Journal of Rail Transport Planning & Management 5 (2015) 78–91

Contents lists available at ScienceDirect

Journal of Rail Transport Planning & Management

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

A multi-criteria methodology to evaluate the optimal location of a multifunctional railway portal on the railway network

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ARTICLE INFO

Article history:
Received 24 February 2015
Revised 25 June 2015
Accepted 29 June 2015
Available online 17 July 2015

Keywords:
Optimal location problem
Multicriteria decision problems
Analytic Hierarchy Process (AHP)
Multifunctional railway portal
Dangerous goods transport

ABSTRACT

The installation of a multifunctional railway portal (or TCCS – Train Conformity Check system) can contribute to improve the safety of a railway infrastructure. The TCCS can detect the conformity of the trains traveling along the tracks, and can transfer the status information to a main traffic control center. This paper proposes a methodological approach based on Analytic Hierarchy Process (AHP) to evaluate the optimal locations to install a TCCS on a railway section. The eligibility and ranking of the potential sites have been defined with respect to constraints related to the rail line track layout and geometry, the TCCS technological features, and the required safety distance allowing the train to stop. The proposed approach has been applied to a real case study on the Italian railway.

1. Introduction

Railway signal control systems typically use the track Circuit Block (CB) as the basic element of train location. There are two different approaches to manage safely the train location with appropriate signaling systems: the fixed block system, and the automatic block system.

Fixed block train separation consists of an apportionment of the railway line in several sections named block sections. A block section may not be shorter than a train, but a train driver may be given a "view" of more than one section. Each block section is controlled by a train detection device that ensures enough free space to stop a train running at the maximum allowed speed. The status information of each block section is transmitted either by means of coded current track circuits or by controlling block equipment from interlocking.

The automatic block system is based on track circuits. Each track circuit is protected by a signal named block signal showing proceed or stop aspect when the next track circuit is free. This is called "two aspects" block system. The speed has to be limited to allow trains stopping if the signal at the end of the section is at stop. In this way, the line capacity is improved as each track circuit may be safely occupied by one train. The line capacity may also be increased, increasing the number of block sections or allowing higher trains speed. In "three aspects" block system, each signal displays different aspect depending on the state of the subsequent sections: yellow if the next section is free, green if the two following sections are free; and finally red if the next section is occupied. In this way, trains may run at maximum allowed speed for a longer distance and enough space to brake safely and to stop is guaranteed.

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http://dx.doi.org/10.1016/j.jrtpm.2015.06.003

Under ERTMS level 1 and 2, movement authorities are determined using fixed blocks systems. With ERTMS level 3, accurate and continuous position data is supplied to the control center directly by the train, rather than by track based detection equipment. As the train continuously monitors its own position, there is no need for "fixed blocks" – rather the train itself will be considered as a moving block. ERTMS Level 3 is still in its conceptual phase.

In the framework of railway safety topic, the introduction of technology and research findings represent ongoing opportunities to advance safety in the future. In the same time, the maintenance of a complex system, such as in rail system transportation, becomes a strategic element for the economic competitiveness of the infrastructure operators. The current progress in sensor technologies makes it possible to monitor the most crucial components of the overall transportation system. In addition, the availability of different methodologies and techniques guarantees the possibility to analyze the measured data.

In the last decade, numerous studies and commercial efforts have been conducted regarding the definition of the best technical solutions for condition monitoring of the railway vehicles (Ngigi et al., 2012). This monitoring technology can be classified as reactive or predictive (Lagnebäck, 2007). The first one is related to the faults on the vehicles that are difficult to be detected by prediction models. The reactive systems are frequently used to avoid further damages to vehicle equipment due to occurring accidents. The reactive systems are event-driven based and interact intensively and continuously with the neighboring environment. Dragging equipment detectors, hot box detectors, hot/cold wheel detectors and sliding wheel detectors (Steets and Tse, 1998) represent some examples of reactive system technology. The predictive technologies aims to acquire data from the different devices of the train and on the railway in order to prevent accident by predicting the likelihood of future equipment failures according to active and potential damage mechanisms. Moreover, the predictive capabilities of various preventive maintenance tools continue to improve, increasingly sophisticated condition-based maintenance systems such as risk-based maintenance, and represent best practice for the railway industry. Actually, current system integrators need to integrate remote monitoring systems to supply continuous asset information for front-end data and back-end data analysis.

Track-based sensors and vehicle-based sensors represent the practical application of condition monitoring of the train dynamics (Ngigi et al., 2012). Bruni et al. (2007) provide a survey on the application of condition-monitoring techniques to rail vehicle dynamics. Axle box-mounted vertical or lateral sensing accelerometer can detect respectively vertical and lateral track irregularities in short wavelength; while bogie-mounted vertical or lateral sensing accelerometer can detect respectively vertical and lateral track irregularities at longer wavelength (Ward et al., 2011).

The track-based sensors usually consist of one or more processor-based controllers, speed measurement and location determination sensors. It is possible to measure the acceleration, speed and position of a moving train along the stabilized axes using an Inertial Navigation Systems (INS) (Mirabadi et al., 1996). An INS basically consists of a gyroscope and accelerometers. This equipment has interfaces both to the train subsystems (including train operator displays) and to the wayside equipment.

In general, several commercial architectures exist for condition monitoring:

- tools to monitor the railway infrastructure installed on the infrastructure;
- tools to monitor the railway infrastructure installed on rolling stocks, i.e. installed on dedicated diagnostics trains or service train;
- tools to monitor the vehicle status installed on board to detect fault mechanics and electrics on board parameters;
- tools to monitor the vehicle status installed on the infrastructure.

The technique of detecting specific faults on rolling stock by interrogation sensors placed along the sides of tracks is called "wayside detection system" (WDS) (Palo et al., 2014). Nowadays, the WDS checks the passing train for safe operation reading data about speed, the temperature of the bearings, weights, wheel condition, etc.

The aim of this paper is to define a multi criteria decisional approach supporting the evaluation of the best sites to locate a specific WDS, called "multifunctional portals", for railway control, based on the Analytic Hierarchy Process (AHP).

2. TCCS – Train Conformity Check System

The TCCS – Train Conformity Check system is a WDS, whose first installation was successfully tested by RFI (the Italian Railway Network) in July 2009 at the Rome-Formia-Naples railway line (Train Conformity Check System).

The TCCS is a non-invasive modular wayside monitoring system which can detect and alert dispatchers about several dangerous or damaging defects on rolling stock that could potentially cause an accident or other undesired effects on the infrastructures (see Fig. 1). The TCCS consists of the following modules (Favo et al., 2010):

- a "tracking subsystem" (core module);
- full thermographic scan of rolling stock and detection of diverse defects (overheated parts and fire on board);
- full 3D scan that detects profile defects on rolling stock (shifted loads on open wagons, open doors and hatches, abnormal tilt from suspensions failures);