International Journal of Transportation
Vol.4, No.3 (2016), pp.63-72
http://dx.doi.org/10.14257/ijt.2016.4.3.05

Car Users' Willingness to Use Public Transport Routes Involving Transfers

Subeh Chowdhury[1*], Damien Rajaobelison[2] and Avishai (Avi) Ceder[3]

[1,3]Transportation Research Centre, Department of Civil and Environmental Engineering, 20 Symonds Street, University of Auckland, New Zealand
[2]Etudiant à l'ENTPE, specialisation Transport, 3 Rue Maurice Audain 69120 Vaulx-en-Velin, France
[3]Faculty of Civil and Environmental Engineering, Technion-Israel Institute of Technology, Haifa, 32000, Israel
[1]s.chowdhury@auckland.ac.nz, [2]damien.rajaobelison@entpe.fr, [3]a.ceder@auckland.ac.nz

Abstract

Globally, public transport agencies are implementing integrated systems to increase ridership through modal shift from private cars. The objective of this paper is to establish the minimum travel time and cost savings which would invoke commuters' willingness to switch from their private cars to a well-integrated public transport route. The psychological model, Weber's Law Just Noticeable Difference, was applied to determine the different thresholds from a user's perspective. A user preference survey was conducted. Findings revealed that, on average, car users desire at least a 29% reduction in their current travel time and at least a 45% reduction in their current travel cost savings, given only one savings is provided. When both are provided, car users desire at least an 18% reduction in their current time with at least a 28% reduction in their current travel cost. This study contributes to existing literature by providing a methodology on how to attain indicative threshold values of the two attributes impacting commuters' decision. It also contributes by providing indicative threshold values which will promote mode shift from car to public transport.

Keywords: *Public transport, transfers, just noticeable difference, route choice, service quality*

1. Introduction

The choice of mode between private cars and public transport (PT) is a complex decision process that is influenced by various factors. Car use has been preferred to PT not only for its instrumental functions (freedom, comfort and convenience) but also for its symbolic (status in society) and affective (driving is perceived as being pleasurable) functions (Hiscock *et al.*, 2002, Beirao and Sarsfield-Cabral 2007). Other literature has shown that once cars are acquired, the use becomes more of a necessity than a luxury to the owner. Private car use can become a habit for a large group of travelers after acquisition (Anable 2005). Increased complexity of trip chains, due to changes in traditional household travel patterns with more women entering the work-force, has also been identified as a barrier to PT use (Hensher and Reyes 2000, Nobis and Lenz 2005). Therefore, methods to instigate mode switch from cars to PT, particularly for commuters, remain a topic of interest for many transportation specialists. There is a global trend to improve service quality through the development of integrated transport systems

[*] Corresponding Author

ISSN: 2287-7940 IJT

(Ibrahim 2003, Matas 2004, Ulengin *et al.*, 2007). Transfers play a key role in an integrated PT system. Creation of transfer routes in an integrated PT network has also been seen to make the service more efficient and reliable (Chowdhury and Ceder 2013). However, prior studies have shown that PT users are negatively disposed towards transfers. Existing users find the uncertainty associated with transfers to be problematic, especially for journeys which are appointment-specific or high in importance (Stradling 2002). Transfers incur an automatic perceived disadvantage related to the amount of transfer-making time and the risk involved in making the connection (Iseki and Taylor 2009).

The main purpose of this study is to determine the minimum travel time and cost savings which will invokes commuters' intention to switch from their private car to a well-integrated PT route. To the best of the authors' knowledge, no study has been conducted on different threshold values of travel time and cost savings required by car users to perceive well-connected PT routes more attractive than their current mode. The study adopts a familiar experimental psychological model, Just Noticeable Difference (JND), to determine the difference threshold from a user perspective. In 2013, Auckland Transport (AT) produced a statutory document, the Regional Public Transport Plan (RPTP). The plan aims to provide commuters with a sustainable transport system in a safe, integrated, responsive and affordable manner. One of the key components by which AT plans to achieve full integration of the network is through facilitation of inter-modal and intra-modal transfers (Auckland Transport 2013). This network redesign has already begun in Auckland, with new interchanges catering for inter-modal transfers between bus and train.

Hereafter, the paper is organized as follows. Section 2 provides the literature review of relevant studies, Section 3 describes the user-preference survey, Section 4 gives the results and discussion and lastly, Section 5 is the conclusion.

