Within-Day Schedule Adjustment Decision Process in a Dynamic Traffic simulation and Assignment Framework

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1 INTRODUCTION

It is well understood that travel itself is derived by fulfilling activities, and there is inter-relationship between the sequence and characteristics of the engaged activities and the travel time from one activity to the next. The traditional trip-based travel demand modeling approach addresses such an issue from a sequential iterative procedure whereas the activity-based modeling approach uses activity chains or tours as modeling entity.

The advancement of supply-side innovation has been realized throught the development of microscopic traffic simulation model as well as the mesoscopic simulation-based dynamic traffic assignment models. These models represent individual travelers (vehicles) and their various choice decisions along a given trip. Some recent studies attempted to perform dynamic traffic assignment in the context of activity chains or tours. (Abdelghany, Mahmassani et al. 2001; Lam and Yin 2001; Abdelghany and Mahmassani 2003; Maruyama and Harata 2005; Kim, Oh et al. 2006; Maruyama and Harata 2006; Rieser, Nagel et al. 2007; Lin, Eluru et al. 2008). Although the modeling framework in this area is still evolving, these studies provide rich insights for further investigations. However, relatively less attention has been given to the decision process in modifying the remaining activity schedule due to time pressure caused by the unexpected changes in network performance or changes in activity attributes.

In this talk, we present a within-day activity rescheduling model which captures the decision process in which once a factor triggers the time pressure or time surplus, the decision process is activated with the objective to maximize the utility. The suggested utility maximization formulation determines not only the rescheduling decision involving changing

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the activity start time, duration, but also the sequences. The novelty of this approach is to place this decision process within the dynamic network simulation framework in which the rescheduling decision process is based on either anticipated travel time or actual travel time depending on the information provision conditions.

2 RESCHEDULING DECISION MODELING FRAMEWORK

2.1 Model Elements

When considering rescheduling the remaining activities, the possible decisions may arise in terms of start time, duration, and location, etc. Recent relevant modeling works in this area provided comprehensive discussions in this regard (Joh, et al. 2002; Joh, et al. 2004; Joh, et al. 2005; Ruiz and Timmermans, 2006; Roorda and Andre, 2007; Clark and Doherty, 2008; Gan and Recker, 2008)

Three elements were considered in the development of our rescheduling decision model. The first element is the definition of activity schedule. Three activity schedules such as executed schedule, preplanned schedule, and updated schedules are defined. The main interest of this research is on the with-day temporal evolution of a pre-planned resulted from exogenously introduced events.

The second element is how to incorporate the notion of time budget constraint in the rescheduling problem. The time budget constraint works as a motive to modify the pre-planned schedule. An individual may be forced to change his/her preplanned schedule due to unanticipated events. The time budget constraint is embodied as a principal constraint. Also, factors relating to the time management of each activity are represented as earliest/latest start time, earliest/latest end time, and required duration length constraints for the modeling purpose. .

The third element is to depict the decision process of rescheduling. With the time pressure occurs, a traveler may need to cancel other pre-planned activities or to rearrange the activity duration length. On the other hand, time surplus becomes available when the exogenous event calls for the cancelation of one or several activities or shortening the duration of remaining activities in the pre-planned schedule. In other words, the rescheduling decision process differs depending on the nature of the exogenous event.

Lastly, it is assumed that the rescheduling is not a random process, but the search of a decision that optimizes the total utility by adjusting the start time, end time and sequence of the remaining activities subject to several constraints such as time budget.

The proposed decision model is realized through the integration with the dynamic traffic simulation and assignment model DynusT (Chiu, Nava et al. 2009) in such a way that

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the network condition and decision models are constantly inter-informing respective counterpart models. The network model provides information regarding network conditions (travel time) for the rescheduling decision process, whereas the rescheduling model results in the changes of an individual's remaining activities (schedule and activity information) and through network loading and simulation in DynusT, resulting in different network traffic conditions (Figure 1).

