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# Exploring the key challenges in tram driving and crash risk factors on the Melbourne tram network: tram driver focus groups

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## Abstract

Tram drivers have a difficult task in controlling one of the heaviest vehicles on the road whilst negotiating in a complex road environment. In Melbourne, Australia this includes operating trams on the largest tram network in the world. Here, tram drivers operate trams on traffic lanes shared with other road traffic, also along separated tram priority lanes, as well as on light rail sections. In addition to different tram lane configurations, tram drivers have to follow traffic signals at intersections whilst serve passengers at various types of tram stops often in close proximity to the waiting passengers. Like other public transport drivers, tram drivers also have the constant pressure for running on-time as well as the need to ensure passenger safety. Despite these clear challenges, very little research has been conducted on evaluating tram driving tasks and even less on relating route and road user factors with road safety from the tram drivers' viewpoint. The aim of this study is to investigate the key tram driving challenges as well as to identify crash risk factors along different tram routes, signal and stop settings from the tram drivers' point of view. Five focus group discussions were conducted involving thirty tram drivers in Melbourne. Key themes emerged inductively from focus groups were identified through audio-recorded data coding process. Findings of this research enhance understanding of tram driving challenges as well as provide an in-depth knowledge of the crash risk factors on tram routes from the tram drivers' viewpoint. The study outcomes could offer effective planning strategies for transit agencies to improve road safety.

*Keyword: Road safety, tram drivers, focus groups*

## 1. Introduction

Trams are light rail vehicles operating on tracks located on roads mixed with general road traffic. Tram systems have a number of attractive features including high passenger capacity, good comfort, and very low emission of pollutants compared to other transport systems. However, they have inherent safety concerns due to design, mass and operational aspects, especially under mixed traffic tram operating environment where general road traffic can use all road lanes including tram lanes (Hedelin et al., 1996, Grzebieta et al., 1999, Currie and Shalaby, 2007, Mitra et al., 2010, Candappa et al., 2013, Kruszyna and Rychlewski, 2013, Vandenbulcke et al., 2014). For instance, only 15% of total tram track length is in mixed traffic in the United States, yet more than 90% of light rail transit-involved crashes occur in the mixed traffic (Korve et al., 1996, Currie and Smith, 2006). A recent

study by Marti et al. (2016) analysed tram safety in Switzerland and identified safety concerns for tram operation in mixed traffic. Their study revealed that most of the tram involved collisions occurred with cars. Melbourne, Australia which has the largest mixed traffic tram network (Currie and Shalaby, 2007), experiences collisions between trams and vehicles, the passenger falls on board, collisions between tram and pedestrians and tram to tram collisions. Several studies have identified pedestrians and cyclists as the vulnerable groups of road users for tram involved serious injury crashes (Corben and Diamantopoulou, 1996, Hedelin et al., 1996, Vandenbulcke et al., 2014, Marti et al., 2016). Previous research has also identified safety issues at tram stops under mixed traffic tram operation (Korve et al., 1995, Korve and Siques, 2000, Currie and Shalaby, 2007, Wong et al., 2007, Naznin et al., 2015).

In addition, mixed traffic tram operation increases tram travel time, reduces average tram travel speeds and contributes to unreliable tram services. Tram priority measures are typically provided with the aim of improving tram travel time and reliability, and to improve the travel experience for tram passengers (Yarra Trams, 2010, Currie et al., 2012). However, the implementation of tram priority measures adjust the nature of road spaces and can have road safety impacts on all road users. A study conducted by authors have identified that the presence of tram priority measures including tram lane, signal and stop priority measures are addition effective for reducing tram-involved total crash incidents in Melbourne (Naznin et al., 2016b). Another study by authors revealed that the probability of tram-involved serious injury crashes is higher on tram priority lane sections (Naznin et al., 2016a). In addition to tram priority measures, the previous studies have investigated several road, traffic, transit, tram vehicle, environmental and driver-related factors that influence the tram-involved crash frequency and severity (Candappa et al., Cheung et al., 2008, Shahla et al., 2009, Mitra et al., 2010, Richmond et al., 2014, Naznin et al., 2016a, Naznin et al., 2016b). However, some of the reasons behind these findings are still not clear.

