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RESEARCH ARTICLE

Changing the timing of activities in resolving Scheduling Conflicts

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Abstract Following the growing interest in the characterisation and modelling of activity scheduling and re-scheduling behaviour, this paper reports the results of a study on the resolution of activity scheduling conflicts. Using empirical data collected through an Internet survey, the modification of the timing of pre-planned activities to accommodate a new activity in the schedule was analysed. Schedule adjustment was studied using a parametric hazard model. The results indicate that the characteristics of the activities involved are the most important factors influencing the process of schedule change. Several correlations among schedule modifications were found.

Keywords Activity scheduling · Duration analysis · Travel behaviour

Introduction

The interest in developing computational process models of transport demand has encouraged transportation researchers to collect data about activity scheduling and rescheduling decisions and develop models to predict activity schedules. Inspired by SCHEDULER (Gärling et al 1998), which at the time was not supported by any data, Ettema et al (1993, 1994) develop interactive computer software, called MAGIC, and two models (SMASH and COMRADE) to simulate how individuals schedule and reschedule their activities. MAGIC, written under DOS, allowed respondents to enter a typical daily activity-travel pattern. Next, they were invited to adjust this pattern by adding or deleting activities or modifying one or more

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attributes of the activities in response to some policy scenario. SMASH (Ettema et al. 1995a, 2000) was developed to model this (re)scheduling process in terms of a nested logit structure. In addition, a competing risk hazard model (COMRADE) was developed to model activity duration and execution (Ettema et al. 1995b).

More recently, Doherty and Miller (2000) developed windows-based software called CHASE to collect data about activity scheduling processes. In addition to a change in software environment, MAGIC was meant as an interactive computer experiment, in which respondents (re)scheduled their activity-travel patterns in condensed time, whereas CHASE was primarily meant to collect data on the actual scheduling and rescheduling process. Although there was nothing fundamental in these tools to circumvent them being used for both these types of applications, their primary focus influenced the kind of research that was conducted with these instruments. Research on scheduling processes further developed along two mostly separate lines of research: (i) development of new software instruments for data collection, and (ii) analyses and modelling of the resulting data.

In an attempt to improve data collection in this area of research, several other similar instruments with added functionality were developed. For example, Kreitz added a geographical information module in a re-programmed version of CHASE (2002). Lee and McNally (2001) developed REACT with similar functionality but based on limited Internet technology. Ruiz (2005) also developed an Internet-based tool which traces how individuals reschedule their activity-travel patterns. In addition, we know of several other very similar, but more advanced instruments, including virtual reality, cellular phones and palm tops, sometimes combined with snuffers, GPS and tools for environment detection, developed by these and other research groups that have been used in data collections but are not reported in the literature.

Although the introduction of CHASE was accompanied by an interesting conceptual model (2001), to the best of our knowledge this model was never fully operationalized and put to an empirical test. Certain aspects however appear in the simulation model, suggested by Gärling and his co-workers (1989), who in particular simulated rescheduling behaviour under time pressure. A more comprehensive model of rescheduling behaviour called Aurora was suggested by Timmermans et al. (2000; see also Joh et al, 2002, 2003). It does not only consider duration of activities, but in principle all facets of activity-travel patterns can be modified. It was meant to complement the Albatross model, developed by the same group (2000, 2004), which includes an agent for activity rescheduling behaviour in response to transport policies. Important for positioning the present paper into this rapidly emerging field of interest is that Aurora has not (yet) been estimated using process data. After a decade of research, the development of an empirically estimated comprehensive behavioural model of multi-faceted rescheduling behaviour still constitutes a major challenge in activity-based analysis.

Most studies, except some reported above, have remained largely descriptive, and reported basically on the effectiveness of the survey method used. These descriptive studies have lately been followed by quantitative analysis of particular aspects of scheduling process data. For example, Mohammadian and Doherty (in press) studied factors influencing the length of time between planning and executing an activity using a hazard model. Roorda and Miller (2005) presented a descriptive analysis of the strategies that individuals use to resolve several types of activity scheduling conflicts. In a similar vein, Joh et al. (2005) found that activity location and co-scheduling with peers were much less frequently modified than activity timing and duration, while Joh et al. (2005), carrying out an empirical analysis of global schedule adjustment between the pre-planned and the actually executed activity schedules, found that the degree of schedule modification is largely determined by characteristics of the pre-planned schedule, rather than by background socio-economic and/or activity-related variables. Ruiz et al. (2005) confirmed this finding that the incidence of changes was mainly related to the characteristics of the existing schedule and that socioeconomic characteristics played a more important role in explaining the amount-of-change implemented in pre-planned activities. None of the observed schedule characteristics considered was statistically significant.