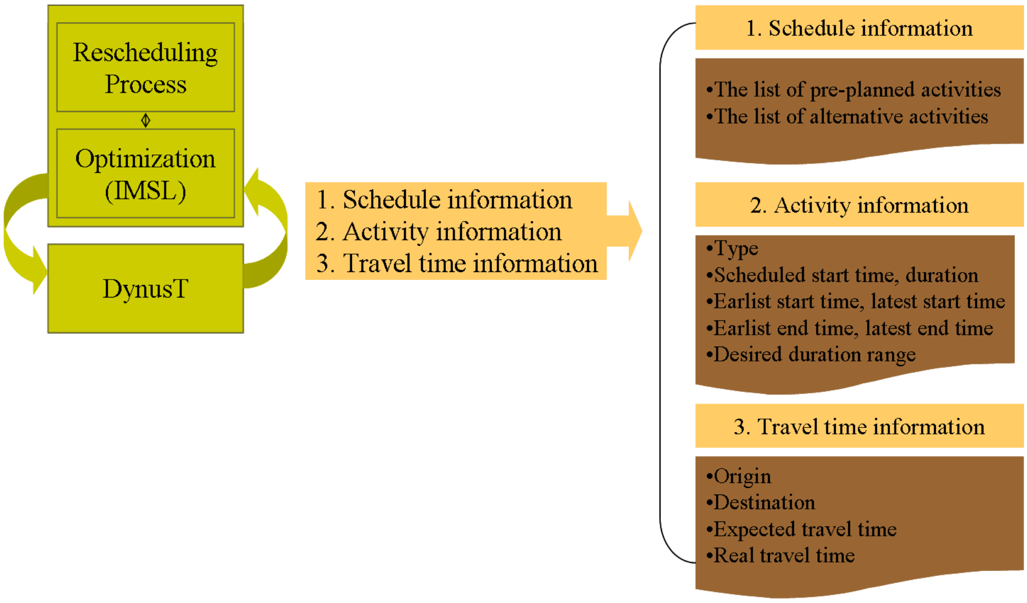

Figure 1: Data Interface between DynusT and Rescheduling Model

2.2 Decision Context

The proposed rescheduling model for an individual traveler is described as follows. It is driven by a random incident that is either due to the change of existing schedule (e.g. last-min canceling of a pre-planned meeting) or network condition (e.g. accident or work zone).

As depicted in Figure 2, at a given decision time instance t during simulation, each traveler would check whether the rescheduling decision process is required or not. If the rescheduling process is not necessary, the pre-planned schedule will continue to be executed without adjustment; otherwise, the rescheduling model will trigger different decision process according to different decision contexts such as network condition change or activity attribute change. The process is repeated when the decision time instance is advanced from t to t+1.

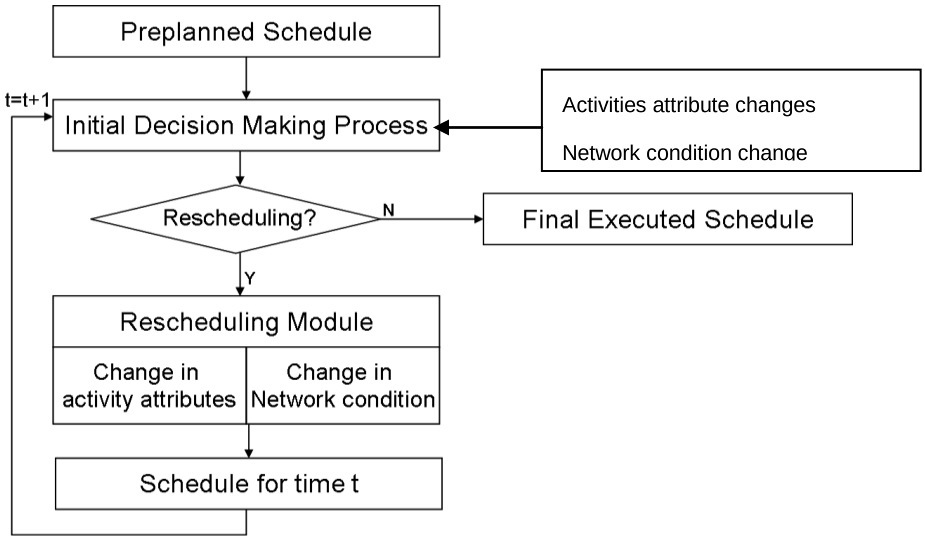

Figure 2 : Framework of Within-Day Schedule Modification

3 MODEL DETAILS AND SOLUTION METHODOLOGY

3.1 Rescheduling Decision Process

As previously discussed, two decision contexts are incorporated in the proposed rescheduling framework, including *network condition change* and *activity attribute change*. As shown in Figure 3, a traveler may or may not be aware of the incident per se, but may just be experiencing excessive congestion enroute to the next activity, or be informed by information dissemination channels. Upon receiving the network condition change information, the traveler first tries to re-optimize the existing remaining activities to obtain the new optimal schedule (start time, duration and sequence for all activities) with the updated (could be informed by information or by anticipation) travel time information between locations of these activities. If no feasible solution can be found, then one discretionary activity is removed from the pre-planned activity schedule. Only discretionary activities will be subject to removal but not anchor activities. The remaining activity in a schedule is then re-searched for the optimal schedule. This process is repeated until a feasible and optimal solution is found.

