FACTORS SHAPING PEDESTRIANS’ UNSAFE BEHAVIOUR AT ACTIVELY PROTECTED LEVEL CROSSINGS

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Level crossings, Pedestrians, Pedestrian Unsafe Level Crossing framework (PULC), Systems approach, Errors, Violations, Direct observations, Focus Groups, and Video-survey
Abstract

In the Australian crossing context, active level crossings can be equipped with the highest level of protections for pedestrians comprising lights and automatic gates. Nevertheless, more unsafe behaviour has been reported at active level crossings than at passive crossings. Level crossings are complex open systems that mix components and dynamics related to both the road and the rail infrastructures. The crossing situations at level crossings are variable and pedestrians’ behaviour is influenced by specific factors likely to change over time. This complex system imposes a difficulty in the study of pedestrian behaviour due to the combinations and interactions of factors related to characteristics of the physical, the social or the organisational environment. Significant gaps in the literature on pedestrian behaviour at such intersections were identified and supported the formulation of three research aims, which were addressed in two research stages. The first two aims concerned the collection of detailed qualitative information on different factors contributing to errors and violations. The third aim was to examine the impact of such factors across various crossing situations.

The first stage of this research was exploratory and addressed the lack of detailed descriptive information on the multiple factors influencing pedestrian behaviour and on the cognitive and motivational precursors underpinning unintentional (errors) and deliberate unsafe crossing behaviour (violations). Two studies with different methodologies were conducted to provide data of a complementary nature. The first study consisted of the direct observations of pedestrian behaviour during three weeks at three black spot level crossings in the Brisbane area (Queensland, Australia). The second study used the method of focus group discussions with pedestrians who were frequent users of black spot level crossings in the same area.

Addressing the first aim, the observations provided for the first time a quantitative and qualitative picture of pedestrian safe and unsafe behaviours at active level crossings in Brisbane. A total of 129 transgressions of the active controls were observed during the 45 hours of observations in the morning and the afternoon peak hours. Looking into the factors associated with transgressions, the results showed
that globally, pedestrians tend to transgress after the activation of the pedestrian lights and sound and to a smaller extent after the gates are closed and in the presence of a visible train. The results also showed that transgression patterns are related to several groups of factors, like the characteristics of the LC design and the physical environment (e.g., the location of the platforms), the personal characteristics and goals (e.g., demographics, crossing to the other side vs. catching the train), the social environment (e.g., the presence of others). Specifically, a lower number of transgressions were observed at the LC where two passenger tracks had to be crossed to access the platforms, the different LC sites were associated with transgressions of different demographic groups of pedestrians adopting different trajectories, and some LCs were associated with group transgressions, and others with transgressing alone.

To address the second research aim – to identify the precursors of behaviour associated with errors and violations – focus groups with a small number of participants were conducted ($N = 12$). This method facilitated the collection of rich information about individual experiences at level crossings and enhanced the sharing of sensitive information between members of homogenous groups. A deeper explanation was obtained of how categories of the previously observed and newly emerging risk-contributing factors influence different types of unsafe crossing (errors and violations). A multitude of risk factors were associated with the formation of attitudes, knowledge and expectations related to safe and unsafe crossing. The structure of the discussions as well the analyses of the results were based on a newly proposed systems-based framework, developed as a tool for the better understanding of pedestrian crossing behaviour at LCs, called the Pedestrian Unsafe Level Crossing (PULC) framework. Unlike other systems-based models, this framework provided a more comprehensive understanding of the cognitive and motivational mechanisms underpinning pedestrian behaviour at LCs. More factors were identified associated with violations rather than with errors. The results were consistent with evidence from the literature suggesting that violations are underpinned by factors related to previous crossing experience at level crossings, and more generally to familiarity with the system procedures (e.g., sanctions) and performance (i.e., previous occurrences). The focus groups provided clarifications on how behaviour is differently influenced by the presence of known versus unknown others in the crossing context. In addition, participants appeared to perceive themselves as less at
risk than specific demographic groups of others. Risk perception was associated with what pedestrians perceive as “common” behaviour amongst the larger population. Motivations were associated with unwillingness to wait (i.e., shortcuts) and time pressure (e.g., being on time somewhere). In the end of the exploratory stage, it could be concluded that crossing decisions are made to a large extent according to the status of the controls and to the train’s position. The results from the exploratory stage underlined the need for further research on the impact of these factors in different crossing situations.

The third research aim was to examine the impact of different risk-contributing factors on behaviour across various crossing situations. To that end, the second empirical stage of research consisted of one survey study, measuring self-reported transgressions and transgression likelihood across various recorded “real-world” crossing situations. The survey was completed by a Queensland state-wide sample of pedestrians (N = 222) who were used to crossing at LCs across all metropolitan rail lines. The study was designed to examine a wide range of cognitive and motivational precursors associated with familiarity and characteristics of pedestrians’ usual crossing behaviour. Furthermore, it measured and compared transgression likelihood and perception of risk across five “real world” crossing scenarios associated with different levels of risk, which were recorded at level crossings in Brisbane. Building upon results from the exploratory stage of research, the trains’ position and the status of the active controls were the main variables manipulated in the five crossing scenarios presented in videos. The first scenario corresponded to crossing during the activation of pedestrian lights and the second to crossing while the pedestrian gate is closing. In these two scenarios an approaching train was not visible. In scenarios 3, 4 and 5 the pedestrian gates were fully closed and a train was visible in different positions (i.e., stopped, express approaching, and two trains approaching from opposite directions – the first train being visible at the beginning of the video and the second in the end). Generalisable to the larger population, the results confirmed that pedestrians from different demographic groups are equally likely to engage in unsafe behaviour. However their behaviour was associated with different precursors. Critical context-related factors were shown to have a strong effect on decision-making, as participants reported different transgression likelihood across the scenarios. Globally, the highest transgression likelihood was reported after the lights
and sound are active but before the pedestrian gates have started moving. The reported perception of risk varied in the presence of other pedestrians, if crossing close to a train station, or if a train was visible. Furthermore, consistent with the findings from the focus groups, participants expressed strong perception of having safer behaviour than others, and of being less at risk than others if crossing unsafely. Demonstrated for the first time in a level crossing domain, these optimistic comparative judgements were strong predictors of transgression likelihood across all crossing situations.

This research program investigated individual behaviour accounting for influences from various components of the larger system. Consistent with modern systems approach and employing traditional individual-centred methods, the cumulative results from the three studies demonstrates the benefits of using both approaches in a complementary manner.

The research program resulted in theoretical and practical contributions. Specifically, a new tool for the investigation of pedestrians’ unsafe behaviour was proposed, which could be used and adapted for various research or practical purposes. The results from the in depth study of the origins of unsafe behaviour provided knowledge, lacking in the literature to date, on the factors that should be considered to reduce unsafe behaviour. The studies also identified issues with the design of concrete LCs which are likely to enhance unsafe behaviour and therefore deserve more attention from rail authorities.
Résumé

Le nombre des collisions avec des piétons aux passages à niveau restant stable dans les dernières années, c’est un problème majeur au niveau international. Suite à la revue étendue de la littérature, des lacunes scientifiques importantes liées à l’étude du comportement du piéton ont été identifiées. L’objectif principal de ce programme de recherche était de contribuer à mieux comprendre le comportement du piéton aux passages à niveau actifs en Australie, où malgré la mise en place des protections renforcées pour les piétons, le nombre de collisions reste plus important que sur les autres types de passages à niveau. Trois études ont été réalisées pour répondre aux trois buts de recherche que nous nous proposons d’examiner dans le cadre de ce programme.

La première étape de recherche qui est exploratoire a été réalisée dans le cadre des études 1 et 2 dont les conclusions ont permis d’identifier les facteurs influençant la prise de décision aux passages à niveau. A la fin de cette étape un nouveau modèle systémique a été développé pour servir d’instrument à l’analyse du comportement du piéton, influencé par des facteurs de tous les niveaux du système. Dans la deuxième étape empirique de recherche, nous avons mené l’étude 3 pour examiner l’impact de facteurs clés sur les comportements à risque dans différentes situations à risque de traversée des piétons. L’articulation des trois études est une illustration des bénéfices associés avec l’utilisation à la fois des méthodes systémiques et traditionnelles, résultant des contributions théoriques et pratiques importantes.
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Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: __________________________

Date: 02/06/2016
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# Glossary of terms and acronyms

## General terms and acronyms

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<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>LC</td>
<td>Level crossing, an intersection where road and rail infrastructures meet on the same level</td>
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<tr>
<td>LC zone</td>
<td>The area of the rail corridor where the crossing of road users is allowed.</td>
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<tr>
<td>LC closure</td>
<td>The period from the onset until the cessation of the active controls at a LC</td>
</tr>
<tr>
<td>Train horn</td>
<td>“All trains using the Queensland Rail network are fitted with a train horn (also known as a klaxon). The sounding of the train horn is a critical safety measure to warn people in or near the rail corridor that a train is approaching or about to move. The sound of train horns is distinctive … and its volume must be high enough to be heard over other sources of noise in the environment, including auditory distractions such as personal music players and car stereos. Train horns are sounded for various situations, including at whistle boards …, when a train is about to move from a stationary position, and when approaching workers or members of the public on or near the track. Horns are also sounded at the discretion of the driver in emergency situations.”</td>
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<tr>
<td>Whistle board</td>
<td>“Whistle boards are strategically located within the rail corridor on the approach to high risk locations such as level and pedestrian crossings, bridges and tunnels. When a train passes a whistle board, the train driver must sound the horn so pedestrians, motorists and track workers know a train is coming. Because people use our crossings during both day and night, train drivers need to sound the horn at whistle boards regardless of the time of day.” (Queensland Rail, 2015)</td>
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<tr>
<td>Road users</td>
<td>Refers to all users of level crossings including different types of motorised vehicles, pedestrians and cyclists.</td>
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<tr>
<td>Motorists</td>
<td>All types of motorised users including but not limited to truck drivers, car drivers, motorbikes drivers, special vehicles drivers etc.</td>
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<tr>
<td>Pedestrians</td>
<td>A person on foot (walking, running, standing, playing etc.), or a person using a pedestrian conveyance (e.g., non-motorised wheelchair, roller skates, roller blades, child's tricycle, skateboard, scooter or other non-powered vehicle, excluding bicycles). Includes a person who is alighting or boarding a vehicle (Transport and Main Roads, 2012)</td>
</tr>
<tr>
<td>Transgression</td>
<td>(A user) Crossing illegally during a closure, without information on</td>
</tr>
<tr>
<td>(transgressor)</td>
<td>the intentionality of the act</td>
</tr>
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<td>--------------</td>
<td>-----------------------------</td>
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<tr>
<td>Trespass</td>
<td>(A user) Crossing unsafely the rail tracks at unauthorized zones</td>
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<td>(trespasser)</td>
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<td>AU</td>
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<td>E.U.</td>
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<tr>
<td>ILCAD</td>
<td>International Level Crossing Awareness Day</td>
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**Terms associated with significant rail unsafe events as per the definitions provided in the Australian Occurrence classification guideline (ONRSR, 2013):**

**Railway**
A guided system designed for the movement of rolling stock, which has the capability of transporting passengers, freight or both on a railway track, together with its infrastructure, and associated sidings, and rolling stock.

**Includes:**
- A system of transport employing parallel rails or monorail which provides support and guidance for vehicles carried on flanged wheels such as:
  - A heavy railway, or light railway with a track gauge equal to or greater than 600 mm;
  - A monorail;
  - An inclined railway;
  - A tramway;
  - A railway within a marshalling yard or a passenger or freight terminal;
  - A private siding;
  - A railway of a kind prescribed by the National Regulations

**Excludes:**
- A railway in a mine which is predominantly underground and used in connection with the performance of mining operations;
- A slipway:
- A railway used only to guide a crane;
- An aerial cable operated system;
- A railway used only by a horse-drawn tram;
- A railway used only for static display;
- A railway that: - is privately owned and operated as a hobby; and - is operated only on private property; and - does not operate on or cross a public road; and - is not operated for hire or reward, or provided on hire or lease; and - to which members of the public do not have access (whether by invitation or otherwise);
- A railway that: - is used only for the purposes of an amusement structure; and - is operated only within an amusement park; and - does not operate on or cross a public road; and - is not connected with another railway in respect of which a rail transport operator is required to be accredited or registered
- A railway of a kind prescribed by the National Regulations to be excluded

### Pedestrians

A person on foot (walking, running, standing, playing etc.), or a person using a pedestrian conveyance (e.g., non-motorised wheelchair, roller skates, roller blades, child's tricycle, skateboard, scooter or other non-powered vehicle, excluding bicycles). Includes a person who is alighting or boarding a vehicle (Transport and Main Roads, 2012)

### Railway operation

Inclusive term used to describe all activities of a railway related to the performance of its rail transportation business. The Rail Safety National Law (RSNL) defines railway operations as: a) the construction of a railway, railway tracks and associated track structures b) the construction of rolling stock; c) the management, commissioning, maintenance, repair, modification, installation, operation or decommissioning of rail infrastructure; d) the commissioning, maintenance, repair, modification or decommissioning of rolling stock; e) the operation or movement, or causing the operation or movement by any means, of rolling stock on a railway (including for the purposes of construction or restoration of rail infrastructure); f) the movement, or causing the movement, of rolling stock for the purposes of operating a railway service; g) the scheduling, control and monitoring of rolling stock being operated or moved on rail infrastructure.

### Railway occurrence

Any accident or incident involving a train or rolling stock whether in motion or not, or other event on railway premises affecting the safety of persons, property or railway operations

**Includes:**

- Collision, derailment, fire, explosion, act of God, or other event;
- Slips, trips and falls on trains or railway infrastructure.

**Excludes:**

- Occurrences in repair shops, not involving a train in motion;
<table>
<thead>
<tr>
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<td><strong>Railway near-miss</strong></td>
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<td><strong>Level crossing occurrence</strong></td>
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<tr>
<td><strong>Level crossing collision with a person</strong></td>
</tr>
<tr>
<td><strong>Level crossing near-miss with a person</strong></td>
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<tr>
<td><strong>Note:</strong></td>
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</tbody>
</table>
### Abbreviations of Governments and private institutions (in alphabetic order):

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ARA</td>
<td>Australian Railway Association</td>
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<tr>
<td>ATC</td>
<td>Australian Transport Council</td>
</tr>
<tr>
<td>ATSB</td>
<td>Australian Transport Safety Bureau (AU)</td>
</tr>
<tr>
<td>BITRE</td>
<td>Bureau of Infrastructure, Transport and Regional Economics (AU)</td>
</tr>
<tr>
<td>CRC for Rail Innovation</td>
<td>Cooperative Research Centre for Rail Innovation</td>
</tr>
<tr>
<td>ERA</td>
<td>European Railway Agency</td>
</tr>
<tr>
<td>FRA</td>
<td>Federal Railroad Administration (U.S.A.)</td>
</tr>
<tr>
<td>ONRSR</td>
<td>Office of the National Railway Safety Regulator (AU)</td>
</tr>
<tr>
<td>MTM</td>
<td>Metro Trains Melbourne</td>
</tr>
<tr>
<td>QR</td>
<td>Queensland Rail (AU)</td>
</tr>
<tr>
<td>RISSB</td>
<td>Rail Industry Safety and Standards Board (AU)</td>
</tr>
<tr>
<td>RSSB</td>
<td>Railway Safety and Standards Boards (U.K.)</td>
</tr>
<tr>
<td>TMR</td>
<td>The Department of Transport and Main Roads (QLD Government), “TMR moves and connects people, places, goods and services safely, efficiently and effectively across Queensland. The role of TMR is to plan, coordinate and facilitate the provision of transport services and infrastructure related to these services so as to enhance the economic development of the State and its citizens, and also to plan, design, build, maintain, operate and manage the state-controlled road network for the benefit of all sections of the community. TMR’s Rail Safety Regulator is responsible for regulating rail safety in Queensland in accordance with the Transport (Rail Safety) Act 2010.” (Transport and Main Roads, 2014)</td>
</tr>
<tr>
<td>TransLink</td>
<td>Agency of TMR (QLD Government), coordinating and integrating</td>
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</table>
Factors shaping pedestrians' unsafe behaviour at actively protected level crossings

<table>
<thead>
<tr>
<th>Abbreviations of generic and used in rail safety models and tools:</th>
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<tr>
<td><strong>ALCAM</strong></td>
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<td><strong>CFF</strong></td>
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<td><strong>SRK</strong></td>
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Acknowledgements

I am sure many PhD students would agree with me in considering this small section of acknowledgements as an entire chapter of the thesis. At the beginning of this PhD I was far from even imagining how important was the help and support I received during the last three and a half years.

Firstly, I would like to acknowledge QUT and CRC for Rail Innovation for the funding of this thesis and their invaluable support, and to thank Queensland Rail for their excellent collaboration. Further, I would like to express my gratitude to my supervisory team – Andry, Patricia, Jean-Marie, Chris and James. I always pictured us as some unusual sport team, of which I was the manager but also the foremost player. I considered myself responsible for keeping you all “in the game”, and most importantly for ensuring that we all play the same game with the same objectives. This was hard! But what kept me going was the feeling that I had the unique opportunity to learn from each one of you as you are all excellent “players” in different fields.

Thank you ! To James, for giving me the opportunity to be a CRC student. All of the CRC student conferences were excellent research and social experiences. To Andry, for your support, and mostly for your patience and understanding during all these years. To Jean-Marie – You always motivated me to go further and further, to dig deeper and deeper in my research … you were always there to set up a higher objective to reach, and I could not think of a better way to motivate a student. To Chris – Your contribution to my studies and articles made a great difference, and for your ongoing support, I’m truly grateful. I had the privilege to have you as a supervisor even though you joined the team later. To Patricia, I would “simply” say that it was a great pleasure and honour working with you!

Secondly, my deepest gratitude goes to my family, friends and colleagues. For all your support and confidence in me I could not consider myself luckier. Special thanks to Seb & Greg who were there for me from my very first day at CARRS-Q, and to Juju who was there until the end at IFSTTAR. Thank you to all the researchers and administration staff from CARRS –Q and IFSTTAR, it was a great pleasure to meet you and work with you all, and in such a welcoming environments! I would
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Chapter 1: Introduction

Of all land transportation modes, railways are globally recognised as one of the safest systems, noting that the estimations of the exact fatality rates (i.e., normalized number of fatalities) between countries could be subject to biases. Table 1 illustrates the relatively stable number and rates of railway fatalities in Australia compared to other types of transport modes for the last ten years.

Table 1. Number and risk rate of railway fatalities between 2001 and 2013 in Australia compared to other modes of transport

<table>
<thead>
<tr>
<th>Year</th>
<th>Road</th>
<th>Rail</th>
<th>Marine</th>
<th>Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1737</td>
<td>53</td>
<td>47</td>
<td>46</td>
</tr>
<tr>
<td>2002</td>
<td>1715</td>
<td>40</td>
<td>50</td>
<td>34</td>
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<tr>
<td>2003</td>
<td>1621</td>
<td>33</td>
<td>43</td>
<td>44</td>
</tr>
<tr>
<td>2004</td>
<td>1583</td>
<td>33</td>
<td>50</td>
<td>34</td>
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<tr>
<td>2005</td>
<td>1627</td>
<td>35</td>
<td>41</td>
<td>45</td>
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<tr>
<td>2006</td>
<td>1598</td>
<td>39</td>
<td>49</td>
<td>40</td>
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<tr>
<td>2007</td>
<td>1603</td>
<td>42</td>
<td>53</td>
<td>44</td>
</tr>
<tr>
<td>2008</td>
<td>1437</td>
<td>31</td>
<td>41</td>
<td>43</td>
</tr>
<tr>
<td>2009</td>
<td>1491</td>
<td>28</td>
<td>53</td>
<td>27</td>
</tr>
<tr>
<td>2010</td>
<td>1353</td>
<td>29</td>
<td>2**</td>
<td>24</td>
</tr>
<tr>
<td>2011</td>
<td>1277</td>
<td>33</td>
<td>6**</td>
<td>38</td>
</tr>
<tr>
<td>2012</td>
<td>1299</td>
<td>20*</td>
<td>6**</td>
<td>39</td>
</tr>
<tr>
<td>2013</td>
<td>1193</td>
<td>7*</td>
<td>6**</td>
<td>46</td>
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</table>

<table>
<thead>
<tr>
<th>Calendar year</th>
<th>Road</th>
<th>Rail</th>
<th>Marine</th>
<th>Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>8.95</td>
<td>0.27</td>
<td>0.24</td>
<td>0.24</td>
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<tr>
<td>2002</td>
<td>8.73</td>
<td>0.2</td>
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<tr>
<td>2003</td>
<td>8.15</td>
<td>0.17</td>
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<td>0.22</td>
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<tr>
<td>2004</td>
<td>7.94</td>
<td>0.16</td>
<td>0.25</td>
<td>0.17</td>
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<tr>
<td>2005</td>
<td>8.06</td>
<td>0.17</td>
<td>0.2</td>
<td>0.22</td>
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<td>2006</td>
<td>7.81</td>
<td>0.19</td>
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<td>2007</td>
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<td>0.25</td>
<td>0.21</td>
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<tr>
<td>2008</td>
<td>6.76</td>
<td>0.14</td>
<td>0.19</td>
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<td>2009</td>
<td>6.87</td>
<td>0.13</td>
<td>0.24</td>
<td>0.12</td>
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<td>2010</td>
<td>6.14</td>
<td>0.14</td>
<td>0.01**</td>
<td>0.11</td>
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<tr>
<td>2011</td>
<td>5.72</td>
<td>0.15</td>
<td>0.03**</td>
<td>0.18</td>
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<tr>
<td>2012</td>
<td>5.72</td>
<td>0.09*</td>
<td>0.03***</td>
<td>0.18</td>
</tr>
<tr>
<td>2013</td>
<td>5.16</td>
<td>0.03*</td>
<td>0.03***</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Note. Rail fatality and serious injury data from 2012 onwards excludes suspected suicide and trespass occurrences. They were compiled using new methodology and should not be compared with earlier results.

**Marine fatalities data from 2010 onwards were compiled using a different methodology and should not be compared with earlier results.

Adapted from: Bureau of Infrastructure Transport and Regional Economics - BITRE (2014), Table T 8.1b. Adapted with permission

However, railway crashes are potentially likely to result in a larger number of fatalities compared to road crashes. As illustrated in Figure 1, a number of developed countries have seen a notable drop in railway fatalities in the last decade. Noting that this is declining at a different pace for each country, Korea demonstrates the most important safety improvement. Australia, on the other hand, is the only country with a stable and even increasing number of victims, even though it is the lowest...
compared to the other developed countries. Despite a substantial decrease, the number of railway fatalities worldwide remains unacceptably high (European Railway Agency, 2014).

Figure 1. Railway fatalities rate (excluding suicides) per million train-kilometres in 2003-2012 for the EU-28, USA, Canada, Korea and Australia.
Reprinted from European Railway Agency (2014), Reprinted with permission

Among all types of railway collisions, those related to actors external to the rail system (e.g., trespassers, level crossing transgressions, or suicides) cause a larger number of fatalities compared to those related to technical failures, sub-optimal rail operations (i.e., signal passed at danger, or SPAD, and derailment) or to rare events, such as fire in rolling stock and accidents involving dangerous goods (European Railway Agency, 2014; ONRSR, 2014).

This thesis is concerned with a particularly important railway issue, which is considered to be among the prime causes of railway fatalities – level crossing occurrences.
1.1 LEVEL CROSSING COLLISIONS ARE AMONG THE MOST SERIOUS RAILWAY OCCURRENCES

In recent years, level crossing (LC) occurrences are a persistent railway issue. After a substantial decrease since the 90s, the most recent annual reports worldwide do not demonstrate further safety improvement in LC occurrences (ATSB, 2012; European Railway Agency, 2014; Evans, 2011b; Metaxatos & Sriraj, 2013a). According to a summary of the available information on railway accidents in Europe between 1980 and 2009, Evans (2011b) concluded that the number of LC occurrences has remained unchanged in the last 20 years compared to a decreasing number of other rail occurrences (e.g., derailments). In Australia, between 1997 and 2002 there were 221 fatalities at LCs only, which is almost the equivalent of the total number of all types of rail fatalities reported for the following six years (2003-2008, N = 213). Despite that decrease, the average annual number of LC collisions in Queensland between 2003 and 2011 remained stable and even increased, although no information is available on the number of associated fatalities (Figure 2). In Queensland, fatalities and serious injuries at LCs represented 25% of the Australian rail toll for the last 10 years (Queensland Government, 2012).

![Figure 2](image)

*Figure 2. Counts Queensland level crossing occurrences involving road vehicles and pedestrians between 2003 and 2011 based on data from ATSB (2012)*

Regarding the involved road users, for the last five years, the number of collisions with motorists is decreasing compared to the number of collisions with pedestrians across Australian LCs and in Queensland, as can be seen in Figure 2 (ATSB, 2012). Similar trends are observed in other countries such as the USA (Metaxatos & Sriraj, 2013a), the United Kingdom (Evans, 2011a), or across 21
European countries where pedestrians crossing unsafely at LCs are the third cause of serious accidents at railways (7.6%) in 2013, preceded by motorists driving unsafely at LCs accounting for 17.1%, and trespassers (i.e., pedestrians crossing the railway tracks at unauthorized zones) accounting for 47.1%. Between 2002 and 2012 the total of 92 collisions with pedestrians represented around 13% of all occurrences at LCs in Australia (ATSB, 2012).

1.2 CLASSIFICATION OF LEVEL CROSSING INTERSECTIONS AND THE ASSOCIATED SAFETY CONSTRAINTS

According to the Road Rules manual (Queensland Government, 2009) a LC is “an area where a road and a railway meet at substantially the same level, whether or not there is a level crossing sign on the road at all or any of the entrances to the area” (Queensland Government, 2009, p. 125). Because LCs are part of road and rail infrastructures, at these intersections a unique set of safety hazards threaten a wide range of road users (e.g., motorists, pedestrians, road and rail passengers and staff).

Road and rail systems are separate entities with different rules, procedures, characteristics and operational limitations (ATSB, 2009). Compared to road vehicles, trains have much greater operational limitations: “Interstate freight trains can be in excess of 1,500 m long and weigh upwards of 5,000 tonnes. Locomotive hauled passenger trains can weigh 2,000 tonnes or more. Trains of this size are, by necessity, driven ‘many kilometres in advance’. In routine operations, brakes are often applied kilometres beforehand to slow or stop a train” (ATSB, 2009, p. 2). Considering such important braking limitations, the road user must always give way to trains at LCs. Therefore, road users are always alerted at the approach of a LC by road signs and markings, an increasing number of which have been installed in Queensland in recent years (Queensland Government, 2012). Once arrived at the LC, road users have to make a decision to proceed or not, according to the existing traffic control systems.

Internationally LCs are classified in two large categories (i.e., passive and active) according to the level of protection they provide to road users. Passive LCs are equipped with road signs (i.e., “STOP” or “Give way”) controlling vehicular or pedestrian traffic called “passive controls”. They are generally installed at intersections with a low volume of road and rail traffic. At the approach of a passive LC, it is the motorist’s or the pedestrian’s responsibility to detect the imminent
approach of a train. At active LCs, however, the movement of vehicular or pedestrian traffic is controlled using automatic devices such as lights, gates, barriers or a combination of these, which activate at the approach of a train, prohibiting the access to road users on the rail tracks. Active controls are installed at LC sites with a high density of road and rail traffic, limited sight distance and/or at intersections with significant accident-prone history. Automatic controls are designed to activate in sufficient time before the approaching train arrives on the LC quadrant, allowing road users to finalise their crossing if already engaged through the rail tracks. In Australia, a special form of active controls designed uniquely for pedestrians can be provided at active LCs (i.e., pedestrian lights, gates and audible alarms).

Currently there are more than 25 000 LCs across Australia with 95 % allowing motorist traffic and only 5% designed solely for pedestrian use (ONRSR, 2014). Almost half (49%) of the pedestrian LCs are equipped with active protection (RISSB, 2009). Private and maintenance LCs, usually equipped with passive controls, account for more than half of all LCs in the country and only around 9400 provide access to the larger public and are therefore referred to as “Public LCs”. More than half of the public LCs are also passive (6000), while about 2700 are active public LCs (ATSB, 2009). In Queensland, there are approximately 1400 public LCs, of which around one third are actively protected (ONRSR, 2014).

