITUs, investments for the terminal, investments for others, direct transhipment is obliged (or not), transhipment speed, and try-out (Langstraat, 2005). In the terminal innovation database, three main categories can be recognized:

- 'New-generation terminal' concepts (e.g. Tuchschmid compact terminal, A-IUT).
- 'Trailers on trains' (e.g. TATRA, Cargo Speed).
- Transhipment techniques (e.g. Transmann, Krupp FHS).

The goals of the survey are to find out about the user requirements for intermodal rail transport, the product characteristics of the innovations, and the user requirements performance of the innovations. A short description of the six innovations has been given to the respondents, after which they have been asked to present their perception of the innovations. More than 500 surveys have been sent by email to terminal operators, experts and terminal users. After several rounds of follow up, unfortunately only 25 respondents reacted. This means that the statistical results should be treated carefully.

First, the respondents have been questioned on the 'stability' of the rail freight market and the expected developments in the market. They view the market as being neither stable nor unstable and quite predictable. Currently, several organizational innovations (ICT (information and communication technology)-oriented) are implemented on terminals. In general, innovations are developed and implemented in relatively more unstable markets. Therefore, the overall conditions of the rail freight market do not suggest a favourable environment for innovations. Intermodal transport literature suggests that reliability and costs are the most important quality aspects. The overall survey results indicate the same two aspects as being important (Figure 5). However, there appear to be a number of differences between terminal operators and market parties. For terminal operators, reliability and flexibility appear to be more important than they are for market parties. This suggests that terminal operators could reduce their focus on these aspects without reducing total perceived quality of market parties. Moreover, less focus by terminal operators on flexibility and reliability offers opportunities for increased focus on other quality aspects (e.g. costs). For market parties, costs and total quality are more important than for terminal operators. Other quality aspects also matter, but are relatively less important. Moreover, the differences among these—relatively less important quality aspects—are less. Terminal operators and terminal users (market parties) were also questioned about their judgement of the quality performance of intermodal rail transport (Figure 6). The overall picture for intermodal rail transport from the literature is not good and this is affirmed by the survey results. Most quality aspects of intermodal rail transport are judged to be moderate or neutral. The differences between market parties and terminal operators are not large for most of the aspects. The most important differences between terminal operators and market parties concern flexibility and capacity. Overall, it can be stated that the market is perceived as neither stable nor unstable and as quite predictable. Terminal operators might change their focus of the importance of several quality aspects and this might

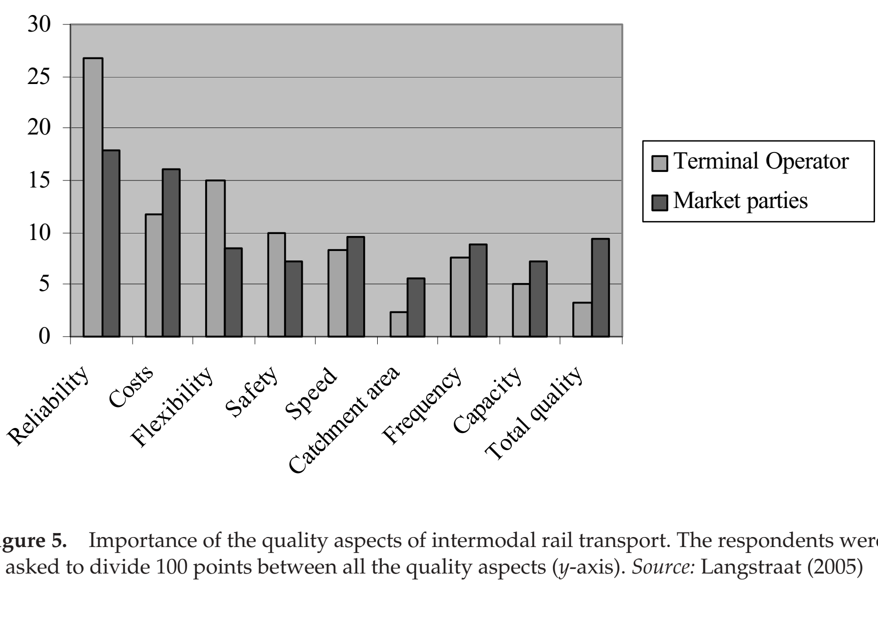

Figure 5. Importance of the quality aspects of intermodal rail transport. The respondents were asked to divide 100 points between all the quality aspects (y-axis). *Source:* Langstraat (2005)