2. Background of Disease Spread

2.1. Just Noticeable Difference

Just Noticeable Difference (JND), also known as the difference threshold, originates in the field of experimental psychology (psychophysics). The concept of JND was first discovered by the experimental investigations conducted by Ernst Weber (1795-1878), an anatomist and psychologist (Baird and Noma 1978). Weber's Law states that when two stimuli are compared, rather than simply perceiving the difference between the stimuli being compared, human beings perceive the ratio of difference to the magnitude of the stimuli. Weber's Law has been mathematically formulated as given in Equation 1,

$$\frac{\Delta \mathrm{I}}{\mathrm{I}} = \mathrm{k} \tag{1}$$

where ΔI is the change required for a JND in the stimulus magnitude, I is the stimulus magnitude, and k is the constant for the particular sense. The values of k have been seen to vary over low, medium and high magnitude ranges of the stimuli. As the k value decreases, the perceptual sensitivity improves (Baird and Noma 1978).

Other studies on travel behavior have commonly used statistical methods such as structural equation models (Golob 2003) and regression analysis (Dell'Olio *et al.*, 2011). The merits of using JND are that the concept is based on perception and is able to quantify the perceived difference. Chowdhury *et al.*, (2015) has shown that perceived attractiveness of a route with transfer can be assess using JND. Results of the study revealed that, on average, users' desire at least a 33% reduction in their current travel time and at least a 16% reduction in their current travel cost given basic comfort amenities at the interchange. For an interchange with more comfort, on average, users' desire at least a 25% reduction in their current travel time and at least a 10% reduction in their current travel cost.

2.2. Travel Time and Cost

Travel time savings, particularly perceived savings, is regarded as one of the most important factors in users transport decisions (Raveau *et al.*, 2014). A study by Dell'Olio *et al.*, (2011) revealed that for potential PT users travel time is more important than it is for existing users. Potential users identified travel time as the most important attribute for attractiveness of PT use. When quantifying the importance of travel time in regards to transfers, the total travel time is split into three components. These components are the in-vehicle time, the waiting time at the transfer station and the walking time when transferring (Raveau *et al.*, 2014). The separation of travel time into these three components emphasizes the importance placed on each as well as the difference between the perceived time and the actual time. The more comfortable and productive the time is, the faster the time is perceived, thus the time taken to make transfers is perceived as being less burdensome (Navarrete and Ortuzar 2013). Travel time savings and improvement in network reliability can be achieved through integration of PT systems (Buehler 2011). Route integration may require a transfer to reach the final destination, but by providing efficient shorter and well-connected routes, the total travel time of the journey can be reduced (Ceder 2007).

The importance of cost saving is often considered the second most influential factor for determining route choice. Low PT fare policies have been shown to be influential in attracting car users (Redman et al. 2013). Fare structure also has an effect on PT use. If the structure is perceived to be overly complex, travelers may 'disengage' and avoid the expense. In some zonal structure, commuters are required to pay two fares when making a transfer. This increases cost as well as complexity of payment. An integrated PT fare system can reduce the cost of travel for users. Matas (2004) investigated the increase in ridership (50% over five years) of Madrid's integrated transport system and revealed that part of the reason is due to the integrated fare system. Sharaby and Shiftan (2012) demonstrated that a well-integrated fare system, which allows no additional cost for transfers, improves traveler's intention to use PT.

2.3. Role of Integrated Public Transport Systems

Integration of multimodal transport systems has received particular interest in recent years to promote mode switch. The main purpose of an integrated transport system is to provide PT users with a "wide spectrum" of destination choices and also with a convenient, accessible, speedy and affordable transport system (Luk and Olszewski 2003, Ulengin *et al.*, 2007). Bak *et al.*, (2012) discussed that effective integration in the form of attractive interconnectivity among routes is required to gain potential users. Therefore, transfers are an important element of integrated systems. The role of transfers is to provide users with: (a) greater destination choices, and (b) reduced travel times and costs (Bak *et al.*, 2012). Chowdhury and Ceder (2013) showed that PT users' are more willing to travel on routes involving transfers given that the connections are "planned". The study defined "planned transfers" in an integrated system as connections which have been intentionally designed by policy makers and network planners in the initial planning stage of the system for the purpose of improving service efficiency and convenience to users.

