PEDESTRIAN PREFERENCES WITH RESPECT TO ROUNDABOUTS – A VIDEO-BASED STATED PREFERENCE SURVEY

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ABSTRACT

Attention to user behavior and preferences has been a helpful tool in improving road safety and accident prevention in recent years. At the same time, there remain some important areas of road safety and accident prevention for which user preferences have not been explored. For instance, so far, road safety research has not addressed pedestrian and vulnerable user preferences with respect to roundabouts, despite the increasing construction of these intersections around the world. The present research stems from the fact that studies related to roundabout safety have typically put drivers in a privileged position, while generally overlooking the importance of safety as it relates to vulnerable users, especially pedestrians. Moreover, it handles this particular issue through an approach that has not been used so far: the Stated Preference (SP) survey.

As such, this paper describes the justification for, the methodology, the analysis and conclusions of a SP survey designed to obtain pedestrian and vulnerable user preferences with respect to roundabout facilities in Quebec. In addition to the fact that an SP survey has not been used in this context before, another innovative facet of the work lies in the use of traffic micro-simulation software to create videos that serve as alternatives in Choice Tasks in the SP survey. The study finds that pedestrian preferences for roundabouts are affected by: the presence of pedestrian crossings (and their location relative to the roundabout), signage and pedestrian islands, as well as the number of traffic lanes they must cross. In addition to these design features, pedestrian preferences for roundabouts are also affected by the speed and volume of traffic – something we were able to evaluate thanks to the use of traffic simulation videos.

Keywords: Roundabouts, pedestrians, stated preference methods, vulnerable user safety
INTRODUCTION

For years, road safety research has focused on explaining and improving drivers’ experience of roads and intersections. However, the increasing use of alternative transportation modes has increased attention to vulnerable users such as pedestrians and cyclists.

Whether they consider all kinds of users or only one, transportation researchers have used many different approaches to studying and improving safety. Perhaps one of the more complicated approaches is to attempt to model human behavior, such as reaction mechanisms and decision making processes. Examples of commonly used tools for obtaining this kind of information, specifically understanding individual choices and preferences, are Stated Preference (SP) and Revealed Preference (RP) methodologies.

RP methods seek to understand peoples’ preferences by asking about, and analyzing, decisions people have actually made. SP methods on the other hand seek to understand peoples’ preferences by asking them what decisions they would make in carefully constructed, hypothetical choice situations (Choice Tasks). The goal of SP surveys is to identify and quantify the effects of different attributes on respondent preferences for the choice at hand.

Understanding user preferences is especially important for components of the transportation system that are increasing in number, and for which user preferences are not yet well understood. This is the case for roundabouts in Quebec, which are increasingly being built due to their advantages in terms of safety, the environment and traffic flow.

Adopted initially in the UK in the 1960s, roundabouts have become increasingly popular in the last two decades in North America. Roundabouts are characterized by a circular intersection where traffic flows counter-clockwise around a central island, preventing vehicles from crossing in a linear, and therefore faster, path. These intersections work based on the principle that vehicles entering the roundabout must yield to those already traveling within the central circle. Although several statistical studies have shown their high levels of safety, there is still a lack of research where safety, behavior and preferences are analyzed in an integrated manner with respect to these intersections.

The Quebec provincial government, having built the first intersection of this kind in Canada in 1996, has shown interest in this research given the dearth of information related to roundabouts: the Fonds de Recherche du Québec sur la Nature et les Technologies (FRQNT), the Quebec Ministry of Transportation and the Fonds de Recherche du Québec sur la Santé are currently funding a project on the safety of roundabouts in Quebec, through three approaches: the statistical analysis of crash data, the direct observations of road user behavior and interaction using video data and a study of behavior and risk perception of vulnerable users.

Although roundabouts are seen as more efficient intersections in terms of capacity and Level of Service (LOS), existing literature shows that for these types of intersections, most of the safety research has been aimed at how drivers perceive them, while very little attention has been paid to vulnerable users and their preferences.