The present study was motivated by the idea that the further development of computational process models is in need of more detailed analyses of different types of scheduling conflicts and associated conflict resolution. This paper represents an attempt to contribute to this end. In particular, it focuses on the case in which a single new activity is inserted in-between two consecutive pre-planned activities. That is, it considers the case where the conflict is resolved by modifying the timing and/or duration of the previously planned activities without changing their sequence in the schedule. Evidently, this analysis only focuses on a specific type of conflict resolution and activity rescheduling behaviour. This type of analysis fits in-between the descriptive studies mentioned before that are still far away for any valuable model of activity rescheduling behaviour and the very few integral models of activity rescheduling behaviour that are typically based on theory and often still lack detailed empirical testing.

The paper is organized as follows. First, we will formulate the specific problem that is addressed in the current paper in more detail. This is followed by a brief summary of the Internet-based activity-travel survey that is used for the analysis. Then, the modelling methodology that is used in the analysis and its results are presented. The paper ends with some conclusions and a discussion of possible shortcomings and avenues of future research.

Problem formulation

Conflicts in activity scheduling arise whenever a new activity overlaps in time with one or more existing activities. Individuals may decide to shorten the duration of the activities involved, equally, proportionally or otherwise, may cancel or substitute activities, or may even change the schedule more dramatically on one or more dimensions. Thus, resolution of conflicts in activity scheduling is a complex matter, and different decision strategies may be adopted. Ruiz et al. (2005) classified conflicts according to the number of activities involved and the type of resolution adopted. In the present study, the focus is on the case in which a single new activity episode is inserted in between two existing consecutive pre-planned activities. Conflicts resolution then consists of modifying the timing and/or the duration of the existing activities in the schedule while maintaining the original sequence of activities. We admit that this restriction is quite artificial since in reality many scheduling conflicts are associated with more than one activity inserted as well as with re-sequencing/deletion of the previously scheduled activities. However, this limitation allows us to single out some important factors affecting the resolution of scheduling conflicts in a simple operational framework.

Our objective is to characterise the adjustment of a pre-planned activity schedule during the re-scheduling process up and including the point of execution. In particular, we seek to analyse to what extent people modify the timing of activities by comparing the pre-planned schedule with the schedule that was actually executed. The start time of the pre-planned activities was selected for measuring shifts in each of the activities. Therefore, the dependent variables of this study are the start time or timing modifications of the pre-planned activities. Travel episodes are always considered attached to the subsequent activity in the schedule (Figure 1) to make the interpretation of results straightforward.

Data

The data on schedule adjustment used in this study was collected through an Internet survey conducted in November and December 2003 with staff members and students of the Avenida de los Naranjos Campus of the Technical University of Valencia, Valencia, Spain (Ruiz 2005). A total of 4385 staff members and students visited the web site. Respondents were asked to provide information about their demographic characteristics and were then randomly given one to four non-consecutive dates on a calendar for which they needed to schedule their activities. This task led to pre-planned schedules (Figure 2).

The pre-planning scheduling process was conducted by adding activities and their specification to the concerned survey day (Figure 3). It should be noted that the survey did not force respondents to list the details for the activities when they thought this was not necessary, and therefore, pre-planned schedules were allowed to have open time slots. On the day after each of the concerned survey days, respondents were asked to report the schedule that was actually executed by adding, deleting and modifying activities in the pre-planned schedules.

Overall, respondents with an executed schedule different from the pre-planned schedule made a total of 2,666 add decisions to define their pre-planned activity schedules. These respondents only made 593 add decisions to describe their executed activity schedules. They also made 905 modify- and 109 delete-decisions to report their executed activity schedules, which in total involved 2,358 activities and 793 trips. On average, this represented 16.8 add, 4.6 modify and 0.6 delete decisions made to schedule 12.1 activities and 4.1 trips per respondent per day.

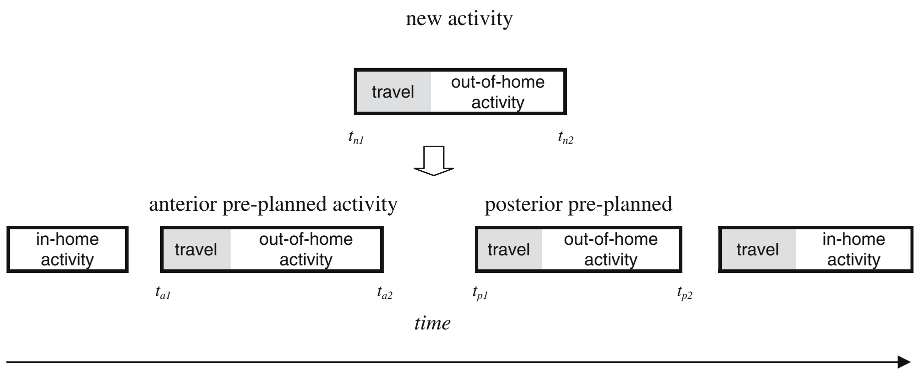

Fig. 1 Example of an activity scheduling conflict considered

Fig. 2 Activity Calendar in the Internet-based scheduling survey website Note: Text in the screen translated from the original Spanish version

After screening, it turned out that 125 cases involved the addition of a single new activity and hence were usable for our intended analysis. These cases included 33 added travel episodes linked to added out-of-home activities. The remaining add decisions were related to multiple insertions (436 add decisions), additions without modification of the pre-planned activities (25 add decisions) and only travel episodes insertions (7 add decisions), which were related to activities that only changed their location. Insertions causing no adjustments were not taken into account because they cannot be modeled using hazard models. Table 1 and Figure 4 show the selected variables that characterize the dataset.