3. Survey

This section describes the design and the implementation of the two surveys that were conducted in Auckland, New Zealand. Auckland metropolis is New Zealand's largest and most cosmopolitan region with a population of 1.5 million (Statistics New Zealand 2013). More than 60 million trips have been estimated to be made annually with the Auckland metropolis's PT-network, which consist of trains, buses and ferries (Auckland Transport 2012). To encourage mode shift from single-occupancy cars to PT, AT has produced a RPTP. The document plans for the next 10 years in detail. It states that the plan aims "to provide a city-wide connected and interlinked network of frequent and reliable services" (Auckland Transport 2013). The current mode share to the city central for PT is 47% during the peak period. The plan aims to increase this mode share to 70% in 2040.

3.1. Questionnaire Design

The objective is to determine the smallest travel time and cost savings which will persuade commuters using private car to switch to a well-connected PT route involving a transfer. As illustrated in Figure 1, commuters were given two options: (a) to use the new PT route with a shuttle bus service, Route B, (b) to continue using their private car, Route A. Node I represents the commuters' home and Node II is their final destination. Route B is part of a proposed integrated PT system while Route A is their existing route and mode. In order to preserve the door-to-door convenience of a car trip, it was assumed that for Route B a circulating shuttle bus service will be provide. This service will act as a feeder to the terminal. Such services are in practice in many American cities as well as developing countries (Cervero 1997).

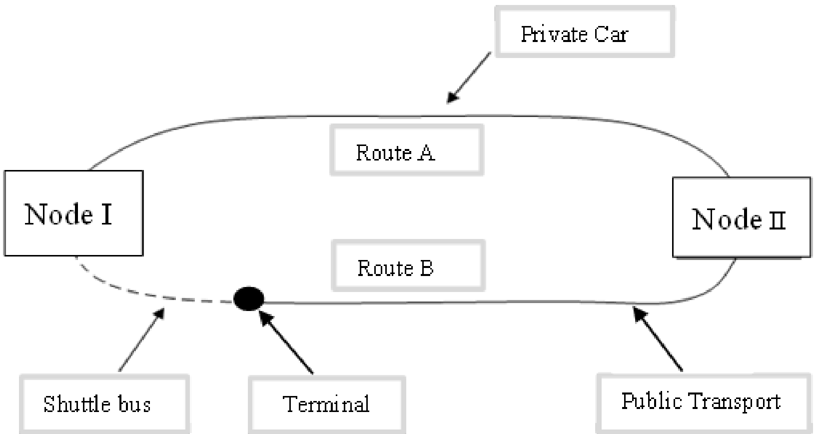

Figure 1. Route Choice for Survey 1 Commuters

Details of the participants' current trip were obtained. Questions included their frequency of travel, current travel time and cost by car and the suburb their trip originated. In addition, participants were asked the three questions:

Item 1 : If you could only save time, what is the minimum total travel time savings you want for Route B?

Item 2 : If you could only save cost, what is the minimum total travel cost savings you want for Route B?

Item 3 : What is the minimum total travel time and cost savings (combined) you want for Route B?

The questions were designed to attain the threshold value which will motivate car users to switch to PT. It was of interest to determine the change in the threshold values for when travel time and cost savings were provided exclusively and combined. Participation was voluntary.

3.2. Implementation

The survey was conducted in the morning (7-9am) and evening (4-6pm) peak periods for 15 weekdays. The questionnaire was self-administered and was designed to take less than 5 minutes. The survey was implemented in three locations around the Auckland Central Business District (CBD): (a) the University of Auckland's Business School, and commercial services near (b) Parnell Road and (c) Eden Terrace. The Business School has a five level car park which consists of 1,200 spaces. This is the largest car park provided to students and staffs. Parnell Road has many commercial services along its route. The suburb attracts approximately 8,770 employees and has around 2,247 businesses (Statistics New Zealand 2013). Connecting local streets offer opportunity for on-street parking. Eden Terrace is a central suburb located in close proximity to the CBD. Due to its street connectivity, the suburb is a common place for commuters to park their car and continue their journey using PT. characteristics of the locations created ideal survey locations to approach car users.

3.3 Limitation

The main limitation of the study is that other factors which affect mode choice such as comfort, convenience and safety were not assessed, only time and cost savings. The reason for this is that the questionnaire was designed to take 2-5 minutes to reduce the burden on participants. Time and cost savings are quantifiable trip attributes and the outcome is expected to assist PT planners and modelers.

