Research in Transportation Economics xxx (2012) 1–16

Contents lists available at SciVerse ScienceDirect

Research in Transportation Economics

journal homepage: www.elsevier.com/locate/retrec

Rail vehicles, environment, safety and security

Emmanuel Matsika [a,*], Stefano Ricci [b], Philip Mortimer [c], Nikolay Georgiev [d], Conor O'Neill [a]

[a] NewRail, Newcastle University, UK
[b] DICEA, Sapienza Università di Roma, Italy
[c] Truck-Train Developments, UK
[d] Higher School of Transport, Bulgaria

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Rail vehicles
Wagon design
Truck-trains
Accidents
Incidents
Safety
Security

ABSTRACT

This paper starts with a discussion on typical vehicles. The concepts and the usual practice for rail wagon design, both freight and passengers are presented. A discussion on rail and the environment comes next followed by Truck-Trains. Accident theories, metaphors and investigation methods are widely discussed; Hazard – Barrier – Target Model, Swiss Cheese Model, Bow-Tie Model, Fault Tree Analysis and Event Tree Analysis are explained. This paper concludes with a technical discussion on safety and security of rail vehicles, standards for safety and measures against terrorist attacks.

1. Typical railway vehicles

Dr. Emmanuel Matsika, NewRail, Newcastle University

1.1. Introduction

George Stephenson developed the first public train in 1825 with the prime purpose of transporting coal. The train was powered by steam which was generated from coal fired boilers. Most of the body structure was made of steel. Today, the rail industry has grown beyond the primary goal of transportation of coal to providing passenger service and transporting various types of cargo. The development of the rail industry has been driven by many factors, the key ones being advancement in technology, market demands, government policies (including standards) and constraints imposed by rail operations (Fig. 1).

The structural design of rail vehicles has been moulded by the development of new materials and manufacturing processes. With the increase of top speeds to over 300 km/h, dynamic stability and aerodynamic drag have mandated the design of streamlined body shapes. Passenger demand for high speed but comfortable journeys has led to the development of axle and suspension systems with superior ride quality.

One notable aspect of vehicle design is the change in propulsion. Today, one would hardly see a steam powered train as diesel and electrical propulsion account for nearly all public railways. Policies developed by governments and subsequent regulations and standards have continued to shape rail vehicle design. Regulations related to fire safety, crashworthiness, vibrations, pollution and noise. Table 1 summarises the designs factors.

1.2. Types of rail vehicles

Broadly, there are two types of railway vehicles that exist – passenger vehicles (Fig. 2) and freight or cargo vehicles (Fig. 3).

This difference in purpose drives the design requirements, and therefore operations. For passenger vehicles increased top speed, ride quality, interior environmental conditioning, crashworthiness, security, noise and application of fire retardant materials are key factors. On the other hand, for cargo transportation, many of these factors may not be critical. Traditionally, freight trains have tended to transport high density, low value goods (such as coal, aggregates, etc.).

However, particularly with the introduction of inter-modal transport, the railway has seen an increase in low density high value goods being transported by rail. Market demand for the transportation of chilled and frozen goods has led to use of refrigerated wagons and also refrigerated containers.

* Corresponding author. NewRail – Newcastle Centre for Railway Research, Faculty of Science, Agriculture and Engineering, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK. Tel.: +44 (0) 191 222 8648.
E-mail address: emmanuel.matsika@ncl.ac.uk (E. Matsika).

0739-8859/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.retrec.2012.11.011

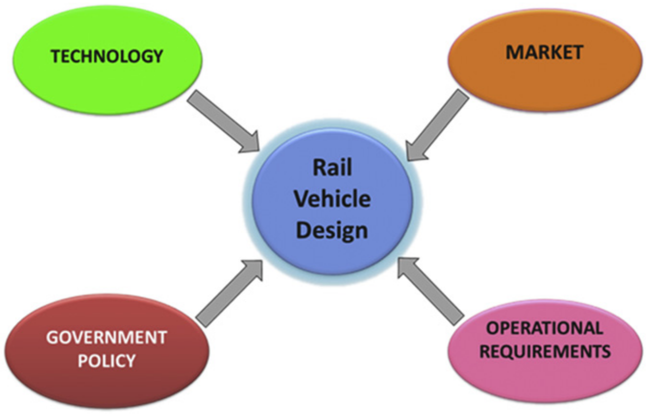

Fig. 1. Factors that affect rail vehicle design.

Fig. 2. Passenger train. Source: TPE (2012).

1.3. Traction (propulsion)

Traction of rail vehicles is generally achieved by the use of dedicated locomotives (Fig. 3). However in the recent past, particularly for passenger vehicles, multiple units (MUs) have been applied, which has the advantage of having an overall shorter train set. In passenger vehicles, each unit provides power for any auxiliary units of the train. The most common power source is diesel engines and electrical units (catenary/pantograph or third rail, with specific frequency and voltage).

While electrical powering is preferred due to its relatively low environmental impact, it is not always possible to have rail infrastructure that has electrical systems. Subsequently, diesel units are sometimes applied. In some cases, hybrid and dual mode units are used. One relatively new technological application for passenger transportation is magnetic levitation (Maglev) (Fig. 4). It has the advantage of being environmentally friendly, and has superior ride quality.

1.4. Passenger railway vehicles

From the functional design point of view, passenger vehicles are categorised depending on the market segment they intend to serve. Four categories exist, namely light rail (trams), metro (subway), heavy rail (general urban trains with top speeds of 100–160 km/h) and high speed trains (HST with top speeds of over 300 km/h). The design requirements are therefore different from one category to another. This includes the dynamic characteristics, interior space design and exterior body streamlining.

Table 1
Factors that drive rail vehicle design.

Design factor	Examples
Market demand	• Type of goods • Value of goods • Cost of purchase/running costs
Technology	• Vehicle performance (acceleration, deceleration, vibrations, aerodynamic, etc) • Structural • Materials • Joining technologies
Government policy	• Environment (CO_2, Oil spillages, energy) • Noise • Standards (TSIs) (structural integrity, crashworthiness, accessibility, FST, etc)
Operational requirements	• Logistics • Security • Safety • Infrastructure (track gauge, loading gauge, catenary voltage, etc) • time tabling

1.5. Freight/cargo railway vehicles

Freight vehicles are characterised by long train sets (Fig. 5) usually travelling at relatively low average speeds.

Within Europe, the typical length of a public transportation train set is 200 m–650 m. However, recently there has been a push to increase the length to between 750 m and 1000 m. Such increase, however, comes with operational challenges. The maximum speed experienced on European railways is 120–160 km/h, with an average speed of only 30–40 km/h. The non-streamlined characteristic of most wagons tends to increase aerodynamic drag and dynamic instability.

1.5.1. Types of wagons

The key factors which determine wagon design are: type of goods to be transported, functional design, load carrying capacity, structural design and dynamic performance. Fundamentally, it is the type of goods that determine the type of wagon to use. These include:

- Flat wagon (for containers, logs, pipes, and piggyback);
- Box wagon (covered or open for palletised goods, coal, aggregate, etc);
- Hoppers (aggregate, grain, coal, etc);
- Tankers (oil, chemicals, etc);

Fig. 3. Cargo train. Source: Thai Mass Transportation (2012).

Please cite this article in press as: Matsika, E., et al., Rail vehicles, environment, safety and security, *Research in Transportation Economics* (2012), http://dx.doi.org/10.1016/j.retrec.2012.11.011