As indicated, in principle respondents could change the timing of both the anterior and the posterior activity. The most frequent modification was shifting forward both the anterior and the posterior of these activities (56.6 percent) (Figure 4). This result likely reflects the situation that individuals modified the pre-planned schedule to allow for the insertion of the new activity and, at the same time, avoid empty time slots. The anterior pre-planned activity was shifted backward and the posterior pre-planned activity was shifted forward in 27.4 percent of the cases. The anterior pre-planned activity was shifted forward and the posterior pre-planned activity was shifted backward in the 11.3 percent of the cases. Finally, both the anterior and posterior pre-planned activities were moved backward in only 4.7 percent of the cases.

To investigate which factors influence this conflict resolution strategy, the explanatory variables were divided into three groups: characteristics of the respondents, characteristics of the executed schedule and characteristics of the pre-planned schedule. Basic statistics of these explanatory variables are presented in

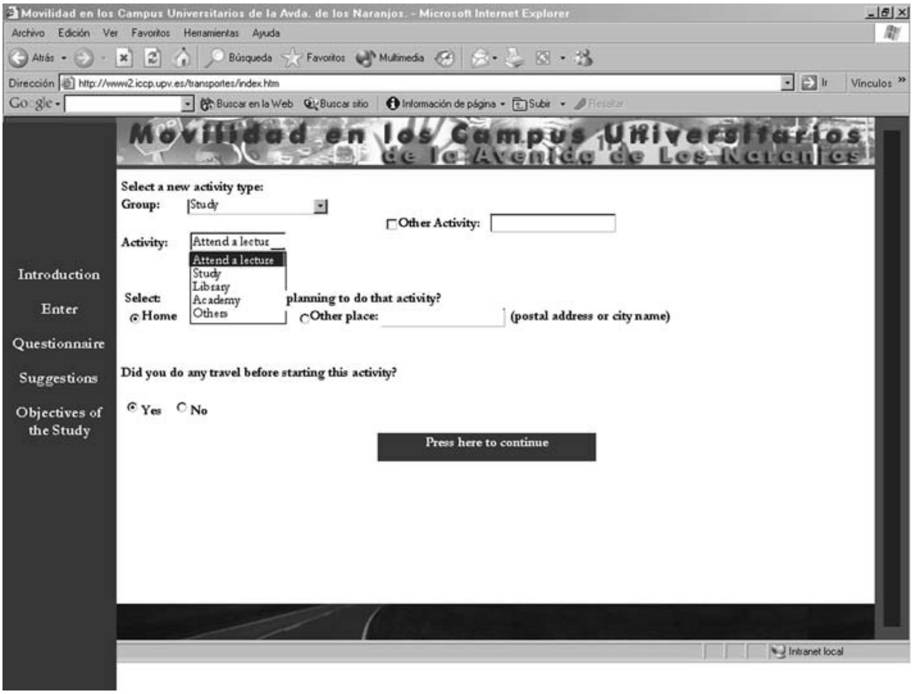

Fig. 3 Dialog screen for adding an activity. Note: Text in the screen translated from the original Spanish version

Table 1 and Figure 5. In Table 1, prefix N is assigned to variable names related to new activities inserted in the schedule, prefix A is assigned to variable names related to anterior pre-planned activities, and prefix P is assigned to variable names related to posterior pre-planned activities. Thus, the total duration (*total_duration*) of new activities is represented by N*total_duration*; and the total duration of anterior and posterior pre-planned activities is represented by A*total_duration* and P*total_duration*, respectively.

Figure 5 presents variable names and the number of cases related to the temporal position of the newly inserted activity versus the pre-planned activities. The most frequently observed (42 cases or 33.6 percent) situation in this regard is the one where the new activity partially overlaps both the anterior and posterior pre-planned activities (Figure 4). In 36 cases (28.8 percent), the new activity partially overlaps only with the posterior pre-planned activity which has an earlier start time. In 15 cases (12.0 percent), the new activity partially overlaps only with the anterior pre-planned which has a later start time. In six cases (4.8 percent), the new activity completely overlaps the anterior pre-planned activity and partially overlaps the posterior pre-planned activity. In five cases (4.0 percent), the new activity is in-between the anterior pre-planned activity or completely overlaps the posterior pre-planned activity and partially overlaps the anterior pre-planned activity. The remaining cases (16 cases, 12.8 percent) show less frequent temporal positions of the new activity in relation to the anterior and posterior pre-planned activities.

