CONCEPTS, MODELS AND METHODS FOR RAIL FREIGHT AND LOGISTICS PERFORMANCES: AN INCEPTION PAPER

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Abstract

The traditional railfreight service has changed. It is believed that logistics concepts will improve rail freight systems performances. New concepts are proposed, studies and projects are undertaken, and new systems for railfreight are developed. If railfreight is to break back into markets by employing logistics concepts, it has to rapidly adapt to changing political measures, economic trends and market conditions. It is therefore a field where reliable, efficient and updated models and tools are required to help railfreight operators improve their operational efficiency and rationalize their tactical planning decisions. The objective of this paper is therefore to present innovative railfreight and logistics concepts; to report on the existing literature for railfreight tactical management and hence to indentify some of the main issues and obstacles in railfreight and logistics performances.

Keywords: Rail Freight, Logistics, Models, Planning, Decision-Making, Performance Assessment

1. CURRENT SITUATION

The world globalization and integration have contributed to remarkable changes in the way we have lived. New mobility patterns are being observed. Population in the cities is on the constant increase. There are a very few activities executed in urban and suburban areas without needing to move some freight. In a liberal economy, a highly urbanised society and transport growth outstripping economic growth, many cities have experienced growing problems with the impact of goods (and service) delivery. These problems include: traffic congestion, illegal parking, just-in-time delivery, pollution, air quality, noise, intrusion upon citizens and environmental impact. These problems are not going to disappear any time soon.

To address these issues several City Logistics concepts have been developed on the basis that “new” organizational strategies for urban freight transportation are needed. The fundamental idea underlying these concepts is that we must stop considering each shipment, firm, and vehicle individually; instead, we should consider them as components of an integrated logistics system, where shippers, carriers, and movements are coordinated and loads of different customers and carriers are consolidated into the same “green” vehicles (see also Benjelloun and Crainic, 2008). This is a systematic approach appealing to transport planners used to managing public transport, but does it fit within a modern deregulated economy? (Zunder and Marinov, 2010)

In the near past, it was thought that rail could provide reliable and efficient freight transport to, from and through urban areas. Where feasible, distribution strategies that transfer freight from urban roads to environmentally sustainable rail and marine systems potentially optimise transport infrastructure usage and relieve pressures on finite urban road space and demands for road developments (Dinwoodie 2006). However, as stated by Robinson and Mortimer (2004 a) rail has not been able to match the technical, operational, commercial and product/service development initiatives that the road transport sector has repeatedly been able to implement successfully, often at timescales rail cannot achieve. Shippers are accustomed to slick, sophisticated, road-based logistics services and are very unlikely to be prepared to sacrifice these for a less capable and more costly alternative. Also, the rail freight infrastructure is very capital intensive; it needs investment and protection measures to make rail in urban freight possible and to avoid the possible loss of long-term solutions to city logistics issues (Robinson and Mortimer 2004b).

City logistics cannot be viewed and studied in isolation, but rather in the context of the integral supply chains that typically cross the geographical boundaries of urban areas. Therefore a new term has been introduced: Freight Transport Logistics.

Freight Transport Logistics focuses on the planning, organisation, management, control and execution of freight transport operations in the supply chain. Production and distribution networks depend on high-quality, efficient logistics chains to organise the transport of raw materials and finished goods across the EU and beyond. It is primarily a business-related activity and a task for industry.

In the Freight Logistics Action Plan of the EC, 2007, one of a series of policy initiatives jointly launched by the European Commission to improve the efficiency and sustainability of freight transport in Europe, a number of short- to medium-term actions are presented to help Europe address its current and future challenges and ensure a competitive and sustainable freight transport system in Europe. These actions are:

1. e-Freight and Intelligent Transport Systems (ITS) - "Internet for Cargo" - a standard for information flows to ensure the integration and interoperability of modes at data level and provide an open, robust data architecture primarily for business-to administration and administration-to administration data flows;

2. Sustainable quality and efficiency:

- Find practical solutions to bottlenecks;
- *Freight transport logistics personnel and training* to improve the attractiveness of transport logistics professions;
- *Improving performance* - Establish, in consultation with the stakeholders, a core set of generic indicators that would best serve the purpose of measuring and recording performance (e.g. sustainability, efficiency etc.) in freight transport logistics chains to encourage a switch to more efficient and cleaner forms of transport and generally improve logistics performance;
- *Benchmarking intermodal terminals* - Elaborate, together with industry, a set of generic (dynamic and static) benchmarks for terminals, starting from multimodal inland terminals, and incorporate them into a code of best practice or recommendation and disseminate information about them.

3. Simplification of transport chains

- *Simplification of administrative compliance* - Establish a single window (single access point) and one stop-administrative shopping for administrative procedures in all modes;
- *Single transport document* - establishing a single transport document for all carriage of goods, irrespective of mode;
- *Liability* - a legal instrument to allow full coverage of the existing international, mode-based liability regimes over the entire multimodal logistics chain;
- *Security* – develop European standards, in line with existing legislation, international conventions and international standards, in order to facilitate the secure integration of transport modes in the logistic chain.

4. Vehicle dimensions and loading standards:

- Study the options for a modification of the standards for vehicle weights and dimensions and consider the added value of updating Directive 96/53/EC;
- Update the 2003 proposal on Intermodal Loading Units to technical progress;
- Establish a mandate for standardising an optimal European Intermodal Loading Unit that can be used in all surface modes;
- Examine the compatibility of loading units used in air transport and other modes.

5. "Green" transport corridors for freight:

- Define green transport corridors and organise cooperation between authorities and freight transport logistics operators in order to identify improvements to ensure adequate infrastructure for sustainable transport;
- Reinforce green corridors in the TEN-T and in the Marco Polo priorities;
- Develop a freight-oriented rail network.
- Etc.

6. Urban freight transport logistics:

- Encourage the exchange of experiences of representatives of urban areas to help establish a set of recommendations, best practice, indicators or standards for urban transport logistics, including freight deliveries and delivery vehicles;
- Make recommendations of commonly agreed benchmarks or performance indicators to measure efficiency and sustainability of delivery and terminals and, more generally, in urban transport logistics and planning;
- Reinforce the freight part of CIVITAS towards better co-ordination, or integration, between passenger and freight transport, between interurban (long distance) and urban transport logistics.

It is believed that these actions will help the freight transport logistics industry towards long-term efficiency and growth by addressing issues such as congestion, pollution and noise, CO2 emissions and dependence on fossil fuels that – if left unchecked – would put at risk its efficiency. *What is the role of rail? What is the current situation with rail freight?*

A new policy has been geared in Europe towards competition on the railway market by the implementation of "*vertical disintegration"* in the sector, meaning separation of infrastructure from operation, and lowering the barriers of entering new railway operators into the Railway European Market. The European Railway Bodies now are supposed to consist of Infrastructure Manager and Railway Operators. In the case of Railway Freight Transportation this stands as "One Infrastructure Manager" and "Two or More Railway Freight Operators" with specific obligations to share the same infrastructure in providing businesses.