4. Results and Discussion

4.1. Results

A total of 300 questionnaires were collected of which 227 were deemed useable for the data analysis. Of the 228 participants, 59% of them originated from the central suburbs, 18% from the eastern suburbs, 16% from the southern suburbs, 4% from the northern suburbs and 3% from the western suburbs. Equal proportion of males and females participated in the study. Figure 2 and 3 give the current travel time and cost of the participants, respectively. Figure 2 illustrates that majority of the participants commuted between 20 to 60 minutes in one direction to the CBD. The cost stated by the participants is predominantly the parking cost.

It has been generally acknowledged that Weber's Law is valid for the middle range of stimulus intensities and not for extreme ranges (Baird and Noma 1978). Wilcox (2009) recommended a 20% trimming of the data to account for outliers. Therefore only the data of PT users with current travel times ≥ 20 minutes and ≤ 60 minutes, in one direction, was analyzed. To determine the average k values, the trimmed means of the two survey data were calculated. Equations 2 and 3 were used to calculate the mean and 20% Winsorized variance (s_w^2), respectively. The ranges of the average k were determined by calculating the 95% Winsorized confidence interval (C.I.) using Equation 4. Table 1 provides the results.

$$\bar{W} = \frac{1}{n}\sum W_i \quad (2)$$

$$s_w^2 = \frac{1}{n-1}\sum (W_i - \bar{W})^2 \quad (3)$$

$$CI = \bar{W} \pm C\frac{s_w}{\sqrt{n}} \quad (4)$$

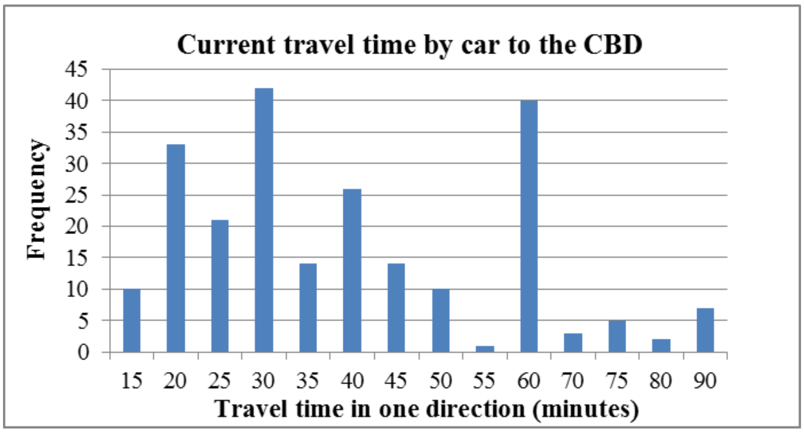

Figure 2. Route Choice for Survey 1 Commuters

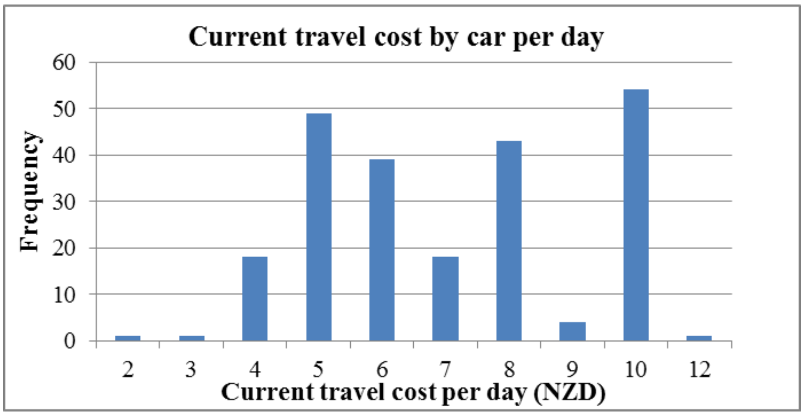

Figure 3. Current Travel Costs for Car Users to Auckland Central

Table 1. Summary of Mean, Variance and 95% Confidence Interval for Travel Time Savings, Travel Cost Savings

Travel time savings	$\overline{W}$	s_w^2	**C.I.**
JND for travel time savings (Item 1 of questionnaire)	0.289	0.006	0.001
JND for travel time savings given cost savings (Item 3 of questionnaire)	0.183	0.002	0.001
Ratio of JND for average travel time savings given cost savings over average travel time savings only	0.633	0.140	0.006
Travel cost savings	$\overline{W}$	s_w^2	**C.I.**
JND for travel cost savings (Item 2 of questionnaire)	0.450	0.008	0.002
JND for travel cost savings given time savings (Item 3 of questionnaire)	0.276	0.005	0.001
Ratio of JND for average travel cost savings given time savings over average travel cost savings only	0.613	0.040	0.003

The results support earlier findings which showed that travel time savings have a greater effect than cost savings on willingness (Chowdhury *et al.*, 2015). For travel cost savings, it was seen from the data analysis that the k values for travel cost savings only

(Item 2) and combined with travel time savings (Item 3) is similar for all current travel cost groups. The ratio between the two groups of JND is on average 0.613. This result shows that the JND for travel cost savings with time savings is less than the JND value of travel cost savings only. It should also be noted that the variance and range (95% C.I.) for the two groups is small, below 0.01.