In addition to these temporal variables, variables related to schedule modification were included in the model (Table 2). These binary variables indicate whether or not

Table 1 Explanatory Variable Definition (I) and Sample Statistics (Number of cases = 125)

Variable	Definition	Mean	Std. Dev.
Individual characteristics			
GENDER	1 if individual is male, 0 otherwise	0.58	0.50
STATUS	1 if individual is student, 0 otherwise	0.76	0.43
CARAVAIL	1 if individual has car availability 3 or more days per week, 0 otherwise	0.39	0.49
TRANSIT	1 if individual has public transport pass, 0 otherwise	0.26	0.44
MEMBERS	Number of family members	3.58	1.25
BORNDATE	Date of birth	1976.66	6.57
Observed activity schedule characteristics			
TIMEHORI	Time gap (days) between the pre-planned and the observed schedules	4.27	4.57
NACTIV	Number of activities in the observed schedule	15.70	3.15
TRAVELTI	Total travel time (min) in the observed schedule	90.09	41.08
NOUTOFHO	Number of out-of-home activities in the observed schedule	3.67	1.76
TRIPS	Number of travels in the observed schedule	4.14	1.36

Table 1 continued

Variable	Definition	N[1]		A[1]		P[1]	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Characteristics of the activities[1]							
$*total_duration*	Total duration of the activity (min)	106.06	77.84	129.72	114.15	198.00	157.73
$*start_time*	Start time of the activity[2]	42.14	19.77	34.68	20.23	47.10	18.66
$*duration*	Duration of the activity episode (min)	99.08	82.20	121.06	113.86	179.46	163.89
$*travel_time*	Travel time linked to the activity(min)	5.91	15.30	14.74	24.85	8.66	17.05
$*location*	1 for out-of-home activities, 0 otherwise	0.38	0.49	0.41	0.49	0.37	0.48
$*basic*	1 for activities related to basic needs[3], 0 otherwise	0.08	0.27	0.48	0.50	0.54	0.50
$*housek*	1 for activities related to housekeeping, 0 otherwise	0.11	0.32	0.02	0.15	0.06	0.24
$*others*	1 for activities related to leisure/social relation/others, 0 otherwise	0.43	0.50	0.14	0.35	0.14	0.35
$*shopping*	1 for shop/service activities, 0 otherwise						
$*flexwork*	1 for activities related to flexible work/school, 0 otherwise	0.06	0.25	0.01	0.09	0.05	0.21
$*workschool*	Reference category: attending/giving a lecture at College	0.26	0.44	0.15	0.36	0.14	0.34

(1) Replace $ with N for New activities, with A for Anterior pre-planned activities and with P for Posterior pre-planned activities

(2) Start time is measured in 15 minutes periods since 6:30 am

(3) Basic needs include night sleep, wash/dress/pack and meals

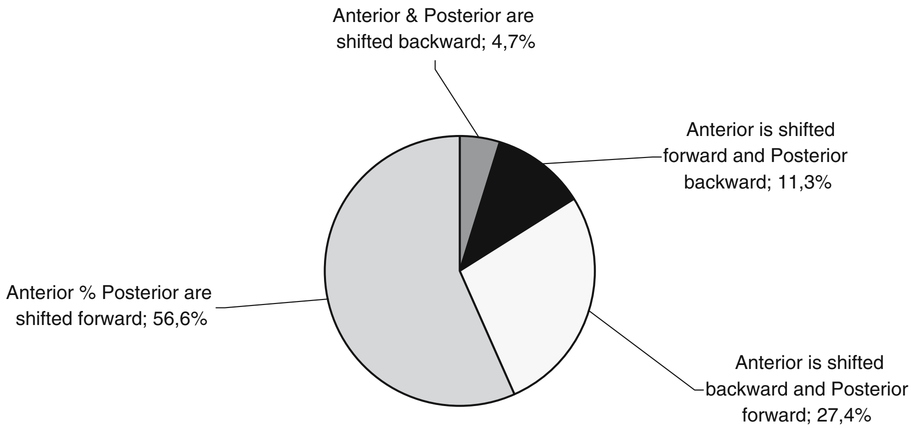

Fig. 4 Selected dataset characteristics: timing modifications in the anterior and posterior pre-planned activities

Table 2 Descriptive Variables of the Schedule Modification

	Variable	Definition	Mean	Std. Dev.
Anterior pre-planned activity	STa	1 if start time is changed, 0 otherwise	0.472	0.501
	Da	1 if duration is changed, 0 otherwise	0.640	0.482
	Ta	Start time change (in 15 min. periods)	0.672	5.984
	DDa	Amount of duration change (minutes)	−31.224	42.951
Posterior pre-planned activity	STp	1 if start time is changed, 0 otherwise	0.736	0.443
	Dp	1 if duration is changed, 0 otherwise	0.808	0.395
	Tp	Start time change (in 15 min. periods)	1.896	3.547
	DDp	Amount of duration change (minutes)	−30.232	27.402

the duration and the timing of the anterior or posterior pre-planned activities were changed. The amount of change in the duration of the pre-planned activities was incorporated as well. Finally, the amount of change in the timing or start time of the pre-planned activities was also included.

