

# Designing Road Tunnels to Optimise User Experience and Safety: A User-Centred Approach

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## Abstract

User-centred design puts user needs and requirements at the center of product design and development. This paper outlines an approach used to define road user needs to optimise the customer experience and safety in Sydney road tunnels. This involved a literature review, focus groups and a self-reported online survey to obtain information regarding what drivers/riders do and do not like about driving in tunnels, and what they perceive they need and would like to see in future tunnels. Six focus group discussions, and three separate interviews, were conducted with Sydney tunnel users. Five hundred respondents completed the survey. This paper describes the study aims, methods and findings.

## Background

The Sydney Orbital Network includes over 160 kilometres of surface roads, tunnels, bridges and underpasses. The Sydney Orbital Network currently includes five main tunnels along the network and additional tunnels are being planned or are under construction. The customer experience and safety as users drive through tunnels are becoming increasingly important, as the future tunnel system will become longer and more inter-connected, and users will spend more time travelling within the tunnel network. The aim of this study is to undertake human factors research activities that will, collectively, provide a scientific framework for the collection of data on user behaviour and requirements that supports user-centred design and evaluation of Sydney tunnels to optimise customer experience and safety in tunnels. The project is being overseen by a project stakeholder group which includes members from government and industry with expertise in project development and delivery, human factors, road safety and road tunnel operations.

## Methodology

The methodology used to identify user requirements for tunnel design is described in Table 1.

*Table 1. Methodology for the identification of user requirements for tunnel design*

Step no.	Description	Tasks
1	Literature review and expert consultation	i. A targeted review of local and international literature was conducted. ii. Targeted consultations with four international road tunnel human factors experts were conducted.
2	Qualitative study	Six focus group discussions, and three separate interviews, with Sydney tunnel users were conducted. A discussion guide was used to structure the discussions.  Participants provided relevant demographic details and were asked 19 questions relating to tunnel use, requirements, driving/riding behaviour, likes and dislikes, design features (in Sydney and overseas tunnels), difficulties, and safety.

		<p>The focus groups included car/SUV drivers, motorcycle riders and a separate group of elderly car/SUV drivers. The three interviews involved truck drivers.</p> <p>Focus group and interview participants (n = 47; 18 females, 29 males) were aged 18 to 73 years, travelled through Sydney tunnels on a regular or irregular basis, and resided in Sydney.</p>
3	Quantitative study	<p>Data from a large-scale survey (n=500; equal numbers of males and females; aged 18 – 80 years) are currently being collected. The survey contained 24 questions relating to the same issues explored in the focus groups.</p>

## Results and Discussion

### *Literature review*

A thorough literature search revealed 49 relevant documents. Driver behaviour in, or adjacent to, a tunnel has been investigated in previous studies (Calvi & De Blasiis, 2011) and findings from them are discussed in the paper. Literature was also found and was reviewed on the impact of different tunnel design features on driver behaviour including entry/exit (Patten & Ceci, 2015), lighting (Domenichini, La Torre, Vangi, Virga & Branzi, 2017; Patten and Mårdh, 2013), tunnel walls (Kircher & Lundkvist, 2011), signs and markings (Upchurch, Fisher, Carpenter & Dutta, 2002), tunnel length (Amundsen, 1994) and communication with tunnel users (Mühlberger et al., 2015). The literature search revealed a number of documents that provide design guidance for optimising tunnel safety (Austroads, 2016; World Road Association, n.d.). These were reviewed, and recommendations made for optimising safety. The paper documents also the outcomes of consultations with four international experts in human factors and tunnel design.

### *Focus groups*

The focus group discussions were audio recorded and transcribed. The findings were divided into three categories (customer experience, feedback on tunnel design features, and safety) which encompassed responses to all of the questions asked in each focus group. The following are some key findings relating to user perceptions of safety in tunnels:

- Most participants from all groups reported that they feel less safe while driving through tunnels and one of the most commonly reported reasons was no or limited room for error.
- Many focus group participants reported tunnel illuminance levels to be either too bright or too dark. While elderly drivers felt lighting in tunnels was too bright, participants of other groups felt that tunnels were too dark and required brighter lighting.
- Participants from all groups reported that they had no clear idea about what to do if there was an emergency incident in a tunnel.

Other key findings relating to user safety, experience in tunnels and feedback on some novel tunnel design features implemented overseas will be reported in the paper.

### *Survey*

At the time this abstract was written 353 participants, aged 18 – 80 years, had completed the survey. The survey will yield a much larger database of information than the focus groups about what tunnel

users think they might need and would like to see in future tunnels. Statistical analyses will be undertaken to explore whether there are significant differences in responses between different tunnel users, by user group (e.g. car/SUV, motorcycle riders), age, gender and regularity of tunnel use. The findings will be reported in the paper.

## Conclusions

User-centred design of the road transport system puts user needs and requirements at the center of the product design and development process, ensuring that the design of the system takes into account human capabilities, limitations and needs. To our knowledge, consultation with end users to inform tunnel design to enhance customer experience and safety in road tunnels is novel in the road safety space. The research findings presented in this paper will also inform development of a Human Factors Integration Framework (HFIF). The framework can be used to audit, from a user-centred perspective, new tunnel designs – before and after implementation – to ensure that they optimise the customer experience and safety. It can also be used to inform tunnel-related community education programs.

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