A curve fitting modelling was undertaken for travel time savings only (R2=0.514) and travel time savings with cost savings (R2=0.629). Figure 4 illustrates that there is an inverse relationship between the k values and current travel time of commuters. Similar to travel cost savings, the variance and range for the two groups is small, below 0.01. It was seen that the ratio between the two groups of JND is similar for all current travel time. The average ratio is 0.633. This ratio (0.633) is greater than the ratio derived for travel cost savings (0.613). Also, the average JND for time savings only (0.289) is nearly equal to the average JND for cost savings in combination with time savings (0.276). The average JND for time savings with cost savings (0.183) is the lowest. The findings reveal that by including travel cost savings to a predominantly travel time savings scheme, PT operators can attract more car users.

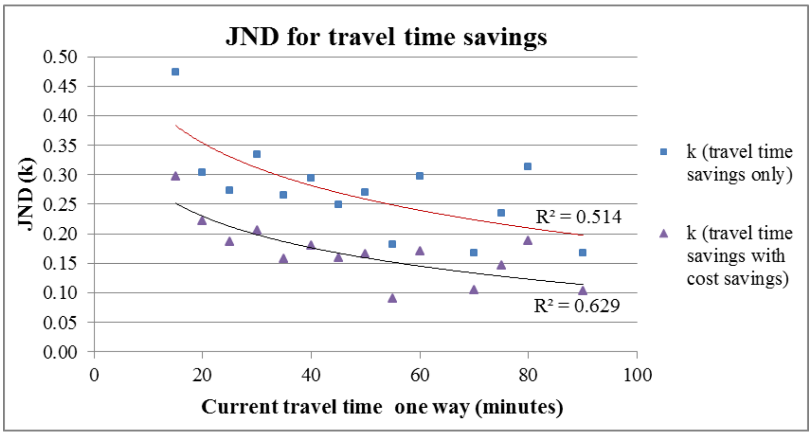

Figure 4. Inverse Relationship between the k Values for Travel Time Savings only and Travel Time Savings with Cost Savings and Current Travel Time for Commuters

In summary, the study has investigated the minimum travel time and cost savings desired by private car commuters in order for them to have the intention to use PT. The findings have shown that the k value range for the travel time savings only is between 0.17 and 0.47; including travel cost savings reduces the range to 0.10 to 0.30. Results of the study revealed that, on average, car users desire at least a 29% reduction in their current travel time given only time savings and at least an 18% reduction in their current travel time when combined with cost savings. For travel cost, users desire at least a 45% reduction in their current cost, given only cost savings and at least 28% in their travel cost given time savings as well. Figure 5 provides the decision process for commuters to adopt a well-connected PT network. The values are obtained from the previous study (Chowdhury *et al.*, 2015) and the present study. To date, factors which were included were travel time and cost savings and comfort level at interchanges. Future research will include other factors which are also important to commuters such as transfer waiting and walking time in conjunction with reliability and safety, respectively. It should be noted that the values are indicative as they are savings which are perceived by car users. Nevertheless, the values can assist PT planners, to a certain extent, in including the complexity of travel behavior when redesigning the route network.

