COMMUTER DEPARTURE TIME CHOICE: A REFERENCE-POINT APPROACH

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1 INTRODUCTION

The departure time decisions of commuters are of fundamental importance to the study of peak-period traffic congestion and to the analysis of traffic control as well as broader demand-side congestion relief measures, such as pricing and ride sharing incentives [1]. Over the past decades, there have been very active research efforts in the departure time problem, both in econometric modeling and dynamic user equilibrium (DUE) fields [2-9]. Although these works provide valuable insights into dynamic commuter decision making, they do not identify the commuter’s asymmetric response to gains and losses related to his/her actual arrival time relative to reference points they may have.

The objectives of the present study are to examine the applicability of the reference point hypothesis of prospect theory to the commuter’s departure time decision-making and to obtain a better understanding of how commuters use arrival time information in daily departure time choice. The actual arrival time and deviation variables related to reference points (gains and losses) are the key factors in the departure time choice model.

The next section highlights the conceptual background and the proposed approach of this study. Conclusions are summarized in the last section.

2 METHODOLOGY

2.1 Conceptual Background

This section describes how the commuter’s daily departure time decision can be modelled while incorporating the reference point hypothesis of prospect theory. In previous studies, an individual commuter behavior is viewed as a boundedly-rational search for an acceptable
outcome [10]. The study by Chang and Mahmassani [11] has confirmed that the indifference band of tolerable schedule delay is the most important criterion governing the day-to-day responses of commuters to congestion. Schedule delay is defined as the difference between the preferred arrival time (PAT) and the actual arrival time (AT) for a given commuter. In a daily commute, a commuter is assumed to maintain the same choice as long as his/her actual schedule delay is contained in the indifference band. Otherwise, if the previous outcome is considered unacceptable, the commuter will adjust the previous decision through some mechanism. A more detailed discussion can be found elsewhere [10, 11].

In this study, pertinent descriptive features of prospect theory, such as framing effects (relative to reference points), differentiation between gain and loss, are applied to more appropriately capture the commuter’s decision behavior. Actual arrival time is an essential feature of our conceptualization in this study. Two reference points are the earliest acceptable arrival time and the work starting time for a given commuter. Prospect theory, unlike expected utility, treats value as a function in two arguments: the asset position that serves as the reference point, and the magnitude of the change (positive or negative) from the reference point [12]. The psycho physics of the value function lead to risk aversion when the decision is framed as a gain, and to risk seeking when it is framed as a loss. In addition, prospect theory proposes that the displeasure of a loss is perceived as greater than the pleasure of a gain of the same magnitude and, therefore, the value function is steeper for losses than gains [12].

Based on prospect theory, the segmented value function of a given departure time choice for a commuter can be assumed to be a function of the actual arrival time (asset position) and the gain or loss of that choice with respect to these two reference points as shown in Figures 1 and 2 (the notations of variables please refer to Section 2.2). A gain occurs when a commuter experiences an actual arrival time that is within the range of his/her earliest acceptable arrival time and work starting time (segments II and III); this is assumed to enhance the prospect of choosing a given departure time. Similarly, a loss is observed when the commuter experiences an actual arrival time which is beyond that range (segments I and IV); this is assumed to reduce the likelihood of choosing that departure time.

Note that a commuter is defined as an early-side arrival if his/her actual arrival time is earlier than his/her preferred arrival time; and is defined as a late-side arrival if his/her actual arrival time is later than his/her preferred arrival time. It is also noted that the shapes of segments II and III could be symmetric or asymmetric depending on the location of preferred arrival time. Figure 2 shows the other property of prospect theory that the difference in subjective value between gains of zero and five minutes is greater than the
subjective difference between gains of twenty minutes and twenty-five minutes. The same relation between value differences holds for the corresponding losses.

![Diagram](image_url)

Figure 1. A segmented value function defined on the arrival time evolution
From the two figures, we can identify the commuter’s response to gains and losses. This approach enables us to perform a hypothesis test of the symmetry in commuter response to gains and losses in the commuter’s departure time decision-making process and to obtain a better understanding of commuter behavior.

2.2 The proposed approach

Statistical models of route and/or departure time switching by auto commuters are developed in this study and the hypotheses regarding prospect theory as applied to commuting decision are examined using empirical data. The variables used in this study are summarized as follows for reference.