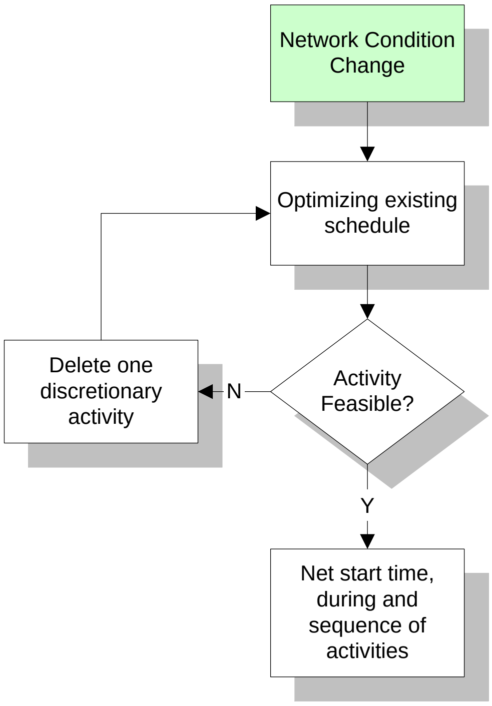

Figure 3 : Rescheduling Decision Process due to Network Condition Change

In the event in which the insertion of new activity/extension of duration or deletion of preplanned activity/shortening duration length is to take place, the former case creates time surplus in which more time may be permitted between existing activities. In this case, if one desired discretionary activity is to be added (this decision is a random process), the expanded activity set is then re-optimized to see if the feasible schedule can be obtained. If so, the new revised schedule is obtained; otherwise, the contemplated activity is removed and the original activities with time surplus are re-optimized according to the new activity attributes. Another discretionary activity may be considered until the traveler is fatigue in decision making.

When time pressure is created either by inserting a new activity or extending the duration of existing activities, the current schedule is re-optimized according to the new requirements. If keeping the newly updated schedule becomes impossible, one discretionary activity is removed. The re-updated schedule is re-optimized to check for feasibility and optimality. The entire process is repeated until an optimal schedule is obtained.