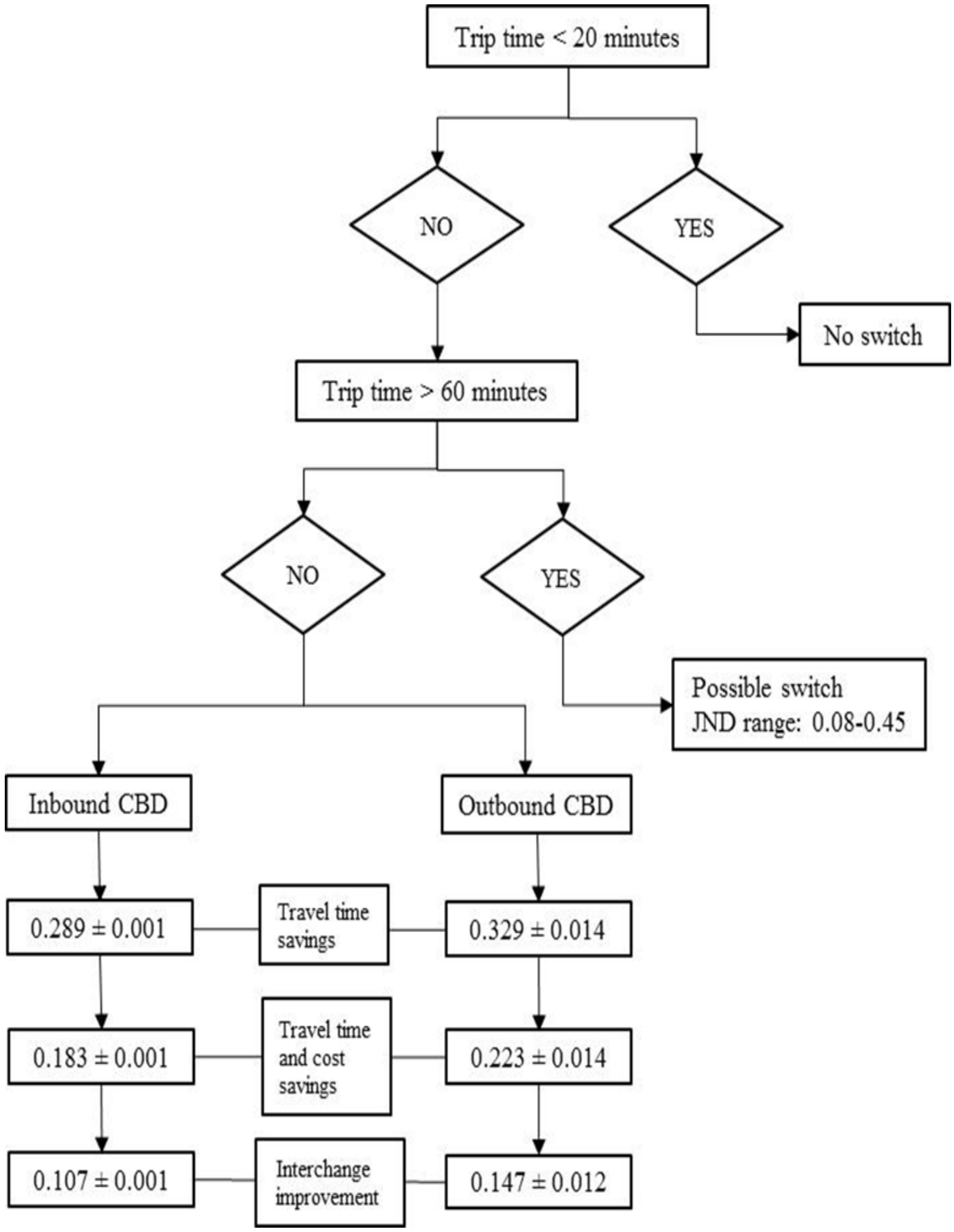

Figure 5. Decision Process to Switch to Routes Involving Transfers

5. Conclusion

Globally, it has been acknowledged that to relieve congestion in metropolitan cities and to reduce greenhouse gas emissions, modal switch from single occupancy private car use to public transport is vital. The aim of the present study was to determine the minimum travel time and cost savings which will invoke willingness in commuters to switch from their private car to a well-integrated public transport route. The study adopted a familiar experimental psychological model, Just Noticeable Difference, to determine the difference threshold from a user perspective. A user preference survey was undertaken in Auckland, New Zealand. Results of the study revealed that, on average, private car users desire at least a 29% reduction in their current travel time and at least a 45% reduction in their current travel cost savings, given only one of each is provided. When both travel time and cost savings is provided, users desire at least an 18%

reduction in their current time with at least a 28% reduction in their current travel cost. This study contributes to existing literature by providing a methodology on how to attain indicative threshold values of the two attributes impacting car users' decision. It also contributes by providing indicative threshold values which will promote mode shift from car to public transport. It should be noted that the values are indicative as they are savings which are perceived by commuters. Nevertheless, the values can assist PT planners, to a certain extent, in including the complexity of travel behavior when redesigning the route network.

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