Analysis and results

The Methodology

Changes in the timing of a pre-planned activity were analyzed using a hazard model. Let T be a nonnegative random variable that represents the extent to what a pre-planned activity was shifted forward/backward to accommodate a new one in the schedule. The probability distribution of T can be represented in a number of ways, of which the survival and hazard functions are the most useful. The survival function is defined as the probability that T is shifted at least t time units is given by

$$F(t) = P(T \geq t), \quad 0 < t < \infty \tag{1}$$

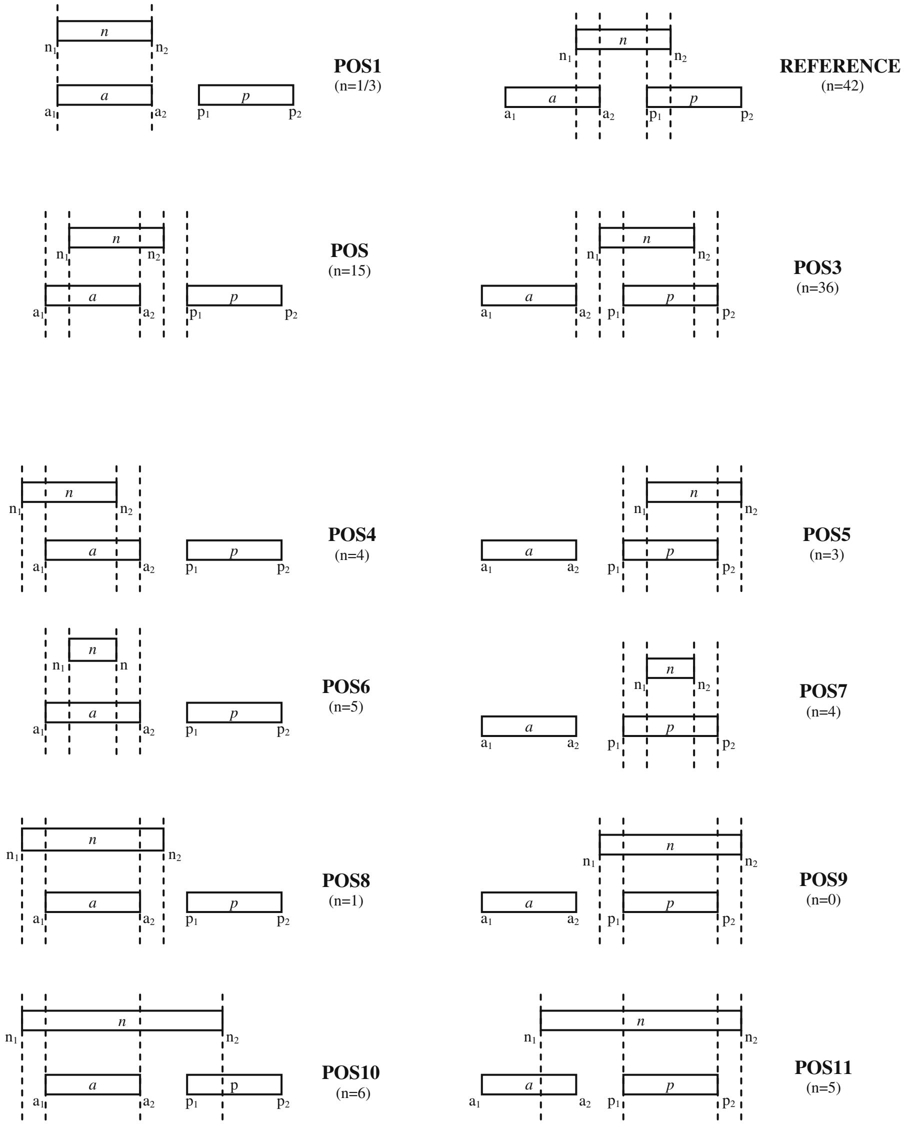

Fig. 5 Explanatory Variable Definition (I) (Number of cases = 125)

Because F frequently refers to the cumulative distribution function and therefore gives the probability of the left rather than the right tail, the notation used here suggests that $F(t)$ is a monotone left continuous function with $F(0)=1$ and $\lim_{t\to\infty} F(t) = 0$. Because the probability of shifting forward/backward a pre-planned activity less than t time units is $1 - F(t)$, the probability density function (p.d.f.) of T is

$$f(t) = \lim_{\Delta t \to 0^+} \frac{P(t \leqslant T < t + \Delta t)}{\Delta t} = \frac{-\mathrm{d}F(t)}{\mathrm{d}t} \qquad (2)$$

