U4IA: Emerging urban futures and opportune repertoires of individual adaptation: program overview

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U4IA: Emerging Urban Futures and Opportune Repertoires of Individual Adaptation

Program Overview

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Abstract: This paper summarizes the goals and scope of a new large scale research project, funded by the EEC. The ultimate goal of this research project is to develop the first comprehensive model of dynamic activity-travel patterns in the world, expanding and integrating concepts and partial approaches that have been suggested over the last few years. Dynamics pertain to different time horizons. Long-term decisions such as demographic change, changing job or house may also prompt or force people to adapt their activity-travel patterns. Exogenously triggered change involves change in the urban and/or transportation environment and/or the larger socio-economic institutional contexts. It may be unplanned or planned (policies). The integrated multi-agent model will simulate the primary, secondary and higher order effects of such emerging urban futures on dynamic repertoires of activity-travel patterns. A multi-agent model will be build to capture these dynamics. In addition to the multi-agent model, the PhD/postdoc projects will result in improved understanding of the effects of various policies, based on a variety of statistical analyses, and in guidelines about the most effective (set of) policies in contributing to integrated urban sustainability, and in elaborated theory about spatial dynamic choice behaviour.
1. INTRODUCTION

An understanding of complex activity patterns (time-space behaviour) of actors is essential for improving the effectiveness of various kinds of policies. An activity-based framework constitutes an integrated framework as it (i) combines economic, social and other activities, (ii) is based on a highly detailed, comprehensive spatial and temporal representations (minutes and geocodes/small postal zones), (iii) combines different methods to simulate behaviour, (iv) focuses on the complex interdependencies between activities, household members, time periods, locations, etc., and (v) constitutes the basis for deriving measures of economic, social and environmental impact. For these reasons, the activity-based perspective has rapidly gained momentum, especially in transportation research, but also in geography and urban planning/design, and to a lesser extent in sociology (new mobilities and time use research). There is evidence that four-step models of transport demand, which have represented the state-of-practice in transport/urban modelling for decades, are slowly but steadily replaced in planning practice by activity-based models, such as Vovsha et al. (2004), CEMDEP (Bhat et al., 2004), Famos/PCATS (Pendyala et al., 2005), and Tasha (Roorda, et al., 2007). Arentze & Timmermans (2000, 2005) developed Albatross for the Dutch Ministry of Transport.

All these models are concerned with the simulation of daily activity patterns and have dealt only marginally, if at all, with dynamics. This is mainly due to two reasons: (i) the lack of any sufficiently large continuous data set of long duration, and (ii) until very recently, the lack of useful theories and integrative, comprehensive modelling approaches. Available data relate to one or two day observed activity-travel diaries, and hence do not allow any advanced dynamic analysis and modelling. The main objective of the research project therefore is to analyze and model endogenously and exogenously triggered dynamics in activity-travel patterns, across different time horizons in the context of particular future urban challenges that to date have received only scant attention.

2. STATE OF THE ART

Research can be divided according to time horizon: long term, mid-term and short-term adaptation. Much research on long-term decisions has focused on particular circumstances that trigger individuals and households to reconsider their habitual behaviour. Waerden, Borgers and Timmermans (2003) argued that key lifecycle events may prompt or force individuals to reconsider their activity-travel patterns and/or resources. Key lifecycle
events are unavoidable (demographic) events, such as reaching the age to get a driver’s license) or planned events that occur during the lifecycle (leaving home, getting married, first child, retirement, new job, new house, etc.). Several qualitative studies have examined a specific type of event in detail and showed that indeed individuals do reconsider or are forced to adapt their activity-travel patterns after key events such as moving house (e.g., Stanbridge & Lyons, 2006).

Three approaches have been explored to modelling the effects of such long-term decisions: Verhoeven, et al., (2005) used a Bayesian network representing interdependencies between life trajectory events, resources and activity-travel patterns. Beige & Axhausen (2006) used hazard models to examine interrelationships between key events (residential choice, education, employment duration) and mobility tools (car availability, driver’s license and season’s tickets). Finally, Vanhunsel, et al. (2007 suggested using a (generalised) Q-learning algorithm and illustrated its potential in the context of obtaining a driver’s license.