1.3 LEVEL CROSSING OCCURRENCES ARE ASSOCIATED WITH IMPORTANT COSTS – A PROGRESSIVELY INCREASING AWARENESS OF THE ISSUE

Although they are rare compared to road collisions, collisions at LCs can have potentially catastrophic outcomes, and are particularly likely to result in fatal consequences for pedestrians, the most vulnerable road users (Haleem & Gan, 2015). Level crossing collisions also cause property damage and significant disruptions on road and rail traffic and are therefore associated with important social and economic costs, such as insurance payments, legal fees or loss of confidence in the public transport system (Iorio, De Marco, & Cosciotti, 2012; Metaxatos & Sriraj, 2013a; Queensland Government, 2012). In the European Union the average cost of a major LC collision was estimated at up to €1.7 million (A$2.5 million) (European Railway Agency, 2014). In Australia, the cost of a LC collision was estimated at A$32 million (€21 million) in 1999 by The Bureau of Infrastructure, Transport and Regional
On the basis of this estimation, the Queensland government announced a more recent (for 2012) estimation of the cost per collision for the state at around A$10 million (€6.6 million), after adjustment for inflation (Queensland Government, 2012). Although still much higher than the costs of LC collisions in the E.U., this significant drop in Australia can be explained by the multiple safety-related actions taken in recent years on a national and a state level. One of the recent measures (2013-2014) in Australia was the closure of a particularly busy LC in Geebung (Brisbane area), estimated to be a high risk spot. The LC was replaced by a road over-pass and a pedestrian bridge. The project was estimated at A$199 million (€128 million) and included also changes in the larger infrastructure in the area (e.g., construction of a new commuter car park and plaza area, opening of new road intersection, realignment and rehabilitation work). Another recent initiative (2015) aims at removing a high risk LC in Melbourne (Victoria), separating the road and rail networks by lowering the rail line and rail station below the road. The costs of the intervention are evaluated at more than A$400 million (€257 million) and the stated Benefit Cost ratio for the project is 0.8:1. As per the assessment brief of the project: “The estimates of the value of reliability changes arising from the project are about one third of benefits. This is larger than most projects, but reflects the impacts of the level crossing on the variability of travel time.”(VicRoads, 2015, p. 3).

1.4 THE LACK OF AVAILABLE DATA ON TRAIN-PEDESTRIAN COLLISIONS AND NEAR-MISSES

The issue of safety at LCs has become an important part of the Australian National Road Safety objectives with the launch of the national and local LC safety strategies in the first decade of this 21st century. The Australian Transport Council (ATC) has elaborated in 2010 the National Railway Level Crossing Safety Strategy 2010-2020 listing the main safety objectives for the decade (Australian Transport Council, 2010). In parallel, the Queensland Department of Transport and Main Roads, in conjunction with the rail industry, have elaborated the “Queensland Level Crossing Safety Strategy 2012-2021”, with the aim to improve safety initiating novel and multidisciplinary research, specifically targeting the improvement of pedestrian safety and risk awareness (Queensland Government, 2012).
While the elimination of LCs where possible is one of the main objectives of the National Level Crossing Safety Strategy, this solution is costly and requires a long timeframe for completion. It is therefore hardly achievable in short term. Given the large number of LC intersections in Australia – the equivalent of almost one quarter of all LCs in the European union (123 000 in 2010, according to Fonverne, 2013), coordinated national and local (for the State of Queensland) efforts have been concentrated towards the implementation of more efficient and cost effective safety measures (Australian Transport Council, 2010; Queensland Government, 2012). Instead of eliminating them, passive LCs have been upgraded to active. To identify the priority sites requiring intervention, a new tool for LC risk assessment was developed in 2010 and has been applied nationwide across Australia and New Zealand. The Australian Level Crossing Assessment Model (ALCAM) is used as a critical but not exclusive tool for the assessment of the comparative safety risk at LCs. ALCAM is a complex scoring algorithm which evaluates the risk factors for a unique crossing, accounting for the physical characteristics of the LC site and for characteristics of the users. ALCAM provides an overall comparative risk score and specific hazards’ evaluation. Along with the consideration of other safety factors (i.e., full social and economic impact on safety or specific safety factors), the ALCAM “risk-scores system” allows to classify LCs according to their level of risk and to the respective types of hazards. The model assists professionals in decision-making on the most cost-effective solutions to the implementation of safety measures. In addition to supporting LC risk evaluation and safety improvement, the model is useful for LC maintenance, but cannot be used to investigate road users’ unsafe crossing behaviour.

Another major objective of the national safety strategy is the improvement of the reporting and classifications methods of crash data, which are associated with multiple biases (presented in detail in Section 2.3.2). The current publicly available accident reports contain only information on the number and the types of occurrences and do not specify the different factors involved. Moreover, because the classification methods of LC occurrences differ across Australian jurisdictions, the interpretation of the limited available data is subject to interpretation biases, as can be seen in Table 1. Given the small number of collisions at LCs, more voluminous information about the contributing factors to occurrences should be sought from
near-miss reports. However, so far only the near-misses report for 2011 (in Queensland) has been made public. Again, a number of important potential biases can be associated with this database, questioning the quality and the usefulness of such information for practical and scientific purposes. Firstly, these data are subject to biases associated with the regularity of reporting. For example, train drivers are only able to report events in the imminent approach of a LC, thus events occurring before the train has reached the LC zone are likely to be under-reported. Secondly, the reports are subject to biases associated with subjectivity. Train drivers or other rail staff members may perceive some events or contributing factors as more important than others and are thus likely to omit important information in their reports. Finally, according to the emotional or the mental state of the person reporting, an occurrence can be perceived differently. Therefore, the reports are to be considered as rather subjective and likely to contain misleading data. For instance, if a train driver has applied an emergency break, feelings of fear or panic may influence his or her perceptions and judgments. Specifically, in a sub-optimal mental state a train driver may perceive the distance between the person crossing and the approaching train as shorter than the real distance.

Following the increasing awareness of the limitations associated with this particular type of data and the critical demand for more specific and detailed information, more efforts are currently targeting the improvement of safety investigation procedures in Australia as well as on an international level. Facing a global issue of data interpretation, in the last decade the ERA, or the European Railway Agency (2004), was initiated with the objective to gather data on railway safety performance across European countries based on similar reporting criteria. Similarly, in Australia, a National system for the reporting and investigation of rail accidents has been developed and implemented since 2009. Based on complex system models for accident investigation, the Contributing Factors Framework (CFF) can be used simultaneously by rail personnel, accident investigators or researchers to code and interpret data related to the systematic factors contributing to occurrences (Rail Safety Regulators` Panel, 2009).

In conclusion, very little is known about the factors involved in train-pedestrian occurrences at LCs in Australia. The active protections for pedestrians are different than the existing protections in other countries. They include pedestrian lights and
Factors shaping pedestrians’ unsafe behaviour at actively protected level crossings

sound and pedestrian gates closing horizontally in front of the pedestrian, unlike the widely-used internationally gates which fall vertically. The specific design and operation mode of pedestrian protections imposes different safety constraints to pedestrians at Australian LCs. Consequently, publications on pedestrian behaviour at foreign LCs should be considered with caution for the understanding of pedestrian behaviour in the Australian LC context.

1.5 DESPITE THE INCREASING SAFETY AWARENESS AND ENFORCEMENT ACTIONS THERE IS A DEMAND FOR MORE RESEARCH IN THE AREA OF LC SAFETY

Within the scope of the Queensland LC safety strategy program, enforcement and education actions were taken at high risk LC intersections through the collaboration between Queensland Police and Queensland Rail (QR) (Queensland Government, 2015). The past decade of growing rail safety awareness was also marked with the initiation of multiple not-for-profit organisations working in collaboration with industry and government towards safety improvement through promotional activities. Among the most influential in Australia and New Zealand, the Track Safe Foundation was established by the Australian rail industry in March 2012 as a Harm Prevention Charity. The foundation participates actively in the organisation and the promotion of broad public LC safety events, such as the International Level Crossing Awareness Day (ILCAD), and the “Rail Safety Week” or the “Dumb Ways to Die” campaign created by MTM, which has won multiple awards in a short period after its initiation in 2012.

Since 1999 and until 2021, the Queensland government plans to allocate over A$250 million (€166 million) to improve LC safety, (Queensland Government, 2012). In 2013 – 2014 Transport and Main Roads (TMR) provided A$2.27 million to maintain and improve controls at LCs such as LC signage, barriers, pedestrian gate installations and other upgrades (Queensland Government, 2015). With the increasing number of safety initiatives in the last decade, the Queensland Government has announced a reduction in risk in 2014, with approximately 200 fewer public level crossings in the state since the Safety Strategy was launched in 2012 (Queensland Government, 2015). However, despite the existing safety measures at Queensland’s active LCs, more occurrences are associated with this type of LCs compared to passive LCs (Australian Transport Council, 2010).
Between 2002 and 2009, 99% of the LC occurrences in Queensland were attributable to road user’s behaviour (Infrastructure, 2009). Indeed, the causes of train-pedestrian collisions at LCs are, to date, a largely under-researched area. A literature review identified only 27 publications on pedestrians’ behaviour at LCs (Section 2.2), a considerably smaller amount compared to the existing literature on drivers’ behaviour. Moreover, these publications are associated with important gaps (detailed in Section 2.3) emphasizing the pressing need for more research and research-based future interventions. Specifically, the literature is lacking empirical research into the multiple and interacting factors shaping pedestrians’ crossing decisions.

1.6 DECISION-MAKING PROCESS IN THE COMPLEX ACTIVE LEVEL CROSSING ENVIRONMENT

Decision-making is an expanded in time process, which depends on the perceived information (i.e., perception), the processing of information (i.e., cognition) and the intention to carry out an action reflecting personal goals and values (i.e., motivation). A sequence of tasks related to pedestrian crossing decisions and behaviour at active LCs has been proposed by Edquist, Hughes, and Rudin-Brown (2011), building upon a previous model of behaviour at passive LCs presented in a report for the U.K. Rail Safety and Standards Board. The sequence comprises nine tasks as follows: 1) recognize the crossing location; 2) stop at the crossing decision point; 3) read and obey the instructions; 3) notice and obey the active controls; 5) check for trains; 6) wait for any train approaching; 7) recheck for trains; 8) cross and 9) exit safely. These tasks can be influenced by factors in the physical environment, such as the presence of vegetation or other obstacles to a good sight distance. The tasks can also be influenced by contextual factors proper to the given crossing situation, such as meteorological conditions, peak hours or unexpected road traffic disruptions. The decision to choose an action among different alternatives could be related to the available information about safety (i.e., enforcement) and security procedures or by knowledge about rail traffic management procedures. For example, unsafe crossing decision could be reduced if enforcement sanctions are implemented, or enhanced in case of familiarity with the train timetables (i.e., if the pedestrian is aware of the exact time of train arrival). In addition, in the LC environment, all types of road users and road/rail authorities are
sharing the same space, and thus decisions can also be influenced by others in the vicinity. While the presence of police or rail ticket officers, called “transit officers”, could deter unsafe crossing intentions, the presence of other users crossing unsafely might enhance such behaviour. Finally, crossing decisions are to a large extent dependent on the person’s characteristics (e.g., risk-takers, impairments), conditions (e.g., mood, fatigue) and motivations (e.g., time pressure).

At active LCs, pedestrian crossing is associated with legal constraints imposed by the provided active controls. Crossing is only allowed if the controls are not active, even though a person might perceive it safe to cross during the activated controls. Thus, unsafe behaviour is associated with different types of behaviour (errors vs. violations) according to the intention to comply with the prescribed norms, in this case “road rules”. Given the existing sanction, if no information is available on the intention (or not) to comply with the rules, unsafe crossing is defined as “transgression”. Inversely, as an “error” is defined a failure to act in accordance with the legal rules, whereas “violations” are associated with an intentional non-compliance with the legal rules. Errors can result from misunderstanding or misperception of the active controls, while violations are to a large extent motivated by social pressures and goal directed behaviour. Goal directed behaviour is associated with a strong intention to carry out an action in order to achieve a valued objective or a higher level goal. While errors can rather be considered as failures in the cognitive processes preceding an action, violations are strongly influenced by cognitive but also motivational precursors of behaviour. Therefore, these two types of behaviour can be explained and are to be addressed differently.

The mental processes involved in the assessment of the ability to carry out an action (i.e. evaluation of the situation, identification of alternative actions, action selection, problem-solving) and those influencing decisions according to the perceived benefits of the action are here referred to respectively as “cognitive and motivational precursors” of behaviour. The generic term of (cognitive and motivational) precursors of behaviour describes mental constructs which guide decision-making in the short or long term. The precursors of behaviour are influenced by different risk-contributing factors triggering unsafe crossing decisions. Risk-contributing factors may influence precursors related to knowledge/familiarity, attitudes, expectations, motivations etc. For example, to comply with active controls,
users have to perceive them as reliable, but also efficient. Previous experience with such controls contributes to the formation of attitudes and expectations about their performance. Thus, as a risk-contributing factor, the repetitive exposure to false alerts (i.e., activated controls when no train is approaching) might hinder the perceived reliability of the controls in the long term and lead users to cross, violating the prescribed rules. A pedestrian might also decide to violate the rules if the controls are activated for an excessively long period of time. In such case the perceived benefits (i.e., saving time) of the crossing would have more weight on the crossing decision than the safety threat or the threat of violating the road rules (i.e., sanctions). Moreover, if more benefits are associated with illegal crossing, the road rules may be perceived as inadequate. Consequently, the more pedestrians engage in deliberate (beneficial) unsafe behaviour (violations), the more they would be likely to perceive the associated benefits and to repeat such behaviour in similar situations.

However, even at the same LC site, the crossing context for pedestrians is highly likely to differ from one situation to another. Pedestrians are exposed to a much wider range of factors likely to influence their crossing decisions and behaviour compared to vehicle drivers, for example. On the approach to a LC pedestrians can move within a larger space, while motorists are obliged to remain in the road lane. Pedestrians can rather easily overcome the physical barriers (e.g., jumping or pushing open the gates), whereas crossing through a fallen barrier for a vehicle implies damage to the vehicle, as well as to the rail infrastructure. Pedestrians have the possibility to directly interact with other pedestrians or rail staff, whereas vehicles are often queuing behind other vehicles and have poor visibility of the LC zone and the actors in close proximity. Thus, both types of users face very different safety constraints.

Arguably, pedestrians may not always be aware of the multitude of factors potentially influencing their crossing decisions and behaviour. Those who frequently use LCs might be oblivious to changes in the environment, performing rather automatically the tasks associated with crossing. For instance, in what can be perceived as an “ordinary” crossing situation (e.g., crossing at the same time with the same others) a pedestrian may underestimate the chances of rail traffic disruptions and the unexpected arrival of an express train. In addition, pedestrians’ decisions are influenced by the signal-to-noise ratio (i.e., the level of a desired signal compared to
the level of background noise) or else by meteorological conditions, which may
decrease the visibility and the audibility of the controls. Technical updates (e.g.,
installation of a locking mechanism on pedestrian gates) or changes in the
organizational procedures (e.g., more transit officers in place) are other factors of
which pedestrians are potentially unaware before crossing, but which might entail
negative consequences of unsafe crossing decisions.

To summarise, pedestrian crossing decisions are subject to the influence of
various and difficult to predict combinations of factors, which make the
understanding of the cognitive and motivational precursors underpinning their
behaviour complex to study. While the precursors of errors can be explained by a
failure of the system to provide adequate safety measures and/or the necessary
instructions to follow them, violations can be associated with a failure of the system
to raise safety awareness and to impose legal actions against deliberate non-
compliance with the system’s rules. More research into the precursors of behaviour
and the associated triggering factors is necessary to, on one hand, identify the failures
in the system (e.g., inadequate controls, LC design) and on the other hand - to
propose future strategies on how to change behaviour (i.e., increase risk awareness
and reduce violations).

To address this issue, this thesis was undertaken as part of a larger project
entitled: “Understanding of pedestrians’ behaviour at level crossings”. This project
was proposed by the Cooperative Research Centre for Rail Innovation (CRC for Rail
Innovation) initiated in 2007 by the Australian Government as part of the
Cooperative Research Centres program. The objective of the CRC for Rail
Innovation was to address through research collaborations the major challenges of
the Australian Rail Industry. The CRC for Rail Innovation sponsored over 100
projects investing A$113 million (€75 million) in seven years.

The main objectives of the CRC project are to identify risk-contributing factors
to different types of unsafe behaviour (errors vs. violations) and high risk groups of
users. This PhD research program complements the project’s milestones with results
from studies adopting different approaches (i.e., systems-based approach) and
methods (i.e., direct observations of pedestrian behaviour in addition to self-reported
data). In addition, this thesis focuses exclusively on the in-depth investigation of
pedestrian behaviour only at active LCs. Unlike the overall project’s objectives, the
thesis aimed to explain the precursors of behaviour of different demographic groups of pedestrians rather than identifying high-risk groups of pedestrians.

1.7 RATIONALE FOR RESEARCH, RESEARCH QUESTION AND STRUCTURE OF THE RESEARCH PROGRAM

Given the lack of knowledge detailing the factors and conditions associated not only with previous collisions but also with near-miss occurrences, this research program seeks to provide extensive descriptive information on the risk-factors contributing to errors and violations. Further, building upon the obtained baseline descriptive data, the research program seeks to provide empirical evidence on the impact of different precursors on unsafe behaviour accounting for differences in the crossing context from one situation to another.

The research question is formulated as follows: “How can traditional individual-centered theories in psychology can be used together with modern system theories to better understand pedestrian behaviour at LCs?”

Three main aims are formulated and articulated in two research stages (Figure 3). The first exploratory stage is essential to the research program and includes two studies with different methodology, which address the first two aims associated with the lack of descriptive information. The exploratory aims are:

1) to identify a broad list of risk-contributing factors influencing crossing decisions at LCs; and to

2) to associate these factors and their interactions with specific precursors of errors and violations

A direct observations study was conducted to address the first aim to identify risk factors to unsafe pedestrian behaviour at LCs. Further, focus group discussions with pedestrians who are frequent users of black spot LCs were conducted to associate the identified risk-contributing factors to different types of unsafe behaviour (i.e., errors and violations). In the end of the exploratory stage of research, complementary data from the observations and the focus groups allowed the development of a new systems-based framework for the investigation of Pedestrian Unsafe Level Crossing (PULC).
Figure 3. Graphical illustration of the research program comprising three studies, which address the three research aims in two stages of research exploratory (lighter cells) and empirical (darker cells)

The PULC framework lists factors from all LC system levels influencing crossing decisions, and associates them and their interactions with potential risk-contributing factors to errors and violations. The exploratory results from this first stage informed the third research aim in the second, empirical stage of research, which is:

3) to examine the impact of precursors of unsafe behaviour across different crossing situations

A video survey method was adopted to examine the impact of the previously identified precursors of unsafe behaviour across different “real world” crossing situations recorded at three LCs in Brisbane. The survey was proposed to a state-wide sample of pedestrians in order to obtain generalisable results informing on potential actions and future research paths towards the reduction of unsafe behaviour.

Given that pedestrians and motorists encounter different safety constraints at LCs, this research program is only limited to the understanding and the explanation of pedestrian unsafe crossing behaviour, nonetheless taking into considerations
influences from the larger social environment (i.e., motorized users, rail staff). The research question only concerns behaviour at actively protected LCs, because of the large number of occurrences at such intersections, and because the crossing decisions at active LCs are subject to legal rules and thus imply different tasks and constraints compared to the decision-making process at passive LCs. The understanding of the origins of trespassing and suicide cases on the rail tracks or at LCs, were also excluded from the scope of the program, because such occurrences also imply different safety constraints compared to transgressions at LCs.

In the next chapter, the current knowledge from the literature on pedestrian behaviour at LCs is presented, illustrating the limited information about how pedestrians make decisions at LCs and the factors that trigger unsafe crossing decisions.
Chapter 2: Literature Review

2.1 CHAPTER INTRODUCTION

To review the current knowledge about pedestrians’ behaviour at LCs, this chapter presents in detail the findings from the conducted literature review. First, the scope of the review and the description of the identified papers are provided, followed by a synthesis of the gaps associated with this literature (Sections 2.2, 2.3). Second, to better understand the main findings from the literature and, most importantly, the extent to which they could be generalised to pedestrian behaviour at Australian LCs, a review of the safety constraints imposed by the most common passive and active controls in the state of Queensland is presented in Section 2.4. Further, a summary of the current state of knowledge is organised in four sections, each presenting factors of a different nature that potentially shape crossing decisions. In the first section (2.5.1) factors related to the physical characteristics of the crossing environment (e.g., presence and types of protection, rail traffic characteristics) and to the contextual characteristics of the situation (e.g., time of the day, LC design) are presented. In the second section (2.5.2) factors associated with different demographic groups of users, and with pedestrian’s characteristics (e.g., risk-taker) and states (e.g., fatigue, mood) are presented. The last two sections explore factors related respectively to the social context of crossing (e.g., presence of others, Section 2.5.3), and to the organisational procedures and management (e.g., enforcement, Section 2.5.4). The conclusions drawn from the literature are detailed at the end of the chapter, and provide the baseline information which underpins the choice of theoretical framework and methods adopted in this research program.

2.2 SCOPE OF THE LITERATURE REVIEW

A literature review was conducted with a specific objective to identify publications targeting pedestrian behaviour as opposed to, or in addition to drivers’ behaviour at LCs. The set of keywords used to identify the relevant papers include but are not limited to: level crossings (i.e., railway crossings, grade crossings, rail crossings); pedestrians (i.e., road/rail users, trespassers); railways (i.e., railway
Factors shaping pedestrians' unsafe behaviour at actively protected level crossings (LCs) were excluded. Scientific papers, government project reports and other publications up to June 2015 were searched in electronic databases (i.e., Science Direct, EBSCOhost, Google and Google Scholar, HERDC), as well as the researcher’s social networks and the web-pages of national railway authorities and other international rail-related institutions (i.e., RSSB, FRA, UIC).

The first outcomes of this literature review were related to publications up to and including 2013, and are published in Stefanova, Burkhardt, Filtness, et al. (2015) (Chapter 4). This list of 23 identified publications was revised to include four additional publications (up to June 2015), and is presented in Appendix A.

Among the 27 identified publications there are six literature reviews or other publications including literature reviews, two experimental studies, and 19 descriptive or correlational studies. Ten of the studies were conducted in Australia, six in the USA, five in the United Kingdom, three in New Zealand, two in Canada and one in Italy.

2.3 GAPS IN PREVIOUS RESEARCH

Four major gaps can be associated with the reviewed publications. They concern: 1) the significantly smaller amount of research into pedestrians’ behaviour at LCs compared to the conducted research into drivers’ behaviour at LCs; 2) the lack of detailed and objective data on the risk-contributing factors to LC occurrences in general, and specifically to train-pedestrian occurrences; 3) the global lack of empirical studies, and specifically the lack of experimental studies testing the effects of safety interventions; 4) the lack of studies examining a large number of risk-contributing factors to LC occurrences and their interactions.

2.3.1 Lack of previous research specifically targeting pedestrian behaviour

According to a literature review on LC issues conducted by Read, Salmon, and Lenné (2013), more than 70% of the existing publications over a 30-year period prior to 2013 focused only on the understanding and the investigation of motorists’ behaviour instead of other users’ behaviour. The current literature review specifically targeting pedestrian behaviour revealed that publications up to July 2015 are to a large extent based on previous research on motorists’ behaviour (in a LC or road traffic context) or on pedestrians’ behaviour in a road traffic context (as opposed to a...
As already mentioned pedestrians’ and motorists’ crossing behaviour is associated with different tasks requiring different skills and is subject to influences from different factors. Furthermore, Read et al. (2013) point out that pedestrians’ behaviour at LCs might be influenced by motorists’ behaviour and vice versa, however, arguably, the two types of influences are likely to be different in nature. Therefore, the degree to which outcomes of driver-focused literature can be inferred to be applicable to pedestrians’ behaviour is unclear, and yet researchers often consider the two groups together.

Only two of the identified literature reviews reported outcomes exclusively related to pedestrian behaviour at LCs (Clancy, Kerr, & Scott, 2006; Metaxatos & Sriraj, 2013b). Two other literature reviews reviewed factors related to both types of users providing a clear distinction between those associated with pedestrians’ and motorists’ behaviour (Davis Associated Limited, 2005; Searle, Di Milia, & Dawson, 2011), and two others provided a summary of risk factors without differentiating their contribution to pedestrians’ or motorists’ behaviour (Caird, Creaser, Edwards, & Dewar, 2002; Edquist, Stephan, Wigglesworth, & Lenné, 2009).

Of the six descriptive studies employing survey design technique, two targeted both pedestrians and motorist users. One of them provided a clear distinction between the repartition of pedestrians and motorists in the sample and the associated results (Beanland, Lenné, Salmon, & Stanton, 2013). The other one, however, did not report the proportion of pedestrian respondents nor the corresponding results (Roy Morgan Research, 2008).

Four out of the six descriptive publications based on occurrence data included crash data related to pedestrians and motorists. In only one of those publications were the results associated with pedestrian behaviour not clearly distinguished (Haleem & Gan, 2015). In fact, this publication provided an analysis of different types of road users as contributing factors to crash injury severity. Only two out of the eight observational studies targeted both types of users and included a clear distinction between the results attributable to pedestrian versus motorist behaviour.
Finally, of the two experimental studies, Basacik, Cynk, and Flint (2012) conducted a simulation experimental study examining the awareness of different users of various cues in the LC environment. However, the type of user was not distinguished in the reported outcomes. The other simulation experimental study examined the estimations of train speed versus car speed on the approach of an intersection provided by different types of users, including pedestrians, cyclists, and drivers (Clark, Perrone, & Isler, 2013). However, the results were reported independently of the types of users.

2.3.2 The currently available occurrence data is limited and associated with multiple biases

Typically, safety investigations are based on available post-crash data, which, in the case of LCs, is not only limited in terms of the rare nature of the occurrences but is also subject to important biases. The criteria for reporting and classifying LC occurrences differ according to government rules and procedures worldwide. In Australia, as a federation of states and territories, transport services are locally operated on a state level. Different rail and road authorities, are both in charge of the collection of LC crash data. This shared responsibility often leads to discrepancies in large national databases according to the source of information, and could also result in misinterpretations. Progressive amendments of the terms used in the national occurrence reports provided by the Australian Transport Safety Bureau (ATSB), are made to improve the national standard of reporting. However, the adopted new definitions and criteria require the re-coding of data in the most recent database versions, associated with potential data loss, as stated in each version of the ATSB reports (ATSB, 2011, 2012). For instance, as can be seen in Table 1, suicides have until recently been considered and classified along with other victims of rail occurrences, although the conditions and factors contributing to these two types of occurrences are very different (Silla, 2012). Level crossing crash reports are therefore considered as insufficient to the understanding of the factors and conditions shaping behaviour (Wullems, Toft, & Dell, 2013). As stated by Kouabenan (2009), research based on crash reports data often leads to the implementation of misdirected and misleading prevention strategies because this type of data is rather subjective and often limited.
In relation to the latter, instead of crash reports, near-miss reports could provide richer and more systematic data on the factors involved in LC occurrences. However, the current publicly available ATSB reports do not include statistics about near-misses at LCs. Queensland Rail has made public a report of LC near-misses for 2011 only, with a full description of the events as reported by rail staff, such as train drivers, station masters or transit officers (Queensland Rail, 2012b). The report classifies near-misses according to the types of users involved with more than half of the reported near-misses involving pedestrians (\(N = 253/473\)). Given the relatively rare occurrence of LC collisions compared to near-misses, the investigation of near-miss precursors are essential to the understanding of unsafe behaviour, but also could provide a better understanding of safety factors likely to prevent unsafe or fatal occurrences (Edquist et al., 2011; Wullems et al., 2013). In reality however, these reports contain only very limited and subjective information about the involved risk-factors and the contextual description of the events. The reporting of near-misses has not been based on strict protocols and typically includes information on the estimated distance-to-collision and the approximate description of the involved road users and their position vis-à-vis the rail tracks. As discussed in detail by Wullems, Toft, and Dell (2013), the subjectivity of near-miss reporting is mainly associated with the individual decision and the estimations of the rail staff, and correspondingly to the overall safety culture of the organisation. The personal motivation or initiative to report a near-miss could be hampered given that the procedure is time consuming. Also, the final reports of near-misses are subject to omissions and inaccuracies as they are completed after the occurrence. Moreover, it is the responsibility of the reporter (i.e., rail staff) to assess the severity and the importance of the occurrence, and to describe the related characteristics. Thus, the estimation of the risk magnitude of the occurrence could be biased because of poor and limited visibility, because of the emotional state of the reporter, or else by their past experience with similar events. For example, experienced drivers could be more familiar with the cues in the environment potentially leading to risk-situations, but could also be less likely to report repetitive occurrences perceived as “everyday, banal events” (e.g., children running together for a train on their way to school). On the other hand, less experienced drivers might be more vigilant to a wider set of contributing factors in the environment, but also more likely to estimate a larger number of occurrences as highly “at risk” due to their lack of previous exposure to unsafe behaviour. While
near-misses have been considered as reportable notifiable occurrences since 2013 (Rail Safety Law) issues of subjectivity severely limit the usefulness of existing data (Wullems et al., 2013). However, new research projects supported by the CRC for Rail Innovation are currently conducted with the aim to develop a new data collection and analysis system underpinned by accident causation models (Wullems et al., 2013).