Regardless of the new rail policy of EC, what is observed is that most European railway operators (i.e., undertakings) cannot serve their clients well and cover their full costs. Therefore, they are considered as "still-ineffective" organizations that continue to lose market shares in favour of road transport.

Within the context of railway freight transportation, there are (at least potentially) many clients with different needs that want to transport different quantities and classes of freights, from many different demand origins to many different demand destinations. Not every consignment corresponds to a full (block) train, so in order to serve them the railway freight operators perform "network-based" businesses. The network-based business consists of consecutive operating processes executed in different places over the railway network. These operating processes are inter-connected and inter-dependent. They consist of many operations. For execution of each operation static and dynamic resources are involved. The quality of provided service strongly depends on the execution of each operation. A single resource is missing, one operation fails and the entire process deteriorates.

The traditional operating railfreight model, also called "Single Wagon Load" is that a single freight wagon (or block of freight wagons) does not move usually on one freight train directly to its demand destination. Instead, the freight wagon moves on various freight trains. This process can be specified by schedules. To some extent, the schedules indicate the connections between freight trains that the freight wagon must be part of in order to arrive at the demand destination at the appointed time. These connections take place at the rail freight yards. If a connection fails, the freight is detained and the client does not receive his freight at the appointed time. Negative effects observed: the yard queue materializes, the yard limited physical/operational capacity is reduced, the yard personnel encounters difficulties to serve the next freight trains, low utilization of moving assets, low efficiency, long term average costs for the railway company increase, the quality of service provided declines, unreliable service seen in infeasible contracts, unfulfilled customer expectations, the rail freight operator loses its reputation as a reliable provider of freight transportation services.

Over the last decade many customers needs have changed. Railway companies have tried to reduce complexity in providing their services by rail. New services have emerged, e.g. Non-Bulk Services by Rail, while some other services have been abandoned by some rail freight organizations in Europe, e.g. Single Wagon Load (Ballis and Golias, 2004; Marinov and White, 2009). Single Wagon Load has been substituted for Block Trains. Operating processes with freight trains at rail yards (shunting and hump yards) have been reduced significantly. Unattended services with block trains have emerged. New concepts and technologies for railfreight have been developed and tested such as CityCargo, CargoSpeed and TruckTrains.

It appears, however, that the scientific contribution to the field is hardly considered and implemented by many rail freight operators. Marinov and Viegas (2009a) reported for a problematic cycle caused by multiple inadequacies involving rail freight tactical management and operation. This is because during the tactical planning processes the processing capabilities of some of the rail facilities are not explicitly considered. Therefore, in many cases the operation unit has encountered difficulties to produce what is planned. At the bottom of this situation lies an incomplete methodology for accurate tactical planning. Such problematic cycles can be stopped by providing reliable tools for analysing and evaluating railfreight systems performances.

Therefore, for performance assessment, operations research and transportation science, as for rail freight transport planning, management, and policy, rail freight and logistics constitute a challenge and an opportunity in terms of both methodological developments and actual social and global impact.

The railfreight service is changing. It is believed that logistics concepts will improve rail freight systems performances. New concepts are proposed, studies and projects are undertaken, and new systems for railfreight are developed. We feel the current state of the art is lacking behind these changes. If railfreight is to break back into markets by employing logistics concepts, it has to rapidly adapt to changing political measures, economic trends and market conditions. It is therefore a field where reliable, efficient and updated models and tools are required to help railfreight operators improve their operational efficiency and rationalize their tactical planning decisions. The objective of this paper is therefore to present innovative railfreight and logistics concepts; to report on the existing literature for railfreight tactical management and hence to indentify some of the main issues and obstacles in railfreight and logistics performances.

2. INNOVATIVE RAILFREIGHT AND LOGISTICS CONCEPTS

The current state of the art suggests that City Logistics are neither an uncritical success nor an unmitigated failure. This solution tends to be hailed as a success publically before failing quietly as a commercial venture. A clear example of innovative city logistics system that failed is CityCargo Tram in Amsterdam.

It had been proposed that with both political pressure based on the Push Concept: encouraging the shift from road to rail; and interventions into the sector based on the Pull Concept[1]: tram (light rail) systems for transporting freight to, from, within and though cities would become reliable providers in the urban freight market, City Cargo aimed to provide evidence for this in trial.

The operation pattern of CityCargo was: The freight to be transported was received in warehouses on the outskirts of Amsterdam, where freight was shipped in CityCargo trams. CityCargotrams took freight to locations inside Amsterdam. They were using alternative routes on the existing tram network of Amsterdam. , The routes of CityCargo trams were not explicitly fixed. Instead, the routes were specified according to demands, congestions, peaks and off-peaks. By using different routes, the CityCargo trams did not intervene with the passenger tram services. After arriving at the desired location deep inside the city of Amsterdam, the freight from the CityCargo trams was moved to “Green” Vehicles. These Green Vehicles then transported the freight to the final customer.

After a pilot exercise the CityCargo initiative failed as a commercial venture without subsidy.

Projects such as: LEAN, BESTUFS and CITYFREIGHT has shown that the use of rail within city centres or on light rail systems is problematic there are opportunities for rail to shuttle goods into the centre of cities for onward distribution, or in the case of some German cities with circular S-Bahn systems, a*round a city.* In Dresden Volkswagen use a dedicated light rail system to move inter-plant components, in Zurich trams are used for waste recycling collections. We would contend these are unique examples with low transferability, and that the use of trams for goods is flawed due to logistics and passenger issues, but that there is an example of how rail can be used to improve goods transport in cities: The French retailer MONOPRIX is using current technology, the Parisian RER network and electric vehicles for onward distribution, to trial rail distribution into the core of Paris over short distances. The mixing of railfreight and passenger trains on urban and sub urban networks has always been prevented by the different operating characteristics of the two services and the impact on capacity management and infrastructure.

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[1] On “Pull and Push” Concepts the interested reader is advised to consult Hopp and Spearman (2004).

There have been prospects for diverting express and freight shipments in Europe from air and road transportation to more environmentally-friendly high-speed rail services. These ideas could be promising but remain caught up in financial and political problems.

Factors such as night restrictions at airports, increasing road congestion and high-speed rail technology made the potential for using rail to carry express and freight shipments within Europe more attractive. Trains operating at speeds of more than 200 km/h could link airports at night, replacing flights and truck journeys. Rail feeder services could market themselves as “better than road, cheaper than air”.

With Euro-Carex and Air Cargo Express, two major projects have been launched to try to set up rail services to carry express and freight shipments between major European airports. Euro-Carex is a Paris-based organisation seeking to link up various Western European airports, while Air Cargo Express would focus on the Leipzig-Frankfurt route and other German destinations. Euro-Carex plans to run high-speed trains between a new express freight station at Paris Charles de Gaulle airport, Lyon, Liege, Amsterdam, Lille and London in a first phase from 2012, and then extend the network eastwards to Cologne and Frankfurt and southwards to Bordeaux and Marseille. Italy and Spain could potentially be linked at a later stage.

Regional and inter-urban passenger trains typically operate at speeds of up to 160 km/hr. In contrast, typical existing freight trains only operate at speeds of up to around 100 km/hr. This discrepancy in the operating speeds of the two types of vehicle makes the running of mixed traffic problematic. The lower speed freight trains compromise line capacity as they consume excessive numbers of train paths and require significant headways to avoid congestion.