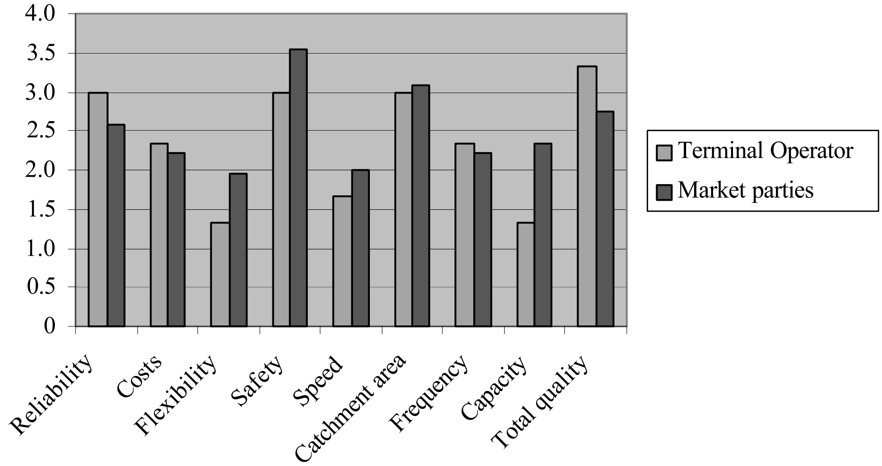

Figure 6. Quality judgement of intermodal rail transport. 1 = Poor, 2 = moderate, 3 = neutral, 4 = reasonable, 5 = good (*y*-axis). *Source:* Langstraat (2005)

result in an overall quality improvement. Current quality of intermodal rail freight transport is judged to be moderate.

Second, the respondents have judged the product characteristics of the six innovations. Table 2 shows the results of the survey (Langstraat, 2005). For each innovation, the respondents have given their perception for that particular innovation on compatibility, complexity, try-out, and uncertainty/risk. Beforehand, literature suggests that the performance for compatibility will not be that good. In the survey, the product characteristics of six rail terminal innovations have been judged by terminal operators, transport companies, and intermediaries (the market parties) on a scale of 1 to 5, where 1 is poor, 3 is neutral and 5 is good. The values assigned by each respondent group have the same weights, as the number of responses is too limited to make a reliable distinction between the different response groups. This appears an interesting point for further research. The product characteristic 'relative advantage' will be dealt with in more detail in Table 3. In Table 2, most product characteristic criteria score around neutral. This indicates that the innovative concepts fail to achieve an overall higher standard (where more of the product characteristics are judged neutral, or higher (4 or 5)). No major problems are expected when implementing 'new generation terminal' concepts. However, the compatibility with service requirements is not good enough and the transhipment is to complex, when compared with current operations. When compared with the other two categories, the 'new generation terminal' concepts do not score well on compatibility and complexity. For the 'trailer on train' concepts there are enough opportunities to experience/try-out. However, the compatibility with current service requirements is not good enough. Furthermore, some problems are expected when implementing a 'trailer on train' concept. When compared with the other two groups, the 'trailer on train' concepts do relatively well on try-out, but relatively worse on uncertainty/risk. No major problems are expected when implementing an innovative transhipment concept. The complexity of the concepts is about the same as current concepts. However, the compatibility with current service requirements is not good