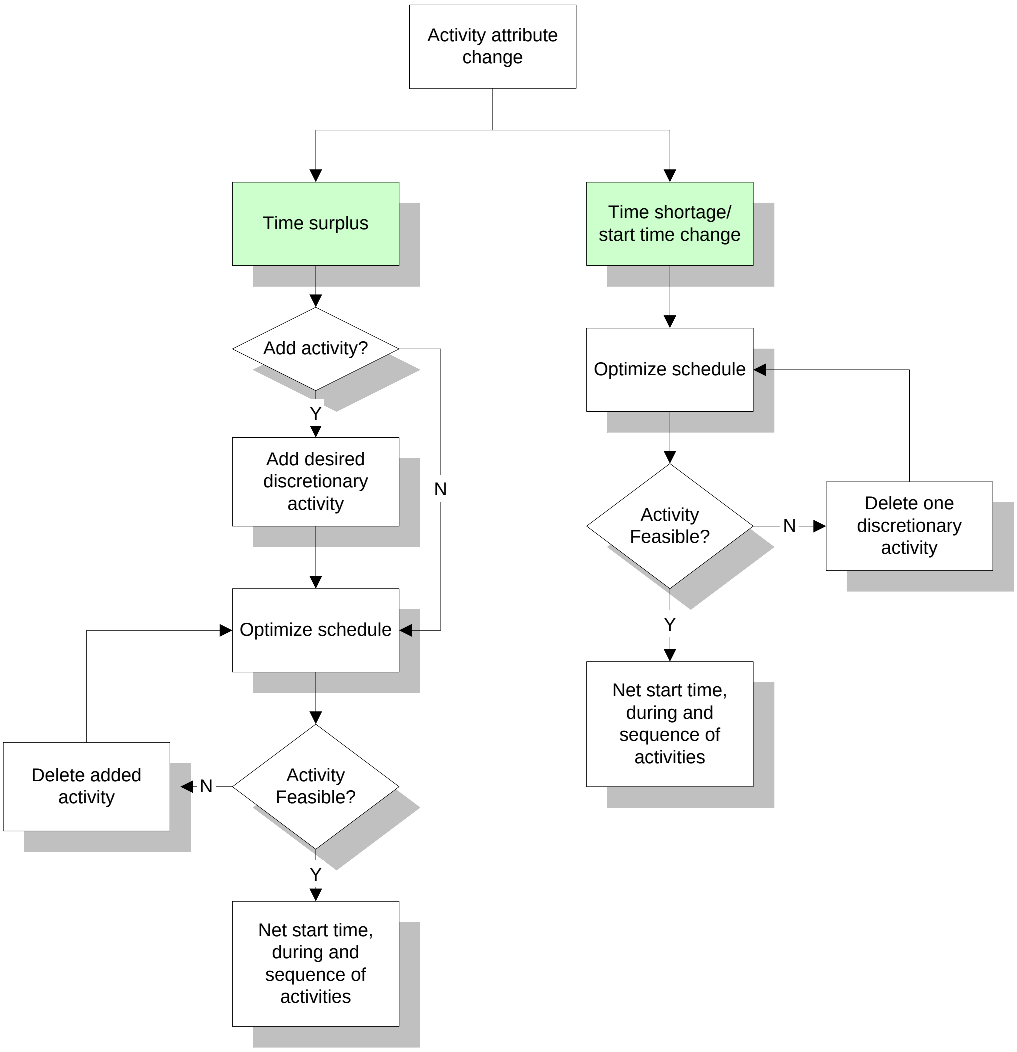

Figure 4 : Rescheduling Decision Process due to Activity Attribute Change

3.2 Mathematical Model for Rescheduling Decision

One can see that the utility maximizing decision plays a critical role in the above decision process. This decision action is characterized by the objective to maximize the total utility. The objective function includes (1) total utility by commencing each activity and disutility incurred by total travel time. The disutility term in the objective function represents the characteristics in which a discretionary activity's start time is likely to be elastic so that higher utility may be obtained by reducing travel time. For example, the sequence of personal errands is likely to be affected by selection of the shortest route with considering the sequence among other activities.

It is assumed that the marginal utility function in an objective function follows a quadratic form, and the magnitude of utility depends on duration of the activity. The values of the coefficients of the marginal utility equation should be estimated by the calibration process with real data. In the present research, the calibration with real data is beyond the scope of this research and is not discussed in detail herein. The followings briefly describe the rescheduling model:

<u>Decision variables:</u>

t_b^s	start of activity $b, \forall b \in A'(i)$
d_b	duration of activity $b, \forall b \in A'(i)$
$y_{b,h}$	sequence variable, binary, $\forall b \in A^{'(i)}, \forall h \in A'(i)$. $y_{b,h} = 1$ if activity b precedes activity h

<u>Data</u>

$A'(i)$	set of remaining activities for traveler i
$t_b^{s\_min}$	minimal start time for activity b
$t_b^{e\_max}$	maximum end time for activity b
$w_{g,b}$	travel time from activity g to activity b
$\theta_{g,b}$	weight of journey from activity g to b
U_b^{max}	maximum marginal utility value for activity b
M	penalty value

<u>Objective function:</u>

$$MAX\ Z = \sum_{b \in A'(i)} \int_{t_b^s}^{t_b^s + d_b} MU_b(t)dt + \sum_{g \in A'(i)} \sum_{b \in A'(i)} \theta_{g,b} \cdot w_{g,b} \cdot y_{g,b}$$

Where $MU_b = at^2 + bt + c$ and $\int_{t_b^s}^{t_b^s + d_b} MU_b(t)dt$ can be expressed as:

$$F_b(t) = 1/3 \left\{ \frac{-U_b^{max}}{\left(\frac{t_b^{e\_max} - t_b^{e\_max}}{2} \right)^2} \right\} \left(t - \frac{t_b^{e\_max} + t_b^{s\_min}}{2} \right)^3 + U_b^{max} \left(t - \frac{t_b^{e\_max} + t_b^{s\_min}}{2} \right)$$

The objective function can therefore be rewritten as:

$$MAX\ Z = \sum_{b \in A'(i)} F_b(t) + \sum_{g \in A'(i)} \sum_{b \in A'(i)} \theta_{g,b} \cdot w_{g,b} \cdot y_{g,b}$$

Subject to:

Activity sequence decision constraints:

$$t_b^s - t_h^s + My_{b,h} + d_b \leq M - w_{b,h}, \quad \forall b \in A'(i), h \in A'(i), b \neq h$$

$$y_{b,h} + y_{h,b} = 1, \quad \forall b \in A'(i), h \in A'(i), b \neq h$$

Start time/end time/ duration flexibility constraints:

$$t_b^{s\_min} \leq t_b^s \leq t_b^{s\_max}, \quad \forall b \in A^{'}(i)$$

$$t_b^{e\_min} \leq t_b^s + d_b \leq t_b^{e\_max}, \quad \forall b \in A^{'}(i)$$

Effectively, the proposed model is a mixed integer programming problem. The general solution approach is to solve for the relaxed nonlinear program in which $y_{b,h}$ is a real-value variable instead of a binary variable. It is also noted that while the model does not provide separate treatment for anchor and discretionary activities in $A^{'}(i)$, the anchor activities can be enforced by imposing a tight upper and lower bounds for the start and end time.

Detailed numerical analysis results and insights on a real-life data set will be presented at this talk.

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