Also, $F(t)=\int_t^{\infty} f(s)ds$ and $f(t) \geq 0$ with $\int_0^{\infty} f(t)dt=1$. The hazard function specifies the instantaneous failure rate at $T=t$ conditional upon survival to time t and can be defined as follows

$$\lambda(t) = \lim_{\Delta t \to 0^+} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t} = \frac{f(t)}{F(t)} \tag{3}$$

It is important to note that hazard functions are extremely useful in this context. They indicate the probability that the start time of a pre-planned activity will not be changed any further, conditional on the fact that the timing has already been changed t time units. This facilitates the analysis of activity scheduling conflicts resolution by adjusting the timing of the existing activities in the schedule when inserting a new one. Also, from Eq. (3) it can be seen that λ (t) specifies the distribution of T since

$$\lambda(t) = \frac{-\mathrm{d} \log F(t)}{\mathrm{d}t} \tag{4}$$

by integrating and setting $F(0)=1$

$$F(t) = \exp\left(-\int_0^t \lambda(u)\mathrm{d}u\right) \tag{5}$$

and the p.d.f. of T becomes

$$f(t) = \lambda(t) \exp\left(-\int_0^t \lambda(u)\mathrm{d}u\right) \tag{6}$$

The literature suggests a wide variety of functional forms for the duration distributions (e.g., Kalbfleish et al. 1980, Lancaster 1994), including the exponential, the Weibull, the Lognormal, the inverse Normal, the Logistic, the Gamma, the generalized Gamma, the Generalized F, and the Gompertz distributions. The maximum likelihood method was used to estimate model's parameters.

Estimation Results

Using the activity scheduling conflicts data and the methodology described in the previous section, Tables 3 and 4 present the estimated parameters for five of the most widely used functional forms in hazard modeling. Dependents variables are the amount of change of the timing of the anterior (Ta) and posterior (Tp) pre-planned activities. Interestingly, different functional forms lead to very different qualitative conclusions. For example, the Weibull distribution is monotonically increasing indicating a continuously increasing hazard rate over time which suggests that the more a pre-planned activity is shifted forward/backward the more likely it is that the process of schedule modification stops. That is, shorter modifications are more frequent. The Exponential function suggests that shifting forward/backward pre-planned activities does not depend on the extent to which their timing was modified. The Logistic function suggests an initial increase and then a decrease in the probability of ending the shifting forward/backward process.

Table 3 Parametric hazard duration models. Dependent variable: *Ta*

Explanatory variable[1]	Weibull				exponential				Normal				logistic				gamma			
	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value
A*start_time*	0.0335	0.0077	4.3282	0.0000	0.0363	0.0092	3.9305	0.0143												
A*others*	0.4418	0.2044	2.1620	0.0306													0.7940	0.2037	3.8974	0.0001
Da																	−0.3496	0.1451	−2.4100	0.0160
P*duration*																	0.0015	0.0004	4.2614	0.0000
N*start_time*	0.0389	0.0074	5.2332	0.0000	0.0381	0.0106	3.5841	0.0024												
P*total_duration*	0.0027	0.0005	5.2337	0.0000	0.0024	0.0008	3.0411	0.0001	0.0013	0.0003	3.6618	0.0001								
POS3	0.4741	0.1575	3.0097	0.0026	0.4608	0.1881	2.4496	0.0003									0.3156	0.1340	2.3546	0.0185
POS4									1.4050	0.3648	3.8518	0.0003	1.4810	0.1948	7.6046	0.0000	0.7654	0.3985	1.9206	0.0548
POS7													0.7127	0.2301	3.0977	0.0020				
POS10													1.1855	0.2414	4.9110	0.0000				
Constant	0.5339	0.1771	3.0139	0.0026	0.4638	0.2312	2.0062	0.0448	0.1024	0.1260	0.8126	0.4165	0.1348	0.0878	1.5355	0.1247	0.1398	0.4123	0.3390	0.7346
Sigma	0.8296	0.0773	10.7281	0.0000	1.0000	0.0000	1.0000	0.0448	0.6583	0.0341	19.2873	0.0000	0.2694	0.0185	14.5635	0.0000	0.5146	0.2573	2.0000	0.0455
Theta																	0.7500	0.6251	1.1999	0.2302
Observations	125				125				125				125				125			
Log Fc	−183.7002				−186.7002				−133.4031				-124.8343				−190.968			
Log F	−160.9434				−165.8678				−125.1047				-98.3538				−160.2963			
McFadden's R^2	0.1239				0.1116				0.0622				0.2121				0.1606			

(1) A*start_time*: Start time of the anterior pre-planned activity (measured in 15 minutes periods since 6:30 am.)

A*others*: = 1 for anterior pre-planned activities related to leisure/social relation/others, 0 otherwise. Reference category: attending/giving a lecture

Da: = 1 if duration of anterior pre-planned activity is changed, 0 otherwise

P*duration*: Duration of the posterior pre-planned activity episode (minutes)

N*start_time*: Start time of the newly inserted activity (measured in 15 minutes periods since 6:30 am.)