Previous tram safety research is almost entirely based on an analysis of historical crash data. However, the reported crash data can be associated with the issue of underreporting, and has the lack of detailed risk factors associated with crash occurrence (Elvik and Mysen, 1999, Lopez et al., 2000, Alsop and Langley, 2001, Giles, 2001). In addition to crash events, there are many ‘near misses’ crashes on roads and potentially serious consequences are prevented by taking evasive action by road users. To better understand a broader range of crash causation factors, researchers have stressed the need to collect near misses crash data which can guide preventive strategies to avoid future crashes (Hydén, 1987, Peden, 2004, World Health Organization, 2009, Van der Schaaf et al., 2013). Several techniques are available to explore factors that could lead to crashes or near miss crashes (Neale et al., 2005, Van der Schaaf et al., 2013) and a common practice is to survey road users, mostly drivers (Ulleberg and Rundmo, 2003, Castanier et al., 2012, Edquist et al., 2012).

A recent study conducted by Naweed and Rose (2015b), examined the tram driving task and evaluated human factors involved in tram-involved collisions in Melbourne. They combined accident reports, on-site observations, focus group discussions and individual driver interviews for their study. The results revealed three basic themes related to tram collisions: driver situation awareness, time pressure, and organizational behavior. Their other study (Naweed and Rose, 2015a) focused on exploring the factors contributing to tram to tram collision at two intersections with high crash risks at Melbourne. They observed tram activities at peak and off-peak periods, followed by 12 individual interviews and a focus group to evaluate the potential conflicting situations at the two intersections. Results identified several human factors including high workload across the network and lack of situation awareness, which increase the chance of crashes. However, both of the studies focused on particular high crash risk locations on tram routes and did not generalize their findings for the entire network.

In summary, very little research has been conducted on evaluating the key tram driving challenges. In addition, no study has investigated road safety concerns along different tram route design configurations, for different signal settings and for different tram stop designs from the tram drivers viewpoint. Therefore, it is worth evaluating the overall tram driving challenges and investigating the road user and road design factors affecting the road safety from the tram drivers' perspective.

# 2. Research aim

The aim of this paper is to investigate key tram driving challenges as well as to identify the crash risk factors influencing road safety along different route, signal and tram stop design contexts in Melbourne from the tram drivers' viewpoint.

# 3. Research method

Previous studies have deployed qualitative, quantitative or combination of both research approaches to survey participants depending on their study objectives (Morgan, 1996, Ghauri and Grønhaug, 2005, Hox and Boeije, 2005, Hennink et al., 2010, Bryman, 2015). Qualitative approach is being adopted by the researchers to examine people's experience in greater detail using several methods such as focus groups, in-depth interviews, observation, content analysis, visual methods, and life histories or bibliography (Creswell and Clark, 2007, Hennink et al., 2010). Among all qualitative research methods, focus groups allow free discussions among participants on multiple issues to a great extent and assist in obtaining insights in greater detail (Kenyon and Lyons, 2003, ETR, 2013). This approach brings a small group of people together to discuss an issue with a structured questions, but with the flexibility to accept any other relevant issues arising from discussions (Connaway and Powell, 2010). Focus group is a widely adopted research approach in the field of transportation research (Billheimer, 1990, MacMillan and Hewitt, 2008, Glendon, 2013, Kellard and Fishman, 2013, Naweed and Rose, 2015b). For this research, tram driver focus groups were considered as the suitable mean of data collection, as this particular research method allowed participants to describe their tram driving challenges and perceptions of road safety in greater detail through group conversation.

## 3.1. Data collection

For the current study, five tram driver focus groups were conducted in Melbourne to explore tram drivers views and opinions regarding tram driving challenges and road safety. This study was approved by both Yarra Trams, the Melbourne tram operating company, and Monash University Human Research Ethics Committee (MUHREC). Participants were recruited with the generous assistance of the Tram Company.

The sampling method adopted for this study was purposeful sampling. The purposeful sampling approach is adopted if the goal of research is to obtain insights into a phenomenon and the researcher purposefully selects individuals, groups, and settings that can maximize the understanding of the phenomenon (Onwuegbuzie and Leech, 2007). In this research, tram drivers who have experience of driving trams along different tram lane configurations (e.g. light rail section, tram priority lanes, mixed traffic lane), under different signal settings (e.g. separate white T light, white arrow, hook turns, turn bans) as well as have experience of serving passengers at different types of tram stops (e.g. platform stops, curbside stop, safety zone stops, easy access stops) were selected for this study.