2.3.3 Lack of empirical research into the origins of unsafe behaviour

Given the small number of publications targeting pedestrian behaviour and the limitations associated with occurrence data, to date pedestrian unsafe behaviour can be considered as poorly understood and far from being rooted out. Understanding unsafe behaviour and identifying its causal factors implies taking into consideration the broader scope of the threatening situation (i.e., accident prone situation) and the different cognitive and motivational mechanisms which underpin the actions taken in order to cope with the threat.

In the pedestrian LC domain, there is a notable lack in “empirical studies – involving the collection of data or information of some type” (Robson, 2011, p. 14). Empirical studies are an important component of scientific research associated with the rigorous systematic collection of data and the utilisation of adequate analysis methods allowing scientific hypotheses to be tested and conclusions to be drawn (Robson, 2011). Observational methods are commonly utilised to obtain exhaustive and “current” description of environmental and individual factors (e.g., demographics) associated with unsafe behaviour. However, in the case of pedestrian behaviour at LCs, it can be argued that very few of the existing observational studies fully satisfy the assumptions of empirical research. Khattak and Luo (2011) for example, conducted direct video observations in a non-systematic manner during large periods of time (i.e., for four, two and three months in three consecutive years between 2008 and 2010), without accounting for potential other changes occurring during these periods, be they in the environment, organisational procedures (e.g., seasonal changes in timetables, rail staff presence) or in the global safety culture (e.g., safety campaigns). Edquist et al. (2011) conducted direct observations at 11 LC sites with different characteristics (i.e., risk rates) over a 3-week period. However, the observations in morning and afternoon peak hours were not equally distributed across observation sites, which could potentially lead to misinterpretation of the data.
and makes it impossible for data from different locations to be compared. The design and adopted procedures of certain observational studies are somewhat unclearly presented, which affects the scientific value of the publications (Davis Associated Limited, 2005; McPherson & Daff, 2005). McPherson and Daff (2005, p. 5) recorded the behaviour of “several thousand pedestrians”, of which only 208 cases were analysed, and no criteria for this selection provided. Davis Associated Limited (2005) conducted observations of users’ behaviour during the validation of a pre-elaborated sheet of human factor issues associated with the specific observation site. However, the authors did not provide any information on the design of the observations (i.e., period, time of observations) nor on the procedure (data collection, validation).

Further, observations were conducted with the aim to examine the effect of different types of countermeasures such as safety and enforcement campaigns (Lobb, Harré, & Terry, 2003; Sposato, Bien-Aime, & Chaudhary, 2006) or interventions targeting the improvement of controls or the environment (Lobb, Harre, & Suddendorf, 2001; Stewart, Brownlee, & Stewart, 2004). All of these studies included before-(during)-after observation design but did not include control sites. Similar study designs are suggested to provide little scientific evidence to support the widespread use of such measures, as they display poor or inadequate control over potentially confounding factors other than those observed or being tested (Edquist et al., 2009). Having conducted a literature review on the existing publications related to LC countermeasures, Edquist et al. (2009) concluded that even the studies including control sites often propose inadequate data analysis methods for the detection of the true relationship between the interventions in question and the outcome.

A small number of studies are interested in the psychological mechanisms underpinning behaviour (Basacik et al., 2012; Beanland et al., 2013; Clark et al., 2013; Freeman & Rakotonirainy, 2015). Almost two thirds of the identified publications (i.e., 67%, excluding literature reviews) focused exclusively on measuring the proportion of safe versus unsafe behaviour, instead of looking into the origins of behaviour. Among the few who examined the cognitive precursors of unsafe behaviour, Basacik et al. (2012) measured risk perception in different crossing scenarios. Beanland et al. (2013) were interested in users’ perception of the LC environment and the different elements shaping crossing decisions. Clark et al. 
(2013) measured the biases associated with the estimation of the speed of large moving objects (i.e., trains) in accordance with Leibowitz’ theory on size-speed illusion. Others clearly excluded the investigation of the cognitive and motivational precursors of behaviour from their investigation of different risk-contributing factors emphasizing the need for future research to be conducted (Davis Associated Limited, 2005; Iorio et al., 2012).

To summarise, the current knowledge based on observations or on before-(during)-after study designs is associated with important biases, and the conducted experimental studies are unlikely to explain behaviour accounting for the variability of the crossing situations. Arguably the investigation of unsafe behaviour has so far been conducted on a very general level instead of looking into the context-specific explanations of behaviour. More context-specific research will provide a valuable input into the development of successful strategies towards the reduction of unsafe behaviour.

2.3.4 Insufficient investigation on the interaction between multiple contributing factors to unsafe behaviour

Although the existing literature reviews discuss a large number of factors potentially contributing to unsafe pedestrian behaviour, the large majority of the reviewed publications involving data collection methods considered a small number of predictor variables to explain unsafe crossing. Such publications often prioritise the comparison of behaviour between different demographic groups of users at active and passive LCs and a small number of other explicative factors such as train visibility or position (Clancy, Dickinson, & Scott, 2007; Freeman & Rakotonirainy, 2015). The review of the literature indicates that only three publications investigate the effects of multiple interacting factors on unsafe crossing (Beanland et al., 2013; Davis Associated Limited, 2005; Metaxatos & Sriraj, 2013b). Among them, Davis Associated Limited (2005) did not undertake an analysis of the interactions between the multiple identified factors and Beanland et al. (2013) were rather more interested in the comparison between factors influencing the behaviour of different types of users.

2.3.5 Summary of the identified gaps in the literature

The gaps identified in the literature raise important issues about the understanding of pedestrian behaviour at LCs and consequently about the efficiency
of the currently implemented risk-mitigation methods. Among the small number of existing publications specifically targeting pedestrian behaviour at LCs, those based on crash report data are likely to provide very limited, subjective and potentially biased information, and those associated with empirical research are typically regarding a single factor’s contribution to the problem, and often suffer from unclear presentation of the study design and methods. As pointed out by many, to fully understand pedestrians’ behaviour, it is necessary to consider their interaction with all aspects of the surrounding environment and identify those factors that have most importance to the process of decision-making (Beanland et al., 2013; Davis Associated Limited, 2005; Read et al., 2013). To identify the risk-contributing factors to unsafe crossing behaviour, it is essential to first understand the safety constraints encountered while performing different tasks preceding the crossing (e.g., availability and salience of information) and during the crossing (e.g., physical barriers to movement, obstructions to the sight distance, distractions).

2.4 LEVEL CROSSING SAFETY PROTECTIONS IN BRISBANE – QUEENSLAND.

To better understand the tasks associated with crossing at LCs, this section presents in detail the characteristics of the most common design of active LCs in Brisbane.

2.4.1 On the approach of a level crossing

The location of a LC is signalled with road markings and a different number and types of signs (Figure 4) according to characteristics of the larger area (i.e., more or fewer signs can be used according to the terrain and respectively the sight distance). As shown in the figure below, signs can indicate the exact location of the LC or its emplacements relative to the road.
The “LC zone” is the area where crossing is allowed through the rail tracks, and is usually marked with yellow criss-cross markings on the road, emphasizing the stopping point to make a crossing decision and the need to verify whether the road is clear in front before engaging in crossing (Figure 5). Additional road markings stating “Keep Clear” may be provided in front of the yellow markings of the LC zone.

**Figure 5.** Level crossing zone marked with yellow criss-cross road markings (Cannon Hill, QLD, Australia),
Photograph adapted from Google Maps. (July, 2015). Level crossing adjacent to Cannon Hill train station [street view]

### 2.4.2 The active controls for motorists

The active LCs in Brisbane are all equipped with standard Red Flashing Lights (FL), with a well-known international design and a sound alarm (Figure 6). Barriers on each side of the road are installed at some LC sites, but not at others.
The red FLs and sound are the first control that activates to signal the approach of a train. At sites without barriers the FL and sound activate a minimum of 18 seconds before the train arrives (Queensland Rail, 2012a). At sites with barriers the FLs and sound activate earlier (i.e., 28 seconds before the train arrives) allowing enough time for motorists to clear the road before the barrier starts falling. Conventionally, the barriers start falling 8 seconds after the activation of the FLs and sound and take around 10 seconds to fully lower (Queensland Rail, 2012a). The period of activation can be longer according to the type of train passing (i.e., slower-freight trains) or its direction (i.e., trains stopping at a station prior their arrival at the LC). The period of activation can also be extended if two trains are to cross the LC in an interval of less than 10 seconds, in which case the barriers remain down (Queensland Rail, 2012a).

2.4.3 The active controls specifically designed for pedestrians

Level crossings in Brisbane are often equipped with “Pedestrian gate systems” which regulate pedestrian flow through the crossing independently of vehicular traffic (Figure 7).
Pedestrian gate systems consist of pedestrian lights similar to road traffic lights, an audible alarm different to the one activating with the FL for vehicles that activates at the same time as the pedestrian lights, and two automatic entry and emergency gates, part of a well-defined pedestrian corridor surrounded by mazes which serves to channelize pedestrian traffic flow (Figure 7). Similarly to the FLs and the barriers, pedestrian gate systems activate 28 seconds before the train arrival. The entry gate starts closing horizontally towards the pedestrian conventionally 8 seconds after the activation of the pedestrian lights and sound, and takes 4 to 6 seconds to fully close, with completion 4 to 16 seconds before the train arrival. The activation time of the pedestrian gate systems vary according to the length of the pedestrian corridor and the number of tracks it comprises. The pedestrian entry gates can be locked after closing, so that they cannot be pushed open. The emergency pedestrian gate is always closed but can be pushed open from the LC zone in case a pedestrian remains inside after the closure of the entry gate. Queensland Rail lists several reasons why pedestrian gates may seem to be operating falsely (i.e., closing even if there is no train passing): 1) maintenance; 2) if a train is stopping in proximity to the crossing; 3) if there is a failure in the system, gates will automatically close until the problem is solved (Queensland Rail, 2012a).

For LCs providing access to a train station or its platforms on a middle island, pedestrian traffic is commonly regulated separately on each side of the island. In this case, two sets of pedestrian gate systems are installed on each side of the LC and on the middle island (Figure 8). Thus, FLs and barriers can be lowered prohibiting
vehicular traffic, whereas pedestrian lights may allow pedestrian crossing through an unoccupied track (i.e., with no train passing).

Figure 8. Graphical illustration of the emplacement of pedestrian gate systems on each side of a LC providing access to train station platforms through a middle island Based on Google Maps (October, 2015). Level crossing providing access to Coorparoo train station [street view]

The design of automatic pedestrian gates in Australia and Queensland in particular is different to the design of pedestrian gates used in other countries such as the U.S.A. (Figure 9). The horizontally closing Australian pedestrian gate restricts people from passing under the gate, which is easier in the American crossing context (i.e., vertically falling gates). However, the horizontally closing gate can be easily pushed open if not locked, and jumped over even when locked, enhancing unsafe crossing intentions. To our knowledge, there is no published evidence comparing the effect of both types of gates on crossing decisions.
Furthermore, given the small number of studies conducted in Australia, it is unclear how pedestrians perceive and understand the variable active controls installed at LC intersections. For example, there is no available occurrence data or research on pedestrian behaviour distinguishing active LCs with and without active controls for pedestrians (i.e., those with only FL and barriers for vehicles).

2.4.4 The passive controls (warning signs) designed for all types of road users

A multitude of warning signs are often installed at the mazes of the pedestrian corridors (Figure 10). Typically, they inform about the number of tracks and protection measures without necessarily specifying the targeted group of road users (e.g., “STOP ON RED SIGNAL”). If they do specify the targeted group of users, information about which signals to follow might be unclear (e.g., Figure 10: “Pedestrians do not cross while lights are flashing or alarm sounding”).

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Figure 9. Pedestrian (vertically falling) gate Park Boulevard in Glen Ellyn
Reprinted from Metaxatos and Sriraj (2013a, pp. Appendix H-5), Reprinted with permission
Considering the generic nature of the messages on passive signs, it is possible that pedestrians perceive the provided information about safe crossing as misleading or unclear. This could be particularly true at LC intersections with middle islands, as at such intersections a pedestrian can face a red FL for vehicles and a green pedestrian light at the same time.

At LCs giving access to train stations, there are often signs printed on the sides of the rail tracks reminding the risk and the illegal nature of crossing the tracks (Figure 11).

Similarly to other passive signs, the contents of such messages could be misinterpreted. Provided that the sign is located on the station platforms, pedestrians
could associate the legal and safety threat only with the crossing of the rail corridor within the station area, where crossing is always prohibited, and not at LCs where crossing is allowed according to the provided controls.

In conclusion, crossing behaviour may be influenced by the types of active and passive controls installed at LCs, but also by to their location, physical properties (e.g., salience) and operation mode (e.g., presence of locks on the pedestrian gates, time and period of activation of the active controls, etc.). Therefore research on a general level failing to account for potential differences in the crossing context is unlikely to provide an in depth and comprehensive explanation on the origins of unsafe behaviour.

2.5 CONTRIBUTING FACTORS TO PEDESTRIAN UNSAFE CROSSING BEHAVIOUR

Given the small number of studies conducted on pedestrian behaviour at LCs and the plethora of different adopted methods and procedures, it is difficult to draw conclusions on the main factors involved in unsafe crossing. The cumulative evidence obtained from self-reported, observational or else experimental studies should be interpreted with caution, as each research method is associated with limitations to the obtained results. While self-reported data can easily identify personal motivations to violate the rules or risk perception (e.g., the train was far), observational studies provide more accurate information regarding transgressions accounting for multiple factors (e.g. train position, activated controls, distractions, etc.). Thus, to avoid misleadingly generalised interpretations of the current knowledge, the following sections present what is known about the potential risk-contributing factors to crossing behaviour with an emphasis on the design and the methods employed in the studies proving the evidence. Firstly, evidence on the factors related to the physical LC environment and the crossing situation is presented in Section 2.5.1. Secondly, factors related to pedestrian’ characteristics, states and motivations and to their social environment are presented respectively in Section 2.5.2 and in Section 2.5.3. Finally, factors associated with the organizational management and procedures are presented in Section 2.5.4.
2.5.1 Characteristics of the physical environment

2.5.1.1 The automatic controls

The automatic controls are meant to reduce unsafe crossing behaviour by providing audible and/or visual alerts and physical barriers obstructing the entry of users in the LC zone. Among the audible alerts, the first and most common type is the “train horn” or the “train klaxon” used by train drivers only at the point indicated by “whistle board” sign on the approach of a LC area. The use of train horns is strictly regulated in Australia and internationally because of possible noise disruptions to residential areas near rail tracks (Queensland Rail, 2015).

Further solid state audible devices were introduced at active LCs. The combination of both audible and visual controls was found to be the most effective when compared to installations of only visual or audible controls (RSSB, 2008). A recent diary study conducted in Australia confirmed the efficiency of the audible alarms to pedestrians’ awareness of an approaching train (Beanland et al., 2013). Participants reported first seeking audible information prior to making a decision of whether to stop at the approach of a LC. Audible alerts have also been tested as a measure against crossing in front of a second train (i.e., after a first train has passed the LC zone). A U.K. study examined the effect of audible devices with change in warble frequency after a first train has passed, however, according to the results, this was poorly understood or not noticed by users (RSSB, 2008).

In terms of the visual automatic controls, six studies between 2005 and 2015 examined pedestrian behaviour in the presence of gates, with half of them comparing behaviour at active and passive LCs (Clancy et al., 2007; McPherson & Daff, 2005; Roy Morgan Research, 2008). According to respondents surveyed by Clancy et al. (2007) the active protection for pedestrians and specifically gates would reduce unsafe behaviour. In line with these reported perceptions by users, Metaxatos and Sriraj (2013b) observed that pedestrian transgressions are less likely to occur at LCs with a larger number of pedestrian gates. Pedestrian gates provide physical protection in addition to audible and visual alerts. However, pedestrian gates could have controversial effects on crossing behaviour. Automatically closing barriers or gates have previously been associated with the so called “beating the gates tendencies”. Richards and Heathington (1990) showed in their observational study that drivers tend to drive around LC barriers after they have started lowering,
explaining such behaviour by a low perception of risk associated with the perception of having enough time to cross before the gates are fully closed. Considering that, for pedestrians, circumventing the gates is physically easier than for drivers, beating the gates tendencies are equally if not more likely to occur among this group of users. Indeed, the previously mentioned self-reported and observational studies identified beating the gates tendencies among pedestrians. Participants responding to the Australian survey reported being likely to transgress “to beat the gates and catch a train” (Clancy et al., 2007, p. 48). Among the observed pedestrian transgressions in the U.S.A., the majority occurred while the vertically closing gates were in motion (i.e., either ascending or descending), although it is not clear what number occurred before a train had arrived at the LC zone (Metaxatos & Sriraj, 2013b). Similarly in Australia, Edquist et al. (2011) observed that almost all transgressions in front of an oncoming train (92%) occur at less than 10 seconds before the train has arrived at the LC zone with the majority occurring while the gates were closing. The same authors note that these results were unexpected because the pedestrian gate should close at least 13 seconds before the train arrival (Edquist et al., 2011). This result emphasises the risk associated with beating the gates tendencies in the case of potential technical issues.

Finally, transgressions after the gates are closed have been associated with crossing after a first train has passed through the LC (Metaxatos & Sriraj, 2013b). This type of transgressions hides the risk of crossing in front of a second train. An American observational study has shown, as could be expected, that pedestrians are more likely to engage in such behaviour than motorists, who are also risking damage to their vehicles (Sposato et al., 2006). As reported by Edquist et al. (2011), new, higher pedestrian gates designed to reduce the risk of closed gate transgressions were trialled in Victoria, with the aim to restrict pedestrian mobility and easy access through the gates. However, the trial was not successful. The new installations resulted in a larger number of pedestrians pushing the gates open, since pedestrians could no longer jump over the gates.

Apart from an outgoing train, the presence of a stopped train could be a contributing factor to transgressions of closed gates. While there is a considerable evidence showing that the presence of a stopped train increases driver violations (Abraham, Datta, & Datta, 1998; Caird et al., 2002; Creaser, Caird, Edwards,
&Dewar, 2002), only a few publications suggest a similar effect on pedestrians’ intentions to violate (Clancy et al., 2007; RSSB, 2008; Stewart et al., 2004). Moreover, transgressions of closed gates by drivers in the presence of a stopped train are explained as motivated by frustration of excessively long waiting times (i.e., a train is topped for too long), while transgressions of pedestrians are explained as motivated by the need to catch the stopped train at the station. Indeed, a large number of the existing publications reveal that circumventing the gates is potentially associated with accessing a station or catching a train (Edquist et al., 2011; McPherson & Daff, 2005). Thus, more research is needed to clarify whether a stopped train is a risk contributing factor to pedestrian violations motivated by catching the train, frustration with waiting times, or simply by low perception of risk as long as the train is not moving.

In conclusion, the literature shows that transgressions of different types of active controls are associated with different levels of risk-taking (i.e., transgressions of closed gates are riskier than transgressions of lights and sound and transgressions of closing gate), with different risk-contributing factors (e.g., absence of a visible train, outgoing train, presence of a stopped train) and with different precursors of behaviour (e.g., low perception of risk, motivations to save time or to avoid missing the next train, beating the gate tendencies, sensation seeking or beating the train tendencies). Therefore it is essential to distinguish between the three “types” of unsafe behaviour. In fact, authors commonly refer to transgression Types I, II and III respectively to describe “transgressions of the lights and sound”, “transgressions of a closing gate”, and “transgressions of a closed gate” (Khattak & Luo, 2011; Metaxatos & Sriraj, 2013b; Sposato et al., 2006).

2.5.1.2 Access to train stations - the location of the platforms

While accessing the station platforms and catching a train has previously been suggested as a prime cause of unsafe behaviour, rare are the authors who have examined the impact of the location of the platforms on unsafe behaviour. According to results of the observational study of Edquist et al. (2011), unsafe crossing is more likely to occur at stations where the platforms are on the outside of the tracks, obliging pedestrians to cross all tracks to access either of the platforms. Nevertheless, the authors point out that underpasses would be unlikely to solve such problems of accessibility (of the station platforms), as pedestrians would always be more
concerned about the time required to catch a train, which in any case is longer if crossing through an under or overpass compared to the LC corridor. The results of a survey conducted by Lobb et al. (2001) in Auckland, New Zealand are in accordance with this assumption, suggesting that the prime cause for unsafe crossing through the tracks reported by pedestrians was the suboptimal location of the overpass making the crossing trajectory much longer. In line with the discussion in the previous section, pedestrians’ choice to cross the tracks could be reinforced if a train is stopped at the station and they are motivated to catch it.

2.5.1.3 Sight distance and train position

In the existing literature, mitigated opinions exist about the effect of sight distance at active LCs on crossing decisions. As the sight distance is closely associated with the approaching train’s visibility, Clancy et al. (2007) suggest that pedestrians are likely to transgress as long as they cannot see a train visibly approaching. Such behaviour could be explained by a lower perception of risk or by a suspected malfunction of the controls. In this relation a U.K. report suggested the obscuration of sight distance as a potential countermeasure (RSSB, 2009). The report concluded that reduced sight distance would not be useful as, while it may increase the perceived risk, it also increases the actual risk of crossing. Most recently, Edquist et al. (2011) did not find a difference in the number of observed transgressions according to the sight distance at different active LCs. However, the train visibility was suggested as the main factor influencing pedestrians’ decisions to cross or not, according to findings from a diary study conducted by Beanland et al. (2013).

According to the results from observational studies, transgressions are mostly observed in front of an approaching train (Edquist et al., 2011; Metaxatos & Sriraj, 2013b). In contrast, in both of these studies, a small number of pedestrians crossed behind a train, thus risking encountering a second train passing through the station. Only Basacik et al. (2012) in the U.K. conducted an experimental study in a simulated environment examining the perceived likelihood that the controls will remain active after a train passage. While they found a poor awareness of a second train’s arrival, the results related to pedestrians were somewhat unclearly presented.

2.5.1.4 The larger urban, economic and cultural environment

Silla and Luoma (2011) have pointed out that rail lines have always divided communities, imposing on pedestrians the need to cross the tracks to access schools,
shopping areas, residential areas etc. Edquist et al. (2011) pointed out that the study of pedestrian behaviour at LCs should include the investigation of factors related to the larger socio-economic environment. They note that pedestrians’ behaviour is a reflection of their socio-economic context, which is to be considered in order to ensure more effective safety measures. For instance, the authors point out that the nearby sport, industrial or tourist facilities could define pedestrians’ most frequently adopted crossing trajectories and destinations. Thus, examining the provided crossing alternatives with regards to the larger area may inform on potential issues and provide effective solutions to reduce unsafe behaviour.

2.5.1.5 Contextual characteristics of the crossing situation - time of the day, weather conditions

While more unsafe behaviours have systematically been associated with morning and afternoon peak hours (Clancy et al., 2007; Edquist et al., 2011), a more recent observational study conducted in the U.S.A. suggested that transgressions reflect the density of the pedestrian flow throughout the day (Metaxatos & Sriraj, 2013b). Morning transgressions have been associated with catching a train, and afternoon peak hours with exiting a train. It is thus logical to consider that in morning peak hours associated with a denser time period (between 7am and 9am) a larger proportion of pedestrians from different socio-economic classes would be likely to cross to catch a train compared to pedestrians crossing out of a train in the widely distributed afternoon peak hours (form 4pm to 8pm).

In the literature there is little evidence to support unsafe behaviour occurring more in adverse weather conditions, in specific periods of the year (school period) or during special events (e.g., sport/cultural events). While Searle et al. (2011) suggest adverse weather conditions as an important factor influencing the train’s conspicuity, they also show that, according to available crash data, train-motorist occurrences and fatalities take place mainly in clear conditions.

2.5.2 Pedestrian’s characteristics and motivations

2.5.2.1 High risk groups of users according to demographics

According to Australian crash data, males were largely overrepresented in railway fatalities between 1997 and 2002, accounting for 84% of all victims (ATSB, 2001). In the same dataset, 43% of the male fatalities were recorded in the 15 to 29 age group which represented less than 30% of the general population, classifying
them as a high risk age group. In contrast, another analysis of the same dataset revealed that while female pedestrians were rather evenly distributed across age groups, almost one third of the victims were over 60 years old age (McPherson & Daff, 2005). However, in more recent crash data there is no indication of the number of male versus female victims. To identify high risk groups of users, the size of the population should be considered along with the number of LC users. To date, there is little empirical evidence to support young males being a particularly at risk group of users in Australia. Among the three surveys conducted in Australia, it is only Freeman and Rakotonirainy (2015) who found that males were significantly more likely to report previous violations defined as deliberate unsafe and illegal crossing during controls’ activation compared to females, not accounting for characteristics of the general population. In their observational study Edquist et al. (2011) witnessed a slightly larger number of male transgressions (59%) at the 10 LCs in the Perth area, noting that no information could be collected on “exposure”or the number of male versus female pedestrians crossing compliantly. The results from observational study with indicators of exposure and population’s characteristics would provide most accurate data on the propensity of both genders to unsafe behaviour, which to date is lacking. The consideration of male pedestrians as a high risk group of users is therefore questionable.

Among different age groups of pedestrians, minor pedestrians and younger adults have been systematically pointed to as a high risk group of users (Clancy et al., 2007; Freeman & Rakotonirainy, 2015; McPherson & Daff, 2005). However, such conclusions are typically based on self-reported data or data associated with other types of users (i.e., not pedestrians at LCs). On the other hand, the results from the observational study of Edquist et al. (2011) show that more than half of the transgressors (60%) were older adults, between 30 and 60 years old.

2.5.2.2 Personal characteristics and states

The personal characteristics most often associated with unsafe crossing are impairments hindering the perception and the recognition of various controls, and sensation seeking associated with an increased risk-taking propensity, typically in young male pedestrians (Clancy et al., 2006; Davis Associated Limited, 2005; Searle et al., 2011). However, according to observational studies, impairments do not seem to constitute an important factor explaining unsafe crossing behaviour (Edquist et al.,
In contrast, “sensation seeking” describes behaviour motivated by a strong need for novel and exciting experiences and a constant search to avoid boredom (Zuckerman, 2014), and has been associated with reported transgressions of pedestrians at LCs (Freeman & Rakotonirainy, 2015). Sensation seeking of drivers at LCs has previously been associated with beating the train tendencies (Witte & Donohue, 2000). As opposed to beating the gate, beating the train could be explained by a motivation to cross before a train or to prove oneself faster than the train.

Similarly, observational or experimental studies have confirmed the impact of only a few of the psychological states potentially influencing unsafe behaviour, such as distraction, fatigue, negative mood or emotions. Edquist et al. (2011) report that only a small number of the observed transgressions were related to distractions from other pedestrians or mobile phones.

2.5.2.3 Motivations - Journey purpose

Being in a hurry to catch a train is a principal motivational factor to transgressions reported as such by pedestrians (Clancy et al., 2007). Self-reported qualitative evidence suggests that people tend to transgress in a hurry to catch a train when going to work/university, when they are impatient to wait for the next train, or simply when they “know they can make it” (Clancy et al., 2007; Metaxatos & Sriraj, 2013b). According to observational studies, transgressions are more likely to occur in front of an approaching train (Metaxatos & Sriraj, 2013b). Such results support the assumption that transgressions and deliberate unsafe behaviour are perceived as justified by motivations to avoid missing the next train and save time. A more in depth analysis of such motivations has not yet been conducted.

2.5.3 The social environment

Transgressions were suggested to increase in the presence of other pedestrians (Clancy et al., 2007). However, data from observational studies shows the opposite trend; pedestrians were more often seen transgressing alone than in groups (Edquist et al., 2011). However, these findings cannot be considered as generalisable due to the small number of transgressions observed overall. In fact, only two observational studies have performed an analysis of the odds of transgressions alone versus in a group, accounting for exposure (Khattak & Luo, 2011; Metaxatos & Sriraj, 2013b). The authors confirmed that larger groups of pedestrians were more risk inclined than
both pedestrians on their own or in groups of two crossing together. Moreover, the authors associated group transgressions with younger pedestrians and/or school children. It was hypothesised that group transgressions occur as a result of reliance on the collective scanning of the group (i.e., diffusion of responsibility) and because of increased distraction (Searle et al., 2011). However, it is also possible that such aberrant behaviour particularly among young people, is driven by social pressure. A substantial amount of research has been conducted on the risks young people take on the roads (e., not wearing helmets, crossing at red lights) in the presence of their peers (REF), but there is still not enough evidence to suggest that children are susceptible to jump in front of a train while “playing chicken”.