Part of the dynamics in activity-travel patterns are related to annual regimes in activity sequences. Events such as birthdays, Christmas, vacation, etc. trigger a series of activities that need to be completed if households wish to participate in such events. Empirical evidence was in found in Arentze, et al. (2006). These effects can be incorporated in dynamic activity-based models using Bayesian networks (Arentze & Timmermans, 2007d), who found evidence of direct and indirect effects in each phase of the chain – the event, preparation and aftermath phase.

As for mid-term dynamics, the topic of daily and weekly rhythms in activity-travel patterns has received most attention, typically centred on available new datasets. All recent research is based on the MobiDrive data (e.g., Schlich & Axhausen, 2003). Using hazard models, these studies have provided evidence of the importance of incorporating such dynamics: travel patterns are characterized by both repetition and variability. Most of this work has been conducted at the individual/household level, but has not examined within-household mechanisms. A very interesting study therefore is Ettema & Van der Lippe (2006) who investigated rhythms in spouses’ task allocation patterns and strategies on a weekly and day-to-day level. They found that spouses apply some form of specialisation to deal with time constraints. In households with an egalitarian expectation of task allocation, the female has a larger share of paid work on all weekdays, including Friday.

Much of this research has traditionally been very empirical in nature. Only recently, some basic theory and the first steps in model building have been
made. Miller (2005) formulated an integrated framework for modelling short-run and long-run dynamics. In more recent work, Nurul Habib & Miller (2007) suggested a model for activity generation, using a utility-maximizing framework. In contrast, Kim, et al. (2006) used mathematical programming techniques. None of these approaches involves the dynamics of activity generation. To address this problem, Arentze & Timmermans (2007a) formulated a need-based theory and operational model, first for individuals and later they extended their theory to households. The authors showed that to a large extent parameters can be estimated on cross-sectional data in a RUM framework (Arentze et al. 2010). When cross-sectional data is complemented with activity-history data several sources of heterogeneity can be estimated as well (Nijland et al. 2010).

Another highly interesting set of papers is concerned with the development of MATSIM-T, a multi-agent environment for travel simulation (e.g. Balmer et al., 2006). Agents select certain plans probabilistically. Simple learning rules are used to dynamically update the suitability/utility of daily schedules. Thus, at the current stage of development, the system depends on ad hoc algorithms and simple concepts; however these could be replaced with theory-driven rules and models of the kind discussed above.

Understanding short-term dynamics (rescheduling behaviour) is especially relevant for urban and transport demand management. Aurora (Joh et al., 2006) is the most advanced comprehensive model of activity rescheduling behaviour in which daily activity (re)scheduling is a complex function of history, available time for the activity and time pressure. The model also allows more dramatic adjustments across other choice facets than duration. Empirical work to data supported the validity of the model (e.g., Van Bladel, et al. 2006). Nijland, et al. (2007) conducted a stated adaptation experiment in which respondents were asked to change their activity schedules in response to time pressure. Results suggested that adjustment is primarily focused on those choice facets that are easiest to change. Roorda & Andre (2007), conducting a very similar analysis, reached similar conclusions.

In addition to this work on adaptation of activity-travel in response to endogenous change, there is a stream of literature that has examined behavioural change in response to particular policy instruments, using attitudinal, self regulation and habit formation theories as a frame of reference (Gärling & Fujii, 2006). It typically involves empirical before-after studies, lacking model application. Examples include Fujii & Kitamura (2003), who studied the effect of providing subjects with a one-month free bus pass, Chatterjee & Ma (2006), and Loukopoulos et al. (2006).

Two newly emerging topics are responses to information provision and the
impact of social networks. An overview of studies on responsive behaviour to various forms of travel information is given in Chorus, et al. (2006). It involves different theoretical constructs, such as regret theory and (accumulated) prospect theory. It appears that none of this research is concerned with multi-faceted activity-travel patterns. Work on the relationship between social networks and travel in transportation research is rapidly growing (e.g., Carrasco & Miller, 2005; Paez & Scott, 2008). Arentze & Timmermans (2006, 2007b) conducted numerical simulations and showed that participation in social networks may lead to adaptation of aspirations and diffusion of knowledge, which in turn may trigger changes in activity-travel choice behaviour. Hackney & Axhausen (2006) conducted a similar simulation.