In terms of existing vehicle design, typical state-of-the-art container-carrying freight wagons tend to be relatively basic. There are two general configurations: flat wagons for carrying non-stacked containers, and double-stack wagons for lines with sufficient overhead clearance. Twin stack is not feasible in Europe due to limitations of the loading gauge, kinematic envelope and the power catenary. The main container-carrying vehicle structure is typically fabricated from steel. Suspension systems tend to be relatively simple steel coil or leaf springs with friction damping. Some vehicles are fitted with low track force bogies to minimise track attrition. The provision of the necessary integral power systems to support refrigerated containers is rare. There have been some trials of freight wagons operating at 160kph in Europe, and some wagons built for specific applications, such as post. Whilst these products are sound reports have emerged of issues with the aerodynamics and safety of containers in configurations using modified configurations.

Due to containerisation rail was able to gain some market share but with finite limits set by the commercial and operational models used by the train service provider. Due to technological progress (e.g. tracking and tracing, improved scheduling and routing, loading/unloading technology, etc.) some but by no means all railways are able to deliver competitive service standards for some products and industry segments (especially in competition with road). Due to environmental reasons the focus of various industries shifts towards alternative modes of transport, where rail has an important part to play. The green attributes of rail cannot be used to mask service, quality, operational, technical and managerial limitations. Shippers may make gestures towards environmental attributes but are still driven largely by commercial imperatives. There is no hiding this fact. Rail has failed to commercialise its inherent energy and green credentials.

To facilitate intermodal operations CARGOSPEED system was developed. This system is a ground-breaking intermodal solution that dramatically increases the volume of road freight carried by rail by facilitating transhipment operations. Unlike other road-to-rail solutions, it is both simple and scalable. Uniquely, it is also the only Roll-On / Roll-Off system that can integrate with existing Lift-On / Lift-Off operation to provide a clear migration path to a more efficient and economical future. The system has been designed to allow terminals to grow as demand increases. From mini-terminals with 2 Pop-Up mechanisms, right up to maxi terminals with 40 Pop-Up units and the ability to handle over 750,000 movements per year. CargoSpeed operates with unique rail wagons to support either Roll-On / Roll-Off operation or Lift-On / Lift-Off operation. This allows the system to be used in existing terminals and provides a clear migration path to a more efficient Roll-On / Roll-Off future. In a Maxi terminal an entire train of 40 rail wagons can be unloaded and re-loaded in only 8 minutes (20 minutes including time for the train to enter, and exit, the terminal). This compares with over 4 hours for existing Lift-On Lift-Off terminals. Multi-directional—trains can arrive and depart the terminal from either direction. This significantly increases the operational flexibility of the terminal and reduces the construction costs. As the system is primarily a Roll-On / Roll-Off system, no lifting is necessary in terminals, meaning electric traction can be used in the terminal and the time wastage and environmental impact of switching to diesel when a train arrives is not necessary.

Although an interesting and very innovative research initiative CARGOSPEED had little impact in the real world. Unfortunately, the market uptake was in fact very poor."

The CARGOSPEED system is ingenious: a train of wagons with removable floors arrives at a terminal and stops between two raised platforms; a hydraulic 'pop-up' column rises from a pit between the rails, raising and then rotating the wagon floor, allowing a lorry to drive onto it from one side, detach its trailer and then drive off on the other side. The wagon floor is then rotated back into position and the train can depart. The process is reversed for unloading. With multiple wells and pop-up columns serving several wagons on the same train, several lorries can deposit or retrieve trailers at once, greatly reducing the amount of time needed to load and unload freight.

The reason that CARGOSPEED has seen no market uptake is simply because it has not a customer. The system works and preliminary studies have shown that lorry drivers and freight transporters would use it, but the parties who could actually put it into practice, that is to say the terminals, just do not want to undertake the investment.

Rail’s ability to move large quantities of freight has never been in question. It is a commonly held opinion that rail can only be economically efficient over longer distances. It was stated by many that rail can only compete with road over longer distances and this is where railfreight possesses business advantages. It is however hard to know where the break-even point comes after which rail freight becomes more economical and efficient than road.

A new concept of designing self-propeled trains aims to show that short haul rail freight services are tenable. These short freight trains propose a fundamental challenge to the orthodoxies that govern the deployment and operation of rail freight services and challenges conventional wisdom on train sizes and competitive journey sector lengths. The self-propelled trains are thought of as TruckTrains capable of operating at inter-urban passenger train speeds that opens up the prospect of using existing line capacity for additional freight services without inflicting delay on following traffic or effectively neutralising train paths. Such trains would have high installed power and be capable of acceleration and braking performance significantly beyond that of conventional locomotive hauled trains. This type of train configuration, by virtue of its flexibility, would also be able to operate over large parts of the main and secondary rail network and potentially induce significant additional traffic volume without creating congestion. Although this concept sounds very promising, we are not aware of TruckTrain pilot projects or real word practice, however.

3. MODELS FOR RAILFREIGHT

In the literature there are three classical decision-making levels of management: *strategic, tactical* and *operational* (Anthony 1965). In the context of rail management these three levels (Assad 1980; Crainic et al. 1981; Crainic and Roy 1988; Crainic and Laporte 1997; Gualda and Murgel 2000; Pachl and White 2003) are, as follows:

The *strategic* level is related to long term vision and involves decisions for setting overall goals and targets, overall level and types of resources available, redesign and reconstruction of the physical railway network, relocation of railway facilities, building and demolishing rail infrastructure, acquisition of new resources that are of big dimension to the company, etc. This is the highest level of management in the railway freight organizations. The decisions made at this level are also known as instalment decisions and go along with huge capital investment. In this paper strategic management level is not of direct concern mostly because at this level the aim is to achieve improvements through changes in the resources of big dimensions to the company (i.e., building new yard; building new line; purchasing 20 new locomotives, etc.). However, as Pachl and White (2003, pp. 2) note, "*that sufficient infrastructure must be available to accommodate two trains when one is meeting or passing the other is a strategic plan element*". Furthermore, they say that "*when strategic planning cannot produce predictable results… there is a constant need for tactical planning. There is no normal condition goal of tactical planning, only a series of short-term solutions for immediate problems. The result is unreliable and inefficient operation*". Consequently, the strategic decisions should provide the minimum amount of required resources for normal operation[2].

The *tactical* level deals with medium term planning. At this level the railfreight transportation plans based on the adopted production scheme in operation are prepared. It is stated that tactical management aims "*to ensure, over a medium term horizon, an efficient and rational allocation of existing resources in order to improve the performance of the whole system*" (Crainic and Laporte 1997, pp. 411). At this level capacity research and congestion analysis are generally conducted.

The *operational* level is for short term planning (i.e., over the same day) and delivery of service. This management level is dedicated to how the railway freight transportation plans are "day-to-day" implemented in fulfilling freight transportation service by rail. This level incorporates tasks, such as: daily empty wagon distribution, daily locomotive assignment problem, daily crew scheduling, daily timetable setting, and daily dispatching.