2.5.4 The system’s organisational procedures and management

2.5.4.1 Familiarity with rail traffic operations

Rail traffic characteristics such as time schedules, directions of train, relative number of trains passing in a given period of time etc. are directly associated with pedestrians’ familiarity with the crossing context. People who use a LC regularly tend to have good knowledge about such characteristics of rail traffic compared to less regular users. However, there may be divergent opinions of whether familiarity is a favourable or unfavourable safety factor. One can argue that familiarity is conducive to safe behaviour, as it allows more accurate expectations of train speed, direction or arrival time. However, familiarity may also create conditions for errors due to overconfidence or perception of control (McPherson & Daff, 2005). In the case of active LCs, a strong familiarity with traffic characteristics may decrease the perception of reliability or utility of the active controls and thus facilitate risk-taking behaviour. To date, a number of authors have associated familiarity with beating the train tendencies and lowered attention to alerts in the environment, as well as with overconfidence and low perception of risk (e.g., “I know that a train will not pass in this period of time”) (Clancy et al., 2006; Davis Associated Limited, 2005). However, to our knowledge to date, no study has examined the impact of the level of familiarity on risk-taking behaviour or intentions of pedestrians at LCs (i.e., apart from Basacik et al. (2012) whose results attributable to pedestrians are unclearly presented).
2.5.4.2 Rail traffic characteristics

Iorio et al. (2012) have shown that the normalized number of “events” (i.e., not resulting in collision, including near-misses) at Italian passive and active LCs is higher at railway lines with a higher density of rail traffic (81-100 trains/day), compared to the normalized number of collisions and fatalities, which are higher at rail lines with 61-80 trains/day, noting that the maximum number of trains passing through Italian LCs per day can reach 140. This evidence can be associated with longer waiting times (i.e., impatience), with low awareness of the rail traffic flow (i.e., crossing right after a first train has passed), or with a greater flow of road users. Arguably the higher density of rail traffic could also be associated with more transgressions occurring in peak hours. This factor should presumably be minimised at LCs with a middle island, which allows crossing on one track while other tracks can be closed. No research has investigated the trends in transgression in peak hours at LCs without middle islands compared to those with. Furthermore, no evidence is available in the literature on the trends in transgression according to the predominant types of trains passing through the LC.

2.6 EXISTING COUNTERMEASURES

According to a literature review on the existing countermeasures of various types (e.g., education, enforcement, LC design and controls upgrades) targeting the improvement of user behaviour at LCs, Edquist et al. (2009, pp. Executive summary, xiii) concluded that “there is little in the way of rigorous scientific evidence to support widespread use”. As noted in Section 2.3.4, the existing publications on safety measures often test the effects of combinations of interventions (Lobb et al., 2001; Lobb et al., 2003), which limits the conclusions related to the contribution of each intervention. As for the local safety campaigns, QR provided an evaluation of a 2010 “Illegal track crossing” safety campaign (Xiao, 2010). Posters displaying the consequences of a real track crossing incident were displayed at 10 black spot LCs in Brisbane (Figure 12). The program was evaluated as globally successful, due to the reduced number of reported near-misses after the campaign, rail staff’s perceptions about changes in pedestrian behaviour, and positive feedback from passengers. However, the effectiveness of the program was also associated with several limitations. On one hand, other factors could have contributed to the reduction in the number of transgressions after the campaign (i.e., a school holiday period). On the
other hand, the behaviour of young children could also have been influenced by the Jonathan Beninca’s visits to local schools, which were conducted in parallel to the poster intervention. Thus, whether the speeches by the victim or the poster had more effect on safety improvement remains unclear.

Figure 12. Poster part of the “2010 illegal track crossing safety campaign” displayed at 10 black spot level crossings in Brisbane
Reprinted from Xiao (2010, p. 68Appendix - A), Reprinted with permission

2.7 CHAPTER SUMMARY

This chapter provided a detailed description of the current state of knowledge related to the risk-contributing factors to unsafe crossing. While the different types of factors were presented in four different sections, it is clear that they are to a large extent correlated and interdependent. However, it is difficult to draw comprehensive general conclusions because the available evidence is obtained from studies with a wide range of designs and procedures. Although very little empirical evidence has examined the multitude of potential interacting risk-contributing factors, the main findings from the literature can be summarised as follows:
Factors in the physical environment seem to play a central role in decision-making and to be associated with various other factors, such as crossing motivations (i.e., journey purpose) or beating the gate or train tendencies. Different types of transgressions (e.g., transgressions of lights and sound, of closing or closed gate) seem to be to a large extent underpinned by the motivation to access a train station and catch a train. But motivations such as being in a hurry and avoiding wasting time are closely related to the LC environment (e.g., the fastest possible access to the platforms) and to characteristics of the larger area. Transgressions after the gate is closed are often associated with crossings behind a train. Familiarity and expectations have been suggested to significantly influence the perception of risk, and consequently pedestrian’s actions, but very few studies have provided empirical evidence on the impact of such factors. Globally there is a considerable lack of knowledge about the precursors of behaviour and to what extent their effect on unsafe crossing could be generalisable across different crossing situations. Theory-based explanations of behaviour are necessary to be able to make predictions about behaviour (i.e., in changing circumstances) and identify successful methods of behaviour change.
Chapter 3: Theoretical approach

This chapter presents the adopted theoretical approach in this thesis. To answer the research question and address the identified gaps in the literature, an innovative approach based on systems thinking combined with paradigms of the traditional individualistic approach was adopted. The research conducted in this thesis aligns largely with the principles of a systems approach, as a large part of the research program was descriptive, aiming to explore a wide range of factors involved in unsafe crossing decisions. In addition, common methods and theories from social and cognitive psychology have been used to explain how behaviour is influenced by such risk factors. The complementarity of these two approaches provides empirical evidence on the key (interacting) factors contributing to unsafe behaviour, which is lacking from the current body of literature, and also to proposes a valuable basis for theory-based research to support the development of future interventions.

3.1 THE EVOLUTION OF TRAFFIC SAFETY PARADIGMS – FROM THE TRADITIONAL INDIVIDUAL APPROACH AND THE RECENTLY APPLIED SYSTEMS THINKING

While research into the traffic safety domain is a relatively new discipline, it has consistently expanded, reaching over 2000 publications per year in 2010, compared to the small number of around 40 publications annually between 1900 and 1960, as per a scientific literature review conducted by Hagenzieker, Commandeur, and Bijleveld (2014). According to the same authors, in the early stages of motorised transportation (1900-1920), crash occurrences were viewed as the result of misfortunes, and the related research was limited to the description of the facts around the events. In later years, with the progressively increasing number of crashes, the scientific community focused on the investigation of human contribution to accidents and hazardous events. Between 1920 and 1950 the causes for accidents were sought in the fallibility of human nature, which meant that the accident-prone users needed to be educated or punished. Thus, it is only since the 60s that traffic accident investigators started looking at multiple causes contributing to accidents. In the early stages of this period, literature focused exclusively on either the road users’
behaviour or the vehicles’ performance (1950-1970). However, for the last 50 years (i.e., from the 1960s on), more and more research has been conducted on the improvement of human-machine interactions and interface. With the fast growing popularity of “traffic psychology” (i.e., psychology applied to traffic safety) since the 80s, the impact of multiple factors on accident causation has become a central principle of accident investigations. Although publications based on “systems thinking” (i.e., viewing accidents as the product of the sub-optimal performance of the system as a whole) first appeared around 1965-1970, the application of system theories and models has been progressively growing with around 800 publications between 2006 and 2010 (Hagenzieker et al., 2014). The analysis of the LC performance viewed from a systems perspective implies the understanding of the decisions and actions of all operators across different hierarchical levels of the rail and road systems. As pedestrians are not directly managed by the rail system, the understanding of their behaviour within the complex LC environment requires an extended application of theories originating from social and cognitive psychology.

3.2 THE PRINCIPLES OF SYSTEMS APPROACH

In the following sections the four principles of systems approach are presented based on a discussion provided by Read et al. (2013).

3.2.1 Complex systems have a hierarchically organised performance

The complexity of the system does not stem from the complicated socio-technological properties of its components, but from the complex net of interactions between components, which perform at different levels of the system in order to achieve the given goal (the system’s objective). Generally, the highest level is associated with the budgeting and planning for the safe system’s performance, the subordinate middle level operationalizes and manages it through procedures and regulations, and the lowest level is directly related to the execution and the physical conditions under which the system performs, taking into account physical and environmental components. Each component of the system is “responsible” for the meeting of a certain (safety) requirement.

3.2.2 The performance of complex systems is variable

Multiple components are involved in the safe performance of complex systems implying the interactions of a large number of actors. Therefore, the system’s
performance is variable from one situation to another. The actors are often presented with a wide range of strategies that can be adopted to achieve a given goal. Moreover, the LC system is open to the environment and its performance depends to a large extent on user’s behaviour, which is hardly predictable.

3.2.3 The performance of complex systems is dynamic

Components on each level of the system interact through feedback control loops, informing on the outcomes of their performance. In other words, the upper components define and shape the performance of the bottom components. In turn, the bottom components return feedback about their performance to the upper levels. Components on the upper levels will then use such information towards the refinement of the procedures and rules to be implemented on the lower levels. Thus, system performance is dynamic, and changes over time in reaction to events such as occurrences, safety measures, and technical or other upgrades. Consequently, the effects of this constant change on the system’s performance cannot always be predicted or tracked.

3.2.4 Safety and accident occurrences are the emergent properties of complex systems

Level crossings are designed to ensure that road users cross safely at the rail tracks which resumes the optimal performance of this system. To achieve it, each component of the system is “responsible” for meeting a certain objective. They address various safety constraints to avoid “failures” or the inability of the component to satisfy its assigned objectives. Therefore, the safe performance of the system is the lack of failures or the successful enforcing of safety constraints on each level of the system (Leveson, 2011a). Safety and accident occurrences are considered to be the emergent phenomena of upward and downward interactions between components of the system (Hollnagel, 2004; Leveson, 2004).

3.3 THE MOST WIDE SPREAD ACCIDENT CAUSATION MODELS AND THEIR APPLICATION TO LEVEL CROSSING SAFETY

The first attempts in the investigation and the understanding of accident causation extends back to the early 1800s when the DuPont explosives factories were founded and developed (HaSPA - Health and Safety Professionals Alliance, 2012). The company policies were oriented towards the understanding of the existing
hazards and supported a multitude of initiatives with an ultimate aim of zero injuries. The performance of the factories was gradually improved for 120 years after its foundation in 1802, a period that was marked with the emergence and the formulation of core principals of the modern accident causation theories.

Hollnagel (2004, p. 5) defined an accident as “a short, sudden and unexpected event or occurrence that results in an unwanted and undesirable outcome ... and must directly or indirectly be the result of human activity rather than a natural event”. The evolution of accident causation models over the years could be summarised by three distinctive underpinning concepts (HaSPA - Health and Safety Professionals Alliance, 2012). Originally, simple linear models supported the idea that a single factor can lead to an accident by impacting other factors of a given chain of events. Next, complex linear models viewed accidents as the result of multiple contributing factors interacting always in a sequential manner. In addition to the factors directly associated with the accident (i.e., triggering the accident) accidents were also attributed to latent failures typically occurring on the higher hierarchical system levels. Finally, the most recently employed complex non-linear models are based on a new generation of thinking associated with the dynamics of modern complex systems (i.e., faster technological progress, complex human-machine interfaces, organisational safety culture). These models share the idea that interactions between different system components are not linear and it is only through the understanding of the combined effect of multiple interacting factors that accidents can be explained.

3.3.1 Traditional sequential and epidemiological models

Heinrich (1931) proposed the first accident causation model, illustrating the causes of accidents using the metaphor of dominos. Called the “Domino effect”, or “Domino theory”, the model associates accidents with five types of factors in a chain event sequence occurring in a fixed or logical order (HaSPA - Health and Safety Professionals Alliance, 2012). According to Heinrich (1931) the causes of accidents are to be sought in one of the following categories of factors: social environment factors, faults of person, unsafe acts, accidents or injuries (Figure 13). Consequently if one of the dominos falls, the entire roll is doomed. Conversely, if the accident-prone factor is removed, the sequence will remain stable, ensuring a safe performance.
With the study of disease epidemics and the factors around their development, a new wave of epidemiological accident models gained popularity in the 1980s (HaSPA - Health and Safety Professionals Alliance, 2012; Qureshi, 2007). These models relate to the latent (i.e., non manifest) environmental factors which can be viewed as hosting a disease (i.e., accident) (Figure 14). One of the most widespread epidemiological model utilised to date is the Reason’s organisational safety model, popularised as the “Swiss cheese model” (Reason, 1990, 1997). This model seeks to identify the “sharp end” actors who are directly related to the accident, and whose actions are referred to as “active failures” (i.e., errors versus violations). To produce an accident however, active failures are combined with “latent conditions”, or failures residing in the management and policies of the system, and with “local conditions”, local triggering events such as adverse weather conditions or location characteristics. Thus, for a given chain of events to result in an accident, the failures on different system levels have to match, as would match the matching holes in different layers of cheese.
Figure 14. Reason’s Swiss cheese model of accident causation

Accidents can therefore be prevented by solid “barriers” that reduce the chances for failures to accumulate and combine. Although this model introduced a no-blame investigation approach as opposed to the previously widely spread “blaming the individual” traditional approaches, it remains limited in the sense that the causal interactions between active and latent failures cannot be well understood and are presented in statically instead of capturing the dynamic, non-linear interactions between system factors (Dekker, 2014; Hollnagel, 2012; Leveson, 2011b; Qureshi, 2007; Shappell & Wiegmann, 2012).

3.3.2 Modern complex socio-technical system models

With the fast pace of technological advances in the 19th century, more attention was accorded to the non-linear interactions between the multiple components of “complex systems”. Perrow (1984) considers complexity the main characteristic of the modern high-technological, high consequence systems (Dekker, Cilliers, & Hofmeyr, 2011). He argues that traditional safety approaches fail to address safety issues because systems complexity allows the slightest disturbance to result in a catastrophic outcome (HaSPA - Health and Safety Professionals Alliance, 2012; Perrow, 1999). Perrow’s Normal Accident Theory (NAT) postulates that accident occurrence is normal (HaSPA - Health and Safety Professionals Alliance, 2012).
Most recent complex system models are consistent with Perrow’s thinking and consider accident as well as safe performance as the emergent properties of the complex non-linear interactions between system components. Several models supporting similar principles but translating different methods and procedures of accident investigation and prevention have been introduced since the 2000s. In a literature review on the existing referencing models and tools based on complex system theory, Underwood (2013) identified three most widely known models (i.e., STAMP, FRAM and AcciMap) described in the following section.

### 3.3.2.1 The Systems-Theoretic Accident Model and Process (STAMP)

The Nancy Leveson’s STAMP model (Systems-Theoretic Accident Model and Process) explains accidents as the failure to exercise control over different safety constraints across different levels of the “control structure” (i.e., hierarchical organisation of the system) (Leveson, 2004). In other words, the model seeks to understand why, if control was imposed, it did not prevent or detect the accident. To give an example from a LC context, if enforcement was ensured but did not prevent unsafe crossing, then the safety constraint could be inadequate (i.e., sub-optimal enforcement procedures). On the other hand, if the safety constraint was adequate (i.e., optimal enforcement procedures), what other factors in the system hindered the exercised control over the safety constraint. Leveson (2004, p. 26) describes the process leading to an accident as “an adaptive feedback function that fails to maintain safety as performance changes over time to meet a complex set of goals and values”. Typically a STAMP accident analysis is conducted by first identifying the hierarchical components of a structure and the safety constraints imposed by their interactions, and then classifying the “flawed control” interactions, including the causal factors, and the reasons for such dysfunctions.

### 3.3.2.2 Functional Resonance Accident Model (FRAM)

Another example of a model incorporating the principles of modern system thinking is the Hollnagel’s Functional Resonance Accident Model (FRAM) (Hollnagel, 2004). FRAM is a qualitative accident model recognising the variability of complex systems’ performance as mandatory. According to the author, there are many subsystems in the structure of a complex system whose performance is variable and interdependent. The main sources of variability are the humans, the technology, the latent conditions and the barriers. In the normal state of a system’s
performance, the variability of some system components is absorbed by the whole. However, if the variability dominates on multiple system levels, than the system performance will result in negative outcomes. The theory based model of Hollnagel can be used to understand the failures of the system resulting from resonance between different system components. Figure 15 demonstrates an example of a FRAM diagram, in which potentially risk prone functions of the system (or the subsystem) are connected through their basic parameters (i.e., input, output, time, control, preconditions and resources). The performance variability of the system is assessed through the identified dependencies between system functions (hexagons). The description of each function allows the identification of the potentially unwanted resonant connections, according to the level of variability of each function categorised on an 11-point scale.

![FRAM Diagram](image)

*Note. I = input, O = output, T = time, C = control, P = preconditions, R = resources*

**Figure 15. FRAM diagram**
Reprinted from: Underwood (2013, p. 59), Reprinted with permission

Even though the model does not include an explicit description of the overall system structure, but only the connections of interest, Hollnagel (2004, p. 197) encourages “analysis of the extended system structure”. Moreover the six standard characteristics of each function facilitate comparison with other functions throughout the system. Finally, while this model identifies the parts of the system requiring remedial actions, it is the analyst’s responsibility to propose interventions.

### 3.3.2.3 The AcciMap Accident Analysis Technique (AcciMap)

AcciMap is a technique based on Rasmussen’s risk management framework (J. Rasmussen, 1997; J. Rasmussen, Svedung, & Svedung, 2000). This tool aims to investigate accident causal factors beyond the classical chain of events sequence.
This is achieved by including in the horizontal sequence of actions leading to an accident a “vertical representation” of the decisions and actions taken on higher system levels, which could in a state of a normal system performance provoke the accident prone situation. Decision and action throughout the system potentially related to an accident are classified in a diagram listing the six main system levels included in Rasmussen’s model (Figure 16). The arrows connecting the identified decisions and actions reflect the causal relationships between system factors and system states.

![AcciMap diagram adapted from Svedung and Rasmussen (2002)](source)

*Figure 16. AcciMap diagram adapted from Svedung and Rasmussen (2002)*

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Thus, AcciMap provides information on the causal effects between different interacting factors, considering all system levels. It has mainly been used in a retrospective analysis of system failures (Underwood, 2013), however there is a growing number of publications applying it to the proactive analysis of accidents and unsafe behaviour (Goode, Salmon, Lenné, & Hillard, 2014; Svedung & Rasmussen, 2002).
3.4 UNDERSTANDING THE ORIGINS OF UNSAFE BEHAVIOUR – ERRORS VERSUS VIOLATIONS

The LC system is “open” in the sense that road users are external actors whose behaviour is not directly managed by the system’s authorities. As stated by Edquist et al. (2009), the human role within a complex system is to perceive and process key information required to emit a decision on an appropriate action and carry out that action. Failure at all of these steps can lead to failure in the system performance, which in the scope of this research can be translated as unsafe crossing behaviour.

Thus, unsafe behaviour can be more or less intentional depending on the level at which the failure occurred. To classify behaviour according to the level of intentionality, we refer to Reason’s classification of unsafe acts based on Rasmussen’s Skill, Rule and Knowledge based classification (SRK) (J. Rasmussen, 1983; Reason, 1990). Reason distinguishes failures on the information processing level, referred to as “errors”, from deliberate failures to comply with the rules prescribed by the system, referred to as “violations”. In the sense that it is the system’s responsibility to provide sufficient and adequate information to users to make their decision, errors can be translated as failures of the system, whereas violations are human failure to abide by the system rules. Unsafe behaviour underpinned by errors is considered unintentional, as the person is not aware of the illegal and unsafe nature of behaviour. In the case of violations, the person is aware of the illegal action and the associated risk.

Reason identifies two main types of error: slips/lapses and rule/knowledge-based errors, associated with failures on different levels of performance (Reason, Manstead, Stradling, Baxter, & Campbell, 1990). Depending on previous familiarity with the environment and previous experience, a task can be performed at an automatic (unconscious) or at a more conscious level of performance (decision-making) (Delhomme, De Dobbeleer, Forward, & Simones, 2009). Delhomme, De Dobbeleer, et al. (2009) review the cognitive processes used at the three levels of performance associated with the risk of committing different types of errors (Figure 17).
Automatic slips and lapses refer to failures in either the storage of information or the execution of actions (e.g., recognition failures, memory failures, attention failures). There is an associated risk of disruption of the automatic task and brusque behavioural change in the case of unexpected events. In the pedestrian LC context, such errors could be the failure to identify the active controls, and would be associated with distractive factors or personal characteristics (e.g., visual/hearing impairments) and states (e.g., absent-minded behaviour). In contrast, rule/knowledge-based errors are more likely to involve failures in the planning process of behaviour. Rule-based errors consist in the “good application of a bad plan” or in the “bad application of a good plan”. They are associated with a conscious control over a routine task. In a LC context an applied “bad plan” could explain crossing if the purpose of the controls was misinterpreted, whereas a misapplied “good plan” could explain crossing perceived as safe, as per the status (de-activated) of the wrong control. In contrast, knowledge-based mistakes occur in
novel situations where a pedestrian would not have any necessary reference information to interpret the purpose of the controls. Violations are underpinned by strong motivational factors which attribute more importance to the perceived benefits of acting against the rules.

Because of the different nature of the mechanisms (cognitive and motivational) underpinning errors and violations, they can be mitigated through different safety measures (Davis Associated Limited, 2005). The precursors of errors and violations can be explained by different theories and models of behaviour and behavioural change.

3.5 THEORIES ORIGINATING IN SOCIAL AND COGNITIVE PSYCHOLOGY CONTRIBUTING TO THE UNDERSTANDING OF PEDESTRIAN BEHAVIOUR AT LCS

Human Factors are widely used in a systems approach. However, the definitions of the discipline’s principles, approach, objectives and methods are currently somewhat differently understood within the wider community of scientists. According to Hollnagel (2014) human factors engineering was recognised as a discipline in the late 1940s with the emergence of important technological and intellectual developments such as the introduction of the first digital computers. Thus, as a continuum of works and theories aiming to improve labour productivity, human factors engineering had a strong emphasis on the interaction between human and modern technology as opposed to the preceding focus of research on the mechanical work flow. To date, not only are various terms used to refer to the same discipline (Wilson, 2014), but also, various definitions of its objectives exist. While according to some, human factors (ergonomics) has originally focused on the improvement of design to fit the needs of the human (Hollnagel, 2014), others suggest that human factors has traditionally employed psychological paradigms to understand “the physical and cognitive capabilities and limitations of humans” in their interaction with the surrounding environment (Read et al., 2013, p. 2). In a similar fashion, there are opinions that human factors has always been a systems discipline (Wilson, 2014), while others recognise it as moving away from the individual approach with the advent of systems theory and distributed cognition (Read et al., 2013). This diversity of points of views between scientists is understandable, given the wide range of domains (some practically-centred, others
more theory centred) in which human factors has found its application. The objective here is not to trace the exact origins of the discipline or to provide a concrete definition, but to review the way human factors methods have been applied to the understanding and improvement of pedestrians’ behaviour at LCs. In the open LC system, various authors have pointed to the importance of investigating human factors issues in order to better understand crossing decisions. Edquist et al. (2009, p. 4), have conducted a literature review discussing human factors issues potentially applicable to Australian LCs stating that “the critical issue at LC systems is to provide the road-user with salient information with sufficient time for them to make a decision and act on that decision”. Other researchers in the U.K. identified a wide range of human factors issues through various methods and classified them according to their potential contribution to deliberate or unintentional unsafe behaviour (Davis Associated Limited, 2005). This large database could be used to underpin the development of tools and assist inspectors in assessing the specific risks at LCs.

Besides the reviews and classifications of human factors issues provided earlier, to date only Salmon et al. employ well known human factors methods (e.g., cognitive task analysis, work domain analysis) to the first full system analysis of LCs. While human factors methods could undeniably provide an extended analysis of issues associated with the global system performance, their effectiveness in the fundamental understanding of behaviour and its precursors is questionable. As previously pointed out by Salmon, Read, Stanton, and Lenné (2013) system approach fails to produce a “fine grained analysis” of individual behaviour. They note that systems analysis methods may not investigate individual behaviour sufficiently in depth and therefore recommend the complementary use of system and traditional psychological approaches to support the development of more effective countermeasures. By adopting methods traditional to the psychology discipline within the scope of this thesis, the objective is to validate their applicability and usefulness within a larger systems based approach. While authors have criticised the utility of an individual-centred approach in comparison to a systems approach, the aim here is to demonstrate that theories originating in psychology could be applied to the investigation of pedestrian behaviour in congruence with the principles of the systems approach.
The following sections review classical theories in psychology explaining unsafe behaviour underpinned by cognitive precursors which could be associated with a low perception of risk (Section 3.5.1), motivational precursors which could be associated with personal goals (Section 3.5.2), or social pressures explaining behaviour as driven by norms of the society.

3.5.1 Definition of risk and perception of risk and theories explaining low risk perception

Various definitions of risk and risk-taking exist across scientific disciplines and time periods. In their book “The psychology of risk: identify, evaluate, prevent” Kouabenan, Cadet, Hermand, and Sastre (2006) define “danger” as an event or situation likely to cause negative consequences or harms to human or the environment, and a “risk” as the possibility of a danger to occur. Risk-taking is the intentional action undertaken despite the perceived risk or likelihood of negative consequences to follow. A long history of expectancy-value theories in psychology and other disciplines explain risk-taking as based on the weighting of the perceived costs and benefits associated with an action. Expectancy-value theories originated with a model proposed by Fishbein in 1970s. Fishbein’s theory of reasoned action (TRA) suggests that people’s choices of how to act are guided by the most perceived benefits and values associated with the outcomes of the behaviour (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). Another theory is the well-known “Risk homeostasis theory”, which postulates that people only take an optimum or desired level of risk (Wilde, 1982). In other words, they adapt their behaviour according to the perceived risk. In riskier situations one would tend to act safely, and inversely one would be keen on taking more risk if the situation is perceived as safer. This theory has been criticised in the road safety domain because of methodological inconsistencies (i.e., lack of clear definition of the optimal level of risk that people accept to take), which respectively questions the utility of the model (Assum, Bjønnskau, Fosser, & Sagberg, 1999; Elvik, 2004).

Whatever the adopted theoretical method, risk-taking is often preceded by a subjective risk assessment. Risk assessment is based on characteristics of the potential negative consequences such as severity, controllability, or frequency. In addition, risk assessment is also influenced by personal factors such as self-esteem,
anxiety, locus of control or perceived control and depends on previous experience contributing to the formation of attitudes and expectations.

Attitudes are defined by Ajzen (1991, p. 188) as “the extent to which a person has a favourable or unfavourable evaluation or appraisal of the behaviour in question”. Attitudes explain how people evaluate places, things or others and as such are formed according to individuals’ past experience. According to the Theory of planned behaviour (Ajzen, 1991), attitudes among other mental constructs such as the perception of control are strong predictors of behaviour.

Perception of control and self efficacy (Bandura, 1982) are both terms widely used in psychology to describe a perceived control over the events and perceived capacity to cope with a risky situation (Ajzen, 1985; Assailly, 2012). The perception of control in a LC context could explain violations justified by the perception of being able to “make it on time”. Evidence suggests that pedestrians report such explanations for unsafe behaviour associated with the environmental characteristics of the crossing (i.e., small distance to be crossed, absence of visibly approaching train, presence of a stopped train at station), but also with the perception that one is more likely than others to avoid negative events (Clancy et al., 2007; Davis Associated Limited, 2005).

Risk-taking behaviour could be influenced by comparative judgements about others’ likelihood of experiencing negative events. This phenomenon in social psychology describes the perceived likelihood of others experiencing more or less negative events compared to oneself. Weinstein (1980) first called this bias in judgements “unrealistic optimism” and “optimistic bias”, demonstrating that people tend to judge their likelihood of experiencing positive events as higher than others’ likelihood, and inversely, their likelihood of experiencing negative events as lower than others’. Authors referred to this phenomenon by different terms such as “illusion of invulnerability” (Perloff, 1983; Perloff & Fetzer, 1986). To date, the most widely used term is “comparative optimism” (Weinstein & Klein, 1996). Among other factors, the emergence of comparative optimism is dependent on the available information about others, on the perception of control over the events, on previous experience and on the perceived characteristics of the events (Harris, 2007; Milhabet, Desrichard, & Verlhiac, 2002). Various theories could explain comparative optimism (Milhabet et al., 2002). Among other theories, the relationship between
expressed comparative optimism and perceived controllability of the events has been demonstrated by McKenna, Warburton, and Winwood (1993). According to the authors, smokers consider themselves more exposed to smoking-related illnesses than non-smokers, but less exposed compared to other smokers. Thus, the more people perceive themselves as able to control the situation and take actions to avoid negative consequences, the more they express comparative optimism. While comparative optimism has been associated with a decreased likelihood of adopting safe behaviours, comparative judgements could also be accurate (Delhomme, Cristea, & Paran, 2014; Delhomme, Verlhiac, & Martha, 2009; Martha & Delhomme, 2014). More recently, the same authors associated the expression of “realistic” comparative optimism with people identifying themselves as risk-takers and sensation seekers (Delhomme, Verlhiac, et al., 2009; Martha & Delhomme, 2014). Thus, a strong comparative optimism could be associated with strong risk-taking tendencies especially when people perceive themselves as likely to exercise control over the events. The strong perceived control could be associated with the perceived benefits of taking a risk (Milhabet et al., 2002). Another branch of the expectancy-value theories in psychology, the theories of “self regulation”, explain people’s decision to maintain or abandon efforts towards the achievement of a given behaviour.