The research described here targets the lack of knowledge about vulnerable user preferences towards roundabouts. These preferences were analyzed through the use of an SP survey – the first of its kind. Specifically, this research sets out to achieve two goals: a) to understand and quantify the geometric and operational attributes that influence vulnerable user preferences for roundabouts in Quebec; and b) to evaluate the safety perceptions of vulnerable users (mainly pedestrians) with respect to roundabouts. It is worth mentioning that neither pedestrian preferences for, nor safety perceptions of, these types of intersections have ever been captured using an SP survey (for drivers or other users). As such, the novelty of the exercise goes
beyond safety research in the region. Moreover, as it will be shown afterwards, the research
involved an innovative approach to SP task delivery: the use of software specialized in traffic
micro-simulation to create videos of roundabouts according to the SP survey design.

Results of this analysis make it possible to understand pedestrian preferences with respect
to roundabout attributes, as well as allowing a comparison of preferences between different
attributes. Finally it helps to provide specific recommendations to allow decision makers to
guarantee safe and comfortable roundabouts for pedestrians.

In order to do this, the paper first explores, through a comprehensive review of existing
literature, the relationship between safety, preferences, vulnerable users and roundabouts that
have previously been studied. Following the literature review, the methodology of the research
tool is described (which includes planning, administration and analysis of the survey), yielding
specific conclusions and recommendations about the relationship between roundabout facilities
and vulnerable user preferences.

LITERATURE REVIEW

Commonly identified benefits of roundabouts have been documented in a significant body of
research. These benefits can be divided into different categories, regarding the environment,
mobility and safety, which can then be further classified between driver and vulnerable user
safety.

How roundabouts improve driver safety is an issue addressed in the majority of the
studies related to this topic, although in some cases vulnerable users are also considered. In the
literature focusing on motorists, but that also mentions vulnerable users, it has been shown that
roundabouts are safer than other types of intersections, both in terms of frequency of accidents
and outcomes (1-3): collisions are less frequent and less severe in roundabouts than in other
intersections. The results are more mixed for vulnerable users, with some geometric elements
such as cycle lanes inside the roundabout being significant risk factors. Moreover, some
literature that has focused on motorists has also reported in a limited way on vulnerable users.
Daniels et al. (1); Daniels et al. (4), who did not distinguish between cyclists and pedestrians,
found that vulnerable users have a higher probability of being injured in roundabouts than could
be expected based on their share of occupancy in traffic. While there is a bit of literature that has
touched on the question of vulnerable users in roundabouts, according to Wall et al. (5) there are
simply not enough studies related to the safety of this type of roundabout user.

While there has not been much research on the safety of vulnerable users in roundabouts,
pedestrian safety has attracted increased attention recently. Papadimitriou, Theofilatos and
Yannis (6) focus on pedestrian perceptions of intersection safety with respect to traffic
characteristics such as vehicle volume and vehicle speeds, Xi and Son (7); De Brabander and
Vereeck (8) on the other hand concentrate on statistical analyses of pedestrian accidents and
injuries, but do not consider pedestrian preferences or behavior explicitly. Finally, Meneguzzo
and Rossia (9) examine the empirical relationships between pedestrian occupancy of crosswalks
and impedance to vehicle flow in roundabouts (9). Despite the literature on this particular type of
intersection, and the literature on pedestrians, there is no research that focuses exclusively on
pedestrian safety in roundabouts.

SP surveys have been used in a limited number of situations to understand vulnerable
user preferences and behavior. The method has been used for example to better understand
cyclist preferences, although never in the context of roundabouts. Furthermore, pedestrian
preferences and behavior analyses have been confined to: route choice and behavior at
intersections (10), the influence of the perceived level of safety at an intersection and where
pedestrians cross (11), preferences with respect to pedestrian crossing facilities (12) and
pedestrian-motorist interactions at intersections (13).

Another aspect of the related literature is the use of visual aids in SP surveys. Studies by
Taylor and Mahmassani (14), Krizek (15) and Arentze et al. (16) can be observed as evidence of
the positive results that visual aids generate in SP surveys. Particularly interesting is the work of
Krizek (15), where the use of visual aids reported an improved performance of the survey: the
author used 10-second clips to illustrate to respondents the characteristics of each alternative. As
can be seen from this literature review, an SP survey solely targeting pedestrians in roundabouts
is an unexplored area of research. Moreover, the use of visual aids in SP surveys to understand
preferences, especially those that are difficult to communicate in words – and particularly in the
context of vulnerable users – is in its infancy. As such, this research contributes to existing
literature along these two dimensions.