In the following section, tasks solved at tactical management level of railfreight transportation are presented. The emphasis is on how these tasks have been addressed in the literature so far.

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[2] The term "normal operation" is also used by Pachl and White (2003, pp. 2).

The railfreight operators provide a "network-based" business, meaning they are organizations that satisfy the expectations of a significant number of customers by using the available production resources involved. Furthermore, the freight is originated in different demand origins and is transported to different demand destination. The railway freight transportation is not an easy task and what is required at the tactical management level is that "*the decisions should be made globally, network-wide, in an integrated manner*" (Crainic and Laporte 1997, pp. 421). This situation invokes different tasks to be solved, as follows:

(a) Service Network Design – this is to identify the transport flows, the quantities and types of freight for transportation, the origins and destinations of demand as well as the possible (existing) routes over the network;
(b) Empty Balancing - this is to specify the general tactical scheme for satisfying the clients' demand with empty freight wagons;
(c) Traffic distribution – this is to specify the movement of empty and loaded freight wagons within and between delineated geographical areas;
(d) Yard Policies – this is to specify the yard processing capabilities and yard workloads;
(e) Line Policies – this is to specify the capacity of railway lines and the movement of freight trains over time;
(f) Network-wide Policies - this is to specify the organization of the freight train movement according to yard policies and line policies.

There is quite a long tradition to use models (such as: optimisation, queueing, and simulation) in supporting rail management. For instance, Assad (1980) made an effort to collect and categorize models for rail transportation by that time. The reminder of this section is organized according to the foregoing "(a) to (f)" classification. A brief formulation of each task is provided. Existing models used to supporting railfreight tactical management are reviewed.

(a) Service Network Design

Service Network Design is to provide decisions on how a specific client demand may be satisfied subject to the physical characteristics of the existing network. More specifically, here decisions need to be made concerning the selection of routes (physical routes, intermediate stops, possible train meeting and by-passing) on which carrier services will be offered and the determination of the characteristics of each service: its mode, speed property, frequency. This problem is based on location formulations and the physical network is usually represented by a directed graph Gph= (N, Aph), where N is the set of nodes or vertices (terminals, stations and junction points or rail crossings) and Aph is the set of links representing the track sections between the notes. Typically, the links are represented by arcs in a network. When it is not necessary to specify a direction, they are represented by edges. Some of the notes (vertices) represent demand origins in the network, while others stand for the demand destinations. Thus, all possible origin-destination pairs are formed. For each OD pair in the graph, traffic demand is assumed as "given". There may be different traffic classes. Links may possess different characteristics such as capacity constraints, length and/or associated costs (fixed and/or utilization). Fixed cost may be associated with maintenance, utilization costs may be associated with the volume of traffic passing through the link. Thus, based on the physical network, i.e. Gph, the service network, say G= (N, A) specifies the set of feasible routes (and their characteristics) on which train services may be operated. So that, the aim is to choose links in the network along with the capacities and additional characteristics in order to enable the freights for transportation to flow between the required demand origins and demand destinations at the lowest possible transport costs (Crainic et al. 1981, Cranic and Roy 1988, Cranic and Laporte 1997). Recent contributions on service network design, e.g., but for intermodal transportation are provided by Farvolden and Powell (1994), Labbe et al. (1995) and Crainic (2002).

(b) Empty Balancing

Empty balancing is a task for the repositioning of empty wagons. In general, it is as follows: in practice, the freight transportation service by rail starts with “the order of empty freight wagons to be loaded.” Such an order comes with the type and required number of freight wagons, the demand origin and destination identified, the date and the hour wanted for those freight wagons to be available at the demand origins. According to “the empty-wagon-orders”, the railway freight operator satisfies the clients’ need with empty freight wagons. Those empty freight wagons are distributed over the railway network and there are nodes that have an excess number of empty freight wagons and respectively there are nodes that have a deficit of empty freight wagons. Consequently, the problem consists of defining the balancing flow of empty freight wagons from the nodes with an excess number of empty freight wagons to the nodes with a deficit of empty freight wagons subject to locations, distances and minimum transportation costs.

35 years ago, White and Bomberaut (1969) used a time-space diagram to construct a corresponding network on which freight wagon movements are interpreted as flows over arcs from node to node. They focused on a single wagon fleet in which all empty freight wagons are assumed to be interchangeable. The allocation problem is mathematically defined as a transshipment problem represented on the network. The transhipment problem is solved by an interactive algorithm.

Today, empty balancing problem is present at either tactical and/or operational management levels. Haghani (1989), Raikov et al. (1992), Karagyozov and Kupenov (1994), Holmberg et al. (1994, 1998), Turnquist (1994), Sorensson (2001), Powell and Topaloglu (2002), Joborn et al. (2004), Razmov (2004), Marinov (2006b) have studied the empty freight wagon balancing problem. For instance, Haghani (1989) formulates a model that considers the empty freight wagon distribution for the purposes of the tactical planning where large-scale advantages are targeted. On the other hand, e.g., Joborn et al. (2004) propose an optimisation model that considers the economy-of-scale effect at the operational level.

Generally speaking, the distribution of empty freight wagons is optimised by solving the classical transportation problem from operations research which is a well known case of linear programming. In solving this task, one may implement one of the algorithms for optimisation of flow in graphs and networks, such as the minimum cost flow algorithm (Cristophidis 1978, Mainica 1981, Filips and Garsia 1984) or the defect algorithm (Filips and Garsia 1984, Karagyozov and Kupenov 1994, Razmov 2004).

In principle, the empty balancing task is a multi-product transportation problem incorporating the distribution of different classes of freight wagons for transporting different classes of freight. Most classes of freight wagons cannot substitute one another. In practice, empty freight wagons are transported together with loaded freight wagons and it does not impose additional traffic constrains. Therefore, the task of optimal distribution for empty freight wagons can be brought to solving *n* mono-product transportation problems (*n* – class of freight wagons), one task for every class of freight wagons.

It should be noted, however, that in the real world there is a strong non-linearity of transportation costs with the distances and the number of freight wagons being transported because of the need for road locomotives, which incurs high fixed cost of any movement and rather low marginal cost of adding another empty freight wagon to the freight train composition. However, if there is already a planned freight train to be made up with loaded freight wagons, the fixed cost of the road locomotive should not be included.

(c) Traffic distribution

The traffic distribution task refers to the repetitive regrouping of traffic towards its demand destinations. Crainic and Roy (1988, pp. 291) formulated this problem as follows: "*for each origin-destination pair (with a positive demand) and, possibly, for each commodity class, the specification of how the freight will be moved, i.e., the services used and the terminals passed through*".

