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A conceptual design for a national transport model with cross-sectoral interdependencies

Milan Lovrić[a,] *, Simon Blainey[a], John Preston[a]

[a]*University of Southampton, Burgess Road, Southampton SO16 7QF, United Kingdom*

Abstract

This paper presents issues, trade-offs and challenges encountered while developing a UK national transport model as part of a large interdisciplinary project, ITRC MISTRAL. The Infrastructure Transitions Research Consortium (ITRC) is a consortium of seven leading UK universities focusing on analysis of national infrastructure systems using a system-of-systems approach. In this paper, we describe a multi-modal multi-scale national transport model being developed by ITRC which includes passenger and freight transport via highways, railways, airports, seaports and local transit networks. The model predicts future demand for each mode on individual flows using an elasticity-based simulation approach. These flows are then assigned to transport networks to assess infrastructure capacity utilisation and obtain new estimates of inter-zonal travel times. The model explicitly considers cross-sectoral interdependencies with other infrastructure networks, including the energy sector (where transport is the largest consuming sector), digital communications (which provide bandwidth to passengers and enable smart mobility), waste management (which requires transport services) and water supply (where flooding poses a major risk of transport disruptions). It is also planned to be capable of estimating environmental emissions and assessing the vulnerability and resilience to risk of transport systems. The enhanced transport model discussed here builds on an existing modelling framework which has been used by the UK government to inform their National Infrastructure Assessment. As such, the model has the potential to support policy making with regards to infrastructure investment on a decadal scale, under a range of possible future scenarios including population growth, new technologies and climate change.

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Keywords: transport modelling; national infrastructure; cross-sectoral analysis; elasticity-based simulation; demand modelling; capacity utilisation; railways; traffic; airports; seaports; freight; policy making.

* Corresponding author. Tel.: +44-23-8059-4639.
E-mail address: M.Lovric@soton.ac.uk

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1. Introduction

1.1. Background to MISTRAL

National infrastructure provides key services to a modern economy including: energy, transport, digital communications, water supply, and waste management. The UK's National Infrastructure Plan, outlining the vision for the future of UK infrastructure, set out over £460 billion of investment in the next decade. However, at this stage, little is known of how this investment will impact the performance of national infrastructure services and how it will influence economy, society and the environment. The complexity of infrastructure networks and their interactions with people, economy and the environment means that infrastructure planning often involves a lot of guesswork. The UK Infrastructure Transitions Research Consortium (ITRC) is a consortium of seven UK universities, established in 2011 with the vision for infrastructure decisions to be guided primarily by systems analysis. When this vision is achieved, decision makers will have a range of models at their disposal that will tell them how all infrastructure systems are performing. They will also be able to assess the resilience and vulnerabilities of infrastructure, and evaluate investment decisions under a range of future scenarios including population growth, new technologies and climate change. Thanks to the first EPSRC Programme Grant (2011-2015), the ITRC has developed and demonstrated the world's first family of national infrastructure system models (NISMOD) for analysis and long-term planning of interdependent infrastructure systems (Hall et al., 2016). The research is already being used by the UK government to analyse the National Infrastructure Plan and inform better infrastructure decisions.

MISTRAL (Multi-scale Infrastructure Systems Analytics) is the second major ITRC project funded by the EPSRC Programme Grant (2016-2020), whose aim is to develop and demonstrate a highly integrated analytics capability to inform strategic infrastructure decision making across scales, from local to global. MISTRAL will thereby extend infrastructure systems analysis capability: 1) Downscale: from ITRC's representation of national networks to the UK's 25.7 million households and 5.2 million businesses, representing the infrastructure services they demand and the multi-scale networks through which these services are delivered; 2) Upscale: from the national perspective to incorporate global interconnections via telecommunications, transport and energy networks; 3) Across-scale: to other national settings outside the UK, where infrastructure needs are greatest. These research challenges need to be tackled because infrastructure systems are interconnected across scales and technological innovation is now occurring that is expected to influence their interconnectedness. MISTRAL aims to quantify these opportunities and risks, providing the evidence needed to plan, design, and invest in sustainable and resilient infrastructure.

1.2. Brief review of existing strategic models

A range of strategic transport models have been developed previously in a number of countries around the world. These include, for example, the long-term public transport model created for the Rhine/Main Regional Transport Association in Germany (Arnold et al., 2013), the Belgian Federal Planning Bureau's PLANET transport demand model (Gusbin et al., 2010), the Dutch National Transport Model (Van der Hoorn and van Wee, 2013), New Zealand's National Long-Term Land Transport Demand Model (Stephenson and Zheng, 2013), passenger and freight transport models developed for Italy (Crissali et al., 2013, Nuzzolo et al., 2013b) and for Europe (De Jong et al., 2004, De Jong et al., 2012, Nuzzolo et al., 2013a).

In Great Britain, there are also a number of existing long-term models, including the Long Distance Model (URS/Scott Wilson, 2011), the National Transport Model (NTM) (Department for Transport, 2009), the PLANET Long Distance model (HS2 Ltd, 2010), the National Trip End Model (WSP Group, 2011), the Great Britain Freight Model (MDS Transmodal Ltd., 2008), the rail Network Modelling Framework (Steer Davies Gleave and DeltaRail, 2007), the Air Passenger Demand Model (Department for Transport, 2011a), and the National Air Passenger Allocation Model (Department for Transport, 2011b). However, the review of these models found that they were unsuitable for the ITRC project because, for example, they did not cover the full study period (2011-2100), or they were not able to offer the national multi-modal coverage, efficient runtimes and flexible scenario capability required by the project. Therefore, a bespoke model (NISMOD-LP-T) was developed. This model generates macro-scale spatially-disaggregated forecasts of multimodal transport demand, capacity, emissions and costs for the whole of Britain down to a local-authority scale.

1.3. Brief overview of previous model's limitations and aspirations for MISTRAL

The MISTRAL transport modelling work will build on the transport model developed at the University of Southampton during the first ITRC project (NISMOD-LP-Transport) and the transport risk modelling work carried out during ITRC at the University of Oxford (components of NISMOD-RV). The transport model has generated a range of useful insights (Hickford et al., 2015) as well as contributed to work for the Infrastructure UK and the National Infrastructure Commission (NIC). However, it has some inherent limitations (described below) which place restrictions on its usefulness for future work. For example, the old ITRC transport model is characterised by:

- Lack of an OD matrix.
- Limited representation of intermodal competition.
- Relatively low resolution of transport network representation.
- No integration with the infrastructure network risk models (NISMOD-RV).