A detailed review of tram routes characteristics suggests that three tram depots in Melbourne (Kew, Southbank and Preston) operate six tram routes (tram route number 11, 12, 48, 86, 96 and 109) which comprise all route, signal and stop features under consideration for this study. Yarra Trams randomly selected tram drivers from the selected three depots who were interested in participating and discussing their driving experiences and concerns. A total of 30 tram drivers (26 male and 4 female) from 3 different tram depots

participated in the study. Participants age ranged from 29 to 63 years, with an average age of 47.6 years (standard deviation of 10.1 years); and tram driving experience ranged from 1.17 to 31 years, with an average experience of 12.5 years (standard deviation of 10.2 years).

**Figure 1** shows the distribution of tram drivers' age and experience for both drivers' population and sample participants in the study. A very similar distribution of drivers' age and experience for both population and sample demonstrated that the participating drivers were representative of the drivers' population in terms of age and experience. Regarding gender representation, the proportion of female drivers (13%) participated in focus groups was close to the proportion of female drivers (16%) in the tram driver population currently working for Yarra Trams.

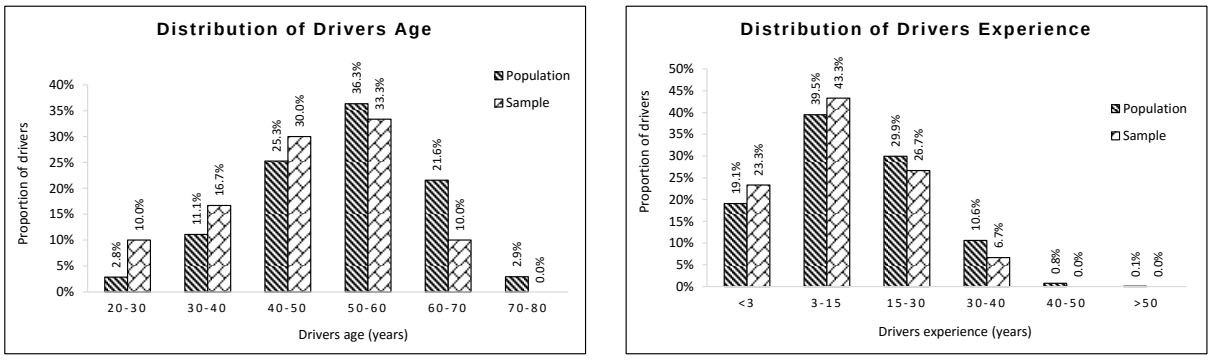


**Figure 1 Distribution of Tram drivers' age and experience**

## 3.3. Focus group format

All five focus groups were conducted during March and April 2016. Each session lasted for approximately 60 minutes. This period allowed the authors of this paper to explore issues in greater depth whilst actively engaging all participants. Four focus groups out of five had 6-7 participants, while the remaining group had four participants. All discussions were audio recorded with the permission of the participants. The detailed composition and location of each focus groups is shown in **Table 1**.

**Table 1: Location and composition of focus group discussion sessions**

| ID | Number of participants | Gender | Age (years) | Experience (years) | Name of Depot | Mostly driven tram routes |
|---|---|---|---|---|---|---|
| 1 | 6 | 2 Female, 4 Male | 29 - 59 | 1.17 - 26 | Kew | 48, 109 |
| 2 | 6 | All Male | 34 - 56 | 2 - 20 | Southbank | 12, 96 |
| 3 | 7 | 1 Female, 6 Male | 29 - 63 | 2 - 14 | Southbank | 12, 96 |
| 4 | 7 | 1 Female, 6 Male | 30 - 57 | 2.5 - 31 | Preston | 11, 86 |
| 5 | 4 | All Male | 49 - 62 | 3 - 31 | Preston | 11, 86 |

## 3.4. Discussion guide and informed consent

A discussion guide was developed beforehand to uphold the discussion and to cover all the aspects of the study. Before commencing each discussion session, the facilitator read aloud the explanatory statement of the research to deliver an outline of the discussion. Participants were given a copy of the explanatory statement for their reference and a consent form to sign.