More profoundly, however, in solving the traffic distribution problem one should propose production schemes for service identifying *how and in what sequence* a set of demand origins/destinations will be served. Razmov (2003, 2004) addresses this problem as concentrated on optimisation models for processing freight wagons in their movement towards the (marshalling) yards. He has suggested three models for "attaching" the loading/unloading terminals to the yards. Each model is based on different criterion, as follows:

In the first model, the movement of the freight wagons toward marshalling yards is fulfilled according to the "shortest paths" criterion. In satisfying this condition, the algorithms of Dijkstra (1959) and Floyd (1962) are used. The process of attaching the loading/unloading terminals to the marshalling yards is dynamically fulfilled depending on the direction of the movement of the block of freight wagons dictated by the obtained shortest paths. This model minimizes the wagon.kms performed and is plausibly applied in case of complex rail networks (i.e., complex graph structure) that suggest many alternative ways for moving the freight wagons from the loading/unloading terminals to the marshalling yards.

In the second model, the concept of "gravitation model" is used. Such models are based on the capabilities of marshalling yards to reassign freight wagons, meaning marshalling yards with higher reassignment capability attract freight wagon flows of higher demand and vice versa. These models minimize the dwell time of freight wagons in marshalling yards based on assumptions of equal travelling speeds on the network and equal efficiency in the yards, providing a plausible optimisation for the movement of the freight trains toward the yards and their processing within the yards.

The third model suggested is based on implementation of stochastic schemes of the movement of freight wagon flows over a railway section and it is as follows: let us imagine that M1 and M2 are two marshalling yards located over a railway section. Also, let us imagine that there are freight wagon flows originated in a loading terminal T which is located on the railway section between M1 and M2. It is assumed that every originated freight wagon flow may be processed in either M1 or M2. Therefore, in order to demonstrate toward which of these marshalling yards a given freight wagon flow originated in loading terminal T should be oriented one computes "α_{M1} (meaning the probability of the flow to go to M1) and $1 - \alpha_{M1}$ (meaning the probability of the same flow to go to M2)" probabilities of each flow. Unfortunately, no further details (for instance, what variable affect these probabilities) are given.

(d) Yard Policies

The yard policies are generally dictated by the characteristics and specificities of the process of gathering of freight wagons into freight trains. In the literature this process could be met under the name of "Process of Freight Train Making (PTM)" (Bodiul 1971, 1972, Kaziulin 1972, Raikov 1985, 1986, Karagyozov et al. 1990a, 1990b, Razmov 2004, Marinov 2006a). Within "Single Wagon Load", the yards play an important role in providing freight transportation service by rail due to the major function of yards: to reassemble the incoming traffic for departure on outbound trains leaving that yard. The yards serve as "*redistributing* *hubs*" of traffic. However, Kumar (2004, p. 25.1) states that "*for a railroad, the yard process is an essential but non-revenue-producing component … It has been estimated that nearly one-fourth of a railroad's expense is yard-related*". This is mostly because a freight wagon in its turnaround spends a significant percentage of its time in yards. This has been reported by many studies (Raikov at el. 1976, 1985, 1986, Peterson 1977a, Turnquist and Daskin 1982, Tarski 1987, Petracek 1997, Razmov 2004). By all means, the operating processes at the yards deserve a deeper examination.

On the one hand, looking at the operating processes with freight trains at the (marshalling) yards one identifies a specific category of queueing system. This category is *bulk service queue*, meaning similar customers are served in batches. In this concept the customers are the freight wagons and they are served in batches when passing through yards. The freight wagon groups are coupled in order to form the freight trains. The freight train consists of one or more freight wagon groups. This is the crux of the PTM. Theoretically, this question might seem simple. One should merely define which freight wagon group(s) should go with which freight train. Practically, this question is not simple at all, bearing in mind how a bulk service process operates, i.e.: Bulk service is characterized with *cyclic recurrence* and has a negative consequence seen in *cyclic queues*. To verify this let us imagine that there is a scheduled freight train to depart from a given yard at 19:00. This freight train consists of four freight wagon groups which are planned to come to the same yard with other (earlier) freight trains, say, one to arrive at 10:00, the second to arrive at 12:00, the third to arrive at 15:00, and the fourth to arrive at 17:00. The freight train arriving at 10:00 will set out the freight wagon group scheduled to be part of a freight train to depart at 19:00. The same will happen with the freight trains that arrive at 12:00, 15:00 and 17:00, i.e., they will set out the freight wagon groups that are scheduled to be part of a freight train to depart at 19:00. Thus, we see that in order for the freight train at 19:00 to be served, there is a set of services to be fulfilled in sequence. However, the whole service of freight train to depart at 19:00 will be complete only when it leaves the formation yard. So, it should be clear now that none of the freight wagon groups are fully served until they all arrive, form and leave all together with the freight train they are scheduled for. In this example, the queue starts to materialize at 10:00 when the first freight wagon group arrives at the formation yard and does not vanish until 19:00 when the scheduled freight train left and its service is completed. During the intervening time, i.e., between 10:00 and 19:00, there is at least one group of freight wagons waiting. Therefore, the queue only grows and does not shrink over a period of service. This phenomenon is a cyclic queue of bulk service (Marinov 2006a).

On the other hand, the yards have always been considered the bottlenecks of the railway network. Shughart et al. (2006, pp. 11) categorize yard studies into two groups:" *1) Early studies focused on analysing the performance of yard operations and evaluating the improvement alternatives. 2) Later studies focused mostly on the classification/sorting operation as the core of all operations where authors have often proposed methods to improve the timeliness and increase the utilization of classification operations."*

The goal of the first group yard studies, which we support, is to precisely understand whether or not a yard can handle a given traffic pattern under a set of predetermined decisions and resource levels. The concept of the second group yard studies is to mostly concentrate on a specific operation among all yard processes. In most cases this is the humping or the block-to-track assignment. However, the yard is a complex production system of which the products are the outbound trains. In order to produce its product, interdependent processes have to be fulfilled. Each process is fulfilled by a yard subsystem. Each yard subsystem performance is crucial for the final product. Next, the performances of yard subsystems do not depend only on internal factors (e.g., classification technology or humping durations), but also on external factors such as variability, time and sequence of arrivals e.g.. In order to produce a quality product and further not to disturb the rail network performance, the yard should be capable of managing external factors.

Therefore, focusing only on one yard operation would not lead to breakthrough. Instead, an integrated approach is required and it seems that these early yard studies were in the right direction. However, as far as our knowledge goes for several decades the academic and practical interest on analysing the performance capabilities of integrated yard systems and evaluating the improvement alternatives has faded in Europe.

In the literature, queueing models and simulations have been used in order to analyse the complex yard behaviour. When using queueing models the concept is that one decomposes the yard being examined into subsystems involving the different operations performed and corresponding physical and human resources (e.g., subsystem dedicated to receiving and inspections; subsystem dedicated to shunting; subsystem dedicated to departure; etc.). After having this done one replicates and analyses the behaviour of each subsystem by a limited class of known queueing systems assuming they operate in *steady state* (Peterson 1977a, b). For more information on queueing systems, the interested reader is referred to Lee (1968), Cooper (1981), Gross and Harris (1985), Hall (1991). These queueing systems are classified by: arrival process; service process; number of servers; and maximum queue size. Generally speaking, this method has a pedagogical foundation and quickly provides insights on the behaviour of a queueing system. There are a few queueing systems, however, that operate with exact formulas (e.g., M/M/1(m)/∞(b) - Poisson Arrivals, exponential service times, a single service (or m - servers), infinite capacity (or b - buffer size);). If an exact formula does not exist, approximations for computation of the measures of subsystem performance are used (Shore 1988a, b; Karagyozov 1990a, b, 1997).