METHODOLOGY

An SP study typically involves a long process that includes: the design, administration and
analysis of the survey tool and data (10; 13; 16-18). In the present research, the purpose of the
survey was to understand what factors (and to what degree those factors) influence vulnerable
user preferences with respect to roundabouts. The first step in the development of an SP survey
is an examination of the existing literature to understand what characteristics and attributes have
been considered important in previous relevant studies. TABLE 1 shows a summary of the
attributes that have been used and evaluated in the most relevant works where vulnerable user
safety has been considered. The literature is categorized by the methodological approach used
(SP or Other) and the type of intersection considered (traditional or roundabout).

As can be seen, most of the research has considered the following attributes: traffic
volume, traffic speed, pedestrian volume, signalization, pedestrian crossing location and the
presence of physical barriers (e.g. pedestrian islands).

While the first step provides an idea of the attributes that are likely to be included in the
survey instrument, further complementary studies, such as focus groups and pilot tests are
necessary to establish which attributes should be included in the final survey instrument. This
constitutes a second step in survey development. A focus group is an exploratory research tool
where a group of potential respondents are asked to identify which attributes they consider to be
important in the question (choice) of interest. While being asked what attributes are important,
respondents are also asked what are appropriate ranges and/or levels of those attributes. In this
study, a focus group of six individuals was convened. Participants were contacted by a survey
company specializing in the recruiting and administering of surveys. They were contacted if they
lived within 1km of roundabouts in the region of Montreal and were asked to participate if they
had accessed a roundabout by foot in the past three months. Gender and age diversity were
sought in the formation of the focus group. Participants were asked at the beginning to simply
share what they thought about roundabouts. Afterwards, they were asked to share their
perceptions in terms of particular roundabout attributes. While previous literature served as a
backdrop of what to expect, the particular attributes to be addressed were left open to the focus
group participants to discuss.
TABLE 1 Attributes and Levels Used in Existing Literature for Evaluating the Pedestrians Safety of Regular Infrastructure and Roundabouts

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Possible levels</th>
<th>Evaluation of safety by other methods</th>
<th>Evaluation of safety using Stated Preference</th>
<th>Evaluation of safety in roundabouts by other methods</th>
<th>Evaluation of safety in roundabouts using Stated Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic volume</td>
<td>Low, Medium, High</td>
<td>(6; 12; 19)</td>
<td>(10; 13; 17; 18)</td>
<td>(1; 4; 20-22)</td>
<td>-</td>
</tr>
<tr>
<td>Traffic speed</td>
<td>Low, Medium, High</td>
<td>(6; 12; 19)</td>
<td>(10; 13; 17; 18)</td>
<td>(1; 4; 20-22)</td>
<td>-</td>
</tr>
<tr>
<td>Pedestrian volume</td>
<td>Low, Medium, High</td>
<td>(12; 19; 23)</td>
<td>(10; 13)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Signalization</td>
<td>No signalization, Yield, Speed limit, Pedestrian crossing</td>
<td>(12; 24)</td>
<td>(10; 17; 18)</td>
<td>(8; 22)</td>
<td>-</td>
</tr>
<tr>
<td>Pedestrian crossing location</td>
<td>In the entrance of intersection, Near the entrance, Far from the entrance</td>
<td>(12)</td>
<td>(10; 17; 18)</td>
<td>(9)</td>
<td>-</td>
</tr>
<tr>
<td>Physical barriers</td>
<td>Vegetation, Median, Non barriers</td>
<td>(6; 12)</td>
<td>(17)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(-) Nonexistent related work

Based on these discussions, five attributes from the literature review were confirmed to be important for potential respondents: Signs, Pedestrian Crossing Position (although a particular preference was not predominant), Traffic Volume, Traffic Speed and Pedestrian Volume. In addition, participants brought up two new attributes: the Number of Lanes, and the Presence of a Pedestrian Island. They also suggested a new level for the Signs attribute: “Flashing signs”. Thus, the very first version of the survey to be tested – the Pilot Survey – included all of these seven attributes.

**Pilot Survey**

A pilot survey is a tool that aids in identifying strengths and weaknesses of the survey instrument. In this case, it was conducted online in order to test not only the instrument itself, but also to test the administration and data collection procedures to be implemented in the final survey. The pilot version had essentially the same structure as the final version of the survey and as such, was structured as follows:

- First section (six questions). Respondent and household general information.
- Second section (two questions). Transportation mode going through a roundabout and frequency of mode in the past three months.
- Third section (three questions). Safety perception and knowledge of roundabout functionality.
- Fourth section (6 Choice Tasks).

