Transportation Research Part B 000 (2017) 1–20

Contents lists available at ScienceDirect

Transportation Research Part B

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

A framework for joint modelling of activity choice, duration, and productivity while travelling

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ARTICLE INFO

Article history:
Received 19 July 2017
Revised 22 October 2017
Accepted 23 October 2017
Available online xxx

Keywords:
Copula
ICT
Productivity
Rail
Travel time use
Value of travel time

ABSTRACT

Recent developments in mobile information and communication technologies (ICT), vehicle automation, and the associated debates on the implications for the operation of transport systems and for the appraisal of investment has heightened the importance of understanding how people spend travel time and how productive they are while travelling. To date, however, no approach has been proposed that incorporates the joint modelling of in-travel activity type, activity duration and productivity behaviour.

To address this critical gap, we draw on a recently developed PPS framework (Pawlak et al., 2015) to develop a new joint model of activity type choice, duration and productivity. In our framework, we use copulas to provide a flexible link between a discrete choice model of activity type choice, a hazard-based model for activity duration, and a log-linear model of productivity. Our model is readily amenable to estimation, which we demonstrate using data from the 2008 UK Study of Productive Use of Rail Travel-time. We hence show how journey-, respondent-, attitude-, and ICT-related factors are related to expected in-travel time allocation to work and non-work activities, and the associated productivity.

To the best of our knowledge, this is the first framework that both captures the effects of different factors on activity choice, duration and productivity, and models links between these aspects of behaviour. Furthermore, the convenient interpretation of the parameters in the form of semi-elasticities enables the comparison of effects associated with the presence of on-board facilities (e.g., workspace, connectivity) or equipment use, facilitating use of the model outputs in applied contexts.

1. Introduction

The time that people spend travelling is a pivotal focus of attention in travel behaviour research. Dimension such as the amount of time that people spend travelling, the influence of travel time on travel-related choice behaviour and the role of travel time savings in policy appraisal and evaluation have all been extensively researched. Until recently, however, the question of what people actually do during episodes of travel – the use they make of the time they spend travelling – has received comparatively little attention. This is a rather curious omission, since except in those rare situations where the

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https://doi.org/10.1016/j.trb.2017.10.010
0191-2615/

performance of the travel task itself is completely all-consuming, leaving little or no physical or cognitive resource available for other tasks, the time we spend travelling is in principle as available, useful and potentially productive as any other type of time.

In recent years however, a number of factors have combined to heighten research interest in the subject of in-travel time use. The first factor is the accumulation of a growing body of theoretical and empirical evidence demonstrating that the use of in-travel time is extensive, multi-faceted and important. Empirical studies conducted in recent years, using both quantitative and qualitative approaches, have consistently demonstrated that travel time can be populated with a range of different economic and social activities conducted individually and in groups (Axtell et al., 2008; Frei et al., 2015; Gamberini et al., 2012; Holley et al., 2008; Keseru and Macharis, 2017; Lyons et al., 2016; Lyons and Urry, 2005; Susilo et al., 2012). This work can be seen as part of a wider discourse concerning the concept of multitasking, i.e. 'simultaneous conduct of two or more activities during a given time period.' (Kenyon and Lyons, 2007, p. 162). The concept of multi-tasking, while recognised in sociology for quite some time (Gershuny and Sullivan, 1998; Harvey, 1993) has only recently seen a more systematic treatment in travel behaviour and time allocation modelling studies (Circella et al., 2012; Pawlak et al., 2016; Pawlak and Polak, 2010). The emerging consensus is, therefore, that the presence of multiple activities, including those conducted while travelling, cannot be neglected, and this consensus is now captured in a number of leading national time use surveys, e.g. in Canada and the UK (Gershuny and Sullivan, 2016; Statistics Canada, 2011).