$t_d$ = departure time;
$t_e$ = expected arrival time;
$t_E$ = acceptable earliest arrival time;
$t_p$ = preferred arrival time;
$t_a$ = actual arrival time;
$t_w$ = work starting time;
$t_o =$ observed departure time;
$\mu =$ expected travel time;
$u_e^G(t_o) =$ GAIN utility of actual arrival time for commuter $i$ (early-side);
$u_e^L(t_o) =$ LOSS utility of actual arrival time for commuter $i$ (early-side);
$u_l^G(t_o) =$ GAIN utility of actual arrival time for commuter $i$ (late-side);
$u_l^L(t_o) =$ LOSS utility of actual arrival time for commuter $i$ (late-side).

From Figures 1 and 2, we can define the utilities accordingly (Equations (1)-(4)). Note that commuters are defined as early arrival, if their actual arrival times are earlier than their preferred arrival times; on the other hand, the commuters are defined as late arrival, if their actual arrival times are later than their preferred arrival times.

\[
u_e^G(t_o) = \beta_2(t_o - t_E)^{\alpha_2} + \epsilon_e^G
\]
\[
u_e^L(t_o) = \beta_1(t_o - t_E)^{\alpha_1} + \eta_e^L
\]
\[
u_l^G(t_o) = \beta_3(t_w - t_o)^{\alpha_3} + \epsilon_l^G
\]
\[
u_l^L(t_o) = \beta_4(t_w - t_o)^{\alpha_4} + \eta_l^L
\]

Let
\[p(S) = \text{probability of switching departure time},\]
\[p(NS) = \text{probability of not switching departure time}.\]

Also, let
\[d = 1, \text{ if commuter } i \text{ switch his/her departure time,}\]
\[d = 0, \text{ otherwise.}\]

\[i_I = 1, \text{ if commuter } i \text{ has an early arrival,}\]
\[i_I = 0, \text{ otherwise.}\]

Commuters will switching departure times as long as their utilities is greater than zero, i.e., their utilities are gains (Equations (6) and (8)); otherwise, commuters will not switching their departure times (Equations (5) and (7)).

\[p(NS_e) = p(d_e = 0) = p(u_e^G(t_o) > 0) = \Phi(\frac{\beta_2(t_o - t_E)^{\alpha_2}}{\sigma_e^G})\ug 5}
\[ p(S_r) = p(d_r = 1) = p(u_r^i (t_a) < 0) = \Phi(\frac{\beta_1(t_E - t_a)\alpha_1}{\sigma_\eta}) \]  \hspace{1cm} (6)

\[ p(NS_r) = p(d_r = 0) = p(u_r^i (t_a) > 0) = \Phi(\frac{\beta_2(t_a - t_e)\alpha_2}{\sigma_\epsilon}) \]  \hspace{1cm} (7)

\[ p(S_l) = p(d_l = 1) = p(u_l^i (t_a) < 0) = \Phi(\frac{\beta_4(t_a - t_w)\alpha_4}{\sigma_\eta}) \]  \hspace{1cm} (8)

The likelihood of total samples is defined as Equation (9).

\[
p(d(i), i = 1,...,n/ \beta, t_a, t_E, t_w) = \prod_{i=1}^{n} [\Phi(\frac{\beta_2(t_a - t_E)\alpha_2}{\sigma_\epsilon})]^{1-d_i} \cdot [\Phi(\frac{\beta_1(t_E - t_a)\alpha_1}{\sigma_\eta})]^{d_i} \cdot [\Phi(\frac{\beta_4(t_a - t_w)\alpha_4}{\sigma_\eta})]^{d_i} \]  \hspace{1cm} (9)

3 SUMMARY

This study has conceptually modelled dynamic commuter departure time choice in the morning commute by incorporating the risk attitude mechanisms of commuters. A descriptive model of decision making under risk, prospect theory, was applied to meet this purpose. The input data was one-week (five working day) commuting trip diaries from samples of auto commuters from Japan and Taiwan, taken in 2002.

There are several unique features included in this work, and which define its contributions, including:

1. the development of four-segmented value functions based on the earliest arrival time, the preferred arrival time, and the work starting time for a given commuter;
2. the application of features of prospect theory to capture more appropriately commuter decision behavior;
3. the empirical examination of the hypothesis of asymmetry in commuter response to gains and losses defined by the difference between the actual arrival time and the reference points.

REFERENCES