Six Choice Tasks with two alternative roundabouts for each were shown to 48 participants in the pilot survey. The alternatives of the individual Choice Task videos were created with the VISSIM software, which is a microscopic simulation tool developed by PTV.
Group for modeling multimodal traffic flows. The attributes of each of the alternatives of the Choice Tasks were pre-determined by experimental design (explained further below) and programmed in VISSIM so that each Choice Task was unique.

After analyzing data from the pilot survey, it was concluded that Traffic Volume, Traffic Speed and Pedestrian Volume did not affect respondent choices with respect to preferred roundabouts, contrary to what was reported in the literature and expressed in the focus group. After closer inspection and discussion with some of the pilot study respondents, we decided to remove Pedestrian Volume as an attribute for Choice Tasks, since roundabouts in Quebec are not subject to high or very different levels of pedestrian traffic in reality. With respect to Traffic Volume and Traffic Speed, it was found that respondents had difficulty distinguishing between the levels (high volume vs. low volume and high speed vs. low speed), thus explaining the apparent indifference towards these attributes.

In order to overcome this obstacle, a restatement of the levels of these attributes was proposed and new videos were generated with VISSIM in such a way that the differences between low and high values of Traffic Volume and Traffic Speed were easily discernible without being unrealistic. These values were tested once again through a simpler online survey, the results of which showed that variations in both volume and speed were easily distinguishable.

Once all attributes and levels, as well as survey questions, had been tested and adjusted where necessary, the survey was put together once again to be administered as the definitive survey instrument.

Final Survey Administration
The definitive version of the research tool was organized in the same manner as the pilot test: the first section focused on the respondent’s socioeconomic status as well as household information; the second part related to mode and frequency of use of roundabouts; the third part revealed preference information on safety issues; and the fourth and final part was the Choice Task section. Based on what focus group and pilot test analyses revealed, the final survey included the following attributes and their respective levels:

- Signs: Absence of signalization, presence of standard pedestrian and cyclist crossing signs, flashing pedestrian and cyclist crossing signs. According to previous literature and the focus group, it was expected that pedestrians would prefer the presence of signs, and flashing signs in particular.
- Number of lanes: One or two lanes per direction. In this case it was expected that pedestrians would prefer a shorter crossing distance (one lane).
- Presence of a pedestrian island: With and without an island. It was expected that pedestrians would prefer the presence of island.
- Distance of Pedestrian Crossing from the Entrance of the Roundabout: Absence of pedestrian crossing, crossing at the entrance of the roundabout, a crossing 5 m from the entrance. In this case there wasn’t a clear preference in focus groups, although existing literature and the pilot survey point to a preference for a crossing far from the entrance over other options.
- Traffic Volume: Low and high volume (100 and 500 vehicles/h). It was expected that pedestrians would prefer lower traffic volumes.
- Traffic Speed: Low and high speed (22 and 65 km/h on average). It was expected that pedestrians would prefer lower traffic speeds.
As explained above, a constant pedestrian volume was used in all simulations. FIGURE 1 shows an example of the Choice Tasks through embedded YouTube videos showing VISSIM simulations.

Figure 1 shows an example of one of the Choice Tasks. The first option shows a roundabout with one-lane roads, no island, regular signs, and a pedestrian crossing at the entrance of the roundabout. The second one shows a roundabout with two-lane roads, pedestrian flashing signs, a pedestrian island and a pedestrian crossing far from the entrance of the roundabouts. While it is possible to distinguish the low (left Choice Task) and high (right Choice Task) traffic levels in this static photo, it is not possible to distinguish traffic speed, without watching the videos.