3. CONCEPTUAL FRAMEWORK

The general framework, underlying the research project is depicted in Figure 1. The problem of organising activities in time and space involves the interdependent choice of which activities to conduct (activity generation), where to conduct these activities (destination choice), when and for how long (timing and duration choice), with whom (choice of travel party), the transport mode(s) involved (transport mode choice) and the route to take (route choice), subject to spatio-temporal (destinations that can be reached within certain time windows), temporal (sequencing of activities) and institutional (e.g. opening hours) constraints and available resources (income, cars and other modes of transport). It is a spatial problem in the sense that attributes of the environment, including the transportation system, influence the decision making process. However, this influence is indirect in the sense that individuals base their choices on the incomplete and imperfect information they have about their environment (their cognitive environment). Some attributes are relatively stable, others vary and yet others emerge as the result of the accumulated decisions of many individuals. It makes the decision context inherently uncertain.

Activities are conducted to satisfy underlying needs and desires. Needs are dynamic and influenced by lifecycle stages. Also the resources change dynamically as a result of lifecycle. It leads to activity agendas that change slowly over time, primarily due to key lifecycle events. Some needs are personal, others are defined at the household level. Consequently, conducting activities may also satisfy needs of others and be beneficial to one or more underlying needs and this interdependency needs to be taken into account.
At the mid-term level, this means that individuals will face a relatively stable set of conditions, will learn until a relatively stable set of context-dependent choice heuristics can be apply to cope with the situation and develop a repertoire of effective choice strategies. Successful strategies will be reinforced. Unsuccessful strategies will no longer be applied. Because needs occur in different cycles, the organisation of activities is a multi-day decision problem, with time intervals depending on the kind of activity, the extent and nature of any substitution and variety-seeking.

In the short-run, at the start of the day, activities for that day need to be scheduled, although the scheduling may also have occurred earlier. However, due to the inherent uncertainty at this time horizon, some activities, including travel may require more time (or less time) than expected, implying that activities need to be rescheduled. It means that individuals can change one or more of various choice facets of their activity schedules.

By implementing activities, individuals visit particular destinations and experience attributes, thereby reinforcing their beliefs and updating their memory trace regarding their awareness of alternative destinations in their environment. In addition to these dynamics that result from conducting activities, individuals may hear of new alternatives through word-of-mouth of members of their social network. Moreover, individuals may be passively exposed to advertisement or other information, or they be actively searching for information. It is assumed that the acceptability of information is a function of the similarity between the people involved and the general
acceptance of the alternative in the social network. Similarity is a function of person characteristics, attributes, group membership and spatial distance.

Adaptation of activity-travel patterns does not only come about due to endogenous factors (changing needs, learning, etc), but also because exogenous factors (changing supply, policies) trigger or force people to rethink they way they have organised their activities in time and space. People will first try easy short-run rescheduling, but if that is ineffective, they will consider midterm or even long-term decisions.

4. RESEARCH QUESTIONS

Based on this conceptual framework, the research programme will address a series of linked research questions, necessary the develop a multi-agent model that will simulate both emerging patterns and evolving dynamic behaviour due to exogenous change and due to exogenous change, triggered by a set of innovative policies aimed at sustainable urban futures. First, relatively little is known about the impact of different types of policies relevant for urban futures on the dynamics of activity-travel patterns and consequently related mobility, accessibility, social exclusion and energy consumption patterns. Thus, a first set of research questions relates to how travellers respond to different types of policies (spatial, economic, social, environmental, information provision, how these responses change over time and how their (dynamic) behaviour is influenced by personal and household characteristics, spatial and transportation context, activity agendas, nature of information provision and costs. Secondly, to provide an integrated framework, these approaches need to be combined into an integrative multi-agent system. Thus, a second series of research questions are concerned with how we can analyze and simulate the effects of the envisioned policies and ICT instruments on dynamic repertoires of activity-travel patterns within a multi-agent framework.