The discussion guide was set in such a way that results are not biased in terms of road safety. Participants were not informed before the discussion that the study was about road

safety, rather their responses to initial questions were about challenges they had in driving. In addition, no attempt was made to ensure that the comments from different sessions are shared between groups. These approaches ensured comments made were the unbiased perceptions of the participants.

### 3.5. Data analysis

Audio-recordings of the focus groups were fully transcribed to yield verbatim transcripts, using NVivo data analysis software (NVivo, 2012). A verbatim transcript is essential to capture information in participants own words, phrases, and expressions. In accordance with the guidance on qualitative data analysis described by Hennink et al. (2010), the codes were developed inductively based on the evidence in the focus groups data through line-by-line reading and re-reading of the transcripts. Finally, key themes were identified from the developed codes using a data coding process.

# 4. Focus group outcomes

Focus group outcomes include key emergent themes, and the key codes formed the themes. All themes are presented with quotations to demonstrate and support the narrative suggested by the data. Quotations identify for the respondent's age and years of tram driving experience.

### 4.1. Key challenges in tram driving

Each group discussion opened with a question to explore participant's key tram driving challenges. A wide range of challenges emerged. However, the first and most unprompted and important challenge identified by most tram drivers is the safety for all people in and around the tram:

> *Avoiding accidents are number one challenge for me (Tram driver of age 49 and has experience of 3 years)*
>
> *Whichever angle you look, safety comes first anyway. (Tram driver of age 62 and has experience of 28 years)*
>
> *The generic answer is to keep everyone safe as much as possible in and around the tram….you just can't take your eyes from the road for as second….. Even a split second. (Tram driver of age 34 and has experience of 7 years)*

On-time running was identified as the second most important challenge for most of the tram drivers. They repeatedly mentioned about their pressure for running on-time urged by the company management. This perceived pressure induces drivers to take more risks while driving and increases the risk of collisions:

> *The key challenge is running trams into a timing frame. That's where we try to take a shortcuts, cut corners. That's why the safety is sometimes overridden…..Because we got our time frame: A to B, B to C and so on…We speed up more than we are supposed to do.....try to go through amber, may be a red light. That's all because of time pressure. (Tram driver of age 62 and has experience of 28 years)*

It is perhaps obvious that tram drivers need a high level of concentration and to be vigilant all the time while driving trams. However, keeping concentration on the road all the time is a big challenge for drivers, because lapses in concentration can result in serious collisions. Serving passengers on board is a key reason for interruption and distraction of drivers' concentration, as noted by most of the drivers:

> *When you are on the road, you have pedestrians, cars, motorcycle, cyclists every users interfere with the tram path…… It's up to the tram drivers to pay extreme attention (Tram driver of age 58 and has experience of 31 years)*

*Lots of the time when you are driving lot of the customers knock and distract you most of the time. Ask questions…….and then sometimes suddenly you talk and miss something. (Tram driver of age 56 and has experience of 7years)*

Tram drivers repeatedly stated their 'defensive tram driving' attitude to avoid any incidents on the road. However, they noted constraints regarding tram operational aspects. Trams operate on a guided track on the road and have complete restraint on any lateral movement. To avoid any crash incident on the road, tram driver's only possible reaction is to brake. However, trams have a long braking distance to a full stop, which makes it impossible to avoid an incident on some occasions. A major requirement is to anticipate likely future movements of other road users to brake early. So anticipating other road users' action in advance is another key challenge for tram drivers, and this prediction skill increases with experience:

*Most of the time we are defensive drivers…. Because it's a big vehicle and heavy, and be carrying at one stage 120-130 people. Can you imagine if something goes wrong (Tram driver of age 59 and has experience of 26 years)*

*People don't realize that many accidents are avoided probably because of our patience. Even though he is not showing his indicator but we know exactly what he is going to do. It's like sometimes you can read their mind. It comes from experience. (Tram driver of age 43 and has experience of 6 years).*

Although tram drivers only reaction in an incident is to brake, many drivers stated that they hesitated when pulling the emergency brake, as it can result in passenger falls inside the tram; a major concern for tram drivers. Sometimes they need to compromise safety between road users and on board passengers, when an emergency arises:

*I think it would be in every tram driver's mind to go into emergency brake could mean someone falling on the tram. And I reckon every driver would hesitate. It may be a microsecond, but they would hesitate before they hit the emergency brake. And that microsecond could be enough to make the difference between not hitting a car or hitting or someone falling. (Tram driver of age 56 and has experience of 7 years)*

Another key challenge for tram drivers is to manage the fatigue workload, which can have negative road safety impacts. They also have inconsistent shift works, which do not allow enough time for drivers to get used to a new shift:

*We got shift work. I found that a bit of an issue as well. Trying to balance your work and social life, because we work in weekends, afternoons, mornings. (Tram driver of age 49 and has experience of 3 years)*

**Figure 2** presents the key themes emerged from focus groups regarding tram driving challenges. The themes are numbered based on their importance to tram drivers by counting the stated frequency. The most frequently noted tram driving challenges are safety in and around trams, on-time running pressure, keeping concentration on the road, tram operational constraints, passenger falls on trams, anticipating other road users' action in advance and fatigue workloads. One interesting finding was that all key challenges were found to be linked with road safety from the tram drivers' viewpoint.


**Figure 2: Major themes emerged from key challenges in tram driving**

In addition to the key challenges in tram driving stated above, participants identified several road user factors which have road safety concerns and are the key challenges for driving trams safely. Tram drivers' perceived other road users are unaware of tram presence, have a poor understanding of road rules while driving with trams and have a tendency to violate road rules around trams.

## 4.2. Safety perceptions on alternative tram route sections

A key focus of this research was to understand participants' perception of road safety along different tram road section designs, including mixed traffic roads, light rail sections and tram priority lane sections. Tram lane priority treatments comprise of raised tram tracks, tramways delineated by yellow strip kerbing, full and part-time tram lanes.

In each focus group, tram drivers were first asked to consider and identify "safe" route sections on their routes to understand their unprompted definition of safe route section. One interesting finding from most of the drivers' opinions is that 'there is no safe route section'; i.e. they do not perceive any route section as safe. This perception helps drivers to concentrate on all route sections to avoid any crash incident. Then the discussion question

was rephrased by the word 'safer' road sections. Participants then mentioned that some route sections are safer than others, but not completely safe:

*There is not such a thing ….this part is safe and this part is unsafe. No no...If we start thinking like that, we are in trouble. For us as a tram driver, every part of our route is unsafe. We have to think like that. Otherwise you hit someone. (Tram driver of age 59 and has experience of 26 years)*

*I don't think any of the section is safe. Because does not matter where on the track you are. Somebody can step in front of you even on the light rail. So none of them are safe. Some of them are safer than others. But not the word safe. (Tram driver of age 55 and has experience of 2 years)*

There was strong support for raised tram tracks in all focus groups in terms of its impacts on improving road safety. These are mostly the new and extended tram route sections in Melbourne. Tram drivers perceived this measure as an effective way to reduce crashes:

*Raised tram track is the one that's what I say the priority for the trams. (Tram driver of age 58 and has experience of 31 years)*

*There are some sections of the city, a bit higher; that's fantastic. If they can do it all in our road, that can be fantastic. If elevated track at least they (motorists) cannot make U-turns. (Tram driver of age 59 and has experience of 26 years)*

Most of the drivers mentioned positive road safety benefits for tramways with raised yellow kerbing beside tram tracks. In this case, motorists better perceive the separation line since they can feel the vehicle tires jerk when crossing the kerbing. Tram drivers felt that this type of kerbing can act to remind motorists to stay clear from the tram track:

*I give that a tick, the raised yellow kerb, it's good. I think people feel it when they (drivers of cars) go over it. (Tram driver of age 48 and has experience of 6 years)*

*Raised yellow kerb, yellow plastic that is good. The reason I said this is along Collins Street I can remember how many accidents every week we used to have on Collins Street. After they put this, it dramatically reduced. As soon as the car hit the yellow kerb they get the feeling they have done something wrong…. That yellow hump sends the message. The tire is bumping. So the drivers know he is almost crossing that tram track. (Tram driver of age 58 and has experience of 31 years)*

However most of the drivers stated that motorists are mostly ignoring part- and full time tram lanes (with painted yellow demarcation line beside the tram track and an overhead sign). Tram drivers held a strong opinion that any potential road safety benefit from these priority tram lanes could not be attained in Melbourne due to poor awareness among car drivers and lack of road rule compliance by other road users, as well as lack of enforcement by authorities. However few did mentioned some partial positive road safety impact of these lanes.