The final version of the survey was planned to be administered to 500 respondents. Thus, an experimental design of 500 different versions (different sets of the six Choice Tasks) was used. These versions were obtained from Sawtooth software, using its “balanced-overlap” design of experiment (DoE) algorithm. Sawtooth is a software specialized in survey tools for conjoint analysis and it offers different design strategies to create a fixed set of profiles by drawing from full factorial designs while considering possible prohibitions set by designers. In this research we used the balanced-overlap strategy. This strategy is a trade-off between the random and the complete enumeration (no overlap) strategies. It permits almost half as much overlap within the same task as the random method. While this approach is statistically less efficient than designs with minimal overlap, it can result in more thoughtful responses, especially when there is the existence of a dominant attribute, by encouraging respondents to ponder and express what would be the effect of additional aspects (other than the dominant attribute)(25). The set design for this work was 24% less efficient than the efficient design, but it allowed us to capture all attribute interactions.
For the final survey, a company specialized in web-based surveys and the administration of online research tools (Groupe Altus) was hired in order to recruit the 500 respondents qualifying for the survey. In order to qualify, respondents needed: to be 18 years old or older, to live within a buffer of 1 km from a roundabout (considering works by Goudie (26), Kelly et al. (18) and Krizek (15) where only respondents located within a specific buffer were considered for the survey) and to have walked through a roundabout in the past three months. In order to select possible respondents within a 1km buffer, the company administering the survey was provided with coordinates of all roundabouts in Quebec (from the project inventory) from which to draw their sample.

The survey was conducted during the first week of July, 2013, finishing with 501 completed online surveys. In the end, 468 surveys were considered for the analysis after having removed some where people responded too quickly to have been able to adequately examine the options (time spent on each task was recorded) or where they had clear patterns (e.g. if the respondent had chosen only the first or only the second task) suggesting they did not pay attention to the tasks.

DATA ANALYSIS

Given that Quebec is a primarily French-speaking province, it is not surprising that 85% of respondents answered the French version of the survey. Additionally, 47% of the respondents were male, while almost 40% of them were between the ages of 40 and 59 years old, maintaining a proportion similar to the actual population in the greater Montreal area, where 52% of the population is between those ages. The location of respondents (entered by respondents as their 6-digit postal code) was mapped and corresponded with the location of roundabouts across the province.

The statistical analysis of the survey data was done using a Multinomial Logit (MNL) model. Future work will include analysis using mixed-logit panel data models in order to account for correlation of errors in the responses of individual participants.

The Multinomial Logit Model

The following description of the MNL draws primarily on Kenneth Train’s book *Discrete Choice Methods with Simulation* (27). It is worth mentioning as well, that MNL is just described briefly since comprehensive explanations can be found in other references.

The logit model is used when trying to explain discrete choices; normally, choices among several mutually exclusive alternatives. Some of the applications of discrete choice modelling are the analysis and prediction of choices based on RP and SP data.

According to random utility theory, a decision maker \( n \) will choose the alternative \( i \) that provides them the highest utility. It is important, nonetheless, to understand that only the decision-maker knows (intuitively) the utility of each alternative; the researcher can only observe the choices made by, and some of the characteristics of, the decision maker. By analyzing the decision maker’s choices, the researcher can estimate a representative utility function (the deterministic portion of the utility). This is typically represented as in equation (1).

\[
U_{ni} = V_{ni} + \varepsilon_{ni} \quad \forall i
\]  

Here, \( U_{ni} \) is the utility individual \( n \) obtains from alternative \( i \). \( V_{ni} \) is the systematic portion of utility and \( \varepsilon_{ni} \) is the random error. \( V_{ni} \) can be re-expressed as in equation (2) where it is a linear combination of the model coefficients and alternative and decision-maker characteristics.
The error is unobserved and unknown and in fact, it is the assumption about its distribution that determines the model used to estimate the utility function. If the error is assumed to be independently and identically extreme value distributed, then the probability that the individual $n$ chooses alternative $i$ will be defined by the closed-form expression of the MNL:

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_{j=1}^{J} e^{V_{nj}}}$$

Although this form of the MNL model makes it straightforward to estimate, interpret and use, the assumptions related to the error in this model are questionable in many choice contexts, such as when observations involve more than one response from the same person. The relaxation of such assumptions can be allowed by the use of models that require numerical integration, such as the Mixed Logit Model. As described above, estimations of these types of models represent future improvements to this research.