5. RESEARCH METHODS

Three types of data will be collected:

1 panel survey recording for 2 months activity-travel patterns of a representative sample of 1500 respondents, using GPS-enabled cellular phones technology and Web based prompted recall. We can automatically trace the space-time behaviour of individuals participating in the survey.
GPS traces provide information about route, destination, timing choice and duration. To avoid any ethical issues, respondents will be invited to participate, and will get full insight in the data that will be collected and in the way these data will be used. The data will be used anonymously; activity-travel patterns will only be linked to general characteristics of the respondents, so the personal identity is fully protected. These data will be enhanced using data fusion and machine learning algorithms to provide additional data on activity participation, and transport mode. Respondents will be invited to check the data for accuracy and consistency, and provide any missing information. We will embed this data collection into a larger Bayesian learning/updating framework, implying that the probability of wrong inferences/misclassification and therefore respondent burden should logically reduce over time.

2 The sample will be divided into sub-samples. Respondents in every sub-sample will be invited to stated choice/adaptation experiments. This means that policies related to urban futures will be characterized in terms of a series of attributes. In turn, each attribute will be defined in terms of a set for attribute levels. Fractional factorial experimental designs will then be used to construct attribute profiles, which define particular policies and/or conditions. Respondents will then be asked to indicate if and if so, how, they likely adjust their activity-travel patterns. Such adaptation may involve any possible combination of choice facets, characterizing a pattern (i.e. duration, destination, timing, etc.). Some of these tasks can be administered in simple surveys. To obtain reliable response data, higher involvement may be required. In these cases, we will develop interactive computer experiments. More complex and advanced travel simulation experiments will also be required for the projects where data about learning is necessary and in case individual respondents are required to respond to emerging aggregate patterns. These patterns or the collected effect of other travellers will be based on computer simulations.

3 Qualitative data (protocols, decision tables, laddering techniques, CNET etc.) will be used to collect data about the reasoning behind responses and serve for triangulation.

Data will be collected in the Brainport area, The Netherlands, the area in Europe with most new patents, and many new knowledge workers. Detailed geocoded data for this area about the distribution of various kinds of land use, characteristics of the built environment, transportation system and institutional context (e.g. opening hours), socio-demographics and functional characteristics at postcode level etc. is already available.
The program consists of five PhD projects and a postdoc project for the integration of the PhD projects. PhD projects address a specific dimension that is assumed to influence the dynamics of activity-travel repertoires, however considering interdependencies with other dimensions. Topics chosen reflect future urban challenges, implying that each PhD project should draw attention in its own right because it addresses a topic that has not been studied yet in much detail. In addition, however, each serves to generate generalisable results and approaches that will be embedded in the integrative multi-agent framework.

### 6.1 Project 1: Effects of future urban form on dynamic repertoires of activity-travel behaviour

**Problem definition**

Urban planners and designs try to create new urban environments that stimulate non-motorised forms of transport and contribute to the reduction of mobility. While much research has focused on cross-sectional relationships between urban form and mobility, very little is known about the impact of residential moves on changing repertoires of activity-travel patterns. This is unfortunate in the sense that people maybe triggered to reconsider their habitual patterns after such major change with long-term effects. Key research questions thus are: What is the effect of urban form on the dynamics of activity-travel patterns? Do such effects differ between segments of the population, types of neighbourhoods and different urban forms? What are the secondary effects of urban form?

**Objectives**

1. increase our understanding of the impact of urban forms on the dynamics of activity-travel patterns
2. develop and test a model of these dynamics
3. embed this model in an integrative multi-agent representation and simulation of dynamic repertoires of activity-travel patterns

**Research design and methodology**

A representative sample of 500 respondents will be selected, who are in the process of moving house to a new neighbourhood, classified according to urban form characteristics, using principles of quasi-experimental design. Changes in their activity-travel patterns will be recorded. Effects of
neighbourhood will be statistically identified using contrast effects in mixed logit and multi-spell, multi-state hazard models. Advanced laddering techniques (Dellaert, Arentze & Timmermans, 2008), together with retrospective surveys will be used to collect qualitative data about the underlying decision making process. These will be analysed using script-protocol formalisms, rarely used in activity analysis. Attitudinal questions will be used and analyzed using structural equation models to understand motivations and address the problem of self-selection. Qualitative interview protocols will be used for triangulation. In additional to descriptive and multi-level correlation analyses, the direct and indirect effects of urban form on dynamic activity-travel patterns will be identified using Bayesian decision networks. These results will be linked to agents, representing individuals, in the multi-agent simulation model.