*One frustration I have is we do have part time tram lanes on some or probably most of the routes in Melbourne during peak hours. There is virtually no compliance. (Tram driver of age 36 and has experience of 12 years)*

*Full time tram lanes are good if they (motorists) can see the yellow line. (Tram driver of age 48 and has experience of 6 years)*

*I saw an accident …..And I asked the motorist, did you see the yellow lines. He said what yellow line. What is the meaning of that? (Tram driver of age 50 and has experience of 26 years)*

Melbourne trams share most of the routes with other road users (termed as mixed traffic tram operation) and experience delays. To maintain the schedule, most of the tram drivers

stated that they speed up along separated tracks i.e. on priority lanes and this increases the possibility of occurring more serious crashes. Some drivers stated that in terms of crash severity, the mixed traffic tram operation is safer than segregated track, as drivers concentrate more in mixed traffic, and speed is lower compared to the priority lanes.

> *[The severity of accidents are much greater at Nicholson Street (separate right of way with raised yellow kerbing). You have got speed, and someone does cut in front of you, its bang. I think the accident probably more likely to far more severe as speed is high... (Tram driver of age 56 and has experience of 7 years)]*

> *Even reserve track are the most dangerous part. We think its reserve its ok to catch up with time. Mostly drivers speed up not for the purpose of enjoy speedy driving, to catch up the time. When you are coming from the city some drivers I am pretty sure 5 to 6mins they are down. So the catch up time is there on the reserve track. At least you can pick up the speed. So any car happened to turn is gone. The problem is cars can make turns through the cut off points by providing right of way to trams but they don't. (Tram driver of age 58 and has experience of 31 years)*

Light rail sections (entirely segregated heavy rail like track) are typically considered safer as the tram has its own right-of-way separated from the road. However, some drivers raised safety concerns along light rail tracks, especially due to unsafe pedestrian crossings on these tracks:

> *We have the light rail sections that is safe. But at night time not have very good lighting, then is not safe. Because you don't know who is walking on the tracks. You are not gonna see them and you gonna hit him. So it's safe during the day but at the nights it can be a struggle. (Tram driver of age 63 and has experience of 11 years)*

## 4.3. Safety concerns at intersections

Tram drivers identified a wide range of factors that affect safety at intersections. They believed that large (or wide) intersections are unsafe, as there are different sets of traffic lights, and road users frequently misread the light sequences and make wrong decisions.

In Melbourne, trams are given priority at intersections by introducing separate 'T' light for trams, as well as by providing 'hook turns'[1] and turn bans for other motorists (Yarra Trams, 2010). Most of the participants highlighted the positive road safety benefits of hook turns. Few of them mentioned about the unfamiliarity and lack of knowledge among motorists regarding hook turn manoeuvre, which could result in collisions at intersections. Tram drivers appreciated the road markings and flashing 'wait' signs at intersections which instruct motorists to make hook turns properly.

> *Hook turn is fantastic. Nothing goes wrong with hook turn. So far I never see any driver come to me and said that I have problem. (Tram driver of age 59 and has experience of 26 years)*

> *It's fine for our (Melbourne) motorists here as they know the hook turns rules, but people coming from other interstate, they don't know the rule. They want to be one step ahead just to avoid the instances. (Tram driver of age late 40 and has experience of 4 years)*

Almost all drivers appreciated the presence of 'T' light for trams, as it improves tram travel time[2]. However, many of them were not sure about the road safety impact of the 'T' light. Some of them mentioned that the 'T' light creates confusion among car drivers as they think it as their light and start to cross the intersection, which is dangerous. In addition to white 'T' light, there is white arrow sign for trams to turn, and this light is frequently being misjudged

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*[1] 'Hook turn' is a unique signal setting in Melbourne, which relocates opposing turning traffic at intersections to allow uninterrupted tram movement through intersections (refer to section 2.2.2)*
*[2] 'T lights' are part of the active signal priority system provided for Melbourne trams.*

by motorists who make turns when the traffic light is reserved for the tram. A very common issue identified from all focus groups is the short duration of 'T' lights which do not allow trams to complete the manoeuvre at intersections.