**Model Results**

TABLE 2 shows the results for the base model with including only the 6 main variables. In the base model all variables have the sign expected *a priori* and they are significant at the 95 % confidence level, except for regular signs. The insignificance of regular signs shows how respondents remained indifferent to this attribute compared to no sign at all; in contrast, flashing signs were significantly preferred to no sign by respondents. In fact, the presence of such signs in a roundabout would increase the odds of a roundabout being chosen by 22 %. As expected, the coefficient for number of lanes is negative, suggesting respondents prefer roundabouts with fewer lanes. It is interesting to notice that the effect size of number of lanes and presence of island are quite similar, although in opposite directions. In other words, the amount by which the presence of an island increases the odds of a roundabout being chosen is about the same as the amount by which the odds are decreased if an additional lane is added: an additional lane would decrease the odds of a roundabout being chosen by 29 %, while the presence of island would increase the same odds by 39 %.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient ($\beta$)</th>
<th>p-value</th>
<th>exp ($\beta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular signs</td>
<td>0.202</td>
<td>0.267</td>
<td>1.224</td>
</tr>
<tr>
<td>Flashing signs</td>
<td>0.563</td>
<td>0.002</td>
<td>1.757</td>
</tr>
<tr>
<td>Number of lanes</td>
<td>-0.343</td>
<td>0.000</td>
<td>0.710</td>
</tr>
<tr>
<td>Presence of Island</td>
<td>0.327</td>
<td>0.000</td>
<td>1.387</td>
</tr>
<tr>
<td>Crossing at the entrance</td>
<td>1.876</td>
<td>0.000</td>
<td>6.527</td>
</tr>
<tr>
<td>Crossing at 5m</td>
<td>2.607</td>
<td>0.000</td>
<td>13.557</td>
</tr>
<tr>
<td>Traffic Volume</td>
<td>-0.079</td>
<td>0.000</td>
<td>0.924</td>
</tr>
<tr>
<td>Traffic Speed</td>
<td>-0.238</td>
<td>0.041</td>
<td>0.721</td>
</tr>
</tbody>
</table>

Final Log Likelihood = -970.835
Pseudo R2 = 0.3857
Number of parameters = 8

Regarding crossing position, the model shows a higher preference for pedestrian crossing far from the entrance of the roundabout among respondents. Moreover, the variable which would increase the odds to be chosen the most (by 1,256 %) is crossing at 5 meters. As expected, any of these two possibilities are more preferred than the absence of crossing. The signs of traffic
volume and speed, on the other hand, confirm what existing literature, the focus group and intuition suggested: respondents prefer roundabouts with lower speed of traffic and volume. Although the base model shows the preferences of respondents, several models with different combination of interactions were tested in order to explain with more detail such preferences. TABLE 3 illustrates the best resulting model.

**TABLE 3 Final Multinomial Logit Model Results for Pedestrian Preferences with Respect to Roundabouts in Quebec with Interactions**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (β)</th>
<th>p-value</th>
<th>exp (β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular signs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interacted with male or female under 60 dummy variable</td>
<td>0.279</td>
<td>0.075</td>
<td>1.322</td>
</tr>
<tr>
<td>Flashing signs</td>
<td>0.615</td>
<td>0.000</td>
<td>1.849</td>
</tr>
<tr>
<td>Number of lanes</td>
<td>-0.348</td>
<td>0.000</td>
<td>0.706</td>
</tr>
<tr>
<td>Presence of Island</td>
<td>0.319</td>
<td>0.000</td>
<td>1.376</td>
</tr>
<tr>
<td>Crossing at the entrance</td>
<td>1.840</td>
<td>0.000</td>
<td>6.294</td>
</tr>
<tr>
<td>Crossing at 5m</td>
<td>2.374</td>
<td>0.000</td>
<td>10.741</td>
</tr>
<tr>
<td>interacted with female over 60 dummy variable</td>
<td>1.004</td>
<td>0.001</td>
<td>2.730</td>
</tr>
<tr>
<td>interacted with male over 60 dummy variable</td>
<td>0.691</td>
<td>0.002</td>
<td>1.996</td>
</tr>
<tr>
<td>Traffic Volume</td>
<td>-0.078</td>
<td>0.000</td>
<td>0.925</td>
</tr>
<tr>
<td>Traffic Speed</td>
<td>-0.324</td>
<td>0.043</td>
<td>0.723</td>
</tr>
</tbody>
</table>

Final Log Likelihood = -965.98  
Pseudo $R^2 = 0.3936$

Number of parameters = 11

As with the base model, this model produces results consistent with *a priori* hypotheses of the influences of the different variables. In addition, the log likelihood ratio test ($\chi^2=9.71$) indicates that the model offers better explanatory power than the base model at the 97% confidence level. With respect to the signs of the coefficients, it can be noticed that both regular signs and flashing signs are preferred over the absence of signs. As far as the crossing location is concerned, the model shows that users prefer roundabouts where the crossing is located far from the entrance (5m in this case); while a crossing at the entrance is preferred to no crossing at all.

