



Analysing the complexity of day-to-day individual activity-travel patterns using a multidimensional sequence alignment model: A case study in the Bandung Metropolitan Area, Indonesia



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ABSTRACT

Using a panel regression model and a multidimensional three-week household time-use and activity diary, this study analyses the complexity of the day-to-day variability in individuals' activity-travel patterns by applying a multidimensional sequence alignment model. It is found that the variability between weekend and weekday pairs is much greater than between weekday-weekday pairs or weekend-weekend pairs. The variability of other household members' activity-travel patterns is found to significantly influence an individual's activity-travel patterns. The results also show that the variability in the activity-travel patterns of workers and students is greater when conducting a particular discretionary activity on weekdays. Due to performing discretionary activities more often and for longer, non-workers tend to have more predictable activity-travel patterns. Undertaking multitasking activities within different activities on weekdays significantly impacted the different degrees of variability in an individual's activity-travel patterns. Having different health and built environment characteristics also corresponds with different degrees of predictability of the activity-travel patterns, particularly in the worker/student case.

1. Introduction

To fully understand the complexity of individuals' activity-travel behaviour, it cannot be treated only as independent entity that varies between different socio-demographic groups and built environment conditions. The activity-travel behaviour must also consider the complex interdependencies among participation in various activities, and between activities and trip variables in an attempt to satisfy individuals' needs and desires. Hägerstrand (1970) and Neutens et al. (2011) argued that these interactions are caused by interactions between individuals' constraints (e.g., capability, coupling and authority constraints) and needs. These constraints and needs are shaped by the uniqueness of individuals' personal characteristics (age, gender and physical disability, etc.) and social characteristics (being a part of a household, a neighbourhood, a company, a citizen, and/or a certain community, etc.). Thus, these constraint-need interactions will form individuals' activity-travel patterns and time-space prisms/paths, which vary from day to day. Some activities are repetitious (such as working, going to work or school, eating and sleeping), but others are new and depend on

their daily needs and constraints (for example maintenance and leisure activities). Furthermore, the availability of “external” resources (e.g., built environment accessibility, access to motorised modes of transport and disposable income) gives more opportunities for some individuals to participate in certain activities and/or travel than others. The understanding of this concept will give us a better understanding of the mechanisms and complexity underlying individuals' decisions with regards to different opportunities offered by time, space and social conditions. This will help us to design better policies and also a more accurate forecast of individual travel needs and demands (Fox, 1995; Flyvberg et al., 2005).

Diaries of individuals' time-use and activity have been used to collect more complete information regarding individuals' daily needs, constraints and the interactions explained above. The data record time duration of travel or activity diary of individuals. A longer term dataset will help us not only to predict the frequency of individual activity participation, but how different activities and different groups of travellers plan and optimise different activity-travel patterns from either a single or multi-facets perspective (Susilo and Kitamura, 2005; Kang and

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Scott, 2010; Chikaraishi et al., 2011; Susilo and Axhausen, 2014; Moiseeva et al., 2014; Dharmowijoyo et al., 2016a). Intra-personal variability has been concerned to influence travel demand models, thus a proposed policy must also consider individuals' day-to-day variability together with the constraint-need interactions within the time-space limitation assumption. Nowadays, researchers are trying to model single or multiple facets of individuals' day-to-day activity-travel patterns in order to forecast individuals' day-to-day activity-travel patterns to simulate a particular transportation policy. The individual's variability or similarity measurement is used to find the goodness of fit between observed and predicted activity-travel patterns (Joh et al., 2002).

Despite there being more and more complete datasets available, most of the previous studies tend to only focus on a single facet of individuals' activity-travel patterns, such as number of trips, trip chains, travel time, share of motorised mode use, certain activities behaviour, and activity episodes alone (a series of Pas studies, such as Pas, 1987; Pas and Sundar, 1995). These studies, however, did not take into account the interdependency between the different facets and dimensions. Previous studies (Koppelman and Pas, 1985; Schlich and Axhausen, 2003; Susilo and Axhausen, 2014) argued that the uniqueness of individuals' activity-travel patterns on each day is not only based on a single facet and dimension, but also on the interaction between multiple facets and dimensions. Considering individuals' activity-travel patterns from multiple facets and dimensions would also represent any linkages or interdependencies in a sequence between individuals' activities and trips or among activities or between two different activities or between certain activities/trips and other multi-dimensions aspects such as travel mode and/or whether individuals undertake or do not undertake multitasking activities. There is a sequence implication when individuals undertake a particular activity which influences the individuals' level of time-space constraints. For example, undertaking working/studying for certain hours would make individuals have tighter time-space constraints level, thus undertake such activities would dictate individuals to perform other activities in next sequence. Undertaking working/studying also make individuals depended on motorised mode more frequent in order to perform other out-of-home activities (Hägerstrand, 1970; Ellegård and Vilhelmson, 2004; Susilo and Kitamura, 2005; Dharmowijoyo et al., 2015, 2016b). Individuals' activity-travel patterns should be seen as a sequence of activities and trips in multiple facets and dimensions rather than in single facet/dimension in order to satisfy their needs and desires, shaped by their constraints. Individuals may have more varied activity-travel patterns when only considering a single facet, but may have more routines when taking into account more facets or dimensions (as argued also by Koppelman and Pas, 1985; Schlich and Axhausen, 2003; Raux et al., 2011).