*T light is better for our time and our priority. I don't think it's good for safety or bad. (Tram driver of age 40 and has experience of 2 years)*

*In some respects T lights are dangerous too as some people just cannot realize that T light is there. So that's when you get T light and you start to move and some other starts driving in front of you. (Tram driver of age 49 and has experience of 20 years)*

*One thing is that we get white arrow and white T. I don't believe we should get white arrow. Because too many car drivers misconstrued the arrow for them to turn. ……when they see a white arrow and they don't know whether the light faded or not green anymore and attempted to go. It happens all the time. (Tram driver of age 55 and has experience of 2 years)*

*It's (T light) not long enough. It's only designed to get you into the intersection. If you are ready to go, it get you into the intersection. (Tram driver of age 55 and has experience of 2 years)*

Some more issues were identified by the tram drivers which can have road safety concerns, including ignorance of 'no right turn signs' by other road traffic.

*'No right turn' sign, who cares. Unfortunately, these signs not even work, the reality is not like as can be seen. (Tram driver of age 59 and has experience of 26 years)*

## 4.4. Road safety issues at tram stops

Road safety impacts of different tram stop types in Melbourne were discussed in all focus groups. The aim was to identify the safety perception of tram drivers for new design tram stops (e.g. platform stops, easy access stops) compared to the older design stops (e.g. kerbside stops and safety zone stops):

'Platform tram stops' were clearly identified as the safest type of tram stop for passengers by almost all tram drivers. Participants stated that platform stops provide long and safe waiting area for passengers and allow level boarding for all passengers, even passengers with a disability. In addition, platform stop design can act to reduce interactions between passengers and vehicles as passengers cross the traffic lane under pedestrian signal lights:

*Anything with the platforms are safe for passengers and for tram also. But without platform stops passengers with walkers, elderly people, shopping bags it's very hard to step up on an E-class tram. It's hard for disability and elderly. Platform stops are safe 100%. (Tram driver of age 49 and has experience of 3 years)*

Some safety concerns at 'kerbside' tram stop were identified by most of the participants. Tram drivers noted that the motorists are unwilling to stop behind a tram at these type of stops and they become impatience in wanting to overtake trams (which must be done on the inside lane where passengers access trams). As a result, passengers are being hit by cars while boarding and alighting and have serious crash risks:

*At road side stops, motorist don't stop. Sometimes they just go between passengers, among passengers, pushing passengers. And you have elderly, you have people with kids that cannot move very fast out of the traffic. At that moment as a tram driver you feel very useless and try to help people. You gong and they don't listen. (Tram driver of age 40 and has experience of 2 years)*

*At stop (kerb side stop), car does not wait there, they are just impatient they go on the other side, the offside. Lot more of that happening. What if a passenger gets off and goes that way from the tram, he sees no one coming and hit. (Tram driver of age 49 and has experience of 3 years)*

Safety zone stops, mostly are located inside and near the CBD, and were in general perceived as safer by tram drivers compared to kerbside stops. However some safety problems were noted as a result of their narrow passenger waiting area design. Participants also explained how these stops get crowded due to growth in passenger numbers after introduction of the free fare tram zone in the CBD:

> *Safety zone stops are fine and safe. Because you don't have that option for cars to pass within open doors like kerbside stops. (Tram driver of age 29 and has experience of 2 years)*

> *I found a couple of old design stops; safety zone stops. There are still a couple in CBD. And it's quite a narrow. And often with the free tram zone there are just so many people now. They really need to be better designed for that just because you often get to the stop. You cannot get in because there too many people there already blocking the tracks. (Tram driver of age 30 and has experience of 2.5 years)*

The 'easy access' stops are a new design stops in Melbourne, which are located in the kerbside lane. The road pavement in the kerbside lane is raised to allow passengers level access from the footpath to the tram door. Among all of the stops, tram drivers consistently perceived these stops as the most dangerous type of stop. Because passengers share these stops with the traffic, and road users often have confusion and lack of knowledge about the right of way of this raised ramp on the road:

> *Recently the new ramps are being created in kerbside lanes called easy access stop. Here we pull up effectively to a platform. Pedestrians come across like on the road. Pedestrians share that stop with the traffic. Pedestrians believe that is a platform stop. So they wander up and down it. Stand in the middle of it. Car users tend to think that it's a launching ramp. The closer they get to the ramp the faster they go. Other drivers get toward it and think do I go left or do I go right. They are probably the worst stop. As no one knows really what they are doing. (Tram driver of age 55 and has experience of 2 years)*

At all types of stops, a common issue identified by tram drivers was passengers' attitudes. Many passengers get down from the tram and go behind the tram to cross the road. This presents a serious crash risk, as trams coming from opposite directions cannot see them, and crashes can occur:

> *I think we have a more of a tendency for people to walk around the back of the tram. And when you are coming at the back of the tram, the hazard is a tram come from the opposite direction they cannot see you. (Tram driver of age 56 and has experience of 7 years)*

### 4.5 Suggestions to improve safety:

Tram drivers made several suggestions to improve road safety. They mostly focused on educating people and introducing safety campaigns to raise awareness among road users in and around trams. All tram drivers were concerned about the absence of law enforcement on the tram network. Although road users are violating road rules, no penalty is being applied to warn them, and this eventually increases the tendency among road users to ignore the road rules more. They believed that the presence of enforcement authority on the tram network can improve road safety significantly.

## 5. Conclusion

The research adopted tram driver focus groups to explore road safety issues on tram routes from the tram drivers' point of view. The discussion started with an idea of exploring the key challenges in tram driving. The first key unprompted challenge identified by most tram drivers is the safety for all people in and around the tram. The other key issues are the pressure for on-time running, maintaining constant concentration on roads for all the time, predicting other road users' behaviour in advance to avoid any crash incident, passenger falls on board and fatigue workloads. One interesting finding was that all key challenges

were found to be linked with road safety from the tram drivers' viewpoint. In addition to the key tram driving challenges, tram drivers' perceived other road users were unaware of safety issues around trams, the poorly understand of road rules about driving with trams and often violate road rules around trams. From the tram drivers viewpoint the above road user behaviours are key challenges for driving trams safely.

Tram drivers discussed road safety issues related to different types of tram lane configurations, signal settings and stop features. Tram drivers perceived raised tram tracks and tramways with raised yellow kerbing beside tracks as safer lane priority features on the Melbourne tram network. Full-time and part-time tram lanes were not perceived to have any road safety benefit due to a perceived lack of road rule compliance by other road users. 'Hook turns' for the general right turning traffic at intersections were identified as a safe form of tram signal priority measure in Melbourne. Tram only signals and 'T' lights at intersections were strongly believed to have positive tram travel time benefits, but tram drivers did not see any road safety benefit available with these measures. Platform tram stops were acknowledged as the safest type of stop design by tram drivers, whereas they raised several passenger safety concerns at kerb side, safety zone, and easy access stops.

Finally, tram drivers made several suggestions to improve road safety. They mostly focused on educating people and introducing more safety campaigns to raise awareness among road users in and around trams. The absence of law enforcement on the tram network was criticized by most tram drivers. They noted that although road users are violating road rules, no penalty is being applied to warn them, and this eventually increases the tendency among road users to ignore the road rules. They have also suggested giving trams absolute priority over all other road users on tram routes to improve road safety. This study deployed focus groups to explore road safety issues on tram routes from the tram drivers' point of view.

This research did not expect an informed and mature discussion on crash risk factors from the drivers, given that they are not road safety experts. However, the aim was to obtain their experiences and insights of tram driving in a very complex environment on the Melbourne tram network. In doing so, the key focus was to develop an understanding of the key road user and road design factors affecting tram safety from tram drivers' viewpoint.

The research outcomes will suggest both transit and road authorities to consider the road safety impacts when planning and evaluating new transit schemes. The outcome of this study will help to develop effective measures to minimize the risks of collisions on tram routes. There is a clear area for future research to statistically validate the findings from the tram driver focus groups by conducting a formal questionnaire survey involving all tram drivers. In addition, other road users e.g. motorists or tram passengers can be interviewed to understanding their perspective of road safety related to trams.

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