Another class of queueing models is a network of queueing systems. This issue is not yet resolved in a satisfactory way. In the literature only few “*products*” on queueing networks are found, but with descriptions that are quite limited in application. These are:

- Open Queueing Network
- Closed (circuit or cyclic) Queueing Network
- Queueing Network Analyser

The closed queueing network products describe systems characterized with a finite number of potential customers, i.e. the number of customers is fixed. Scientifically, those models are only important when the number of potential customers is relatively small. Otherwise, in the case of a very large number of potential customers, they are accepted to be infinite and the system is treated as an open queueing network product. If the arrival process is accepted to be Poisson, the service times are accepted to be exponential, and the buffer sizes are accepted to approach infinity, then one is dealing with a classical exponential queueing network product of Jackson (Jackson 1963).

In fact, the customer arrival process is not always plausibly described with a Poisson distribution and the usage of Jackson network is inappropriate. In these cases one better uses the queueing network analyser which is said to provide a fast solution for large networks with fixed routing probabilities. The arrival process is formulated as a renewal process defined by the first two moments with independent and identically distributed inter-arrival times. The service process must also be defined by the first two moments (Whitt 1983). Generally speaking, the main idea behind this tool is to solve the traffic equations and then decompose the network into single G/G/m queues and solve those individually. This tool employs mainly approximations.

As far as our knowledge goes there are very few sources available on application of queueing networks in examining rail facility behaviour. van Dijk (2000, pp. 150) reports that "*a railway station can in essence be regarded as a circuit switch queueing network, …, for which analytical queueing results are available under the 'lost' assumptions*", however no further details are provided. Lost assumption means that if the buffer size of the queue is full the subsequent customers that require service are rejected and it is further assumed unrealistically that they never return. One might debate the realism of this assumption in terms of railway freight transportation.

Analytical Network models cannot handle non-stationary behaviours and the performance measures estimated are not susceptible to variations. They are much more restrictive than simulation. The results obtained by simulation are susceptible to random fluctuations and simulation captures non-stationary behaviours. However, as stated by Hall (1991, p. 392) *"…simulation is dangerous…there is even a tendency to forget that simulation models require empirical data … - data that must be obtained through observation*".

Conceptually, simulation should take place at the end of analysis. It is an effective tool for evaluating "*What-if*" alternatives, tactical approaches, production schemes, design changes and capacity expansions. The strength of simulation model lies in its capability to capture a large amount of processes, decisions and details. We further comment on simulation models and simulation tools in (f) below.

To make the best use of simulation, when analysing the complex yard behaviour (or any other complex system) one better operates with a specific simulation tool created for this particular purpose, as in Germany (Pachl and White 2003) or the software package VIRTUOS (Klima 1997, 2001, Kavicka 2000). When no specific yard simulation software is available or appropriate, one needs to analyse, choose and adapt an existing simulation tool for this purpose. A simulation language that has been used in examining terminal behaviour is General Purpose Simulation System (GPSS). GPSS is a process-oriented simulation language that combines sequence of events into single subroutines called blocks (Nadel and Rover 1967, Karagyozov 1983, Katchaunov et al., 1998, Razmov 2004, Ivanov 2005). Marinov and Viegas (2009b) developed a simulation modelling methodology for analysing flat-shunted yard performances using SIMUL8. We are also aware of a class project on hump yard simulation performed by Harrod (2003). The subject of this independent project is Queensgate yard - one of North America's largest hump switching yards. Harrod has studied Queensgate yard performances by using Arena Simulation Tool. Arena employs an object-oriented design for entirely graphical model development. Simulation analysts place graphical objects—called modules—on a layout in order to define system components such as machines, operators, and material handling devices. The core technology of Arena is the SIMAN Simulation Language (Takus and Profozich 1997). After creating a simulation model graphically, Arena automatically generates the underlying SIMAN model used to perform simulation runs.

(e) Line Policies

Capacity research is required to guarantee "*slots*" for the freight trains to run over the railway lines. Capacity of a line depends on how the "key line policies" (i.e., train scheduling, timetabling and traffic rules) are regulated. Capacity of a railway line is analysed through analytical models and/or simulation.

In fact, in the recent literature the analytical models are not widespread in analysing line capacities for tactical planning purposes. Simulation is much more commonly used. However, Huisman et al. (2002) make an effort aiming to develop a solvable queueing network model that computes performance measures of interest without requiring train schedules. In their paper they start with the partition of a railway network into stations, junctions and sections, arguing that by a careful definition of these components, the railway network is transformed into a so-called product from queueing network. This product form result justifies a decomposition of the network in its components, which in turn justifies a more detailed analysis of components in isolation. However, to obtain this product result some simplifying and modifying assumptions have to be made. The presented model employs M/M/m queues and thus closed form expressions for mean delays are obtained. Also, the model is capable of evaluating network designs, traffic scenarios and capacity expansions.

In the early 1980s, Peterson and Taylor (1982) presented a model for rail line simulation and optimisation. The modelling concept is to divide the rail line into segments that represent the track stretches between adjacent switches. Peterson-Taylor's model is implemented in "FORTRAN" language. Their model contains 1800 lines of code.

Katchaunov et al. (1998) developed a simulation model for analysing a railway section using General Process System Simulation (GPSS) language. Their aim is to obtain the main technological indices for the exploitation of a railway section through different equipment and changes made in technical configuration, and infrastructure. Their simulation model contains 350 lines of code. Other contributions are provided by Pachl (2002), Goossens et al. (2004), Moreira et al. (2004), Pachl and White (2004), White (2007).

We shall not discuss "line policies" further because firstly this takes greater importance in the context of passenger services especially when the rail lines are saturated and 30 seconds delay is crucial for the quality of provided service, which is not the present case; secondly the "slots-guarantee" policy is a dispatching problem, which takes place at the operational planning, and thirdly combined line policies and yard policies determine network-wide policies. We comment further on this below.

(f) Network-wide Policies

The network-based business requires a network policy. In the case of railway freight transportation the network policy integrates certain decisions for the movements of freight trains over the lines and the allocation of work between marshalling yards. The railway freight system should neither be idle, nor oversaturated at any time. The analysis of "network-wide policy" by rail falls into the concept of network models. Here, optimising network models and simulation network models are broadly used.