6.2 Project 2: Effects of pricing strategies on dynamic repertoires of activity-travel behaviour

Problem definition
Various pricing strategies have been suggested and/or implemented to induce individuals to change their space-time behaviour. In addition to congestion pricing, new pricing strategies such as carbon tax, tax reduction for fuel-efficient cars, environmental taxes for airlines, energy vouchers and free public transport for certain age cohorts have been suggested. It is not known whether such policies will lead individuals to change their current behaviour and if so how. Key research questions thus are: What are the primary and secondary effects of these pricing strategies on the dynamics of activity-travel patterns? Do they differ between population segments and types of neighbourhoods?

Objectives
1. increase our understanding of the impact of various pricing strategies on the dynamics of activity-travel patterns
2. develop and test a model of these dynamics
3. embed this model in an integrative multi-agent representation and simulation of dynamic repertoires of activity-travel patterns

Research design and methodology
A representative (sub)sample of 300 respondents will be selected for participation in stated adaptation experiments. These experiments systematically vary the levels of various new pricing strategies, related to carbon tax, tax reduction, energy vouchers, etc., using fractional factorial designs and bifurcation points. Respondents will be asked to indicate if, and if so, how they would change their activity-travel patterns. The combined
effect of the pricing strategies will be examined using portfolio conjoint analysis, recently introduced in transportation (Wiley & Timmermans, 2008). The effects of single policies will be analysed using mixed logit models. Effects of sociodemographics and spatial variables will be reflected in the coefficients of the model. It will result in probabilities of change of the main dimension of activity-travel patterns. Rule-based scheduling mechanisms will be used to simulate comprehensive, consistent schedules. For triangulation, qualitative data about the reasoning behind the provided responses will be collected as well.

6.3 Project 3: Effects of dramatically increasing energy prices on dynamic repertoires of activity-travel behaviour

Problem definition
The recent discussion on climate change and energy resources suggests dramatically increasing energy prices. The attention this topic attracts in the academic and popular media, may change people attitudes toward environmental issues, which in turn may be instrumental to behavioural change. Key research questions thus are: What is the effect of dramatically increasing energy prices on the dynamics of activity-travel patterns? Do such effects differ between segments of the population, and types of neighbourhoods? Can we identify any bifurcation points in behavioural change in this context? What are the secondary effects of dramatically increasing prices?

Objectives
1. increase our understanding of the impact of dramatically increasing energy on attitudes about the environment and the dynamics of activity-travel patterns
2. develop and test a model of these dynamics
3. embed this model in an integrative multi-agent representation and simulation of dynamic repertoires of activity-travel patterns

Research design and methodology
A representative (sub)sample of 300 respondents will be selected to participate in a stated adaptation experiment. Pricing levels will be systematically varied, together with context effects, using fractional factorial designs. They will be asked to indicate if and how their activity-travel patterns change when faces by the increasing prices. The experiment will be designed such as to identify bifurcation points. Qualitative data about motivations underlying the response will be collected used for triangulation.
In addition to conventional descriptive and multi-level correlation analyses, the results of the stated adaptation experiments will be analysed using mixed nested logit models and ordinal probit models. Effects of sociodemographics and spatial variables will be reflected in the coefficients of the model. It will result in probabilities of change of the main dimensions of activity-travel patterns. Rule-based scheduling mechanisms will be used to simulate comprehensive, consistent schedules.

6.4 Project 4: Effects of social networks on dynamic repertoires of activity-travel behaviour

Problem definition
Current policy instruments in stimulating sustainable urban development include neighbourhoods of mixed social composition. It is expected that such neighbourhoods are not only instrumental in stimulating cultural integration, an urgent topic in many European cities, but will also be beneficial to creating social networks that serve as support systems. Localised support networks may become increasingly relevant due to an aging society, the need for increased and longer labour participation and the increasing of the civil society in light of partially retrieving government and changing concepts of urban governance. The success of such policies however largely depends on the local foundation of social networks and the extent to which they serve or can serve as support systems. Key research questions thus are: What is the effect of social networks on the dynamics of activity-travel patterns? Do such effects differ between segments and types of neighbourhoods?