In the case of two-level attributes, the signs of coefficients obtained in the model correspond to what was expected: vulnerable users prefer roundabouts where roads have fewer lanes as well as those with pedestrian islands. Lower traffic volumes and speeds are also preferred.

Still, one might ask just how important the different attributes are. To answer this question, we start with crossing distance. The presence of a pedestrian crossing at an intersection is obviously preferred to an intersection without a crossing. In fact, if a roundabout has an intersection with a crossing at the entrance, its odds of being selected increase by 529% over an intersection without a crossing. If a roundabout has a pedestrian crossing far from the entrance of the roundabout, its odds of being chosen are increased by almost ten times relative to one without a pedestrian crossing. Moreover, it is particularly important to notice the high preference that elderly people, especially women, have for this kind of crossing.

With respect to signs, the model reports that the presence of a flashing crossing sign increased the odds of choosing a roundabout by 85%, while regular signs are not significant to females over 60.

The analysis also reported that a greater number of lanes reduced the odds of a roundabout being chosen: an extra lane in the road represents a decrease of 29% in these odds. If the intersection had an island, the odds of being chosen would increase by 38%. As expected, the presence of high traffic volumes and speeds in the scenarios would decrease the odds of an
alternative being chosen: for every additional 100 vehicles per hour the odds of choosing a roundabout decrease by 7%, and for every additional 10 km/h in speed, these odds decrease by 28%.

Although the results confirm what we might expect by intuition (apart possibly from the location of crossings), the interest in using an SP analysis and estimating a discrete choice model lies in the ability to quantify the effect of each of the attributes, while controlling for the effects of all the other attributes.

Without a doubt, the results of the analysis can aid in proposing roundabout configurations that pedestrians prefer in terms of geometric and traffic control characteristics.

DISCUSSION AND CONCLUSIONS

Both the administration of the SP survey and the analysis of its results provide a rich field for discussion. First, it is necessary to highlight the methods used for delivering Choice Tasks to the respondents. As was alluded to in the literature review, there is little research where animations (simulated or recorded) are used in Stated Preference surveys. This research provides evidence for the feasibility of using micro-simulation videos in the context of SP surveys.

The modeling results can be interpreted as solid recommendations for the improvement of roundabout configuration in order to improve how vulnerable users view these intersections. A variety of pedestrian crossing positions can be found in roundabouts across Quebec, regardless of land use, levels of service of the road or neighborhood type where they are located. In this sense it is quite clear that vulnerable users would more readily accept the implementation of a roundabout if it had a pedestrian crossing away from its entrance. This is particularly important for users who are elderly. Although many operational attributes are difficult to control in the field, respondents have demonstrated through the survey that they feel safer when traffic volume and speed are low. Many different means of reducing both attributes exist, this research has also confirmed that vulnerable users consider a pedestrian crossing flashing sign (a speed control device) to be preferable to no signs or even regular signs. Evidently, it is difficult to imagine that all roundabouts in the area of study could be designed according to what pedestrians perceive to be their preferred characteristics: pedestrian crossing flashing signs, one-lane intersections, presence of an island, pedestrian crossing far from the entrance and low traffic speed and volume; but it is well worth taking them into account when implementing this type of intersection in the region.

Finally, this work presents a contribution to road safety research. As was previously shown, existing research exhibits no apparent use of SP survey data that considers pedestrians and vulnerable users of roundabouts. Moreover, this research explores methods not commonly used to deliver Choice Tasks to respondents.

FUTURE WORK

The innovative aspect of this current research suggests that there is plenty of room for testing findings and improving procedures. First, it would be interesting to compare the method presented here to a traditional text-based survey to evaluate which type of instrument would be better to use in this context. Without a doubt, this is a next step to consider for consolidating the use of simulations in this area of research.

More important, however, is the comparison between safety perception and actual safety. Although perceived safety is important for the acceptability of the design, the direct observation of user behavior and accident analysis relating to roundabouts and pedestrians (or vulnerable
users) would allow future research to propose well-defined recommendations in terms of safety regarding this type of intersection for these users. Assuredly, the best scenario to offer to vulnerable users is that in which guaranteed safety is closely linked to those items perceived as safer.

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