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# Towards a microeconomic framework for modelling the joint choice of activity–travel behaviour and ICT use

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## ABSTRACT

The rapid development of information and communication technologies (ICT) has been argued to affect time use patterns in a variety of ways, with consequent impacts on travel behaviour. While there exists a significant body of empirical studies documenting these effects, theoretical developments have lagged this empirical work and in particular, microeconomic time allocation models have not to date been fully extended to accommodate the implications of an increasingly digitised society. To address this gap, we present a modelling framework, grounded in time allocation theories and the goods–leisure framework, for joint modelling of the choice of mode of activity (physical versus tele-activity), travel mode and route, and ICT bundle. By providing the expression for a conditional indirect utility function, we use hypothetical scenarios to demonstrate how our framework can conceptualise various activity–travel decision situations. In our scenarios we assume a variety of situations such as the implications of severe weather, the introduction of autonomous vehicles, and the interaction between multiple decision makers. Moreover, our approach lays the microeconomic foundations for deriving subjective values of ICT qualities such as broadband speed or connection reliability. Finally, we also demonstrate the means by which our framework could be linked to various data collection protocols (stated preference exercises, diaries of social interactions, laboratory experiments) and modelling approaches (discrete choice modelling, hazard-based duration models).

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## 1. Introduction

Developments in information and communication technologies (ICT) have brought about the idea that physical presence might not be essential for activity participation, since individuals can increasingly undertake various tasks remotely, by means of ICT. This ever-expanding capability of remote participation which does not require travel has been gradually relaxing the long-established spatio-temporal constraints formally defined by Hägerstrand in his concept of ‘daily space–time prism’ (Hägerstrand, 1970). Such activities, referred to as tele-activities, following the term *telecommuting* coined by John Nilles in the 1970s, have received considerable attention from a number of researchers for almost 40 years, especially from the perspective of transport studies (Salomon, 1986; Bailey and Kurland, 2002; Mokhtarian et al., 2004; Andreev et al., 2010). Moreover, due to their spatio-temporal flexibility, tele-activities display also higher potential for being undertaken

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simultaneously with other activities, thus linking to the phenomenon of travel time use, and wider concept of multitasking (Lyons and Urry, 2005; Kenyon and Lyons, 2007; Pawlak et al., 2011).

For the purpose of this paper we find it useful to provide a working definition of tele-activities as *those activities traditionally involving travel which can now be conducted by means of ICT without recourse to travel*. Such activities can range from simple exchange of text messages or voice calls, to sophisticated, graphic-rich, immersive technologies of virtual reality. What is common is that in both cases an individual is capable of projecting his or her *tele-presence* by means of ICT medium to a location (physical or virtual) without any travel requirement (Steuer, 1992). As such the location can be the workplace or office, but also the virtual reality of an online shop or offline computer. At the same time we also acknowledge the existence of activities which have emerged only as a result of developments in ICT, and may not have unambiguous and direct counterparts in physical reality, for instance microblogging (tweeting) or flash mob. While such activities could still be encapsulated within the current framework, e.g. as in-travel activities, or activities for which there is never travel requirement, in the current contribution we choose not to focus on them given our primary interest in the ICT–travel interaction.

Tele-activities have been the focus of considerable interest due to their potential influence on time use patterns, travel behaviour, and hence infrastructural and policy needs (Salomon, 2000; Gann et al., 2010). Neglecting their existence may result in the inability of the modelling frameworks to accurately capture and reflect individual time use patterns in the increasingly digitised world. In the past such a claim would apply only to highly-skilled and mobile professionals due to the exclusive nature and price of advanced ICT. However, falling costs leading to mass ownership of personal ICT devices such as laptops, smartphones or tablet computers, together with the increased availability of mobile and wireless Internet have made the issue far more important today. In such a situation, even small changes to individual behaviour, if aggregated over the entire population, can have profound implications for various systems such as transport, health care, or labour market (Golob and Regan, 2001).

While a significant number of studies have explored the field empirically, the existing microeconomic frameworks (on which most of the current understanding of the time allocation, activity scheduling and travel demand models rests) appear to have lagged behind, not always appropriately capturing the effects of developments in ICT. It is the purpose of this study to address this gap. In Section 2 we present a brief review of the studies on the relationships between ICT, tele-activities, time use, and travel behaviour, which helps in shaping the conceptualisation of our modelling contribution, and indicates link to the existing body of knowledge. Subsequently, in Section 3 we develop a microeconomic framework for the joint choice of pre-, in-, and post-travel activities (including their mode of conduct, i.e. physical or ICT-based/tele-activity), their timings and durations, travel mode and route, as well as ICT use. Following that we introduce five scenarios in Section 4 which demonstrate how the framework would be able to conceptualise various instances of ICT and travel behaviour interaction that have been observed in empirical studies elsewhere. As the current paper constitutes a theoretical contribution, Section 5 discusses possible ways in which the framework could be operationalised and linked to the existing econometric tools. The final Section 6 provides conclusions and directions for further research.

## 2. ICT, tele-activities, time use, and travel behaviour: a brief review

One of the earliest and most significant conceptual contributions to understanding the relationship between tele-activities (in fact, more widely ICT) and travel can be attributed to Ilan Salomon and Patricia Mokhtarian. Not only have they shed light by defining four possible relationships between ICT and travel, i.e. complementarity, substitution, modification, and neutrality (Salomon, 1986; Mokhtarian, 1990), but also subsequently produced a number of studies investigating the issue empirically (Mokhtarian and Salomon, 1996; Mokhtarian and Salomon, 1997; Mokhtarian et al., 1998; Mokhtarian and Salomon, 2001).

From the perspective of transport planning, the assumption of ICT emerging as the ultimate solution to traffic problems through mass substitution from travel to tele-activities was attractive and prevalent in the early studies even without sound empirical evidence. Salomon (1986: 235) noted that such approach resulted from:

‘coincidence of strong vested interest on behalf of producers of telecommunications technologies and the quest of transport planners to solve problems via technology-oriented solutions rather than through measures that require changes in consumer or institutional behavior’.

However, reality proved more complex and Mokhtarian (2009) noted twelve possible reasons why simple ICT–travel substitution was not the only observed consequence. This has been confirmed in numerous studies reporting a whole range of different effects, depending on the activity, context as well as ways in which ICT-use, tele-activity participation, and travel behaviour were used and defined (see review by Andreev et al., 2010). For instance, from an aggregate perspective of large-scale studies in Hong Kong (Wang and Law, 2007) and in the US (Choo and Mokhtarian, 2007; Choo et al., 2007) dominance of complementarity effects was suggested while the results of Konduri and Pendyala (2009) indicated prevalence of substitution. However, in both cases authors noted simultaneous interplay of substitution and complementarity effects later re-confirmed in a cross-national study by Pawlak et al. (2014).

Other empirical studies in the field tended to be of a more disaggregate nature and dealing with specific instances of tele-activities such as tele-commuting, tele-conferencing, tele-shopping, tele-leisure, or various tele-services. Those studies have considerably increased the understanding of people’s motivation for participating in tele-activities (e.g. Mokhtarian and

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