3.5.2 Self-regulation and goal directed behaviour

Goals direct behaviour and serve as reference values for feedback processes (H. N. Rasmussen, Wrosch, Scheier, & Carver, 2006). Goals are defined as “the mental representations of desired outcomes to which people are committed” (Mann, de Ridder, & Fujita, 2013, p. 488). Self-regulation theories explain the various processes that identify which goals are to be pursued (i.e., goal setting) and the methods to attain them (i.e., goal striving) (Mann et al., 2013). Goals are thus associated with the expected valued and successful outcomes of one’s behaviour. Goal striving implies the identification of different opportunities and actions allowing the achievement of the desired goal (Mann et al., 2013). Indeed, “goals differ in their level of abstraction” (H. N. Rasmussen et al., 2006, p. 1724). Different goals may be more or less related to the same mental representation (e.g., the goal of being a good person implies different behavioural goals). In fact, Powers (1973) reasoning on the organisation of discrepancy-reduction feedback loops modulating
behaviour, is in accordance with the idea that actions are guided by a complex hierarchical organisation of goals (H. N. Rasmussen et al., 2006). The achievement of higher level goals is often dependent on the acquisition of multiple lower level goals or objectives.

In the LC context, the goal of catching a train seems hardly sufficient to the understanding of pedestrians’ motivations to take a risk. Catching a train can be associated with more or less positive expectations according to the more abstract goal this behaviour is linked to (e.g., meeting an old friend, be on time for a professional appointment, be on time for an important event). Consequently, crossing while warnings are operating might be associated with the perception of more or less risk compared to the importance of the expected outcomes. The perceived opportunity to achieve more important goals may hinder the perceived risks associated with a given situation.

3.5.3 Social influences

Research into social or group dynamics is rooted in the disciplines of psychology and sociology and consists of the study of the decision making processes and behaviour of people interacting within or between social groups. Group dynamics depend on a concept known under various denominations: “social norms” (Perkins & Berkowitz, 1986), “subjective norms” (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975), or “normative influences” (Cialdini, Reno, & Kallgren, 1990). Independently of the term used, this concept refers to the way human behaviour and decisions are shaped by pressures from the social environment, such as social norms. Social norms have different role to the interpersonal interactions. To clarify this, Cialdini et al. (1990) distinguish between descriptive and injunctive norms. “Descriptive norms” can be viewed as illustrating what is perceived to be a common behaviour. According to the authors, the observation of others’ behaviour would inform on what is considered to be an effective and adaptive action in a given situation: “If everyone is doing it, it must be a sensible thing to do” (Cialdini et al., 1990, p. 1015). In contrast, “injunctive norms” represent what is perceived as “morally approved or disapproved conduct” (Cialdini et al., 1990, p. 1015). According to Reno, Cialdini, and Kallgren (1993, p. 104), injunctive norms guide behaviour according to the perceived and expected “social sanctions for normative or counter normative conduct”. Contradictory opinions exist in the literature on whether
Factors shaping pedestrians’ unsafe behaviour at actively protected level crossings

Social norms are a reliable predictor of behaviour. On one hand, the distinction between descriptive and injunctive norms is not always evident given that often widely observed behaviour is considered morally approved and thus it is likely that the influence of both types of norms is misinterpreted while they have an impact on different sources of motivation (Cialdini et al., 1990). On the other hand, according to the same authors, norms should only guide behaviour if the person is focused on normative considerations (i.e., by making a norm salient), while in reality people are unlikely to act according to normative considerations in all moments and situations in life. Although the predictive value of the concept has been largely confirmed in scientific literature, this research adheres to the opinion that in order for a social norm to have an influence on behaviour it has to be “activated” (Cialdini et al., 1990, p. 1015). In a LC context, social norms would be activated observing other pedestrians’ behaviour. A pedestrian could imitate the behaviour of others crossing unsafely (i.e., descriptive norms), or identify him/herself as a member of a valued social group in the presence of other members of such group (injunctive norms).

3.5.4 Chapter summary

To understand the importance of applying a modern system approach to the understanding of occurrences in complex environments such as LCs, in this chapter were first presented the benefits of applying such approach compared to the now less popular epidemiological models for accident investigation. The four main principles of systems approach were reviewed to insist on the importance of acknowledging in the analysis of unsafe behaviour: the risk-contributing factors from all hierarchical levels of the system; the variable impact of such factors on behaviour from one situation to another; and the impact of the dynamic system performance on the precursors of behaviour associated with different risk-contributing factors (i.e., the effects of risk-contributing factors are subject to changes in the systems’ performance introduced with time). Further, widely used system based models of accident investigation in complex systems were presented to highlight on one hand the benefits of using such models in terms of the identification of risk-contributing factors across system levels, and on the other hand, the weakness of applying such models to the in depth investigation of the cognitive and motivational precursors of behaviour and correspondingly, to the identification of adequate strategies to behaviour change. Provided that pedestrians are external users of the LC system, the
understanding of the core origins of their behaviour is of prime importance to propose effective safety measures. In this relation, different types of unsafe behaviour were reviewed associated with failures on different levels of decision-making process and action execution. Finally, classical theories of social and cognitive psychology were presented as an example of the different explanations that could be provided to unsafe behaviour according to its origins. Such theories should be used to propose and examine strategies to reduce unsafe behaviour.

As little descriptive information is available on the current risk-contributing factors to unsafe pedestrian behaviour across all system levels, an extended exploratory stage of research was prioritised within the research program. This plan allowed the examination of a broad range of risk-contributing factors through different methods and to a smaller extent the dynamics of the systems’ performance on pedestrians’ behaviour. The exploratory stage of research was followed by an empirical stage of research in which the precursors associated with the previously identified risk-contributing factors were examined more in depth. Traditional methods of psychology were utilised to verify the impact of these factors on transgression likelihood, accounting for variability of crossing situations. The overview of the studies comprised in the research program is presented in the next chapter. Each study has been published or submitted for publication in scientific journals.
Chapter 4: **Overview of the research program and the related publications**

4.1 **CHAPTER INTRODUCTION**

This chapter provides an overview of the overall structure of this thesis. A research question was formulated in relation to the identified gaps in the literature. To respond to the research question three main research aims were formulated. The research aims supported the choice of studies comprised the research program. The studies were designed so that the results from each could inform the method of the following study. The overall thesis structure is graphically illustrated at the end of this chapter (Figure 18).

4.2 **RESEARCH QUESTION**

Informed by the conclusions drawn from the literature review, an analysis of the trends in train-pedestrian occurrences according to the available crash data, and onsite visits of LCs in Brisbane, the research question leading this program is formulated as follows:

“How can traditional individual-centered theories in psychology can be used together with modern system theories to better understand pedestrian behaviour at LCs?”

4.3 **AIMS OF THE RESEARCH PROGRAM**

There are three main aims of the research program. The first two were addressed in the exploratory stage of research and the third during the second stage, using an empirical and quantitative-oriented approach. Based on the identified gaps and conclusions drawn from the literature review, the three aims are formulated as follows:

AIM 1 addressed in STUDY 1: identify current factors influencing pedestrian decisions in a LC context.
AIM 2 addressed in STUDY 2: associate these factors with either erroneous or deliberate unsafe behaviour.

AIM 3 addressed in STUDY 3: examine the impact of the identified risk-contributing factors on decision-making and to what extent such factors could predict future unsafe behaviour across a variety of crossing situations.

4.4 OVERVIEW OF THE RESEARCH PROGRAM AND THE PRODUCED PUBLICATIONS

During the first exploratory stage of research, two distinctive qualitative research methods were adopted in a complementary manner. Study 1 employed a direct observations method to identify factors within the larger physical and social environment. Apart from directly observable factors, such as the pedestrian-controls interactions (e.g., pushing the pedestrian gate open), the observations method allowed the identification of potential risk-contributing factors related to user motivations or factors associated with the larger LC environment (e.g., presence of busy nearby road intersections, schools, shopping areas defining pedestrians’ crossing trajectory). For instance, observing pedestrian behaviour identified potential deliberate risk-taking motivations (e.g., pedestrians running right after the activation of the controls or while exiting the LC could be associated respectively with the motivation to avoid missing a train, or avoid waiting at a nearby road crossing intersection).

In Study 2, the directly observed and potential risk-contributing factors were verified and complemented by self-reported data that revealed the cognitive and motivational precursors associated with different risk-factors. Interviews were conducted to provide further knowledge about human factors at LCs which could not be obtained through observational methods only (Davis Associated Limited, 2005). Therefore, to enhance the collection of information related to various crossing situations and to facilitate the sharing of sensitive information like previous risk-taking behaviour, group discussions, or focus groups, were organised with a small number of pedestrians of similar age, all familiar with the riskiest LC in Brisbane. The results of this study helped classify the risk contributing factors according to their association with errors and/or violations.
This first exploratory qualitative stage underpinned the development of the method and material used in the second quantitative stage of research. In this stage, Study 3 was designed to collect data from a wider sample of pedestrians at Brisbane’s LCs (i.e., crossing at LCs at all urban rail lines) with the objective of providing empirical evidence on the effect of different precursors of unsafe crossing across different video recorded situations. More concretely, the predictors of (reported) previous unsafe behaviour were measured among pedestrians with different crossing profiles (i.e., crossed rail line and LCs, crossing frequency in different time slots, period of LC use, train users, age groups and demographics, etc.). In addition, the factors most likely to predict future crossing likelihood were examined across the recorded crossing scenarios, accounting thus for similarities and differences between the crossing contexts.

Study 1 is presented in Chapter 5 as taken from Paper 1 and explores the observed risk-contributing factors to pedestrian unsafe crossing at three LCs in Brisbane with different physical characteristics. Similarities and differences in the results obtained for each LC are presented, accounting for the importance of factors pertaining to the LC layout and the larger socio-economic area in addition to other factors related the available safety protections and the individual characteristics.

Study 2 is presented in Chapter 6 as taken from Paper 2, and builds upon the first exploratory data, presenting the results from the focus group discussions with pedestrians familiar with the riskiest LC in Brisbane. This second study marks the culmination of the exploratory stage of research by proposing a new theory-based framework for the investigation of pedestrian unsafe behaviour at LCs (PULC). This model supports the identification of risk-contributing factors across the hierarchical system levels and their classification according to their contribution to errors and/or violations. As this model can be used in a proactive manner, the conclusions drawn from this study underpinned to a large extent the development of the last study of this program. Study 3, presented in Chapter 7 as taken from Paper 3, examines to what extent the identified interacting risk-contributing factors could predict previous deliberate violations and transgression likelihood. Concretely, the interactions between the status of the active controls (i.e., pedestrian lights and gates) and the train’s position (i.e., visibly approaching versus stopped versus none) were operationalized through the recording of five “real world” crossing scenarios.
Consistent with systems thinking, this study design measured the differences in transgression likelihood not only according to the articulated variables, but also according to other additional factors included in the scenarios (i.e., LC layout, presence of other pedestrians) and moreover, according to respondents’ personal characteristics and their previous experience at LCs (e.g., previous sanctions, familiarity with the controls).

Figure 18. Structure of the thesis program of research
Chapter 5: Direct observations of pedestrian unsafe crossing at urban Australian level crossings - Paper One

5.1 INTRODUCTORY NOTES ON THE PUBLICATION

This chapter comprises Paper 1 as taken from:


Paper 1 was published in a peer reviewed international journal “Urban rail transit”, available since 2015. The candidate, as first author, accepts the overall responsibility for this publication. The candidate was responsible for all aspects of the manuscript preparation, including reviewing the literature, formulating the research question, conducting and supervising data collection, analysing and interpreting the results and writing and submitting the final manuscript. All co-authors meet the criteria for authorship and take responsibility for their role in delivering the publication. All of the co-authors of this paper are members of the candidate’s supervisory team and their contribution to this paper was supervisory in nature. Written permission was provided from each to include the publication as part of this thesis and its publication on the QUT ePrints database (Appendix L).

The study presented in this paper was part of the first exploratory stage of research. It addresses the first research aim of this thesis, which is to identify the risk-contributing factors to pedestrian unsafe behaviour at active LCs. Direct observations of pedestrian behaviour were conducted at three black spot LCs in Brisbane. In total, 129 transgressions were observed for a total of 45 hours of observations. Unlike observational studies in the literature reporting primarily on the
frequency and types of observed transgressions (i.e., according to status of controls),
the results of this study privileged the investigation of factors related to the LC
design and the larger area and the interactions between multiple factors. Different
transgression patterns were identified according to status of controls and the LC
design. In the next step of research, the conclusions from this study were
complemented with information on the cognitive and motivational precursors of
behaviour in order to better understand how unsafe crossing decisions are shaped and
should be addressed.
5.2 ABSTRACT

The number of pedestrian victims at Australian and foreign level crossings has remained stable over the past decade and it continues to be a significant problem. To examine the factors contributing to pedestrians’ unsafe crossing behaviours, direct observations were conducted at three black spot urban level crossings in Brisbane for a total of 45 hours during morning and afternoon peak. In total, 129 pedestrians transgressed the active controls. More transgressions were observed at the crossings located in more populated suburbs in close proximity to large shopping centres and school zones, whereas the smallest number of transgressions were observed at the least populated locations. In addition to characteristics associated with the larger socio-economic area, the patterns of transgression could be associated with the properties of the existing safety equipment and the design of each level crossing (i.e., location of the platforms, number of rail tracks). Indeed, the largest number of crossed unoccupied but “at risk” rail tracks (where a train could have passed), was observed at the crossing with the least transgressions. Contrary to previous findings, younger adults were the most frequent transgressors. School children and elderly were most likely to transgress in groups. Potential directions for future research and more effective measures are discussed.
5.3 INTRODUCTION

Level crossings (LCs) are generally classified according to the protection systems with which they are equipped. Active LCs are equipped with automatic controls (e.g., red flashing lights, boom gates), whereas passive LCs are signalled with passive signs (e.g., “STOP”). At passive LCs road users cross when there is no visible approaching train, whereas active LCs assist or enforce users’ movement (i.e., crossing is prohibited in the presence of activated controls). In Australia and Queensland in particular, LCs in urban areas can be equipped with special form of protection for pedestrians. The pedestrian flow is directed through a pedestrian corridor surrounded by mazes. Additional pedestrian lights and gates positioned on each end of the pedestrian maze activate on the approach of a train, regulating pedestrian traffic independently of vehicular road traffic. In the Brisbane area this measure is particularly important at sites where access to a train station is provided via the LC. In this case the rail tracks are likely to be separated by a middle island and pedestrian traffic can therefore be regulated separately on each side of the middle island hosting a train station or a platform.

While such additional measures that specifically target the improvement of pedestrian safety at LCs have been taken in Queensland, the number of collisions involving pedestrians compared to those involving motorists has remained stable in the last decade. A similar trend has also been observed in other countries (ATSB, 2012; Metaxatos & Sriraj, 2013b). In addition, more than half of the reported near-misses for 2011 in Queensland (54%, N = 253) were between a train and a pedestrian, noting that such data is likely to be underreported (i.e., these reports are provided by rail staff and therefore do not represent systematic counts) (Queensland Rail, 2012). Collisions between rail vehicles and pedestrians are not only more likely to result in severe injuries and fatal consequences for victims (compared to other road crashes), but are also related to serious economic costs in the short and long term (Iorio et al., 2012).

Each LC is unique, defined by the complex environment and surroundings comprising road and rail infrastructures and the actors involved in both systems (Edquist et al., 2009). Thus, safety constraints in this complex environment are subject to variability and are highly dependent on the dynamics of the larger system and the specificities of the crossing context. Building upon findings from a previous
analysis of factors at play specific to LCs in Brisbane, the present paper presents the results from direct observations of pedestrian unsafe crossing behaviour at three actively protected black spot LCs (Stefanova, Burkhardt, Filtness, et al., 2015). Three sites with different, but common characteristics of the local Brisbane railway lines were selected to examine trends in pedestrian unsafe behaviour related to three main categories of factors.

After a brief review of the related literature, the study methodology is explained in detail and selected results are presented and discussed in context of previous findings and potential future research opportunities.

5.4 RELATED WORK

A literature review on 23 papers related to pedestrian behaviour at LCs showed that, to date, a greater emphasis was directed towards studying the risky crossing behaviour of drivers as opposed to pedestrians’ (Stefanova, Burkhardt, Filtness, et al., 2015). In most of the papers, the focus is on quantifying non-compliant behaviour according to legal norms – referred to as “transgressions”, instead of looking at empirical evidence on the origins and the multiple factors contributing to unsafe pedestrian crossing behaviours. Seven of the studies included observation methods (Edquist et al., 2011; Khattak & Luo, 2011; McPherson & Daff, 2005; Metaxatos & Sriraj, 2013b; Parker, 2002; Sposato et al., 2006; Stewart et al., 2004). Six of them were based on the analysis of video recordings of pedestrians crossing, and one (conducted in Australia) adopted a similar approach to ours, with observers coding the variables manually (Edquist et al., 2011). In the following paragraphs, main findings from observational and other studies are summarised in three large categories of factors that are likely to explain pedestrian unsafe crossing: 1) environmental and temporal characteristics of the crossing context; 2) pedestrian characteristics; and 3) social environment characteristics.

5.4.1 Factors related to the physical characteristics of the environment and the dynamics of the crossing context

5.4.1.1 Presence of active controls – pedestrian gates

The presence of active pedestrian gates has been suggested as the most efficient type of controls by a number of authors (Basacik et al., 2012; Edquist et al., 2011). Metaxatos and Sriraj (2013b) observed that the odds of transgression
decreased with the larger numbers of pedestrian gates at the LC compared to LCs equipped with only one pair of pedestrian gates (i.e., on one side of the crossing) or without gates. However, the presence of automatic gates has been associated with three distinctive transgression types and could therefore be associated with a sub-optimal safety performance. In some cases, the presence of pedestrian gates was suggested to increase the so called “beating the gate tendencies” or the perception of control over the risk as long as the gate is not fully closed. In line with this assumption, Edquist et al. (2011) noted that 50% of the observed transgressions (i.e., at LCs in Western Australia) occurred before the pedestrian gates had closed. Moreover, Metaxatos and Sriraj (2013b) observed more transgressions after the gates had started lowering and before they were in horizontal position than after. Transgressions after the gates were fully lowered were mainly observed after a train had already passed through the LC. Thus, the presence of pedestrian gates could be associated with an increase in risky crossing behaviours right after the activation of the lights and before the gate have started closing (i.e., people assuming that “they can still make it safely on time”), but also after a train had passed through - often corresponding to the last seconds of closure.

5.4.1.2 Position and number of trains during crossing

Train position has been identified as a key factor influencing crossing decision (Clancy et al., 2006). One observational study demonstrated a significant effect of train position, such that the odds of transgression (versus safe crossing) were higher if crossing in front of an approaching train compared to behind an ongoing train (Metaxatos & Sriraj, 2013b). Such behaviour could be explained by the lack of visibility of the approaching train or by a perception bias (i.e., a misjudgement of train speed or perception that the train is “far away”). Indeed, respondents in a survey conducted by Clancy et al. (2007) indicated that they had previously transgressed as they believed that they “had sufficient time to get across before the train reached the crossing” (p. 23). In relation to this, Clark et al. (2013) have demonstrated that the estimation of the speed of large moving objects such as and specifically trains is likely to be erroneous. In their experimental simulation study, the same authors confirmed that consistent with Leibowitz’ theory (1985), a visible approaching train is perceived to be moving slower than an approaching car and therefore could be a contributing factor towards pedestrians’ low perception of risk.
While the risk of crossing in front of a second train has been largely demonstrated and discussed previously (Basacik et al., 2012; Clancy et al., 2007; Parker, 2002; Sposato et al., 2006; Stewart et al., 2004), it might not be as important in the current crossing context at LCs in Brisbane (2014), given that often a single track is operated by a separate set of active controls (pedestrian gates and lights) which deactivate allowing crossing soon after a train has passed. Nevertheless, the separately operated pedestrian corridors on both sides of a middle island could engender a high risk of crossing in front of a “second train”, considering that controls on the opposite side of the middle island could activate anytime. Moreover, at middle islands, the presence of a stopped “at station” train could hinder vigilance and the perception of the activation of the second pair of controls if pedestrians are transgressing in a hurry to catch the stopped train.

5.4.1.3 Platforms’ location

To our knowledge, only Edquist et al. (2011) have, to date, correlated unsafe crossing with the platforms’ location vis-à-vis the rail tracks. According to the authors, pedestrians are more likely to transgress if the rail tracks are between the station platforms than if they are separated by a middle platform forcing thus pedestrians to cross more than one track at the time, to access either of the platforms.

5.4.1.4 Temporal characteristics of the crossing situation

Morning and afternoon peak hours are associated with an increased number of pedestrian transgressions (Clancy et al., 2006). Nevertheless, while Edquist et al. (2011) observed more transgressions in afternoon peak hours, Metaxatos and Sriraj (2013b) demonstrated that transgressions in different times of the day correspond to pedestrian traffic volumes particularly high in the morning and more widely distributed in the evening peak hours.

5.4.2 Factors related to pedestrian’s characteristics and motivations

Two types of unsafe crossing behaviours can be distinguished according to pedestrian’s intention. The term “violation” is frequently used to distinguish deliberate crossing in the presence of active controls from unintentional rule breaches that are referred to as “errors”. In observational and other studies, young pedestrians are considered a high risk group of users who deliberately violate rules (Clancy et al., 2007; McPherson & Daff, 2005). Their crossing behaviours have been associated
with sensation seeking tendencies (thrill-seeking) or perception of control, compared to elderly for example. Furthermore, male pedestrians are associated with higher risk-taking tendencies than females, however such a trend was only confirmed by one observational study in which male transgressors were identified slightly more often than females (59%) (Clancy et al., 2006; Edquist et al., 2011). Finally, according to Clancy et al. (2007) as well as Metaxatos and Sriraj (2013b), motivations to deliberately transgress are associated with the given journey context (e.g., being in a hurry, avoiding missing the next train, being on time at work/school). In contrast, errors are often associated with elderly pedestrians likely to experience hearing, motor or visual impairments (Clancy et al., 2006; Khattak & Luo, 2011; McPherson & Daff, 2005; Stefanova, Burkhardt, Filtness, et al., 2015), or with distraction (Metaxatos & Sriraj, 2013b; Stefanova, Burkhardt, Filtness, et al., 2015).

5.4.3 Factors related to the social context of crossing and interactions between multiple factors

The presence of others has been shown to increase risk-taking likelihood in previous observational studies. Accounting for differences in the size of pedestrian flow in and out of peak hours, Metaxatos and Sriraj (2013b) and Khattak and Luo (2011) found that the number of transgressions increase with an increasing platoon size. According to the observations of Edquist et al. (2011), crossing in groups could be more common among school children encouraging each other to deliberately transgress. Similarly, Khattak and Luo (2011) showed that group violations increased in the presence of young children. More generally, being in a hurry or trying to avoid missing the next train were associated with an increased number of transgressions in the presence of a stopped at station train (Clancy et al., 2006; Metaxatos & Sriraj, 2013b).

While previous observational studies provide some interesting insights on factors likely to impact unsafe crossing behaviours of pedestrians, the current knowledge-base remains limited. Moreover, the generalisability of previous findings is questionable when comparing different countries, territories or even urban areas with different environmental characteristics. Differences between the results from previous studies or their interpretation could be explained by the variability of the adopted research designs, procedures (e.g., the periods of data collection, utilisation
of recording devices) or data analysis methods. For instance, the number of observation sites varied between one (Khattak, 2009; McPherson & Daff, 2005; Parker, 2002) and ten (Metaxatos & Sriraj, 2013b). In addition, data collection was conducted between 1997 and 2011 and could last from several days (10) to several months (two and nine). The longest data collection period spanned three consecutive years (Khattak & Luo, 2011). Most of the previous observational studies were conducted in the USA where LCs have similar, but not identical, design compared to Australian LCs. At American LCs, pedestrian gates are similar to those for vehicles prohibiting pedestrian crossing while lowered, whereas pedestrian gates in Brisbane close horizontally blocking the access through the path. Arguably, the existing findings are unlikely to reflect the “current” and broad pedestrian crossing context at LCs. They are unlikely to relate to LCs, where specific measures targeting pedestrian safety have been taken, as is the case in Queensland. Therefore more in depth and context-centred research is needed.

5.4.4 Rationale for the adopted research method and research question

Compared to self-reported or crash data, direct observations allow for the detection of factors likely to impact decision-making without participants being necessarily aware of their influence (e.g., presence of others crossing unsafely). Providing more objective and descriptive information than any other methods, direct observations are fundamental for the investigation of pedestrian unsafe crossing, as a highly under-researched area.

This study is to our knowledge the most recently conducted in Australia, investigating multiple factors and their interactions that are likely to contribute to unsafe pedestrian crossing behaviours. Our main aim is to examine such factors and how they can be associated with different patterns of unsafe crossing, accounting for the specific crossing contexts of three typical LCs in Brisbane.

5.5 METHOD

5.5.1 Choice of observation sites

The first stage of site selection consisted in the review of the available indicators on unsafe crossing tendencies across LCs in Brisbane. According to the most recent data provided by the urban rail operator in Brisbane (Queensland Rail - QR), almost half of all reported near-misses with pedestrians for 2011 occurred at
LCs on the same rail line, the Cleveland line (42%). The second stage of site selection consisted in random direct observations at LCs black spot locations on the Cleveland line and other rail lines, during which information was collected on:

- Characteristics of the physical environment (e.g., number of rail tracks, location of the platforms and station, over bridge access, number of pedestrian corridors);

- Technical properties of the controls (e.g., progress of activation and duration of the active controls for pedestrians, presence of locking mechanisms on pedestrian gates);

- Characteristics of pedestrian-users (e.g., school children, dressed in business attire) and the most commonly adopted trajectories (i.e., in relation to pedestrian paths/shortcuts).

Finally, additional information was collected from rail professionals (e.g., train drivers, station masters and transit officers) and QR safety experts who contributed to our decision to select three intersections adjacent to suburban train stations - all actively protected and part of the Cleveland rail line: Coorparoo, Cannon Hill, and Wynnum Central (Figure 19). The selection of LCs that are part of the same rail line ensured that the observation sites had similar rail traffic characteristics and technical properties of the active controls (i.e., unlike the controls at other rail lines, the pedestrian gates on the Cleveland line do not lock when closed).
Figure 19. The Cleveland rail line

Note. The rail line joins Cleveland – suburb of Redland city and with Brisbane the capital of the Australian state of Queensland. Part of the Queensland Rail City train network, the Cleveland line extends 37.3 km east-southeast from CBD (Brisbane Central Business District). In red are indicated the three selected LCs for observation sessions.

Adapted from Queensland Rail (2014)

With a long history of reported accidents and the highest number of reported near-misses for 2011, the LC at Wynnum Central has been identified by QR as one of the worst black spots in Brisbane. By far, the largest percentage of near-misses reported on the Cleveland line occurred at Wynnum Central (41%), compared to Coorparoo accounting for 8.5% and Cannon Hill accounting for 5%, noting that the number of reported near-misses should only be considered as an approximate indication of the risk rate, given the reporting reliability issues that have previously been raised (Wullems et al., 2013). The most recent fatal collision with a pedestrian in Queensland occurred at Cannon Hill LC in January 2014, raising significant safety concerns among rail authorities. Finally, QR provided information about an increasing number of pedestrian violations at Coorparoo in recent years – 2013/2014.

All three LCs are equipped with pedestrian gate systems consisting of an entry pedestrian gate that closes when activated (but can be pushed open from outside) and an emergency pedestrian gate that remains closed at all times. The emergency gate can be pushed open from inside in the case that a pedestrian is caught inside the tracks during a “closure” defined here as: the period from the onset until the cessation of the controls. Pedestrian lights and audible alarms are installed in each pedestrian gate system (Figure 20).
5.5.2 Architectural characteristics of each LC and land use of the larger areas

The suburbs of Wynnum Central and Coorparoo are more populated with 12,229 and 14,944 inhabitants (respectively) compared to Cannon Hill with a population of only 4,507 inhabitants. All three LCs are in close proximity to schools and industrial zones. While Wynnum Central LC is positioned on a main road giving to a large shopping district, Cannon Hill and Coorparoo LCs are also in a close proximity to shopping centre zones.