Table 2. Product characteristics for rail transhipment innovations

	New-generation terminal concepts		Trailer on train concepts		Transhipment concept	Transhipment concept
	Tuchschmid	A-IUT	TATRA	Cargo speed	Transmann	Krupp FHS
Compatibility	2.7	2.6	2.7	2.8	2.3	2.6
Complexity	2.7	2.8	2.9	3.0	3.2	3.1
Try-out	2.8	2.9	3.3	3.1	3.0	2.8
Uncertainty/ Risk	3.5	3.6	2.8	2.9	3.5	3.6

Compatibility: this transhipment concept is compatible with service requirements.
Complexity: the transhipment becomes less complex with this new concept.
Try-out: there are enough opportunities to experience/try out this concept.
Uncertainty/risk: no major problems/surprises will arise when implementing this concept.
N = 25; 1 = totally disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = totally agree.
Source: Langstraat (2005).

enough. It appears that the compatibility with service requirements of this innovation category is valued the lowest, when compared with the other two innovation categories. Overall, it seems that the six concepts will not be able to have an overall positive influence on the terminal operations. The concepts seem able to improve certain product characteristics, but it seems too difficult to get them adopted.

Third, the respondents have judged the perceived performance of the user requirements of the six innovations (Table 3). The user requirements that have been judged are reliability, costs, efficiency, flexibility, safety, speed, space savings, automation, size, and catchment area. Overall, the innovations score around neutral on the different user requirements. This indicates that the improvements offered by the innovations seem not enough to adopt them. The 'new-generation terminal' concepts seem to be reliable, efficient, flexible, secure, deliver high speed, and provide an adequate catchment area. However, from literature it follows that the innovative concepts appear to have high costs. Thus, compared with current techniques, the performance of the new-generation terminals seems not sufficiently better whereas costs are higher. The low score on flexibility might be explained by the focus on container transhipment. Respondents value both innovations more or less the same. The performance of the A-UIT innovation is slightly better. Overall, the performance of both 'new generation terminals' seems insufficient to adopt them. The trailers on train concepts seem to be reliable, efficient, secure, deliver moderate to considerable speed, and provide an adequate catchment area. The TATRA is non-automated, low cost, and flexible. The TATRA concept is suitable for low- to medium-scale terminals with a small to medium catchment area. The Cargo Speed is highly automated; however, it appears to have high costs, a fixed nature, and no space savings. The Cargo Speed concept is suitable for medium-scale terminals with a medium catchment area. Compared with current techniques, the performance of the new trailer on train concepts do not seem much better and therefore, adoption seems not likely.

Both the transhipment innovations appear to perform well on the user requirement safety. The Transmann concept seems to be efficient, flexible, secure, speedy, and provide an adequate catchment area (the Transmann concept is

Table 3. User requirements for rail transhipment innovations

	New-generation terminal		Trailer on train concepts		Transhipment concepts	Transhipment concepts
	Tuchschmid	A-IUT	TATRA	Cargospeed	Transmann	Krupp FHS
Reliability	2.9	2.9	3.0	2.9	3.0	2.8
Costs	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Efficiency	2.9	2.6	3.2	2.4	3.1	3.0
Flexibility	2.5	2.6	2.9	2.8	2.5	3.0
Safety	3.5	3.6	2.8	2.9	3.5	3.6
Speed	3.2	3.2	2.8	3.2	3.0	3.8
Space savings	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Automation	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Size	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Catchment area	2.5	2.5	3.3	3.2	2.5	2.6

Reliability: the terminal service will be more reliable with this concept.
Costs: are not available and therefore this question has not been answered by the respondents.
Efficiency: this concept will not require extensive training of current personnel or require new personnel.
Flexibility: this concept enables the terminal a more flexible response to problems.
Safety: this concept reduces the risk for damages and/or loss.
Speed: this concept increases the number of transhipments per hour.
Space savings: this has been indicated by the respondents as being not important.
Automation: this has been indicated by the respondents as being not important.
Size: this has been indicated by the respondents as being not important.
Catchment area: this concept makes intermodal rail transport more attractive.
n.i. = this has been indicated by the respondents as being 'not important'.
Source: Langstraat (2005).

suitable for small-scale terminals with a small catchment area and transhipment under an overhead line). However, the innovation appears to have high costs. The transhipment 'Krupp FHS' concept seems to be reliable, efficient, secure, delivers high speed, and provides an adequate catchment area. The 'Krupp FHS' has been especially designed for fast handling. The concept is suitable for large-scale terminals with a large catchment area. However, the innovation concept appears to have high costs and is inflexible. Adoption of both transhipment innovations seems not likely.