Objectives
1. increase our understanding of the impact of social networks on the dynamics of activity-travel patterns
2. develop and test a model of these dynamics
3. embed this model in an integrative multi-agent representation and simulation of dynamic repertoires of activity-travel patterns

Research design and methodology
A representative subsample will be identified. Ego-centric social networks will be constructed. Questions will be asked about the relevance and role of members of the social networks as a support mechanism to cope with required change in activity-travel patterns. This will involve the current situation, but also possible future situation. To that end, stated choice experiments will be conducted to collect data on response patterns under different scenarios related to time pressure, and the urgency of activities. Current approaches a priori define each context. A new approach will be
tried in this project, which incrementally changes conditions and records further changes in the way activities are organised and support is organised. Qualitative data will be used for triangulation. In addition to the conventional descriptive and multi-level correlation analyses, the results of the stated choice experiment will be analysed using mixed logit models. Effects of socio-demographics, nature of the social network and spatial variables will be reflected in the coefficients of the model. Graph theory will be used to characterise the social networks. Spatial statistics will be used to quantify the degree of localisation of the network. Changes in the sequencing of activities, which can also be observed in the other experiments, but seems most likely in this context, will be analysed using multidimensional sequence alignments. It will result in probabilities of change of the main dimensions of activity-travel patterns. Scheduling mechanisms will be used to simulate consistent schedules.

6.5 Project 5: Effects of ICT on dynamic repertoires of activity-travel behaviour and network learning

Problem definition
ICT can be used to reduce such uncertainty in activity-travel decisions by providing information. The next generations of information provision services will allow personalized guidance to trigger change in behaviour that would be beneficial to underlying control strategies (maximize capacity, reduce emissions, etc.). Policy makers have high expectations of such technology on network operations, sustained accessibility and reduction of environmental impact (e.g. Ministry of Transport, 2002; European Commission, 2007). Little is known however about individual responses to strategic guidance. Because such guidance is not necessarily in the interest of the individual, strategic behaviour may occur, implying that individuals will make decisions in light of their expectations about the (strategic) decisions of others, and the underlying objectives of the information/guidance provider. Proving credible information is critical in inducing particular behaviour and accepting such new technology. If the actual situation turns out to be different from expectations derived from guidance, individuals may ignore guidance completely in the future and not accept the technology. Key research questions thus are: What is the effect of personalised guidance on the dynamics of activity-travel patterns? What is the impact on route and network learning? Do such effects differ between segments of the population, and nature of the activity? Do individual behave strategically in this context?
Objectives
1. Increase our understanding of the impact of personalised guidance on the dynamics of activity-travel patterns
2. Develop and test a model of these dynamics
3. Embed this model in an integrative multi-agent representation and simulation of dynamic repertoires of activity-travel patterns

Research design and methodology
A representative (sub)sample will be identified to participate in an experiment. A (virtual reality) travel simulator will be designed, varying the credibility of the information and confirmation levels. Respondents will be asked to make repeated decisions in following the recommendation or not. The impact on route and network learning will be investigated. Qualitative data about reasons underlying response patterns will be used for triangulation.

6.6 Postdoc project: Integration in a multi-agent simulation

Problem definition
In order to assess the effectiveness of various policies, in isolation and combined, the direct and secondary effects of such policies on a series of indicators of urban sustainability need to be developed. A multi-agent representation seems to have most potential as (i) it allows a detailed analysis, (ii) can be based on theoretical concepts, and (ii) allows flexibility.

Objectives
1. Integrate the various submodels into a multi-agent simulation
2. Show case the system
3. Assess the value of such systems in terms of computational limitations and planning support

Software developed from scratch will be combined with open source multi-agent platforms to add further functionality (different scales of spatial resolution; links with geographic information systems; visualisation and animation of dynamics, different simulation principles, etc.).

7. CONCLUSIONS

This paper has briefly described the motivation, scope and project description of the U4IA research project. Although undoubtedly various operationalizations will require much further thought, it seems that most key
theoretical concepts, research methods, modeling principles and data challenges have been sufficiently explored to combine these into an integrated multi-agent model. We plan to report progress of individual projects and the integrated systems in future publications.

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