A second, and closely related factor has been the continuing evolution of Information and Communication Technologies (ICT), especially mobile services (Lyons and Urry, 2005; Wardman and Lyons, 2015). In particular, new ICT mobile services provide a means through which travel episodes, conventionally seen as 'wasted', can be transformed into more usable, enjoyable, and often personalised experiences (Watts and Urry, 2008). Whilst the field of ICT and travel behaviour relationships has traditionally focused on substitution and complementarity between physical travel and virtual participation in so-called tele-activities (Andreev et al., 2010; Salomon, 1986), developments in mobile ICT services have encouraged research on the modification of travel, such as travel time use and the associated productivity. Wardman and Lyons have asserted that 'past revolutions in transport that have made longer journeys possible are now joined by a digital revolution that is reducing the disutility of travel time' (Wardman and Lyons, 2015, p. 507). Investment in communications infrastructure to enable mobile connectivity has emerged as a commercially potent topic in a wide range of contexts, including e.g., provision of high quality in-flight connectivity; this market alone is estimated to amount to between $2.1 and $4.62 billion by the mid-2020s (Euroconsult, 2014; SMR, 2016).

The third factor driving increased interest in in-travel time use is its implications for the appraisal of transport investment. In particular, if travel time is more useful than was previously thought, how should investments in *reducing* travel time be appraised compared to those that *improve the capacity of* travel time to be used constructively? Any departure from the typically prevailing assumption that travel time is 'wasted' might have major implications for transport modelling and investment appraisal practice. Despite the fact that this issue was recognised by Hensher as far back as in 1970s, who suggested a systematic treatment of time use in the evaluation of employer and employee benefits (Hensher, 1977), there remains no consensus regarding the extent to which such effects should be accommodated in appraisal methodologies (Wardman and Lyons, 2015). This has been in spite of the fact that this issue was recognised as far back as in 1970s by Hensher who suggested a systematic treatment of time use in evaluation of employer and employee benefits. The so-called Hensher's equation has been subsequently formalised and derived from first principles (Batley, 2015; Fowkes et al., 1986), although its application remains fairly limited, especially with respect to the understanding of the role of various factors, including ICT. Indeed, the continuing rapid evolution in ICT capabilities magnifies the challenge faced by policy-makers and practitioners in seeking to adapt existing approaches when there is no clear and stable theoretical framework or practical roadmap for change. It is hence not atypical to observe a resort to status quo assumptions or ad-hoc approaches in light of the lack definitive evidence or a means of systematic treatment (cf. Batley et al., 2012; Mackie et al., 2003).

The final reason for the re-ignited debate on the nature of in-travel time use is the continuing development in vehicle automation technologies, and hence the prospect of fully driverless and connected vehicles. One of the primary benefits asserted for such technologies is the re-purposing of the previously, seemingly 'wasted' driving time, for more enjoyable and productive activities (see Milakis et al., 2017 for a review of relevant studies). For example, Thomopoulos and Givoni (2015) quote a US Department of Transport analysis putting the productivity gains at $507 billion/year in the United States alone. This has all been in spite of growing evidence that there are complex trade-offs between potential improvements in network capacity and ensuring an enjoyable and productive on-board experience (Le Vine et al., 2015). Nevertheless, when, or if, the full automation of vehicles becomes possible and widely adopted, it is very likely to lead to step-changes in how transport systems function. Hence a framework that can suitably model in-travel time use and productivity is essential to understand adoption and use patterns of connected and autonomous vehicles (CAV) as well as their impacts on transport systems.

1.1. Objectives and structure of the paper

Motivated by the context outlined above, in this paper we develop a unified and comprehensive empirical framework enabling the investigation of factors driving in-travel time use and experience, including productivity. We demonstrate how this empirical framework is based on the microeconomic theoretic framework recently presented by the authors (Pawlak et al., 2015), referred to below as the PPS framework. The empirical framework is operationalised by using a copula formulation to

Please cite this article as: J. Pawlak et al., A framework for joint modelling of activity choice, duration, and productivity while travelling, Transportation Research Part B (2017), https://doi.org/10.1016/j.trb.2017.10.010