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An evaluation of the introduction of the Global Navigation Satellite System for regional railways: Case studies from Italy

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ABSTRACT

This paper aims to carry out a comprehensive cost-benefit analysis of the introduction of the Global Navigation Satellite System (GNSS) technologies into train control systems based on ERTMS (European standard) to increase the efficiency and safety of railway lines. To this end, the GNSS-based system is compared to other solutions along an appropriate time horizon. In our analysis, we consider several case studies from Italy and a range of benefit/cost ratios from 0.9 to 4.1 is found for the GNSS-based projects, depending on the different types of lines, their characteristics and their current endowment.

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1. Introduction

The increase of transport safety is now very high on the agenda of European Union policy makers (El Koursi et al., 2007). The European Railway Agency estimates an average fatality risk of 0.31 deaths per million train/km for the period 2009–2011 (European Railway Agency, 2013). This average, however, hides large differences between West and East European countries, so that fatality risk ranges from 0.1 in the UK to 2 in Lithuania.

This situation calls for policy actions to increase safety especially in certain countries. One of the policy options is the adoption of satellite-based technologies to monitor traffic and, in this context, the Global Navigation Satellite System (GNSS) is a European technology of satellite sensing and monitoring able to increase efficiency, reliability and safety of railway networks (Jonas, 2011; Salmi and Torkkelli, 2009).

This paper aims to assess economic costs and benefits of GNSS-based solutions by relying on case studies from Italy to inform Europe-wide decision making. In particular, we carry out an extensive cost-benefit analysis (CBA) of the introduction of such new technology in four case studies in Italy, concerning railways with and without automated protection systems. To be noted is the fact that the increase in railroad safety is particularly important for lines not equipped with automated protection systems. However, it must be stated that the GNSS technology is still being tested, so that precise estimates of the reduction in accident risk are not available. This, in its turn, makes the sensitivity analysis presented in section 4 particularly important to assess the relevance of the assumption of the impact of GNSS on accidentality. Furthermore, our aim is not to propose an entirely new methodology to evaluate the introduction of an innovative technology, rather, we aim to provide preliminary (and case-specific) estimates of the social welfare variation induced by the hypothetical introduction of the satellite-based navigation system.

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Our result points at a Benefit/Cost ratio ranging from 0.9 to 4.1 and hence supports the introduction of GNSS technology in most of the cases.

This paper contributes to the literature on railway safety and on the introduction of new technologies in transport sectors by providing one of the few cases of CBA currently available (Evans, 2013; Savage, 1998).

2. GNSS technologies for train control systems

The Global Navigation Satellite System is a network of satellites that provide geo-spatial positioning with global coverage. Location is provided by Global Positioning System, which has been developed in the USA, and by GLONASS (Global Navigation Satellite System), developed in Russia, and it will be provided by GALILEO, a system developed in Europe, which is expected to be active in 2014.

The European Union is considering the introduction of the GNSS to the local and regional railway network, which covers about 176 000 km and represents 60% of the entire European network (ERRAC, 2006; INTER-Region-Rail, 2011). The regional network is characterized by short distance trips and by low density lines; additionally the time interval between two trains of the same line is, on average, 15–30 min. Train operation are conducted by mechanical and electro-mechanical safety systems or, in some other cases in which there are no safety systems and the signalling is based on human decision, by telephone block operation or visual evaluation of train positioning.

Given the features of the regional railway network, the introduction of GNSS is expected to increase safety in most local and regional lines up to the safety standard of ERTMS, and decrease time intervals between trains.

The introduction of such an instrument in the rail sector would play a major role in the implementation of the overall network's safety; this would be mainly based on the reduction of the number of accidents caused by human errors. Moreover, it will maximize the use of the infrastructure; in fact, through a more efficient signalling system, there will be an increased use in the number of trains and this will consequently optimize the investment made to maintain and operate the network.

The Galileo satellite asset would be incorporated in the European Train Control System (ERTMS-ETCS), the Train Control System will be then articulated over different architectural elements, namely: a space segment, an augmentation and integrity monitoring network and on board units (Obrenovic et al., 2006; Smith et al., 2012; UIC, 2003, 2007; 2010). The space segment would provide the reference satellite system allowing the identification of a train's position, the on board units would respond to the satellite using the GNSS signal and the augmentation and integrity monitoring would be an alternative implemented in some areas not covered by the EGNOS (European Geostationary Navigation Overlay System) signal. Conventional ERTMS is based on the use of balises in between tracks, that communicate with the on board unit of trains as they pass over them, giving information on the train position to both the train and the central control. The main difference of satellite-based ERTMS is that it removes the need of physical balises, using "virtual balises", i.e. selecting discrete points along the tracks upon which the train is located not by the physical transponder but rather by the satellite signal.

Such a new system would improve the safety of low traffic lines and would also reduce the impact of safety related costs on those lines. In fact, the conventional system based on balises and track circuits has a relevant impact on the cost function, while on the other hand the satellite system, mainly due to the reduced hardware installations, will have a lower impact on the investment and operating costs; such features, together with the possible increased use of the infrastructure, would relevantly reduce the cost of use of the infrastructure.

As of now, no proper cost-benefit analysis concerning GNSS-based signalling systems in the rail sector exists. An analysis of cost effectiveness of the introduction of GNSS-based technologies in the aviation market exists (LEK Consulting, "EGNOS Aviation CBA", Milan, 2010); however, because the different framework of application (air transport rather than rail) its approach bears little useful indications for the present analysis.

3. The identification of costs and benefits

In this paper, we aim to evaluate the impact of the introduction of GNSS technologies on social welfare through a cost-benefit analysis (CBA). To this end, the identification of costs and benefits is preparatory to the computation of social welfare variation.

The introduction of GNSS technologies on the train control systems will require investment costs not only in terms of equipment and rolling stock, but also – at a macro level – investment in order to adapt the rail infrastructure to the improved train standards that are necessary to meet the ERTMS standards. In general, costs can be divided into two main categories: investment and operating cost. Investment costs can be divided into three main categories:

- Ground investment. The investments on the lines consist of the investment in the ground equipment and in the ERTMS Central Control System. Such investments are articulated over different dimensions: ERTMS planning, installation and interfacing. This dimension will take into consideration the cost per km related to the introduction of the ERTMS equipment on those lines that have not been upgraded with such technology. This is an initial investment and the total amount has to be split over the first three years of the entire time horizon considered in the CBA. In fact, the initial stage of the investment in ground systems will include: planning, installation and interfacing in the concerned parts of the network and the installation of ERTMS central controls through Radio Block Center (RBC) (NERA, 2003).

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