Considering the results of the evaluation of the product characteristics and the user requirements as a whole, it seems unlikely that any of the concepts has a reasonable chance to be adopted soon. None of the concepts had an overall positive score on the product characteristics and the user requirements. However, there are a number of different opportunities to make the innovations more attractive on the user requirements side (e.g. flexibility). A conclusion that can be drawn from the literature is that the costs of the innovations are (too) high. This is probably one of the major barriers to the successful adoption of the innovations in the rail transhipment market. In this market, costs are very important and cannot always be recovered through charging higher prices. Another conclusion is that most innovations focus on the improvement of a certain problem. Often, the improvements for the total rail transport solution are limited and/or new problems arise from the adoption of a certain innovation. By looking at the impact of the concepts on the transhipment at terminals and on the intermodal rail transport, it would appear that the concepts impact the user requirements on terminal level more than on the intermodal rail transport level. The associated reliability and costs of the innovative concepts will not do enough to improve the reliability and costs of the total rail transport solution offered by the rail transport companies. A final conclusion is that it appears that the investments in the innovations have to be made by the terminal, while the improvements caused by the innovations end up by the terminal customers. For the terminal operators it proves to be difficult to recapture their investments by raising prices.

Conclusions

The central place of transhipment in rail transport solutions and the lack of innovations in this connection has been the focus in this paper. The problem definition of this paper was as follows. Why are the majority of innovations in rail terminal transhipment not adopted and how can this be changed? The application of the theoretical framework leads to a number of conclusions.

First, the majority of the innovations in rail terminal transhipment are not adopted due to limited (or no) improvements in product characteristics, limited (or no) improvements in user requirements, high costs, and limited effects of the innovations on the total transport solution. The second conclusion is that the user requirements of the different innovations show a more or less neutral picture in terms of improvements. Even so, several different opportunities exist to make the innovations more attractive on the user requirements side. The third conclusion is that, as mentioned above, the cost of the innovative concepts is (too) high. In most cases, the costs are higher then conventional/current techniques, although the higher costs appear to be accompanied by better performance at the terminal or for the total rail transport solution (in, for example, reliability). A final conclusion on the causes of a lack of adoption is that the innovative concepts appear to have the most effect on the rail terminal. However, the innovation must also affect (improve) the total rail freight transport solution.

Having determined the reasons for the lack of adoption of innovative concepts in the rail terminal market, it is important to answer the following question: How can this be changed? The lack of adoption of innovations in the rail terminal market can be changed through the development of new innovations, more research, cost reductions of existing innovations, or by accepting a limited role of rail transport and terminals. First, new cheaper innovations might be developed that focus on quality and/or efficiency improvement in the total rail transport solution. Second, more research into product characteristics and user requirements might help to improve current innovations that look promising, but at the moment are not adopted. Furthermore, research is needed that offers a better and more reliable insight into the differences between a terminal operator and a terminal user. Third, suppliers of terminal innovations might strive for cost reductions for the offered innovations. This might reduce one of the barriers that prevent adoption. Fourth, a limited role of rail transport and terminals can be accepted. However, mounting problems for road freight transport mean that alternatives are needed and rail freight transport and terminals is one of them. As most companies in the rail transport and transhipment sector are engaged in cost reductions and efficiency improvements, innovations that help them with cost cutting or deliver increased efficiency might have a (better) chance of adoption in the short run.

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