P*total_duration*: Total duration of the posterior pre-planned activity (minutes)

POS3: The newly inserted activity partially overlaps the posterior pre-planned activity with an earlier start time

POS4: The newly inserted activity partially overlaps the anterior pre-planned activity with an earlier start time

POS7: The new activity is inserted in-between the posterior pre-planned activity

POS10: The newly inserted activity completely overlaps the anterior pre-planned activity and partially overlaps the posterior pre-planned activity

Note: the variables related to the temporal position of the pre-planned and new activities are referenced to the case in which the newly inserted activity partially overlaps both the anterior and posterior pre-planned activities

Table 4 Parametric hazard duration models. Dependent variable: *Tp*

Explanatory variable[1]	Weibull				exponential				Normal				logistic				gamma			
	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value	Coeff.	Std. Err.	t-ratio	*P*-value
DDp									−0.0052	0.0013	−4.1710	0.0000	−0.0037	0.0010	−3.5021	0.0005				
GENDER													0.2320	0.0914	2.5397	0.0111				
N*total_duration*	0.0041	0.0008	4.9733	0.0000	0.0033	0.0016	2.0155	0.0438									0.0046	0.0010	4.6287	0.0000
N*travel_time*									0.0132	0.0050	2.6472	0.0081	0.0064	0.0032	1.9812	0.0476				
P*location*	−0.2936	0.1158	−2.5342	0.0113													−0.2724	0.1161	−2.3473	0.0189
P*basic*									0.2840	0.1313	2.1628	0.0306								
P*flexwork*													−0.2488	0.1132	−2.1982	0.0279				
POS2	−0.8003	0.2069	−3.8680	0.0001	−0.8543	0.4375	−1.9527	0.0509									−0.7989	0.1893	−4.2207	0.0000
POS5									1.7222	0.4013	4.2921	0.0000	1.6300	0.2704	6.0283	0.0000				
POS7													0.6979	0.2833	2.4635	0.0138				
POS11													0.8252	0.2135	3.8650	0.0001				
Constant	0.8983	0.1387	6.4779	0.0000	0.7834	0.2691	2.9108	0.0036	0.3752	0.1224	3.0658	0.0022	-0.1419	0.1726	−0.8224	0.4108	1.0480	0.4415	2.3739	0.0176
Sigma	0.6631	0.0549	12.0785	0.0000	1.0000	0.0000			0.6526	0.0562	11.6228	0.0000	0.2791	0.0215	12.9744	0.0000	0.5564	0.2635	2.1115	0.0347
Theta																	0.7500	0.6179	1.2138	0.2248
Observations	125				125				125				125				125			
Log Fc	−159.8188				−165.0451				−144.7154				−149.3544				−162.8198			
Log F	−141.1837				−157.3756				−124.0219				−116.9498				−142.5814			
McFadden's R^2	0.1166				0.0465				0.1430				0.2170				0.1243			

(1) DDp: Amount of duration change of posterior pre-planned activity (minutes)

GENDER: = 1 if individual is male, 0 otherwise

N*total_duration*: Total duration of the newly inserted activity (minutes)

N*travel_time*: Travel time linked to the newly inserted activity (minutes)

P*location*: = 1 for out-of-home posterior pre-planned activities, 0 otherwise

P*basic*: = 1 for posterior pre-planned activities related to basic needs (night sleep, wash/dress/pack and meals), 0 otherwise. Reference category: attending/giving a lecture

P*flexwork*: = 1 for posterior pre-planned activities related to flexible work/school, 0 otherwise. Reference category: attending/giving a lecture

POS2: The newly inserted activity partially overlaps the anterior pre-planned activity with a later start time

POS5: The newly inserted activity partially overlaps the posterior pre-planned activity with a later start time

POS7: The new activity is inserted in-between the posterior pre-planned activity

POS11: The newly inserted activity completely overlaps the posterior pre-planned activity and partially overlaps the anterior pre-planned activity with a later start time

Note: the variables related to the temporal position of the pre-planned and new activities are referenced to the case in which the newly inserted activity partially overlaps both the anterior and posterior pre-planned activities

We used McFadden's R^2 ratio test to compare functional forms and to select the best fitting distribution. The test is necessary since graphical approaches to evaluating model fit may be severely biased. McFadden's R^2 ratio indicated that the Logistic form is most appropriate for the data that were used. Therefore, the extent of shifting forward/backward the start time of pre-planned activities to resolve the activity scheduling conflict under investigation seems to have some optimum value. The hazard function in this case is given by

$$\lambda(t) = \alpha \quad (7)$$

where a is a constant hazard rate and the parameter p=1/s specifies the form of the duration dependence. If $p < 1$, the hazard is monotonically decreasing from infinity; if p=1, the hazard is monotonically decreasing from a; in this case $p > 1$, which means that the hazard takes on a non-monotonic shape increasing from zero to a maximum of t=$[(p-1)^{1/p}]$/a, and is decreasing thereafter. Consequently, the probability of ending the timing modification is high when it has not done so up to t and then becomes low.