5.5.2.1 Wynnum Central level crossing and the adjacent train station

Wynnum Central LC has two rail tracks separated by a middle island giving access to the train station (Figure 21). The middle (station) island comprises the two platforms typically giving access to passenger trains services in the direction to Cleveland – Outbound (i.e., Platform 1) and in the direction to Brisbane CBD- City (i.e., Platform 2). Two sets of pedestrian gate systems (i.e., one on the centre side and one on the residential side) activate simultaneously independently of the track or the direction of the approaching train. This implies that while an Outbound train (in direction to Cleveland) is stopped at station - pedestrian traffic is prohibited, whereas soon after a train in direction to the City had passed the LC (independently of whether the train is stationary or not), pedestrian traffic is allowed. A third set of pedestrian gate system regulates traffic on the opposite station road side.

The pedestrian corridor on the station road side is approximately 16 meters long (8 meters on both sides of the middle island) and the opposite station side pedestrian corridor is approximately 14 meters long.
Two QR car parks are provided for users of the train station: one North and one South of the LC. A third car park, further West in the Centre side of the LC provides access to the station through an over bridge (not illustrated on Figure 21).

5.5.2.2 Cannon Hill

Cannon Hill LC has three rail tracks separated by a middle island (Figure 22). The station is external to the LC giving access to Platform 2 where typically passenger train services run in the direction to the City. Platform 1 located on the middle island typically gives access to Outbound trains. The third track serves only freight trains passing in both directions. Two sets of pedestrian gate systems activate separately prohibiting pedestrian traffic on either side of the middle island. Thus, pedestrian traffic is prohibited on the 3rd track side only during the rare passage of freight trains which do not follow a strict timetable. Similarly to Wynnum Central, when an outbound train is stopped at the station pedestrian traffic is prohibited, whereas as soon as a City train has passed through the LC, pedestrian traffic is permitted. There is not a pedestrian corridor on the opposite-station road side.

The pedestrian corridor is approximately 20 meters long (7.50 meters on the 3rd track side and 12.50 meters on the station side of the middle island).
There are a number of primary schools on each side of the LC and a shopping centre is east from the LC (station side). Two QR car parks are provided for station users on both sides of the LC. An over bridge further south connects the two platforms and provides access to the middle island from the 3rd track side car park.

![Figure 22. Bird’s eye graphic view of Cannon Hill LC based on a Google Earth photograph.](image)

Based on Google Earth (2009) corresponding to 151m eye altitude

5.5.2.3 Coorparoo

Coorparoo LC (Figure 23) has three rail tracks separated by a middle island giving access to the train station. The middle (station) island comprises the two platforms typically giving access to passenger Outbound (i.e., Platform 2) and City (i.e., Platform 1) services. The third track serves only freight trains passing in both directions. Two sets of pedestrian gate systems activate separately prohibiting pedestrian traffic on either side of the middle island. Thus, every time an Outbound service is passing, pedestrian traffic through the freight track is also prohibited and inversely every time a freight train is expected, the crossing of the Outbound rail track is prohibited. Similarly to the other two LCs, pedestrian traffic is prohibited while there is a stopped Outbound train at station, and renewed - as soon as a City train has passed the crossing. There is not a pedestrian corridor on the opposite-station road side.
Figure 23. Bird’s eye graphic view of Coorparoo LC based on a Google Earth photograph.

Based on Google Earth (2009) corresponding to 151m eye altitude

The pedestrian corridor is approximately 26.5 meters long (17.5 meters on the 3rd track side and 9 meters on the station side of the middle island). There are a number of schools mostly East from the LC (station side) and a shopping centre in the same direction.

5.5.3 Research design and participants

5.5.3.1 Choice of time frames for morning and afternoon observation sessions

To capture the busiest pedestrian traffic periods, observation sessions took place at morning and afternoon peak hours, respectively from 7am to 9.30am and from 3pm to 5.30 pm. They were conducted systematically every (working) Monday, Wednesday and Thursday in three consecutive weeks, thereby avoiding the collection of data associated with specific social events likely to take place on weekends or public holidays. This organisation of the observation shifts allowed the conduct of one morning and one afternoon session at one of the three LCs on each of the three week days. All three LCs were visited during each week of observations following a random order.

Observations started in the first week after school holidays as students were among the targeted groups of potentially “at risk” pedestrians. The hours of the observation shifts were also planned in accordance with the crossing time frames of various socio-demographic classes (e.g., construction workers, office workers, school
children and pensioners) and corresponded to the typical start/finish working (school) hours.

5.5.3.2 Observers

Five researchers from the Centre for Accident Research and Road Safety Queensland (CARRS-Q) were trained by the lead researcher for data collection and entry, during a week of pre-observation. To enhance familiarity, pre-observations took place at all LC sites and each observer was trained to code data related to two main observer’s roles: 1) coding transgressions and 2) coding train times. Two “Transgressions” observers per session coded the personal and crossing characteristics of transgressors. They were positioned close to the pedestrian corridors on each side of the LC and coded: the gender and the approximate age of transgressors; the adopted crossing trajectory; the number of people crossing in groups; and the number of people waiting for the controls to deactivate (compliant crossing behaviour). One other “Train times” observer per session was in charge of coding the exact time (hh/mm/sec) when a train has reached the LC, stopped or left a station as well as the number and types of trains per closure and their respective direction and platform. Depending on the site, “Train Times” observers were positioned at a station (Figure 22, Figure 23) or at a nearby car park (Figure 21). The variables related to Closure characteristics (e.g., the exact hour of each control’s activation) were taken either by observers coding train times (Figure 21) or by observers coding transgressions – where the controls on the two sides of the middle island activate separately (Figure 22, Figure 23).

5.5.4 Material

Observation sheets and chronometers (on android mobile devices) were used for data collection. Variables related to each closure were coded on a separate sheet independently of whether a transgression took place or not. A closure identification number was coded on each observation sheet, facilitating the synchronisation of data between observers during data entry. All observers were equipped with a set of observation sheets in the form of a notebook.

5.5.4.1 Transgression Sheets

Transgression sheets (Appendix B) had two main parts. In the first part, a rough plan of each LC’s platforms and pedestrian corridors served to trace the
trajectory of transgressions. The same method was used to code the number of people at each angle of the LC who did not transgress (compliant crossing group) at the end of each closure. It is important to note that where pedestrians waiting at the angle exceeded ten, the counts should be considered approximate due to poor visibility.

In the second part of the sheet were coded demographic and other characteristics of the pedestrians who transgressed: gender - male vs. female; approximate age – baby/toddler (0-4 years old) vs. school children (5-15 years old) vs. young adult/teenager (16-30 years old) vs. older adult (30-70 years old) vs. elderly (70+ years old); exact time of transgression – exact hour when the pedestrian stepped on the LC platform (hh/mm/sec); status of controls at the moment of transgression - pedestrian lights flashing vs. pedestrian gates closing vs. pedestrian gates fully closed. It is worth noting that the time difference between the three is typically 8 seconds, meaning that 16 seconds after the activation of the pedestrian lights, the pedestrian gates are fully closed. In addition, observers were trained to identify a minimum set of variables related to the description of the transgressors: crossing pace – walking vs. speeding/running; social influences – crossing alone vs. in group, journey purpose – on the way to catch a train (yes vs. no, where possible to identify).

5.5.4.2 Train and Closure Times Sheets

Train time sheets (Appendix C) were used to code the following variables: order of train passing at the LC (the order of arrival at the LC or at the station); number of platform; direction – City vs. Cleveland; type of train - stopping at station vs. express, independently of whether it was an empty service, a train that does not serve the station or else, a freight train (i.e., typically long trains passing on the 3rd track at Cannon Hill and Coorparoo); hour of train passing - three times were taken for stopping trains (arrives at LC vs. stops at station vs. leaves station) and one for express trains – the hour it arrived at the LC.

Closure times were coded by multiple observers at each LC and included the following variables: start closure – hour of the activation of the pedestrian flashing lights (hh/mm/sec); gate closing - hour when the pedestrian gate starts closing (hh/min/sec); gate closed - hour when the pedestrian gate is fully closed (hh/min/sec); end closure – hour when the pedestrian lights deactivates (hh/min/sec).
To avoid mistakes in data entry, these variables were entered on the observation sheet only after the end of each closure, given that the times remained recorded on the chronometer screen.

5.5.5 Procedure

Having obtained permission from QR to conduct this study on their property, all visits of LC sites were preceded by safety instruction sessions for observers. Observers were in contact with rail staff at all times. Pre-observations were conducted for one week prior to the actual observations. During this period, the first researcher familiarised the four assistant observers with the objectives of the study, the coding process and the specificities related to each LC site. The actual observation sessions were conducted by three of the five researchers each. The larger number of observers allowed the shuffling of shifts and thus to avoid fatigue related issues. Each observation session was preceded by a synchronisation of all chronometers. No breaks were taken during observations. It is likely that the presence of observers was noticed by pedestrians even though the most discrete positions were selected considering safety procedures (e.g., remain in a significant distance from roadside) and the visibility of the targeted variables. After the end of the sessions, all observers were debriefed by the first researcher. Questions around data were discussed and resolved. All observers together started data entry shortly after the end of each session using a laptop and pre-established Microsoft Excel sheets. Data entry took approximately 1 hour and 30 minutes. This study was approved by the university ethics committee.

5.5.6 Collected data and statistical analysis

The data was collected during three consecutive weeks between 28 April 2014 and 15 May 2014, representing a total of 45 hours of observations across all sites. In total 438 closures were observed, each lasting from 12 seconds at Wynnum Central, where crossing through the two passenger services tracks is prohibited simultaneously, to 3 minutes and 51 seconds at Coorparoo, where the two passenger services tracks close autonomously. There was not a significant difference between the average duration of closures at all three LCs (M = 75.06 seconds, SD = 35.62 seconds), F(2, 435) = 1.23, ns. It should be noted that during the last afternoon observation session at Wynnum Central, a cancellation of all train services following an incident resulted in a smaller number of closures and a higher volume of
passengers leaving the train station (after having disembarked a City train). Nevertheless, the number of closures at each site was relatively constant over the three days of observation, $\chi^2(4, N = 438) = 2.17, ns$. One “false closure” was observed at Cannon Hill during which a train did not pass. Instead, both sides of the LC were closed for maintenance during 21 seconds, noting that no transgression took place.

Most of the closures were for the passage of a single-train (84%), two trains passed in 15% of the closures, and only on three occasions did three trains pass during the same closure (Table 2). Because of this small number of three train closures, they were considered together with two train closures for the remainder of the analysis. Regarding the types of train passing during closure, most of the closures included at least one stopping train, accounting for 76% of the single-train closures and for 93% of the multiple trains closures (Table 2). Closures involving only express trains represented 21% of all 437 closures with passing train/s. The distribution of number and types of trains passing during closures did not differ according to the three LCs (Fisher, ns.).

<table>
<thead>
<tr>
<th>Table 2. Types of trains observed during closures</th>
</tr>
</thead>
<tbody>
<tr>
<td>One train closures</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Express train</td>
</tr>
<tr>
<td>Stopping train</td>
</tr>
<tr>
<td>Both</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Note: The false closure” has been omitted in the table as not implying a train passage.

For the analysis of the collected data, a series of Chi-square tests ($\chi^2$) were performed to test the significance effect between two discrete variables. Fisher’s exact test was used for contingency tables that contain small expected values (<5) in more than 20% of the cells (i.e., only $p$ - value is reported). Cramers’ $V^2$ statistic was used to report the strength of association between discrete variables typically applied to 2xn tables, which is conventionally considered to be low if $< 0.04$, medium if between 0.04 and 0.16, and high if $> 0.16$ (Kotrlik, Williams, & Jabor, 2011). Relative Deviations (RDs) were used to inform on the strength of association between the modalities of the two discrete variables. Relative deviations are calculated on the basis of the comparison between the observed and expected frequencies in each cell. By convention, there is a high positive or negative
association when the absolute RD value is > 0.20. Only associations > 0.10 are described in the results section. Finally, analysis of variance tests (ANOVA) and correlations were used to test the effects on continuous variables. Post-hoc tests using Bonferroni correction were used to examine the relationships between the modalities of continuous variables (only $p$ – value is reported where the means are presented in tables).

5.6 RESULTS

5.6.1 Frequency and proportions of observed transgressions at the three LC sites

As per Table 3, the largest number of transgressions was observed at Wynnum Central and Coorparoo accounting for respectively 46.5% and 41.9% of all 129 observed transgressions across the three LC sites. In contrast, Cannon Hill was characterized with a low number of transgressions representing only 11.6% of all transgressions. Twenty percent of all closures included at least one person in transgression. The proportion of closures with at least one transgression varied significantly between sites, $\chi^2(2, N = 438) = 28.03, p < .000$, with the largest ratio of closures with transgressions observed at Wynnum Central and the least - at Cannon Hill, the strength of association between the variables being moderate, $V^2 = 0.06$.

Table 3. Counts and percentages of closures with at least one pedestrian in transgression per LC site.

<table>
<thead>
<tr>
<th>Closures</th>
<th>Closures With transgression</th>
<th>Transgressions</th>
<th>Transgressions per closure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Wynnum Central</td>
<td>117</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>149</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>172</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>438</td>
<td>88</td>
<td>20</td>
</tr>
</tbody>
</table>

Looking into the number of pedestrians in transgression during the same closure, a maximum of five were observed at Wynnum Central and four at Coorparoo, both on a single occasion. Most commonly, between one and three transgressors were observed per closure with no significant difference in the distribution across the three LCs, Table 3 (Fisher, ns.).
5.6.2 Transgressions associated with the physical characteristics of the environment and the specific crossing context

5.6.2.1 Types of transgressions according to the status of the controls

Comparing transgressions according to the status of the controls, more than half were observed during the first seconds after the activation of the pedestrian lights (transgression of lights and sound); almost one quarter were observed in the riskiest moment while the gates were closed (transgression of closed gates); and the smallest amount occurred while the gates were in the process of closing (Table 4). The distribution of transgressions according to status of the controls differed significantly among the LC sites (Fisher, \( p < .01 \)), with an intermediate strength of association between the variables, \( \chi^2 = 0.08 \). The analysis of the RDs revealed that Cannon Hill was particularly associated with transgressions of the lights and sound, Coorparoo with transgressions of closing gate and Wynnum Central with transgressions of closed gate.

Table 4. Counts and percentages of transgressions according to the status of active controls

<table>
<thead>
<tr>
<th>Transgression</th>
<th>Ped. Lights</th>
<th>Transgression gates closing</th>
<th>Transgression gates closed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( N )</td>
<td>%</td>
<td>( N )</td>
</tr>
<tr>
<td>Wynnum Central</td>
<td>32</td>
<td>53.3</td>
<td>6</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>13</td>
<td>86.6</td>
<td>2</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>30</td>
<td>55.5</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>58.1</td>
<td>23</td>
</tr>
</tbody>
</table>

Note. Transgression ped. lights - from activation of pedestrian lights until activation of pedestrian gate; Transgression closing gate - from activation of pedestrian gate until full closure (period of closing); Transgression closed gate – from the full closure of pedestrian gate until deactivation of pedestrian lights

5.6.2.2 Transgressions according to train’s position

According to the position of the train during a transgression, only one pedestrian was observed crossing in front of a stopped at station train and a small number of transgressions were observed behind a passing (express) train. These crossing situations were merged as “other train position” modality for further analysis. Globally, the large majority of transgressions (85%) occurred in front of an approaching train (Table 5). However, there was a significant difference in the number of transgressions according to train’s position between the three sites (Fisher, \( p < .05 \)), with an intermediate strength of association between the two variables, \( \chi^2 = \)
0.05. The estimation of the RDs showed that among the three sites, Wynnum Central was the one preferentially associated with transgressions behind a stopped train and in “other positions”, all of these situations characterised by the presence of a visible train.

Table 5. Counts and percentages of transgressions according to train position across the three LCs

<table>
<thead>
<tr>
<th></th>
<th>In front of an approaching train</th>
<th>Behind a stopped train</th>
<th>Other train position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wynnum Central</td>
<td>44</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>51</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>110</strong></td>
<td><strong>15</strong></td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>

*Note.* The category “Other train position” included (1) transgressing behind an express passing train, and (2) transgressing in front of a stopped at station train.

5.6.2.3 Transgressions according to crossing trajectory and LC angle

Looking into the adopted trajectories during transgressions (Table 6), the largest proportion of pedestrians were observed on their way towards a middle island (71.3%), whereas crossing out of a middle island (15.5%) and just crossing the road (13.2%) were less frequently observed trajectories during transgressions. A Fisher’s exact test showed a significant difference in the adopted trajectories between the three LCs (Fisher, *p* < .001). The association between the modalities of the variables was moderate (*V*^2^ = 0.08), suggesting that Cannon Hill, contrary to the other two LCs, was associated with the two less common trajectories (i.e., out of a middle island or just crossing the road).

Table 6. Counts and percentages of transgressions according to the adopted crossing trajectory

<table>
<thead>
<tr>
<th></th>
<th>To middle island (train station)</th>
<th>Out of middle island (train station)</th>
<th>Just crossing the road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wynnum Central</td>
<td>46</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>4</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>42</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>92</strong></td>
<td><strong>20</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

The patterns of the adopted trajectory could be associated with the specific design of each LC. To examine further these patterns, Figure 24 illustrates graphically the distribution of the transgressions among the three LCs, according to
the three trajectories and the crossing angle. While at Wynnum Central and Coorparoo the majority of transgressions occurred on the way to a middle island (i.e., corresponding to the emplacements of a train station), pedestrians at Wynnum Central adopted visibly more variable trajectories, particularly when crossing from the Centre side of the LC (i.e., diagonal through the road and crossing in the middle of the road). In contrast, at Coorparoo more transgressions were observed from the Station side of the LC and none on diagonal which could be explained by the absence of pedestrian path on the opposite station side. However, the only transgression on a diagonal out of a station line was observed at the same LC, which could be associated with an impatience to wait at the adjacent road traffic lights. The majority of transgressions at Cannon Hill out of the middle island or just crossing the road seemed to be associated with accessing the train station positioned externally to the rail tracks or the large car park adjacent to the Station side of the LC.

Figure 24. Patterns of transgressions according to LC angle at each LC

5.6.2.4 Transgressions according to the number of crossed tracks

A significant difference was found between the number of rail tracks crossed while transgressing between the three LCs, such that transgressions at Wynnum Central implied the least number of crossed tracks ($M = 1.15$, $SD = 0.36$), followed by Coorparoo ($M = 1.54$, $SD = 0.66$) and the largest number of crossed rail tracks per transgression was observed at Cannon Hill ($M = 2.13$, $SD = 0.51$), $F(2, 126) = 23.06$, $p<.000$, $\eta^2 = .26$, the difference comparing all three sites being significant at $p<.000$.

To investigate further the risk-taking tendencies accounting for the number of crossed tracks, an additional variable was computed corresponding to the number of crossed “Unoccupied tracks”. This variable corresponded to the counts of crossed tracks where a train could have passed during the closure given that crossing through the same track after a train had already passed is not associated with a real risk of being hit by a train. As shown in Table 7, more than half of the pedestrians across all
three LCs crossed at least one unoccupied track (48% + 4.6%). Here again, a significant difference was found in the number of crossed unoccupied tracks according to the LC (Fisher, \( p < .01 \)), with an intermediate association between the variables \( V^2 = 0.05 \). The estimation of the RDs revealed different risk-taking patterns across the three sites. Consistent with the total number of crossed tracks during transgressions, Wynnum Central was moderately associated with crossing one unoccupied track, whereas Cannon Hill was at the same time moderately associated with the crossing of one and strongly associated with the crossing of two unoccupied tracks. In contrast, Coorparoo was associated at the same time with crossing none and two unoccupied tracks.

Table 7. Counts and percentages of crossed unoccupied tracks during transgressions at the three LCs.

<table>
<thead>
<tr>
<th>None</th>
<th>1 Track</th>
<th>2 Tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wynnum Central</td>
<td>27  45</td>
<td>33  55</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>4  26.6</td>
<td>8  53.3</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>30  55.5</td>
<td>21  38.8</td>
</tr>
<tr>
<td>Total</td>
<td>61  47.2</td>
<td>62  48</td>
</tr>
</tbody>
</table>

5.6.2.5 Transgressions according to time of the day

More than two thirds of the closures with at least one transgression took place in morning peak hours (69.7%), \( \chi^2(1, N = 438) = 9.67, p < .01 \) (Table not provided). Similarly, two thirds of all transgressions were observed in morning peak hours (Table 8). Although systematically more transgressions were observed in the morning than in the afternoon, there was a significant difference between the three sites according to the time of day. \( \chi^2 (2, N = 129) = 7.04, p < .05 \), with an intermediate strength of association between the variables \( V^2 = 0.05 \). The estimation of the RDs showed that unlike the two other sites, Wynnum Central is more associated with transgressions in the afternoon, (Table 8).
Table 8. *Counts and percentages of transgressions according to time of the day (morning vs. afternoon peak hours)*

<table>
<thead>
<tr>
<th></th>
<th>AM (7-9.30)</th>
<th></th>
<th>PM (3-5.30)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Wynnum Central</td>
<td>36</td>
<td>27.9</td>
<td>24</td>
<td>18.6</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>12</td>
<td>9.3</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>44</td>
<td>34.1</td>
<td>10</td>
<td>7.8</td>
</tr>
<tr>
<td>Total</td>
<td>92</td>
<td>71.3</td>
<td>37</td>
<td>28.7</td>
</tr>
</tbody>
</table>

5.6.2.6 *Transgressions according to exposure*

In total 2446 pedestrians were counted crossing compliantly during all observed closures (i.e., closures with and without transgressions). The number of pedestrians crossing compliantly per closure varied between 0 and 77 ($M = 5.58$, $SD= 8.13$). As indicated in Table 9, the largest number of pedestrians crossing compliantly per closure was observed at Wynnum Central $F(2, 435) = 23.17$, $p < .000$, $\eta^2 = .10$. Also, more compliant crossings were observed during the afternoon closures, $F(1, 436) = 4.09$, $p< .05$, $\eta^2 = .02$. The interaction between the two variables (Sites * Time of the day) was also significant, $F(2, 432) = 10.14$, $p< .000$, $\eta^2 = .05$, suggesting that the largest number of pedestrians crossing compliantly was counted at Wynnum Central compared to the other two LCs ($p< .000$). This result could be related to the exceptional cancellation of the train services. In contrast, there were a similar number of people in the morning peak hours at the most and least populated LCs (i.e., respectively Coorparoo and Cannon Hill).

The 129 observed transgressors represented around 5% of all people crossing during the closures. Accounting for compliant crossing, at Wynnum Central was observed the highest percentage of transgressors in the afternoon peak hours and at Coorparoo – the highest percentage of transgressions in the morning peak hours (Table 9).
Table 9. Counts of pedestrians crossing compliantly and proportion of transgressions per LC

<table>
<thead>
<tr>
<th>Location</th>
<th>AM (7-9.30)</th>
<th>PM (3-5.30)</th>
<th>Total (AM+PM)</th>
<th>AM (7-9.30)</th>
<th>PM (3-5.30)</th>
<th>Total (AM+PM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wynnum Central</td>
<td>425/68</td>
<td>6.25</td>
<td>663/49</td>
<td>13.53</td>
<td>1088</td>
<td>9.29</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>330/80</td>
<td>4.12</td>
<td>277/69</td>
<td>4.01</td>
<td>607</td>
<td>4.07</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>420/93</td>
<td>4.52</td>
<td>331/79</td>
<td>4.19</td>
<td>751</td>
<td>4.37</td>
</tr>
<tr>
<td>Total</td>
<td>1142/241</td>
<td>4.88</td>
<td>1304/197</td>
<td>6.45</td>
<td>2446</td>
<td>5.58</td>
</tr>
</tbody>
</table>

5.6.3 Transgressions associated with pedestrians’ characteristics and motivations

5.6.3.1 Transgressions according to demographics

All 129 transgressors were distributed among five approximate age groups. Two babies (toddlers) were merged for further analysis with the young adults group as they were accompanied by adults of this age group. Male transgressors were slightly more numerous than females, and young adults were the most numerous among all age groups, \( \chi^2(3, N = 129) = 2.59, \text{ns.} \) (Table 10). Similarly, there was not a significant difference in the number of transgressors according to age (Fisher, ns.) or gender (\( \chi^2(2, N = 129) = 1.41, \text{ns.} \)) between the three LCs (Table not presented).

Table 10. Counts and percentages of transgressors according to gender and approximate age groups

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>School children</td>
<td>16</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>Young adults</td>
<td>33</td>
<td>26</td>
<td>59</td>
</tr>
<tr>
<td>Older adults</td>
<td>21</td>
<td>15</td>
<td>36</td>
</tr>
<tr>
<td>Elderly</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>73</td>
<td>56</td>
<td>129</td>
</tr>
</tbody>
</table>

Note. The approximate age of transgressors was coded according to five pre-determined age groups as follows: baby/toddler (0-4 years old); school children (5-15 years old); young adult/teenager (16-30 years old); older adult (30-70 years old); elderly (70+ years old).

5.6.3.2 Journey context and crossing pace

Among all 129 transgressors, 91 were seemingly going to catch a train with most of them (\( N = 86 \)) accessing the train station through a middle island (at
Wynnum Central and Coorparoo). The remaining five accessed the station at Cannon Hill either on their way out of a middle platform \( (N = 2) \), either crossing all LC tracks to access the station on the opposite road side \( (N = 3) \). Only 66 of all pedestrians going to catch a train appeared to hurry while crossing, while the remaining more than a quarter crossed at a walking pace.

### 5.6.4 Transgressions associated with pedestrians’ social context

Globally, pedestrians crossing alone (not in groups) accounted for more than three quarters of all transgressions (Table 11). However, there was a significant difference between the three LCs in the number of transgressions while alone, in a group of two, and in a group of more than two pedestrians (Fisher, \( p < .05 \)). The association between the variables was weak \( (V^2 = 0.03) \), with the estimated RDs indicating more likelihood to transgress alone at Cannon Hill, and in groups of two and more pedestrians - at Coorparoo.

<table>
<thead>
<tr>
<th>Pedestrians</th>
<th>Alone</th>
<th>In group 2 pedestrians</th>
<th>In group 3-4 pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Wynnum Central</td>
<td>40 39.6</td>
<td>7 6.9</td>
<td>2 1.9</td>
</tr>
<tr>
<td>Cannon Hill</td>
<td>13 12.8</td>
<td>1 0.9</td>
<td>0 0</td>
</tr>
<tr>
<td>Coorparoo</td>
<td>27 26.7</td>
<td>7 6.9</td>
<td>4 3.9</td>
</tr>
<tr>
<td>Total</td>
<td>80 79.2</td>
<td>15 14.8</td>
<td>6 5.9</td>
</tr>
</tbody>
</table>

### 5.6.5 Transgressions accounting for the interactions between factors

#### 5.6.5.1 Time of the day, status of the controls and high risk groups of pedestrians

The distribution of transgressions according to the status of the controls differed significantly according to the time of the day, \( \chi^2(2, N = 129) = 9.98, p < .01 \), with an intermediate association between the variables \( (V^2 = 0.07) \). The estimation of the RDs, revealed that transgressions of the lights and sound were likely to be observed in morning peak hours, whereas transgressions of the closed gate with afternoon peak hours. Pedestrians of different age groups also showed significantly different crossing patterns according to the status of the controls (Fisher, \( p < .05 \)), the association between the variables being also intermediate \( (V^2 = 0.05) \). The RDs associated school children with transgressions of the lights and sound, whereas older adults and elderly were associated with transgressions of closing gates, and younger...
adults with transgressions of closed gates. On the contrary, there was not a significant difference in types of transgressions between male and female pedestrians, $\chi^2(2, N = 129) = 1.08, \text{ns.}$

In contrast, the two genders showed different patterns of transgression according to the time of the day, $\chi^2(1, N = 129) = 5.66, p< .05,$ the association between the variables being weak ($V^2 = 0.04$). According to the RDs, female pedestrians were more likely to be observed transgressing in the morning, whereas male pedestrians - in the afternoon. Concretely, the odds of observing a male pedestrian transgressing in the afternoon peak hours were .37 times higher than observing a female. Pedestrians of different age groups also appeared to be likely to transgress in different times of the day, $\chi^2(3, N = 129) = 8.31, p< .05.$ The strength of association between the two variables being intermediate, the estimation of the RDs showed that young adults/teenagers were associated with transgressing in afternoon peak hours, whereas older adults and elderly were associated with transgressions in the morning peak hours ($V^2= 0.06$).