There are many ways to measure individuals' variability and similarity on different days with multiple facets (Schlich and Axhausen, 2003). However, most studies only measured two or three facets of structural information such as trips/activities and their purpose (Huff and Hanson, 1986; Pas, 1980, 1983) or trips/activities and time interval (Jones and Clarke, 1988) or trips/activities and activity location/travel mode (Susilo and Axhausen, 2014) or combinations among multiple dimensions such as trips, their purpose, travel mode and time interval (Koppelman and Pas, 1985). However, those previous studies did not measure the difference of sequential information on different days. The sequence alignment model (SAM) tries not only to gather more facets of structural information than previous studies, but also sequential information (Wilson, 1998; Burnett and Hanson, 1982; Moiseeva et al., 2014). Joh et al. (2002) extended the method by which they account for multidimensional information as much as possible, such as activity type and sequence, timing, location, with whom the activity was undertaken, and travel mode.

There have been a number of studies which applied either unidimensional or multi-dimensional analyses of individual activity-travel patterns; either only for single day (Wilson, 1998; Shoval and Isaacsson,

2007) or by classifying travellers into different homogenous segments (Wilson, 1998; Schlich and Axhausen, 2004; Shoval and Isaacsson, 2007). However, the multi-faceted and multi-dimensional analysis rarely includes in-home activities - previous studies only include out-of-home activities (Wilson, 1998; Joh et al., 2002; Schlich and Axhausen, 2004; Shoval and Isaacsson, 2007; Moiseeva et al., 2014). Individuals carry out around 75% of their activities at home (Hägerstrand, 1970; Marchetti, 1994; Ellegård and Vilhelmson, 2004; Dharmowijoyo et al., 2015) which obviously shapes individuals' activity-travel patterns particularly out-of-home ones. Moreover, before this study, the multi-dimensional sequence alignment model was utilized as the main or one of several selected variables to aggregate certain travellers which may need to be treated differently in the process of designing activity-travel policies. There is a lack of knowledge in understanding the complexity of the activity-journey which underlies the degree of dissimilarity in individuals' daily activity-travel patterns.

The discussions above emphasize three research questions. First, what is the degree of variability/similarity of individuals' activity-travel patterns when including more complete facets such as in-home and out-of-home activities and multiple dimensions such as activity type, activity location, type of travel mode and whether multitasking activity is recorded or not. Previous arguments exhibit that disregarding how individuals arrange their activity-travel in multiple facets and dimensions can lead to underestimating the degree of variability/similarity in individuals' activity-travel patterns. In-home activities will include the most undertaken activities in a day; excluding such activity will undervalue how individuals set and undertake their day-to-day activity-travel. In addition, understanding why individuals tend to have more predictable or random activity-travel patterns on different days of the week shaped by time-space and health components is a second research question in this study. Individuals' activity-travel patterns are a subject of interaction between individuals' time-space constraints and needs represented by time duration of a certain activity, socio-demographic, built environment and health variables. Health constraints are part of individuals' capability factors which interconnect and interrelate with individuals' coupling and authority constraints in shaping individuals' activity-travel patterns. Individuals' coupling and authority constraints can be mostly captured by individuals' time allocation to certain activity. Health variables used in this study are not only defined as physical health, but also any social and emotional problems which can also influence individuals' activity-travel behaviour (Suzukamo et al., 2011; Zhang, 2013; Dharmowijoyo et al., 2015, 2016b). Taking in health variables in this study will indicate the relation between having more varied or similar activity-travel patterns on certain days pair with having better health conditions. Understanding this will suggest a particular individuals' activity-travel pattern either more random or more predictable which affect better health performance. Furthermore, this study also accounts for multitasking activities as an influential variable in shaping individuals' activity-travel patterns. Individuals with different levels of time-space constraints tend to perform multitasking activities within different activities (Sullivan and Gershuny, 2012). Undertaking/not undertaking multitasking activities within a certain activity can also indicate the difference of individuals' level of time-space constraints when individuals undertake same primary activities, but having different degrees of variability of individuals' activity-travel patterns. Revealing the impact of multitasking activities on individuals' degrees of variability of activity-travel patterns will give another dimension in time-space perspective on how individuals optimise their time and space limitation in order to fulfil their needs and desires. The last research question in this study is what would be the impact of other household members' activity-travel engagements in one's shared trips and participation in activities. Most previous studies also ignore the impacts of other household members' travel patterns on individual trip and activity participation.

This study used a three-week time-use and activity diary in households, including individual health-related quality of life questions,

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