We concentrate now on the results to investigate the influence of the independent variables on the amount of change of the start time of the pre-planned activities involved in the schedule conflict. Positive coefficients indicate that the hazard is higher. Therefore, variables with positive coefficients lead to less modification of the start time of the activities, whereas variables with negative coefficients are indicative of larger modifications. The results of the analysis show that most significant independent variables concern characteristics of both activities involved in the schedule conflict. As for socio-demographics, only the gender of the respondent is significant in explaining how much the timing of the posterior pre-planned activity is modified: males change the timing of the posterior pre-planned activity more than women do.

The incidence of changing the duration to resolve the conflict is also significant. If the duration of the anterior pre-planned activity is changed, there is a tendency towards a large change of its timing (Ta). The same relationship is found in the models that explain change in the timing of the posterior pre-planned activity (Tp). This suggests that people simultaneously decide whether or not to change the duration of the pre-planned activities and the timing of these activities.

As noted before, the majority of the significant variables in the models are related to the duration, nature, location, timing and relative temporal position of the activities involved in the scheduling conflict. Anterior activities pre-planned later in the daily schedule are related to smaller timing modifications. New activities planned later in the schedule are also related to smaller modifications of the timing of the anterior pre-planned activities. Therefore, as activities are planned later during the day, they are less modified to resolve the scheduling conflict. The type of activity is also of interest. If the anterior pre-planned activity belong to the category "others" (leisure, social relation, etc.), its timing is modified less than attending/giving a lecture. This counter-intuitive finding was also found in other studies (Doherty, forthcoming, Ruiz et al, 2005), perhaps suggesting the need of considering other descriptions of activities. Large total or episode durations of the posterior pre-planned activity are related to small changes in the timing of the anterior pre-planned activity. This suggests that an activity is changed to a lesser extent to resolve the scheduling conflict when it is followed by a large activity in the schedule. Several relative temporal positions of the activities involved in the scheduling conflict explain the timing modification of the anterior pre-planned activity to resolve the scheduling conflict.

In terms of the timing modification of the posterior pre-planned activity, if the new activity has a large total duration or large associated travel, it is more likely to result in small changes in the timing of the posterior pre-planned activity. Therefore, if respondents are going to insert new activities that involve a substantial amount of (travel) time in an existing schedule, they tend to pre-plan activities more accurately. Posterior pre-planned out-of-home activities are more likely to undergo small changes in timing than in-home activities. Posterior pre-planned activities related to flexible work/study have their timing changed more than attending/giving a lecture, which is logical because the latter types of activities are less flexible. But posterior pre-planned activities related to housekeeping have their timing changed less than attending/giving a lecture, which is inconsistent with the classification of activity types. Finally, several relative temporal positions of the activities involved in the scheduling conflict are also significant in explaining the amount of shifting forward/backward the posterior pre-planned activity.

Conclusions and discussion

This study focused on analyzing shifting forward/backward two consecutive pre-planned activities to accommodate a single new activity in-between them. Only cases in which the sequence of activities was maintained in the final schedule were considered. Parametric hazard models with several distributional forms were used.

The analysis suggests that shifting forward/backward the pre-planned activities to resolve the activity scheduling conflict primarily depends on the characteristics of the activities involved in the conflict, and to a lesser extent, several characteristics of the schedule modification. The characteristics of the final schedule are not significant in explaining the modification. As for socio-demographics, only gender is significant. Activities scheduled later during the day are modified less. The type of activity is not necessarily a good indicator of the relative fixity of that activity.

The results of this study suggest that changing the duration of pre-planned activities is more likely to result in a change of start time. Therefore, there is a need of modelling a simultaneous process that includes both types of modifications to confirm such endogeneity. Also, in this paper, we only studied the amount of change, not the direction of change. Thus, for future research we propose including whether the pre-planned activities are moved forward or backward to accommodate a new activity in the schedule.

Finally, we wish to discuss some limitations of this study and reflect on their implications. First, the sample size was rather small. There is a need to repeat this type of research for larger samples. Second, the sample was very specific in terms of its composition (students and staff) and consequently perhaps in terms of the kind of activities that are scheduled and underlying constraints. This implies a need to repeat this study for more representative samples, involving more variability in socio-demographics, types of constraints and activity-travel patterns. Third, the kind of schedule conflict analyzed in this study is just one type of conflict. Therefore, there is a need to conduct similar analyses for other types of scheduling conflicts. The results of such studies together may help in improving computational process models of activity-travel demand. Alternatively, they may be the stepping stones to building computational process models that simulate more complex, co-evolutionary multi-faceted activity-travel rescheduling processes.

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