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Railway operations, time-tabling and control

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ABSTRACT

This paper concentrates on organising, planning and managing the train movement in a network. The three classic management levels for rail planning, i.e., strategic, tactical and operational, are introduced followed by decision support systems for rail traffic control. In addition, included in this paper are discussions on train operating forms, railway traffic control and train dispatching problems, rail yard technical schemes and performance of terminals, as well as timetable design. A description of analytical methods, simulation techniques and specific computer packages for analysing and evaluating the behaviour of rail systems and networks is also provided.

1. Rail operations and management

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1.1. Nature, resources and operating forms

The complex nature of the rail operations will always hold a fascination. It is a combination of activities that are executed in a specific order to ensure the final goal is achieved. Namely that trains are run effectively and provide services of good quality to the customer.

Rail operations involve static and dynamic resources. Static resources are all resources that belong to the rail infrastructure, such as: tracks, lines, signals, platforms, buildings, sidings, catenary, junctions, switches, bridges and interchanges. Static resources define the standing capacity of the components of the rail infrastructure which can be classified by their layouts and technical schemes.

Dynamic resources include all the moving assets such as passenger and freight wagons, diesel and electric locomotives, whole train sets and machines for rail maintenance. Staff involved, plans, schedules, administration, commercial departments and the like, are also identified as dynamic resources.

Together static and dynamic resources define the processing capacity of the components of the railway system. It should be noted that the processing capacity of a rail component is always lower than its standing capacity. Consequently, the productivity of the railway systems is constrained by the existing rail infrastructure.

Demands for rail services, production patterns, traffic rules and priorities dictate the movement of trains. Demands specify all the demand origins and destinations in the rail network. Production patterns indicate the operating form by which a service is provided. Traffic rules guarantee safety in providing the service. Priorities dictate what order different train categories should run in the rail network.

Operating forms for passenger trains differ from operating forms for freight trains, in addition every country has its own model. Operating forms for passenger trains in Portugal are shown in Table 1. We shall not discuss how different these models can be and how they can vary from country to country. Instead what is common for passenger trains is that the highest priority is given to high speed trains, followed by international trains, inter- city/inter-regional trains and regional multi stopping trains, and finally suburban/urban passenger trains.

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Table 1
Operating forms for passenger trains in Portugal.

Example: Operating forms for passenger trains in Portugal
1. *High speed train*: "Alfa Pendular": • Is a tilting train which travels up to 220 km/h; • Operates on the main North – South line of the country; • Stops at the end destination and a few major intermediate cities.
2 *International passenger trains:* • Passenger trains from major Portuguese cities to Madrid, Vigo and Hendaye.
3. *Inter-cities:* • may travel up to 200 km/h; • operate on main lines of the country; • stop only at cities and a few towns.
4. *Inter-regional:* • May travel up to 120 km/h; • operate on main lines; • stop at main towns and a few smaller towns.
5. *Regional multi stopping train:* •may travel up to 120 km/h; • operates on main lines of the country • stops at all stations in the region.
6. *Suburban/urban passenger train:* • Is a commuter train; • operates in the major cities of the country.

Operating forms for freight trains have been discussed by Ballis and Golias (2004, pp.422–423) and Marinov and White (2009, pp.14–15). The following definitions are suggested (Fig. 1):

- *Direct trains*
  - o run between two loading/unloading terminals without stopping on the way;
- Block trains
  - o are direct trains by nature;
  - o the number of freight wagons they carry in their compositions vary according to the demand for transport;
- Shuttle trains
  - o are direct trains too;
  - o the number of freight wagons they carry is fixed;
  - o coupling/uncoupling is not required at terminals and/or yards.
- *Group trains* or feeder trains:
  - o provide services in a region between loading/unloading terminals and yards;
  - o may stop at a few way stations to set out and pick up freight wagons (both loaded and empty);
  - o may fulfil long distance transport services as well;
  - o may serve less-than-train load (LTL) traffic;
  - o coupling/uncoupling might be required at terminals and/or yards.
- *Liner trains* or multi stopping freight trains:
  - o provide service in a region between demand origins/destinations and rail yards;
  - o serve less-than-train load (LTL) traffic;
  - o stop at way stations on their route to set out and pick up freight wagons (both loaded and empty);
  - o coupling/uncoupling is required at demand origins/destinations and yards.

Most rail networks operate mixed traffic, which requires thorough management procedures to ensure safe and efficient rail operations; discussion of which follows.

1.2. Management

Classical management aims to improve systems efficiency and productivity, and can be classified as:

- Bureaucratic;
- Scientific;
- Administrative.

Bureaucratic management operates with a set of guidelines, which specify the rules and procedures, hierarchy as well as labour conditions and categories.

Scientific management aims to find a better way to do a job, meaning that scientific management is aimed at optimising and improving the current level of system efficiency and productivity.

Administrative management controls the information flow within an organization (Miles, 1975).

Bureaucratic and administrative management will not be discussed further; instead a greater focus is aimed at scientific management. More specifically, how system efficiency and productivity can be improved through changes in the production process (where time, human efficiency and utilisation of resources are crucial) is examined.

Frederick W Taylor in the early 20th century developed new methods and generated alternatives with the purpose to increase system productivity. Taylor focused on worker behaviour whilst at work. One of his experiments aimed to identify a way to increase the output of a worker loading pig-iron to a freight wagon. Taylor's starting point was to break the whole process down into its components, so he can better understand of the job and what operation it includes. Then he timed each operation with a watch. As a result he was able to generate a number of alternatives and ultimately, this is how Taylor realised that the whole process can be executed with less effort and the worker's output was increased from 12 to 47 tons per day (Taylor, 1911).

The utilization of resources is a fundamental economic problem. Economics advises that resources are efficiently utilised when they produce the greatest amount of satisfaction (or utility) possible per unit of input. In order to ensure that resources produce satisfaction per unit of input, companies plan their performance in advance. Planning is a management activity which can facilitate the decision making and improve significantly the system performance.

In the body of literature there are three management levels: *strategic, tactical* and *operational* (Anthony, 1965). As discussed by many (e.g., Assad, 1980; Crainic, Ferland, & Roussean, 1984; Crainic & Roy, 1988; Crainic & Laporte, 1997; Gualda & Murgel, 2000; Marinov & Viegas, 2009, 2011a,2011b,2011c; Pachl & White, 2003; Watson, 2001) in the context of rail operations these three management levels are, as follows:

- The strategic level encompasses long term planning of company development. Decisions made at this level set the strategic goals of the company, which include assessment resources, strategic changes in the company structure, redesign and reconstruction of the physical railway network, relocation of railway facilities, construction of new rail lines, acquisition of new resources and technologies, etc. This is the highest level of management in the railway organizations. Although the decisions made at this level are capital intensive they should provide the minimum amount of required resources for "*normal operation*" Pachl and White (2003, pp.2).
- The tactical level deals with medium term planning. At this level all the plans, timetables and schedules are developed. As stated by Crainic and Laporte (1997, pp.411) tactical planning is "*to ensure, over a medium term horizon, an efficient and rational*