Optimising Network Models have been widely used in resolving transportation vehicle routing problems. Usually, the network is presented as a graph with finite number of nodes and arcs. The nodes replicate the transportation facilities. The arcs represent the physical links between the facilities. The nodes and the arcs are specified with technical characteristics and processing capabilities that identify the constraints of the optimisation task. In the network, there are transportation units routing in order to satisfy a given demand. The objective is to define an optimal routing of the transportation units through the possible itineraries in the network with respect to some objective function such as minimizing costs, minimizing waiting times, maximizing transportation unit utilization, maximizing throughput. However, in the context of railway freight transportation, one must consider the heterogeneous freight traffic, the sequence and the repetitive regrouping of freight wagon groups when travelling from its demand origins towards its demand destinations as well as the very significant non-linearity of transport costs associated with the need for a locomotive, independently of having to move one freight wagon or (say) 20 freight wagons. Therefore, the problem of implementing optimising network models in analysing railway network behaviour is brought into how the railway freight system is transformed into plausible shape for optimisation. Normally, this is overcome with heuristics, auxiliary networks and/or processes to represent yard operations, relative priorities in providing the service, groups of wagons travelling in the same train as well as time-space attributes corresponding to gauge, length, running times, operating times, etc. Optimising network models, e.g., that integrate the service network design and multiple-flow routing with yard policies are reported by Crainic et al. 1984, Crainic and Roy 1988, Powell et al. 1995, Powell et al. 1998, Fernandez 1999, Gualda and Murgel 2000, Razmov 2004. Optimising network models are an effective tool in analysing multiple-flow routing through complex congested networks. Furthermore, the optimising network models identify with great precision the “bottlenecks” (e.g., groups of rail sections with “minimum-cut-values”[3]) over the network. The optimising network models are effective at revealing benefits and losses accumulated through small changes in the railway network entire. Therefore, they are very adequate tools in supporting processes that require “prompt decision-making”. An important class of “prompt decision-making” processes is the decision-making processes at operational level.

Simulation network models are evaluation tools. The railway industries use simulation network models to evaluate the system capacity and resource requirements as a check before implementation of a new network-wide policy, for instance. In (d) we mentioned simulation yard models. All said there holds here as well. Usually, yard models are incorporated into network models where a given yard is linked with other yards in the railway network so that the global impact of a set of policies (i.e. yard and lines’ policies) is not neglected.

Simulation network models generally include the use of simulation software that operates with comprehensive data input. The input data encompasses a set of policies involving infrastructure characteristics, itineraries, arrival rates, service rates, incorporated interruptions, etc. The plausible replication of the rail network and the output statistics obtained by the simulation experiments depend upon the simulation input data. Decisions are generally based upon statistical analysis of the obtained simulation output.

A specific simulation tool is required in order to make the best use of simulation. For instance, the planning of the Dutch railway service is fully supported by the Decision Support System DONS (Designer of Network Schedules). In order to evaluate the robustness of network timetable planning, a simulation tool called “DONS – Simulator” is available, which is equipped with its own database (Hooghiemstra and Teunisse 1998). The DONS-Simulator is built on the template technology of Arena simulation tool (Takus and Profozich 1997).

In North America, simulation software is commonly used for determining the railway infrastructure changes required for a change in traffic as well as in support of rationalization plans. The simulation process is heuristic. The infrastructure for subsequent simulations is modified in ways suggested by the analysis of the earlier simulation outputs. The process is repeated until an acceptable result is achieved, as determined by analysis of the simulation output statistics. A simulation clock measures the passage of time for all calculations and simulated activities (White 2005a).

In the course of the successful development of modern computers and software, computer-aided simulation models were established to support long-term railway planning in Germany as well. The Network-Evaluation-Model NEMO is such a tool, developed at IVE, University of Hannover, which is based on the macroscopic approach of data aggregation. The railway infrastructure is modelled as a network containing nodes and links.

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[3] The group of tracks whose sum of capacities (for parallel utilization) is minimal, thus defining the network capacity

Another user-friendly railway simulation product is "OpenTrack". This software operates with three-modules-input data (rolling material, infrastructure and timetable) and can answer many different questions concerning railway operation aspects. In general, predefined trains move on a designed track layout according to a given timetable data.

However, when no specific network simulation software is available or appropriate, as above stated, one should analyse, choose and adapt an existing simulation tool for this purpose.

Dessouky and Leachman (1995), Dessouky et al. (2002), Lu et al. (2004) developed simulation modelling methodologies to assess the rail track infrastructure in dense traffic areas with the purpose of determining the best trackage configuration to meet future demand. In these methodologies the freight train movement is replicated as a stochastic process; the passenger train movement as a fixed schedule. The main idea behind the presented modelling approach is to divide the rail network into track segments. The simulation models are developed in SLAM II Simulation Language where, by using the built-in functionality such as activities, queues, resources, and complicated logic, train movements at the source and destination terminals are integrated. In this methodology the majority of the classified trains are assumed to arrive by Poisson arrival process. The arrival times of a fewer trains are predetermined and assumed to be known. For most studied terminals, they consider the limited capacity of tracks for trains to wait for loading and unloading. The layover time depends on the terminal; some of them are modelled as a fixed time. The train movement into and out of the intermodal terminals as well as the train dwell times vary according to the terminal configuration. The storage time is modelled as an exponential random variable with the mean equal to 1 day. In conclusion, suggested are modifications to the current trackage configuration of proposed rail corridor in order to handle an increased demand.

4. COMPARATIVE METHODS

Best Practice Frontiers (such as DEA, see e.g. Norman and Stoker 1991) are analytical methods that create a production function integrating a set of performance measures/indicators. This class of performance assessment methods operate with Input-Output ratios. Klein (1953) and Farrell (1957) are among the pioneers. The key concept used here is that of a frontier or 'best practice' production function which defines for any set of observations the outer boundary of possible input-output combinations. Granted that such a frontier cannot be found in the blueprints of engineers, it has to be constructed from a sample of possibly inefficient observations.

These methods deal with technical efficiency, which is of interest to us, and this is: *for a given input pattern, more of any outputs cannot be produced* (Perelman and Pestieau 1988). The goal is to provide a frontier with respect to which the technical efficiency of each observation can be evaluated by measuring the relative distance between the frontier output and the actual output, given a certain level of input. The observation which has the highest positive residual is by definition 100% efficient.

Next, one is able to use all the available data and focus on the cross-section comparison. The inputs can be labour (staff), energy, rolling and fixed stock (number of freight wagons and locomotives), tonnes, kilometres of routes, etc. The outputs can be labour per tonne-km, tonnes transported per rolling stock and the like.

Contributes at this front have been reported by many, e.g. Christensen (1980) Caves et al. (1981); Deprins and Simar (1988); Gathon and Perelman (1992); Coelli and Perelman (1996), Coelli and Perelman (1997); Coelli and Perelman (1999). Further to this Technical efficiency of West European railways has been recently studied by De Jorge and Suarez (2003) and Hilmola (2007). Birgun and Akten (2005) as well as Min and Park (2005) have completed comprehensive sea port terminal productivity analysis. Next, Jaržemskienė (2009) has compared productivity indicators of airport terminals using DEA.

However, these methods have significant shortcomings. Generally, by relating output levels to input levels through the estimation of a function, one gets a quite general and relatively satisfactory best practice frontier. This might be true when the systems operate in the same environment and can truly be assumed to use the same technology. There are many instances, particularly when dealing with international comparisons, in which systems do not face the same institutional and geographical environment. In these instances, systems can be legitimately inefficient with respect to best practice function estimated regardless of these specific environmental factors.