5.6.5.2 Train position, trajectory and number of crossed tracks

The number of transgressions was significantly different according to the train’s position in interaction with: status of the controls, time of the day and crossing trajectory. The status of the controls was strongly associated with train’s position, Fisher, $p< .000,$ $V^2 = 0.27.$ The estimation of the RDs showed that transgressions of the lights and sound and closing gate occurred in front of an approaching train, whereas transgressions of closed gates occurred in the presence of a visible train (i.e., behind a stopped train and other positions). In contrast, a weak association between train position and time of the day suggested that transgressions in the presence of a visible train (behind a passing train and other positions) were likely to be observed in afternoon peak hours, Fisher, $p < .05,$ $V^2= 0.04.$ The adopted trajectory was also weakly associated with train position, $\chi^2(4, N = 129) = 9.04, p < .05,$ $V^2= 0.04.$ The estimation of the RDs showed that crossing behind a stopped train was associated with going towards a middle island, whereas other train positions (i.e., crossing behind a passing express or in front of a stopped train) were associated with going out of a middle island.

The adopted transgression trajectories differed significantly according to time of the day, $\chi^2(2, N = 129) = 6.82, p < .05,$ $V^2 = 0.05.$ According to the estimated
Factors shaping pedestrians’ unsafe behaviour at actively protected level crossings

RDs, the intermediate relationship between the variables suggested that leaving a middle island and just crossing the road were associated with transgressions in the afternoon peak hours. There was not a significant difference in the adopted trajectories according to the status of controls.

The total number of crossed rail tracks during transgression was significantly different according to the status of the controls, Fisher, \( p < .05 \), the association between the variables being moderate, \( V^2 = 0.04 \). The RDs revealed that the crossing of more than one rail track (i.e., two or three) was more likely to be observed during transgressions of closing gate, whereas transgressions of closed gate were associated with the crossing of one rail track. However, the number of crossed unoccupied tracks was similar independently of the status of the controls (Fisher, ns.), noting that 11.6% of the pedestrians crossed one unoccupied track after a first train had passed, taking the potential risk of crossing in front of a second train.

5.6.5.3 Crossing alone and in group, demographics and time of the day

There was a significant relationship between transgressions alone or in group and the age of pedestrians \( (\chi^2 (3, N = 129) = 23.20, p < .000, V^2 = 0.17) \), the adopted crossing trajectory \( (\chi^2 (2, N = 129) = 6.70, p < .05, V^2 = 0.05) \) and the time of the day \( (\chi^2 (1, N = 129) = 4.11, p < .05, V^2 = 0.03) \). The strong association with the age groups of participants indicated that school children and elderly were more likely to transgress alone, whereas older adults were more likely to transgress in groups. According to the RDs, the intermediate relationship with the adopted trajectory revealed that transgressing alone was associated with going out of a middle island or just crossing, whereas group transgressions were associated with going towards a middle island. Finally, according to the RDs the weak association with time of the day indicated that group transgressions were more likely to be observed in the morning, whereas pedestrians transgressing alone were associated with afternoon hours.

5.7 DISCUSSION

Pedestrians’ unsafe crossing at LCs has been identified as a highly under-researched area lacking notably in the understanding of the key factors influencing decision-making of this particular population. This paper presented the results from direct observations conducted at three key black spot LCs in Brisbane, providing
novel and contextual relevant evidence on the role of multiple factors contributing to risky crossing behaviours. Despite the short duration of the observations, a relatively large number of transgressions ($N = 129$) was observed corresponding to more than 5% of all pedestrians present at the LCs at the end of the observed closures, noting that information on the moment of their arrival at the LCs was not collected.

The following sections contrast the simple effects of risk factors on unsafe crossing at the three LCs (generalised case) with the effects of the same risk factors on unsafe crossing according to the specific characteristics of the crossing context at each of the three LCs.

5.7.1 The simple effects of risk factors at LCs in Brisbane

The observed transgressions seemed to differ according to the status of the controls, the time of the day and the adopted trajectory, which were directly or indirectly associated with different demographic profiles of pedestrians. The links between different types of transgression and other risk factors are described in the following paragraphs, representing thus findings informing on three potential key at risk transgression patterns adopted by pedestrians, users of the Cleveland rail line.

5.7.1.1 Transgressions of pedestrian light and sound

In line with previous findings, the largest proportion of transgressions occurred before the gates are closed and even active. Such transgressions were particularly associated with crossing in front of an approaching train (unlikely to be visible), and with transgressions in morning peak hours. In fact, contrary to what has been demonstrated by Edquist et al. (2011) and Metaxatos and Sriraj (2013b), the largest proportion of transgressions at all three LCs occurred at morning peak hours and this was even after accounting for the number of pedestrians crossing compliantly during all closures. The observed transgressions in morning peak hours were associated with female pedestrians and school children. Unlike previous findings, school children were linked with crossing alone. The summary of all these simple effects could explain transgressions motivated by a fear of missing the next train and of being late for school. Transgressions before the gates have started moving and in front of an approaching train were consistently associated with crossing towards a middle island. This was globally the predominantly adopted trajectory during all transgressions potentially related to the motivation of catching the next train as was visible in 70%
of the cases, noting that the journey purpose was not identifiable for all transgressions.

5.7.1.2 Transgressions of closing gate

A larger number of pedestrians were observed transgressing once the gates were fully closed compared to while they were closing. Such findings are in contradiction with “beating the gates” tendencies and the obtained results by Metaxatos and Sriraj (2013b). Nevertheless, the results from these observations associated older adults and elderly with transgressions of closing gate and with afternoon peak hours. Older adults were associated with crossing in groups and elderly associated with crossing alone. The combination of these results could explain an increased perception of control (e.g., “I could make it on time”) before the gate is fully closed, rather than sensation seeking tendencies.

5.7.1.3 Transgressions of closed gate

Crossing after the gates are closed was also associated with afternoon peak hours and with the presence of a visible train (stopped or passing through). Crossing in the last seconds of the closure was common to young adults/teenagers, who themselves were also associated with crossing in the afternoon peak hours. Transgressions of young adults/teenagers in afternoon peak hours corresponded to crossing out of a middle island or just crossing. All these results taken together could be associated with impatience to wait for the controls to deactivate after disembarking from a train in the afternoon peak hours, potentially taking the risk of crossing in front of a second train. Examining the risk of crossing in front of a second train according to the number of crossed unoccupied rail tracks, no significant difference was found according to the status of controls, meaning that pedestrians were equally likely to cross one or more unoccupied potentially “at risk” of second train tracks, while transgressing during activated light and sound, closing gate or closed gate. Similarly, transgressing after the gates are closed was strongly associated with the crossing of one rail track, most likely after a train has passed the LC, which could explain a certain awareness of the risk of second train. Still, in total, a large number of pedestrians crossed one unoccupied track after the gates were closed (11.6 %) embracing the risk of crossing in front of a second train. Taken together, these results suggest that crossing once the gates are fully closed is highly influenced by the train’s visibility and is indeed a serious potential threat for crossing.
in front of a second train. Being associated with younger adults, such risk-taking behaviours could be explained by the perception of control or familiarity with the LC design and rail traffic. It could also be explained by sensation seeking tendencies or “recreational” risk-taking in the late afternoon peak hours. It would be worth looking further into the patterns of transgressions according to whether one or both sides of the middle island were closed during transgression in front of a second train. Such evidence would contribute to a better understanding of the pros and cons of having a separate regulation of pedestrian traffic at both sides of a middle island, especially in the case that there is a train station on the middle island.

5.7.2 The effects of interacting factors associated with the crossing context at three typical black spot LCs within Brisbane area

Different transgression patterns across the three LCs were identified depending on the characteristics of the larger area, the LC and station environment, as well as according to rail traffic characteristics. The largest number of pedestrians crossing compliantly and transgressions were counted at Wynnum Central, the second most populated suburb, giving access to the train station through a middle island where crossing is prohibited along the pedestrian corridors for each train passage independently of its direction. In contrast, the largest proportion of transgressions accounting for the total number of people crossing during closures was observed at Coorparoo, the most populated suburb where the total number of people crossing compliantly and transgressing was lower compared to Wynnum Central. Having a similar design comprising the train station at a middle island, the main difference between Coorparoo and Wynnum Central is the presence of a third track and the separately operated pedestrian corridors on the two sides of the middle island at Coorparoo. On the contrary, Cannon Hill was the least populated suburb with the lowest number of pedestrians observed to cross compliantly and transgressing at this LC not giving access to the train station but to a middle platform separating the three tracks. Contrary to previous findings, the location of the platforms outside of the rail tracks was not associated with a larger number of transgressions. However a more in depth analysis of the results revealed that at Cannon Hill pedestrians were observed to take the most risk by crossing the largest number of rail tracks where a train could have passed (unoccupied tracks).
5.7.2.1 Transgression patterns related to the crossing context at Wynnum Central

Wynnum Central was associated with transgressions of closed gate, with the presence of a visible - stopped or passing train (i.e., the majority observed behind a stopped at station train) and with afternoon peak hours. At this site, pedestrians crossing right after the train has passed the LC (City train) could still catch it from the station. Such transgressions behind a stopped train and after the gates are closed were also associated with younger adults. Moreover, in the afternoons more transgressions were observed in groups. Wynnum Central stood out as the LC where most variability was observed in the adopted trajectories towards the station. A large number of transgressors came from the large shopping Centre side and crossed on diagonal or even through the centre of the LC. Crossing on diagonal could be explained by the motivation to avoid waiting to cross at a nearby intersection with four pairs of pedestrian traffic lights connecting the different sides of the road (Figure 21). The large number of transgressions from either side of the crossing could be associated with catching the City Train service (i.e., if crossing behind a stopped train). For those transgressing from the Centre side of the LC, being in a hurry to catch the City train implies crossing through the Outbound track. If pedestrians are familiar with such crossing situation, they can easily assume that even if there is an approaching second train (coming from the City) it will stop at station before reaching the LC platform. However, in reality an express train could be approaching anytime at full speed. Consequently, it can be argued that the simultaneous regulation of pedestrian traffic on both sides of a middle island could lead people to underestimate the risk of second train arrival even it is visible. Such risk could potentially be avoided if pedestrians were to use the existing over bridge that provides access to the platforms from the car park. However, pedestrians might be unlikely to cross the overbridge given its distant location from the main road, which is a main adopted trajectory if coming from the shopping centre. Consequently, a more adequate location of the over bridge or a separate regulation of both tracks at this LC could potentially minimise the risk of transgressions and especially - in front of a second train.

5.7.2.2 Transgression patterns related to the crossing context at Cannon Hill

Cannon Hill was associated with transgressions of lights and sound. Such transgressions were predominantly observed in morning peak hours, in front of an
approaching train and by school children. School children were likely to be seen crossing alone and so were in general transgressors observed in the morning peak hours. Contrary, to previous findings the location of the train station externally to the rail tracks was associated with a lower number of transgressions compared to the other two LCs. However, looking into the adopted trajectories a strong pattern of transgressions was identified, corresponding to the crossing of multiple tracks to access the station (City train service platform), including crossing the road and going out of a middle island. In fact, among the three LCs, only Cannon Hill was associated with just crossing the road or exiting the middle platform, trajectories corresponding to the emplacement of the train station at this particular site externally to the rail tracks. While the existing over bridge linking the middle island platform and the train station could have contributed to decrease transgressions, the separation of the third track from the passenger services tracks could potentially be associated with an increased level of risk during transgressions as pedestrians crossing through the passenger services corridor are obliged to cross both tracks at the same time.

5.7.2.3 Transgression patterns related to the crossing context at Coorparoo

Finally, Coorparoo was associated with transgressions of closing gate. Such transgressions were predominantly observed in afternoon peak hours and by older adults and elderly. Moreover Coorparoo was mostly associated with crossing in groups of two and more pedestrians, noting that group transgressions were also associated with older adults and with crossing towards a middle island. Coorparoo was also the only LC associated at the same time with crossing none (not at risk) and two unoccupied tracks. Thus in addition to the trajectory corresponding to crossing from either side to catch a City train, pedestrians at Coorparoo also transgressed on their way out of the middle island after disembarking a train. Thus, this LC seems to be associated with two different transgression patterns: one describing transgressing in groups to catch a train, and one crossing towards a car park in the afternoon hours (Figure 23). Indeed, the diagonal transgression towards the LC’s angle without a pedestrian path could explain the motivation to avoid waiting at pedestrians’ road traffic lights on the way to a nearby smaller car park (not illustrated on Figure 23). Compared to Wynnum Central where the station is also on the middle island, at Coorparoo more transgressions occurred on the City train rail track than on the
Outbound rail track. Therefore, the introduction of an external platform similarly to Cannon Hill could help improving the safety of City train passengers.

5.8 LIMITATIONS AND FUTURE PERSPECTIVES

A number of limitations can be addressed to the collected data and the adopted observations method. The presence of observers could unduly influence participants’ behaviour. Indeed, it is possible that pedestrians have refrained from transgression in the presence of observers. Moreover, given that there is a legal sanction for crossing at red signal, such bias should not be underestimated. In terms of the adopted procedure, data could not be considered as representative to the larger Queensland area, as the observations were conducted at only three LC sites and the data collection period was limited. Nevertheless, the results give an approximate indication on the number and proportion of transgressions at each LC site, given that observation sessions lasted for five hours per day. Also, the method facilitated gathering a detailed body of data, including description of potential risk prone crossing situations at LCs part of the riskiest Brisbane railway line, although not exhaustive. For instance, no indication was collected on the patterns of behaviour out of the two peak time zones. In addition, an estimation of the size of pedestrian flow, not only during the closures, would enhance the understanding of the proportion of transgressors among pedestrians crossing compliantly. Furthermore, a more in depth analysis of the characteristics of the respective populations at the three LC sites would enhance the understanding of high risk groups of pedestrians. Video data could provide complementary information on the proportion of transgressors compared to compliant pedestrians from each demographic group, and is therefore a potential path for future research. Moreover, the interactions between multiple factors could be further tested in simulation studies with the possibility to recreate various realistic crossing situations. Such studies are likely to provide a more in depth explanation of the precursors of behaviour and would therefore enhance the development of more effective safety measures (be it through safety campaigns aiming at the reduction of motivational factors, be it through updates of the environment improving pedestrian traffic conditions). Moreover, simulation studies would allow to pre-test the effects of already identified risk factors on a wider range of crossing situations (e.g., passive LCs, different active or passive controls).
5.9 CONCLUSION

The interactions between different factors were examined, contributing to the better understanding of the larger pedestrian crossing context likely to be influenced at the same time by the environmental properties of the LC, by personal motivations and characteristics of pedestrians themselves or else, by the presence of other individuals. As opposed to a large part of previous studies emphasising on a single factor’s contribution to unsafe crossing, this analysis of the interactions between factors illustrates potential highly “at risk” crossing situations, taking into consideration similarities and differences across typical for the area LC designs and socio-economic contexts. Arguably, the discussed interactions between risk contributing factors suggest that independently of the LC site and its design, transgressions correspond to the fastest and most convenient path of accessing the platforms in order to catch a train. However, the analysis of the specific crossing context also reveals that such transgressions can be associated with a different level of risk-taking. In addition, transgressors at the three observation sites adopted different crossing trajectories likely to be associated not only with the design of each LC in terms of the location of the platforms and rail tracks, but also with characteristics of the larger area, notably in relation to the provided access points to the station’s platforms. Thus, arguably, the role of characteristics of the larger area, such as the presence of car parks, road traffic lights, over bridges, main roads are often underestimated as potential risk-contributing factors to pedestrian crossing. Therefore, to improve safety, each LC environment should be optimised according to the characteristics of the area and the population.
Chapter 6: **Systems-based approach to investigate unsafe pedestrian behaviour at level crossings**

### 6.1 INTRODUCTORY NOTES ON THE PUBLICATION

This chapter comprises Paper 1 as taken from:


Paper 2 was published in a peer reviewed international journal: Accident analysis and prevention. The 2014 Impact Factor for this journal is 2.07. The candidate was responsible for all aspects of the manuscript preparation, including reviewing the literature, formulating the research question, conducting data collection, analysing and interpreting the results and writing and submitting the final manuscript. All co-authors meet the criteria for authorship and take responsibility for their role in delivering the publication. The second and third co-authors, as specialists in human factors and systems models, participated actively in the refinement of the PULC framework and the associated data analysis and interpretation. All other co-authors of this paper are members of the candidate’s supervisory team and their contribution to this paper was mainly supervisory in nature. Written permission was provided from each to include the publication as part of this thesis and its publication on the QUT ePrints database (Appendix M).

The focus groups study presented in this paper was part of the first exploratory stage of research. It addressed the second research aim, which was to associate the previously identified risk contributing factors to errors and/or violations identifying the specific cognitive and motivational precursors of behaviour. A new systems-based framework (PULC) was presented in this study, with a demonstration of its application. The results associated more factors with violations than with errors. Specific interactions between factors from different system levels were associated
with each type of behaviour. These links allowed the identification of failures at
different levels of the system potentially responsible for either errors or violations,
and informed on how the negative effect of such interacting factors on behaviour
could potentially be reduced.
6.2 ABSTRACT

Crashes at level crossings are a major issue worldwide. In Australia, as well as in other countries, the number of crashes with vehicles has declined in the past years, while the number of crashes involving pedestrians seems to have remained unchanged. A systematic review of research related to pedestrian behaviour highlighted a number of important scientific gaps in current knowledge. The complexity of such intersections imposes particular constraints to the understanding of pedestrians’ crossing behaviour. A new systems-based framework, called Pedestrian Unsafe Level Crossing framework (PULC) was developed. The PULC organises contributing factors to crossing behaviour on different system levels as per the hierarchical classification of Jens Rasmussen’s Framework for Risk Management. In addition, the framework adapts James Reason’s classification to distinguish between different types of unsafe behaviour. The framework was developed as a tool for collection of generalisable data that could be used to predict current or future system failures or to identify aspects of the system that require further safety improvement. To give it an initial support, the PULC was applied to the analysis of qualitative data from focus groups discussions. A total number of 12 pedestrians who regularly crossed the same level crossing were asked about their daily experience and their observations of others’ behaviour which allowed the extraction and classification of factors associated with errors and violations. Two case studies using Rasmussen’s AcciMap technique are presented as an example of potential application of the framework. A discussion on the identified multiple risk contributing factors and their interactions is provided, in light of the benefits of applying a systems approach to the understanding of the origins of individual’s behaviour. Potential actions towards safety improvement are discussed.
6.3 INTRODUCTION

6.3.1 Level crossings are complex intersections

Level crossings (LCs) are complex intersections where rail and road systems converge. At such intersections, road users are permitted to cross rail tracks when it is safe to do so (i.e., in the absence of an approaching train). There are two main categories of LCs according to the level of protection they provide to users. Passive LCs are equipped with static controls such as “STOP” or “GIVE WAY” road signs whilst active LCs, which are often riskier locations, are equipped with automatic controls such as red flashing lights or barriers. Based on feedback loops (top-down and bottom-up flow of information) between components, the ultimate objective of LCs’ performance is to ensure road users’ safe crossing through the rail tracks. At active LCs in particular, the system must provide enough and reliable information for the pedestrian to safely negotiate the crossing. Such information mainly consists of: raising the awareness of the crossing (e.g., LC approach signage); providing adequate physical characteristics of the crossing path (e.g., visibility, well defined LC quadrant); ensuring visibility and awareness of the warning controls and their purpose; raising awareness of the potential hazards at such crossings (e.g., risk of second train). Fatal crashes are more frequent at active LCs (characteristic of urban environments) than at passive (Australian Transport Council, 2010). Pedestrians are particularly vulnerable users of active LCs given the higher flow of pedestrian traffic in such areas (Cairney, 1992). Australia has widely deployed engineering interventions to improve pedestrian LC safety, such as automated pedestrian gates. However, despite such interventions pedestrian LC crashes still occur.

6.3.2 Crashes at level crossings

Despite a substantial decrease since the 1990s, the annual number of LC crashes worldwide remains unacceptably high (ATSB, 2012; Basacik et al., 2012; Evans, 2012; Werkman, Sjamaar, Coenders, van Meer, & de Hek, 2012). Although not as frequent as other types of road traffic crashes, they are associated with greater potential for fatal outcomes for victims and are related to serious economic costs (Evans, 2012; Iorio et al., 2012; Werkman et al., 2012). Not only do crashes at LCs impede on the operation and effectiveness of both rail and road infrastructure, but
they also result in significant economic costs due to railroad property damage, insurance payments and legal fees (Iorio et al., 2012; Metaxatos & Sriraj, 2013a). In 2003, a cost per crash was estimated to range from $180,000 (AUD) in urban areas to $430,000 (AUD) in rural areas (Australian Transport Council, 2003). Data from the ATSB (2012) suggests that, similarly to data from the United States (Metaxatos & Sriraj, 2013a), the number of crashes involving vehicles has noticeably declined in the last decades (i.e., between 2003 and 2007), whereas there has not been a significant change in the number of crashes with pedestrians.

6.3.3 Pedestrian behaviour at LCs

In a review of the literature examining the extent to which the systems approach has previously been applied to the investigation of a broad range of LC issues, Read et al. (2013) found that more than 70% of all existing publications on safety at LCs focused on the understanding and reduction of drivers’ unsafe behaviour. Thus, only very limited information on the factors and conditions shaping pedestrians’ unsafe behaviour at LCs is currently available. We subsequently carried out an in-depth review of the literature with a strong focus on pedestrians’ unsafe crossing.

A number of keywords were used to identify publications relevant to: level crossings (i.e., level crossings; railway crossings; grade crossings; rail crossings); pedestrians (i.e., pedestrians; passengers; rail users; trespassers) and the rail industry more generally. The search was undertaken in the following electronic databases: Science Direct; EBSCOhost; Google and Google Scholar; HERDC (Higher Education Research Data Collection; Australia); and among researchers’ network (conference proceedings and publications). Only 23 relevant publications; up to and including 2013 were identified. Four major gaps in the literature on pedestrian crossing at LCs emerged from the review of these papers:

6.3.3.1 The influence from research on motorists’ behaviour.

Consistent with the large majority of the existing publications being on motorists, the review of the contributing factors applicable to pedestrian unsafe crossing have often been based on research on drivers’ behaviour at LCs or on road safety publications more generally. Literature reviews underpinning past studies include only a small number of publications on pedestrians’ behaviour at LCs.
Moreover, there are publications which do not clearly report outcomes which apply to pedestrians versus motorists. The degree to which outcomes of driver focused literature can be inferred to pedestrians is unclear as the required skills and the corresponding constraints (e.g., legal, social) related to both types of users are different.

6.3.3.2 The availability and quality of occurrence data.

In Australia and worldwide, the criteria for the classification of occurrence data are not always consistent between authorities and may include cases of suicide or trespass (i.e., walking across or along rail tracks at non designated crossing areas), which are known to have different precursors than transgressions at LCs (Evans, 2012; Meiers, Guo, & Levasseur, 2012). Thus, outcomes based on such data are hardly applicable between countries and even between regions. In addition, such data is associated with a limited range of identifiable risk factors, and struggles to comment on the cognitive or motivational origins of behaviour.

6.3.3.3 The lack of empirical research into the origins of unsafe behaviour.

Instead of investigating the origins of unsafe crossing, studies often focus on providing frequencies of illegal behaviour or identifying high risk groups of users, and examine only a small number of key variables such as the observed reported efficacy and awareness of various controls (Basacik et al., 2012; Parker, 2002; Stewart et al., 2004) or else the efficacy of education and enforcement campaigns (Lobb et al., 2001; Lobb et al., 2003; Sposato et al., 2006). One study demonstrates pedestrians’ likelihood of under-estimating the speed of an approaching train as a result of a perception bias (Clark et al., 2013). Self-reported data from another study provides indication of the most relevant factors influencing decision-making of different types of users (Beanland et al., 2013).

6.3.3.4 The lack of research on multiple interacting risk-contributing factors.

Several authors have pointed to the advantages of investigating simultaneous interactions between multiple risk contributing factors as opposed to considering a single factors’ contribution in isolation (Iorio et al., 2012; Read et al., 2013; Werkman et al., 2012). High risk groups of users (i.e., young males) or times of the day (i.e., peak hours) have been predominantly associated with risky crossing along with a number of contributing factors such as: large groups of pedestrians, being in a
hurry, inattention (distraction), sensation (thrill) seeking tendencies, status of the controls (closing vs. closed gates) or presence of a (visible) approaching train (Beanland et al., 2013; Clancy et al., 2007; Edquist et al., 2011; McPherson & Daff, 2005; Metaxatos & Sriraj, 2013a; Searle et al., 2011; Sposato et al., 2006). Davis Associated Limited (2005) are among the few who provided a classification of multiple factors influencing crossing behaviour, however they did not investigate the associations between different factors. In contrast, examining the interactions between various contributing factors Metaxatos and Sriraj (2013b) showed that the presence and the larger number of pedestrian gates (i.e., at all LC quadrants) reduced the reported deliberate and observed (legal) violations independently of the train’s direction. They also reported an increase in violations with the increasing number of pedestrians in a group (i.e., alone vs. in a group of two vs. in a group of more than two) independently of the time of the day. Finally, even though a number of authors have recently recognised the need to consider characteristics of the socio-economic area (e.g., presence of schools, industrial buildings) as a key factor shaping behaviour, to our knowledge such results have not yet been demonstrated (Edquist et al., 2011). While initial steps have been made to undertake research considering LCs as a complex system, these are rare and even rarer still is pedestrian focused systems research.

### 6.3.4 Systems approach

Systems theory, rooted in natural sciences has further been applied to the improvement of safety in complex systems. The systems approach aims to look at the problem as a result of the interaction of all the system’s components, considering the whole as the unit of analysis, not just individual’s behaviour. The utility of a systems approach in identifying factors which contribute to different types of errors has been demonstrated in a variety of complex systems such as aviation and, most recently, in the railway domain (Hobbs & Williamson, 2003; Li, Harris, & Yu, 2008; Maurino, Reason, Johnston, & Lee, 1995; Rail Safety Regulators’ Panel, 2009; Read, Lenné, & Moss, 2012). Read et al. (2012) were pioneers in applying a systems approach to the investigation of the associations between system factors and types of unsafe behaviour in rail incidents and accidents. However, they excluded occurrences at LCs from the scope of their analysis, given the added complexity of interactions between components of the road and the rail system. With the fast pace of
technological changes, there is a pressing urge to apply system models of safety and risk management to a broader range of domains (Hollnagel, 2004; Leveson, 2004). So far, a number of models have been developed and predominantly have been applied to, or underpinned accident analysis within complex systems: Rasmussen’s risk management framework and AcciMap (J. Rasmussen, 1997) Reason’s Swiss Cheese Model (Reason, 1997; Reason et al., 1990); Nancy Leveson’s STAMP (Systems-Theoretic Accident Model and Processes, Leveson (2004)); and the Safety through prevention and protection model (Hollnagel, 2004). While all of these models have emerged from the systems theory approach, each of them proposes a specific understanding of accident causation, investigation and prospective prevention. Traditional sequential and epidemiological models prioritise the analysis of the chain of events preceding an accident and are therefore considered inadequate to capture the dynamic nonlinear interactions between system components. Reason’s Swiss Cheese Model (1990, 1997) for example, identifies latent system failures (e.g., inadequate procedures, decisions) which combined with active failures (errors) create conditions for accidents. However, it has been demonstrated that this model fails to explain how these factors are associated with the active failures and other system factors due to the static view of the state of the system (Johnson & Botting, 1999). In more recent models, accident causation is viewed as a complex network of nonlinear interactions between various levels of the system where decision-makers at higher system levels are considered as equally responsible for failures as frontline actors (Hollnagel, 2004; Leveson, 2004). For example, Jens Rasmussen’s AcciMap technique graphically illustrates the causal relationships between actions and decisions on higher system levels according to the information flow between different system components (J. Rasmussen et al., 2000). The risk contributing factors in an AcciMap are distributed over the six hierarchically organised system levels proposed in Rasmussen’s risk management framework. Another example is the Nancy Leveson’s STAMP approach seeking to explain accidents as failures to exercise control over concrete tasks contributing to the global system performance (i.e., safety constraints) (Leveson, 2004). The graphical representation of the STAMP technique is based on the identification of system constraints and causal factors associated with reasons for flawed control and dysfunctional interactions.
Independently of the applied method, the detection of causal factors implies an in depth description of the current state of the system’s performance – a task implying serious methodological challenges. The system’s performance is subject to constant changes related to time passage, scientific advances or the outcomes of past events and occurrences (Dekker et al., 2011; Leveson, 2011b). The more the systems performance is dynamic and variable, the more actors’ behaviour becomes hard to predict. This is particularly true for open systems such as LCs – allowing interactions between systems’ internal elements and the environment. Pedestrian crossing behaviour is influenced by the system’s managing structures, by the actions and decisions of other independent actors (e.g., other pedestrians or motorists) and by a multitude of environmental characteristics (e.g., socio-economic and architectural characteristics of the urban and the narrower LC environment, weather and time conditions). Retrospective analysis of the relatively rare previous crashes is therefore limited in capturing risk factors at play in the specific circumstances and provides insufficient information about the current systems’ state and performance. At the same time, prospective analysis is better placed to consider and predict systems’ dynamics, although it would always be subject to changes over time and limitations related to the method of data collection and analysis (Dekker et al., 2011).