It appears that the "*best practice frontier*" methods provide a general and rough assessment of performances, but they do not consider what are the services, what is the performance standard, whether or not new services contribute to significant improvements, what are the main changes in the system after having implemented new technologies, traffic rules, production schemes etc. These methods tell us which system is likely to be most efficient according to a selected inputs/outputs ratio. Also, these methods deal with a certain level of complexity and maths. Issues the practitioner tries to avoid. They do not deal with time-factor as well. A more practical and partial performance assessment approach is therefore needed that would analyse whether rail freight systems are currently developing and improving their performances because of new services implemented and next what are the new standards of performances.

On the other hand, since best practice frontier methods provide an overall picture, it may not be of interest to neglect them completely. They might be incorporated into a methodological framework of performance assessment for analysing the level of compatibility between freight wagons, transport units and freight services.

A broadly used method is: "Benchmarking". According to Camp (1989) "Benchmarking is systematic research into the performance and the underlying processes and methods of one or more leading reference organizations in a certain field, and the comparison of one's own performance and operating methods with these ''best practices'', with the goal of locating and improving one's own performance."

On the other hand, according to Bagchi (1996) "*Benchmarking is a systematic management process that helps managers to search and monitor the best practices and/or processes. The search for the best practices may not be limited to direct competitors. The goal is to emulate and exceed the "best in class". Therefore, the search goes beyond the practices of direct competitors, and encompasses all leading organizations regardless of industry affiliation"*.

A good description of the steps involved in benchmarking, presented as a continuous improvement process (plan-do-check-act cycle or Deming cycle), can be found in Watson (1992) (see Figure 1 below). It is claimed that these steps can be applied regardless of function.

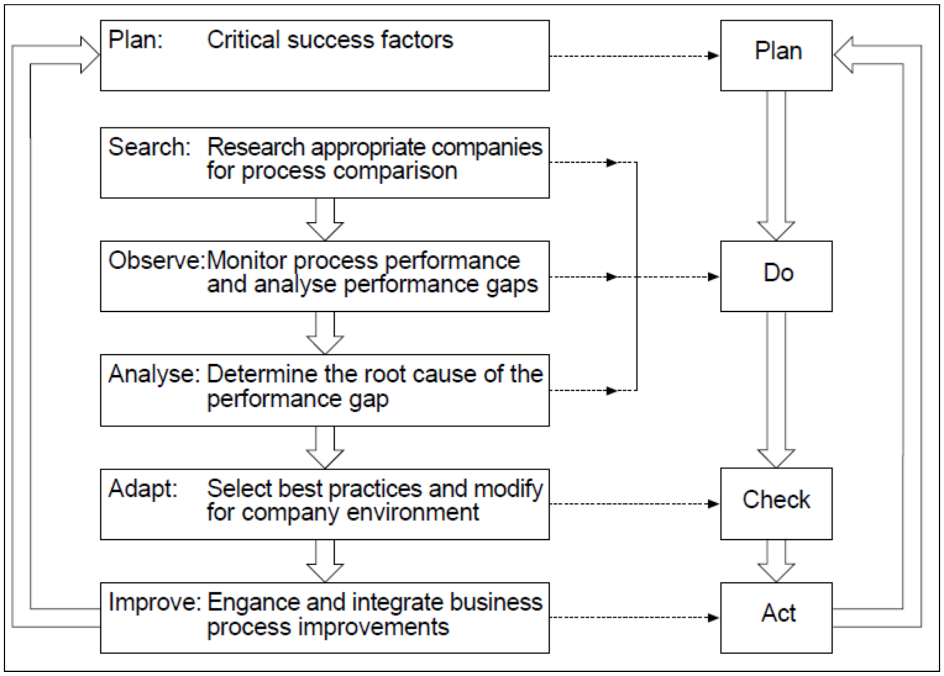

Figure 1 Steps in Benchmarking
Source: Watson (1992) used by (Bagchi 1996, p 7)

Benchmarking in rail has been implemented to answer:

1. How do rail systems compare with rail systems?
2. What criteria should we use to make a meaningful comparison?

According to Hatano (2005) the first part of the benchmarking, which is mostly complete, is a database of simple data comparisons of railway systems operational performance. The rail systems are spread world-wide and there is at least one system from each continent in the database.

The categories for each of the systems include historical data for population, rail route length, freight and passenger traffic and motor vehicles in use. There is also the most recent information for such categories as land area, population density, purchasing power parity, rail revenue and financial data, rolling stock, high-speed lines, road route length and motor vehicle usage, among others.

Sources used in the initial comparison study include collections of international historical statistics, data from rail companies and statistical organisations in various countries, the World Bank and UIC databases.

The second part of the benchmarking is a more in-depth benchmarking study with a reduced number of rail systems. This part of the study will examine in more detail management and operational processes by looking at a number of key performance parameters and researching, where possible, the processes involved in each. Sources for the benchmarking part of the study will be produced data sources and the companies themselves, including questionnaires and interviews with staff.

In benchmarking exercises overall efficiency is measured in total traffic units per annum per km of route. Freight efficiency is measured in Freight tonne km and Total million freight units per annum per km of route.

In terms of intermodal freight transport, a number of national and international organizations fulfil benchmarking analysis. For instance OECD focuses its work on “benchmarking” to compare the relative efficiency of modes, modal combinations and modal interfaces OECD (2002).

Government policy makers (along with transport industry and logistics service providers) have an interest in the efficiency (including time, cost and reliability), safety and sustainability of transport systems, although at a more aggregate level than the private sector. Benchmarking is used to identify appropriate benchmarks that could be applied to assess the relative efficiency of modes/modal combinations and intermodal transfers, and to identify sources of inefficiency that could contribute to modal choice.

The benchmarking analysis also seeks to develop policy options for governments to address impediments to intermodal transport efficiency, encompassing institutional aspects, technology, including the role of intelligent transportation systems (ITS) and infrastructure. As such, the focus is on organisational aspects, from a government public policy perspective, rather than on the performance of industry players. The conclusions should be seen as a guide to improving system performance, rather than a regulatory framework.

5. SUMMARY AND CONCLUSIONS

This paper aimed to show that if railfreight is to break back into markets by employing logistics concepts, it has to rapidly adapt to changing political measures, economic trends and market conditions. It is therefore a field where reliable and effective models and tools are required to help railfreight operators improve their operational efficiency and rationalize their tactical planning decisions.

Within the context of Supply Chain, transport is the physical movement of goods, whereas logistics can be seen as part of the value chain through the delivery of other specialised services. Transport is always part of a logistics concept. Over 70% per cent of goods transport overland is by road. It appears that rail has been unable or unwilling to participate in traffic and commodity flows and preferred to operate as a wholesale block train operation. The orthodox railfreight model has shown to be inadequate and unable to match the requirements of shippers and wider cargo interests. Therefore, the traditional service has changed. It is believed that logistics concepts will improve rail freight systems performances. This paper showed that new concepts are proposed, studies and projects are undertaken, and new systems for railfreight are developed. It is our contention, however, that the current state of the art lacks to offer reliable and effective models and methods for analysing and evaluating railfreight and logistics performances because it follows the orthodox railfreight model. The paper is therefore an invitation to join forces and invent sustainable railfreight systems of the future employing logistics concepts and develop these models and methods for railfreight and logistics performances, and help in making our railfreight systems efficient.

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