6.3.5 Aims of the paper

This paper aims to define a new tool for the better understanding of pedestrian’s behaviour accounting for the individual’s interaction with other system components. The framework is supported by well-known theories in psychology and systems approach methods.

Given the infrequent nature of pedestrian crashes at LCs, the investigation of the links between precursors of behaviour and system factors would benefit from the use of prospective methods. In an effort to investigate the cognitive and motivational precursors of behaviour along with the contributing factors they are impacted by, a new system-based framework is proposed – “Pedestrian Unsafe Level Crossing framework” (PULC). In line with modern systems approach, this framework is also designed to be used in a prospective and predictive manner.
6.4 PEDESTRIAN UNSAFE LEVEL CROSSING FRAMEWORK (PULC)

6.4.1 Origins and Structure

The proposed PULC framework is inspired by two key sources: the Contributing Factors Framework developed for the classification of contributing factors to rail accident occurrences (Rail Safety Regulators’ Panel, 2009), and which is based on James Reason’s Organisational accident causation model; and the Jens Rasmussen’s risk management framework. Elements from both models have been combined to highlight potential links between specific risk factors identified in the existing literature and unsafe behaviour according to its level of intentionality. The PULC identifies factors on four system levels and is tailored to the particular context of pedestrian crossing behaviour (Figure 25).

Each level lists system components responsible for various safety constraints associated with corresponding risk-factors potentially contributing to unsafe crossing. Unlike the proposed classification of system levels in Jens Rasmussen’s model, in the PULC factors on the individual level (Pedestrian level) are distinguished from factors associated with the presence and behaviour of other actors in the immediate crossing context (Social environment). The Organisational and the Equipment and surroundings levels include components related to respectively systems’ management and physical environment. Based on the current knowledge, components on each level have been identified in relation to their potential influence on pedestrian behaviour. The associated risk-factors are likely to have an impact on different types of unsafe behaviour.
We refer to James Reason’s classification of “unsafe acts” which builds upon Jens Rasmussen’s Skill, Rule and Knowledge based classification (SRK), to distinguish between errors and violations (Reason et al., 1990). While errors result from failures on different levels of information processing (skill, rule, knowledge-based levels of performance) and are thus associated with cognitive precursors; violations emphasise on the role of social context in decision-making (e.g., social norms, rules, operating procedures) and are therefore associated with motivational factors which lead the person to intentionally deviate from the prescribed rules.
(Reason et al., 1990). According to Parker, Reason, Manstead, and Stradling (1995) errors are more likely to be minimised through “retraining, redesign of the human-machine interface, memory aids, better information”, whereas violations are more likely to be reduced by the modification of attitudes, norms, beliefs or the overall safety culture (p.1036).

The arrows in Figure 25 represent the complex interactions between components within and between system levels. However, despite their interconnectedness various authors have demonstrated that system factors of different nature contribute to a larger extent to either errors or violations (Hobbs & Williamson, 2003; Read et al., 2012).

Reason defines skill-based errors as actions which did not go as planned in automatic routine tasks requiring low attentional resources. In a LC context, such errors can be associated with internal or external distractions related to the perception or recognition of key elements in the LC environment (e.g., the activation of the automatic controls). Findings from previous studies have shown that the use of mobile devices while crossing alters pedestrians’ vigilance and thus contributes to such errors (Clancy et al., 2007; Metaxatos & Sriraj, 2013b). Moreover, Hobbs and Williamson (2003) demonstrated that skill-based errors in aircraft maintenance are associated with factors related to the use of equipment, equipment malfunctions and environmental characteristics. Therefore, in the context of crossing at LCs, skill-based errors could be associated with risk-contributing factors on the Equipment and surroundings level. Such factors describe the characteristics of the LC environment (e.g., number of rail tracks, presence of controls), the larger urban area (e.g., key industrial and economic buildings within the area of the LC) or else, the temporal characteristics of the crossing situation (e.g., time of the day, weather conditions).

Rule and knowledge based errors occur on the more conscious action-selection level. Rule-based errors occur in familiar situations when a person could misapply a good rule (e.g., assumptions: crossing is safe as long as there is not a visible train at active LCs) or apply a bad rule to a given situation (e.g., habits: crossing is perceived as safe as long as one train has passed even if the gates are not open). In contrast, knowledge-based errors describe failures related to a lack of information in novel situations. Thus, past experience (familiarity) would favour the formation of attitudes, strong expectations or habits likely to be associated with rule/knowledge
based errors. In the context of crossing a LC, past experience would be associated with factors related to various laws, regulations and procedures governing the LC system (e.g., rail traffic management, enforcement, security, safety campaigns, road rules). In line with this assumption, Hobbs and Williamson (2003) demonstrated that risk factors associated with tasks requiring training, supervision, coordination or past experience with procedures were particularly associated with rule/knowledge based errors in aircraft maintenance. Within the PULC, factors related to the system’s management are identified within the Organisational level, encompassing four higher system levels adopted from Jens Rasmussen’s model.

Violations originate under the influence of various psycho-social constraints (e.g., attitudes, norms, beliefs) attributing a given value (importance) to the behaviour or to more abstract goals, and are generally carried out in the belief that they will result in more positive than negative outcomes. Reason (1990) defines violations as underpinned by risk/benefit trade-offs (e.g., “I can take the risk to cross in order to catch the next train”).

Goal attainment is a central concept in theories of self-regulation which explain individual’s conscious efforts to influence thoughts, feelings and behaviours towards the achievement of goals in a dynamic environment (De Ridder & De Wit, 2006). While theories of self-regulation offer different perspectives, they share the idea that goals direct behaviour and give meaning to people’s lives (Baumeister, 1989). Carver and Scheier (2001) propose a model of self-regulation rooted in the long tradition of expectancy-value theories in psychology explaining the persistence of efforts towards a given goal as driven by the perception of favourable outcomes. Such behaviour is defined in this paper as “goal directed behaviour”. Having been widely applied in the domain of health and risk-taking, this model is based on the idea that goals differ in their level of abstraction and have a hierarchical structure. Goal directed behaviour can therefore explain risk-taking at LCs underpinned by the motivation of attaining higher level goals (e.g., “I need to violate the rules in order to be at work on time”). In this relation, Hobbs and Williamson (2003) demonstrated that time pressure was strongly associated with violations. In a LC context, Clancy et al. (2007) showed that 31% of survey pedestrians reported intentionally engaging in violations “to be on time” or to “catch a train”. Violations can also be explained by social influences (i.e., crossing for a dare, to be part of the group).
Various authors have shown that the larger number of pedestrians crossing together increases risk-taking propensity at LCs (Khattak & Luo, 2011; Metaxatos & Sriraj, 2013b).

Nevertheless, deliberate violations can and often are underpinned by precursors of errors. In familiar situations decision-making and specifically risk/benefit trade-offs are often influenced by past knowledge and experience which potentially contribute to the formation of expectations, attitudes towards safety procedures or perception of risk (see examples of quotes in Appendix D related respectively to Safety checks, Safety campaigns and Unsafe behaviour).

6.5 APPLYING THE PULC – A FOCUS GROUP STUDY WITH PEDESTRIANS

Focus group discussions with pedestrians who frequently use LCs were organised. Participants were invited to share their past experiences at LCs, perception of risk and safety issues, opinions and observations of other pedestrians’ behaviour. Such qualitative approach is a promising method to conduct exploratory baseline studies on the identification of interactions between risk contributing factors within complex systems (Read et al., 2013; Werkman et al., 2012).

In the next sections, the method of the study and some of the results are described to illustrate how the framework might contribute to a better understanding of the system's dynamics.

6.5.1 Method

6.5.1.1 Participants

Twelve participants between 16 and 75 years old ($M = 42$) took part in the focus groups. Two thirds of them were female (9/12). All were familiar with Wynnum Central LC. Participants reported also crossing LCs adjacent to Wynnum North train station ($N = 3$), Lindum train station ($N = 1$) and Cannon Hill train station ($N = 1$). All of these users were crossing from one to four times per day.

Four focus groups were formed as follows: one group of younger pedestrians (16–30); two groups of middle aged (31–55) and, one group of older pedestrians (56+). The focus groups had on average three participants per group.
Participants were recruited via posters, inviting people who “regularly or occasionally walk through a level crossing” and are “over 15 years old”. Posters were distributed at train stations and LCs within and nearby the Wynnum area (Queensland, Australia), as well as at large shopping centres in a close proximity. The rationale for targeting a sample from this area is that the majority of the reported near-misses with pedestrians from 2011 took place on this particular rail line (42%), and specifically at the LC adjacent to Wynnum Central station (41%) (Queensland Rail, 2012).

6.5.1.2 Description of the frequented LCs by participants

Wynnum Central is commonly frequented by all participants. It is equipped with active controls (flashing lights, barriers, a single pair of pedestrian lights and pedestrian gates on each side of the crossing) regulating pedestrian flow through the two rail tracks (Figure 26). Some participants were also familiar with two other LCs (i.e., Cannon Hill and Lindum). These LCs differ from Wynnum Central as three rail tracks are separated by middle islands with active controls providing independent regulation of the pedestrian flow on each side.
Note. Wynnum Central train station is located on a middle island accessible through one of the two rail tracks of the LC. The station side of the crossing is operated by pedestrian gate system on each side of the road (indicated with rectangles) and at the middle island. Unlike common design of other LCs giving access to train stations, during the activation of the controls pedestrian crossing is prohibited on both sides of the middle island irrespectively of the expected train’s direction. On the opposite-station side, pedestrian gate systems are located on each end of the pedestrian corridor. Each pedestrian gate system consists of an entry gate which closes automatically at the approach of a train and an emergency exit gate, which remains closed at all times but which could be pushed open from the inside of the LC if needed, or pulled open from outside the LC. (Source: Google earth 2014, eye altitude: 84 meters)

Figure 26. Wynnum Central level crossing.
Adapted from Google earth (2011)

6.5.1.3 Materials

The focus groups were semi-structured utilising open-ended questions that covered six main themes incorporating all elements identified in the PULC (Appendix D). The first theme consisted of introductory questions about participants’ habitual crossing behaviour as a pedestrian (familiarity/frequency/purpose of crossing at concrete LC-site/s and knowledge about various aspects of crossing) and was simultaneously used as “breaking the ice” technique between participants. The remaining themes were discussed in each group in a non-systematic order. Each theme corresponded to a set of broad questions and probes developed beforehand to guide but not delimit the discussion. The second theme was developed to capture
precursors of skill-based errors (e.g., absent minded behaviour, internal or external distractions, low vigilance). The third theme probed detailed description of unsafe crossing context and the explicitly provided causes (e.g., key elements of the environment, goal directed behaviour). Finally, the three last themes dealt with information on past experiences and attitudes, expectations and perceptions related to different aspects of: enforcement policies and procedures (e.g., likelihood to be penalised); education campaigns (e.g., exposure, perceived relevance, effectiveness); and general public safety awareness (e.g., perception of hazards or risks). It must be noted that because of ethical reasons, the last theme “Past occurrences at LCs” did not consist of pre-identified questions related to fatal occurrences.

6.5.1.4 Procedure

The aims of the study and privacy policies were explained to participants prior to the discussions. The sessions were conducted in a quiet environment, with groups of participants of similar age in order to enhance interactions and in particular the potential for sharing past illegal experiences (Yardley & Marks, 2004). Even though participants were asked to describe past crossing experiences they tended to talk more generally about their habitual safe or unsafe crossing. Probes based on five W-questions (“Who-have you done that?”; “When – could you describe the situation?”; “What – what happened exactly?”; “Why- was there any particular reason?”; “Where – where did this happen?”) were used to extend the discussion, provide clarifications and enhance the interaction between participants. Where possible (without interrupting the natural flow of the discussion), participants were asked to share their own knowledge, experience or opinions about topics raised by others. For example, if a pedestrian knew the exact amount of the sanction for illegal crossing – others were also explicitly asked. At the end of the discussion, all participants received an incentive for their time.

6.5.2 Analysis

Our analysis method was twofold. First, applying the PULC, factors potentially logically related to crossing behaviour and their interactions are identified. Second, two illustrative case studies of specific unsafe crossing occurrences are presented in AcciMaps format.
6.5.2.1 Applying the PULC to identify and classify factors contributing to crossing behaviour

• STEP 1. Identification of units of analysis – Cases

Two researchers combined all the verbal exchanges that related to a depicted distinctive “Case” of crossing behaviour or elements likely to influence behaviour. For a case to be considered, even if it included the interaction between multiple participants, it had to meet one of three criteria:

- Description of a crossing or events occurred at a specific time and place.
- Description of aspects of habitual behaviour (e.g., crossing before the pedestrian gates are closed).
- Description of aspects of habitual behaviour (e.g., crossing before the pedestrian gates are closed).
- Description of general aspects of the system’s properties (e.g., amount of the sanctions, existing safety campaigns) likely to influence behaviour.

• STEP 2. Categorisation of the profile of participants

Participants’ crossing profile was evaluated according to quantifiers identified in the verbatim informing on the frequency that a given behaviour was undertaken. Pedestrians who did not report any previous unsafe crossing were assigned to “safe crossing profile”. Error and violation profiles were assigned to pedestrians who reported at least one risky crossing experience. In this sample, all three participants who reported errors did not report any violations.

• STEP 3. Coding of factors potentially influencing crossing behaviour

This coding was based on four variables:

- Factor: any reference to a rationale, information or explanation regarding crossing behaviour or intentions. Two researchers used the pre-established categories of risk factors in the PULC as a first list for screening the case content. Multiple factors were identified within each case considering the wider context of the narratives. With the aim to detect a wide range of factors instead of quantifying their importance or
Factors shaping pedestrians’ unsafe behaviour at actively protected level crossings

prevalence, each was coded only once in relation to a given behaviour independently of the number of times or the number of participants it was mentioned by among all focus groups.

- Actor (engaged in crossing): self (participant reporting own behaviour) vs. others (participant reporting observed behaviour).
- Type of behaviour: safe crossing vs. error vs. violation.
- Nature of unsafe crossing: past experience (own, observed or information about an occurrence/behaviour) vs. hypothetical experience (expressed crossing likelihood for the self or others).

Factors identified within cases describing aspects of crossing (but not behaviour) were associated with safe behaviour, errors or violations according to the crossing profile of the participant. However, if for example a pedestrian assigned to error profile was talking about a hypothetical violation - then the factor was only associated with “hypothetical violation”.

Finally each factor was associated with at least one and a maximum of ten different behaviours according to their type (safe vs. error vs. violation), their nature (past vs. hypothetical experience) and the actor (self vs. others).

- **STEP 4. Classification of the factors within the pre-identified categories at each level of the PULC framework**

  The researchers used a bottom-up process to group similar factors together and organised them in categories of risk factors corresponding to system components within the PULC framework. A more detailed list of risk factors were identified thus extending the proposed categories in the PULC. For example, factors related to “Active controls” and “Passive controls” were organised in separate categories as being likely to influence different cognitive and motivational precursors. While signs are likely to be overlooked, audible alarms or pedestrian gates’ activation would more likely be misinterpreted than unnoticed.

- **STEP 5. Coding of the interactions for each factor on the Pedestrian level with other system factors**

  Finally, for each factor on the Pedestrian level one or two interactions (i.e., logical relationships) with other factors on the same or other system levels were
identified. Only the system level of the identified interacting factors was taken into consideration (e.g., a factor within Goal directed behaviour category interacting with a factor on the Equipment and surroundings level). For each interaction, the number of behaviours accounting for the type, the actor and the nature of behaviour was counted. Three researchers participated in the coding process, discussed and resolved any discrepancies in opinions.

6.5.2.2 Illustration of concrete relations between interacting factors and precursors of behaviour utilising the AcciMap technique

To illustrate concrete relationships between precursors of behaviour and multiple factors on various system levels we adopted Jens Rasmussen’s AcciMap technique, which has previously been applied to the investigation of the contributing factors to unintentional non-compliance at LCs (Salmon et al., 2013). The AcciMap analysis allowed representing the causal relationships between factors on the lower system levels and the implied contribution of factors from the higher Organisational level. The contribution of the latter was inferred as pedestrians were unlikely to provide information on organisational factors. Instead, exchanges with industry partners and rail experts allowed discerning governmental and industrial structures on each system level corresponding to the identified system components in the PULC framework. Thus, the inferred factors were assigned to each system level and category of factors in the AcciMap illustrations.

Each AcciMap included risk-factors within the four higher system levels as per Jens Rasmussen's model associated with specific organisational structures governing in Queensland and Brisbane area and likely to be responsible for the inferred risk-contributing factors. The typical Rasmussen’s level “Physical processes and actor activities”, which normally incorporates decisions and actions of frontline actors in the chain of events prior to the critical event (accident) was, for the purpose of this study and corresponding to the structure of the PULC, split into “Pedestrian level” and “Social environment level”. Consistent with the adopted approach, this separation allowed the inclusive investigation of the origins of pedestrian behaviour taking into consideration influences from the surrounding social environment.

6.5.3 Results

Results are organised in three sections. First, descriptive statistics on the frequency and the types of unsafe behaviour are presented. Second, the classification
of factors across system levels is presented followed by a discussion of the interacting factors associated with each type of behaviour. Finally, two case studies of violations are presented in AcciMaps format.

6.5.3.1 Reported unsafe behaviour and perceptions of high risk groups of users

Eight out of the twelve participants mentioned at least one crossing experience which could be considered unsafe, the majority being reported by daily users \( (N = 6/8) \). Considering each age group, unsafe behaviour \( (N = 7/8) \) was mostly associated with younger (16–30 years old) and middle aged (31–55 years old) participants, while older adults (56+ years old) were most likely to report safe behaviour \( (N = 2/4) \).

Three crossing experiences associated with errors were identified in each age group of participants: one was inferred as such by the researchers and the others were recognised by the pedestrians after crossing. The three errors were classified as: a rule-based error (i.e., pushing the entry pedestrian gate while it had already started opening); a skill-based error (i.e., the participant failed to identify the activation of a second pair of pedestrian lights at a middle island); and a knowledge-based error (i.e., the participant was not aware of the presence of an emergency pedestrian gate during a first crossing experience in the country). In contrast, five younger and middle aged participants reported violations – deliberate crossing during active controls’ activation, and being aware of the illegal nature of such behaviour.

Finally, within each participant’s narrative we identified words and phrases describing other pedestrians as high at risk groups of users. All age groups of participants perceived younger pedestrians as high risk groups of users, even though some participants also suggested that school children tend to cross safely. Middle age participants were most likely to perceive older adults (elderly) as a high risk group, while only older adults did not perceive their age group as being at risk.

6.5.3.2 The applied PULC

After the coding, 298 factors were identified across all levels of the PULC. The Pedestrian level cumulated the largest number of identified factors distributed in 12 categories. The Environment and surroundings level comprised factors classified in 10 categories. The least number of factors were found on the Organisational and on the Social environment levels. Figure 27 illustrates the distribution of factors within
each category accounting for the number of factors associated at least once with safe crossing and/or error and/or violation (independently of whether the behaviour was hypothetical or past experience of the self or others).

Table 12. Distribution of factors across system levels associated at least once with each type of behaviour

<table>
<thead>
<tr>
<th>System level</th>
<th>Type of behaviour</th>
<th>Safe</th>
<th>Error</th>
<th>Violation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian</td>
<td></td>
<td>68</td>
<td>27</td>
<td>139</td>
</tr>
<tr>
<td>(Tot. factors = 193)</td>
<td></td>
<td>35%</td>
<td>13%</td>
<td>74%</td>
</tr>
<tr>
<td>Equipment &amp; surroundings</td>
<td></td>
<td>26</td>
<td>8</td>
<td>46</td>
</tr>
<tr>
<td>(Tot. factors = 64)</td>
<td></td>
<td>40%</td>
<td>12%</td>
<td>71%</td>
</tr>
<tr>
<td>Social environment</td>
<td></td>
<td>6</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>(Tot. factors = 14)</td>
<td></td>
<td>42%</td>
<td>0%</td>
<td>57%</td>
</tr>
<tr>
<td>Organisational</td>
<td></td>
<td>11</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>(Tot. factors = 27)</td>
<td></td>
<td>40%</td>
<td>0.03%</td>
<td>66%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>111</td>
<td>36</td>
<td>211</td>
</tr>
<tr>
<td>(Tot. factors = 298)</td>
<td></td>
<td>37%</td>
<td>12%</td>
<td>70%</td>
</tr>
</tbody>
</table>

Note. The percentages across each row do not add to 100% as each factor could be associated with more than one behaviour (i.e., self vs. others; past experience vs. hypothetical experience).

“The majority of the identified factors on each system level were associated with violations and the least number – with errors” (Table 12). The Pedestrian level accounted for the largest number of identified factors. These factors were organised within categories corresponding to various cognitive and motivational precursors of behaviour. Factors within the Physical and mental states (e.g., impairments, emotions, moods), Crossing characteristics (e.g., crossing with earphones, carrying bags) and Safety checks categories were mostly associated with cognitive precursors of skill-based errors (11 out of 36). Factors within the Perception of risk, Attitudes, Past experience and knowledge and Expectations categories were mostly associated with cognitive precursors of rule/knowledge based errors (13 out of 36). Throughout the remainder of the analysis error types are considered together. Finally, factors within the Goal directed behaviour (e.g., time pressure, impatience with waiting times), Crossing and Journey context (e.g., going to work/school), Crossing trajectory (e.g., short-cuts, crossing on diagonal), Perception of deterrence and Perception of security categories were mostly associated with motivational precursors of violations.
Factors shaping pedestrians’ unsafe behaviour at actively protected level crossings

Note. For each category of factors are provided: the number of factors associated with safe crossing (S); the number of factors associated with errors (E); the number of factors associated with violations (V) and last the total number of factors identified in the category, noting that each factor could be associated with more than one type of behaviour

Figure 27. Applied PULC: Detailed classification of contributing factors to pedestrian crossing behaviour.

To further examine the influence of different system factors on the precursors of behaviour, in the following sections the interactions between factors within each category of the Pedestrian level and other factors on the same or other system levels are discussed in light of their association with either type of behaviour.

6.5.3.2.1 Interactions between factors associated with safe crossing

Among the 68 factors on the Pedestrian level associated with safe crossing (Table 12) five were found to interact with other factors on more than one system level. Thus a total number of 73 interactions associated with safe crossing were identified. Among these interactions 76 behaviours were counted, meaning that three of the interactions were associated with safe crossing reported both – for the self and for others.

Figure 28 illustrates the contribution of interacting factors which were associated with safe crossing most often, independently of whether they were associated with the participants’ own behaviour or with the behaviour of others. Among all categories on the Pedestrian level, the largest number of behaviours was associated with factors related to Past experience and knowledge, Expectations,
Safety checks and Attitudes (68%). The majority of factors associated with safe crossing interact with other factors on the Equipment and surroundings level (51%) and to a smaller extent with factors on the Organisational and the Pedestrian levels. Influences from the social environment were least mentioned in relation to this type of behaviour.

Factors on the Equipment and surroundings level were found to influence a large number of cognitive precursors of behaviour such as perception of risk, familiarity, attitudes and expectations but also motivational precursors. Among the cognitive precursors, knowledge about characteristics of the LC environment and rail traffic (e.g., the platform’s height, the number of rail tracks, the angle or the distance to an approaching train) was often associated with an estimation of risk preceding the crossing decision (e.g., “If it was touch and go I wouldn’t risk it”). Familiarity with active controls was associated with low likelihood of missing the controls' activation (e.g., the audible alarm can be heard before the gate system is active). In relation to this, participant’s perception of risk appeared to be associated with checks for the status of the pedestrian gate or with checks for a visible approaching train. Among the motivational precursors, journey contexts were mentioned in relation to characteristics of the urban and the LC environment. For example safe crossing was associated with a goal of crossing the road instead of crossing to catch a train, but also with crossing in order to catch a train for leisure as well as for work.

Factors on the Organisational level seemed to contribute as well to the formation of attitudes and expectations and enhanced familiarity and knowledge about different aspects of the system’s performance (cognitive precursors). For example, safe crossing was associated with: attitudes towards the amount of the sanction for illegal crossing; expectations based on others’ experience with sanctions, expectations based on familiarity with train timetables; or else, awareness of previous occurrences or safety campaigns. Specifically, participants crossing safely expressed expectations that more express trains (not stopping at station) pass in the morning.

The influence of factors of the Social environment level mainly described crossing motivated by social influences. Specifically, safe crossing was associated with crossing with family (e.g., crossing with baby or with a partner) and crossing among random other pedestrians (e.g., not following other pedestrians). Moreover,
crossing with known others was associated with more safety checks, whereas crossing among random others – with less. Finally, the interactions between factors within the Pedestrian level often described the relationship between past experience and perception of risk (i.e., knowledge about previous occurrences was associated with increased perception of risk).

Note. Arrows illustrate the interactions most frequently associated with safe crossing; N = the number of safe behaviours identified: 1) within each category of factors on the Pedestrian level; 2) in interaction with other factors on each system level.

Figure 28. Illustration of interactions mostly associated with safe crossing

6.5.3.2.2 Interactions between factors associated with errors.

Among the 27 factors on the Pedestrian level associated with errors, four interacted with factors on two different system levels. Thus, in total 31 interactions were identified associated with 34 different behaviours. In other words, in three cases the same interaction was associated with more than one error. There were slightly more behaviours related to participants’ own past experience or likelihood to commit an error (59%) than were for others.

Figure 29 illustrates the interactions between factors mostly associated with errors reported for the self (solid arrows) and with errors reported about others (dashed arrows). Among the categories of factors on the Pedestrian level, more than
half of the identified errors (62%) were distributed between Past experience and knowledge, Physical and mental states and Crossing characteristics. The largest percentage of factors associated with errors interacted with other factors on the Equipment and surroundings level (41%) and the least percentage—with factors of the Organisational level (12%).

Factors associated with participants’ previous recognised errors and perceived likelihood to commit an error, were mainly identified among the following categories of contributing factors: Past experience and knowledge, Attitudes and Goal directed behaviour and were interacting with other factors on the Organisational, the Pedestrian and the Equipment and surroundings levels. These interactions suggest that the likelihood of committing an error can be associated with less than adequate performance of rail staff (e.g., station masters do not act upon signalled problems) or else, with inadequate characteristics of the passive and active controls (e.g., frustration to wait for pedestrian gates to open, abundance of passive signs). The lack of previous experience at LCs, infrequent crossing and familiarity with more than one LC, were also associated with errors. Thus, the reported for the self, past experience and likelihood to commit an error was associated with failures on the rule/knowledge based level of performance and even with goal directed behaviour.

On the contrary, participants’ perception of the likelihood of others to commit an error was predominantly associated with Physical and mental states and social influences, both hampering the capacity to detect the controls’ activation (e.g., hearing/visual/ motor impairments, absent-minded behaviour, alcohol intoxication, crossing among a large group of pedestrians). Thus, unlike the factors associated with participants’ own behaviour, reporting on others’ behaviour was more likely to be associated with skill-based errors.
6.5.3.2.3 Interactions between factors associated with violations.

The largest number of interactions \((N = 165)\) was found for factors at the Pedestrian level associated with violations \((N = 139, \text{Table 12})\). Among all factors associated with violations, 26 were in interaction with other factors on two different system levels. Moreover, these interactions were mostly associated with more than one behaviour (i.e., reported past experience and/or hypothetical behaviour for the self and/or for others). In total 275 violations were identified, with the majority associated with participants' own reported behaviour (68%, solid arrows) than with the observed or hypothetical behaviour of others (dashed arrows) (Figure 30).

While the largest number of violations (21%) was identified within the Past experience and knowledge category, factors within the following categories were associated with more violations per interaction: Goal directed behaviour, Crossing and Journey context, Crossing trajectory, Perception of deterrence and Perception of risk. Most violations, in total and per interaction, were associated with interacting factors on the Pedestrian and the Equipment and surroundings levels. Interacting
factors on the Organisational level accounted for the least number of violations, however they were associated with more violations per interaction. On the contrary interacting factors on the Social environment level were associated with least behaviours per interaction although the total number of behaviours was higher.

Note. Solid arrows correspond to interactions most frequently associated with participants’ reported past experience or likelihood to commit violations. Dashed arrows correspond to interactions most frequently associated with knowledge or observed behaviour of others clearly intentionally violating or with the perceived likelihood of others to commit violations. N= the number of violations identified: 1) within each category of factors on the Pedestrian level; 2) in interaction with other factors on each system level

Figure 30. Illustration of interactions mostly associated with violations reported for the self and for others.

Violations reported for the self and associated with motivational precursors were identified within the following categories Goal directed behaviour, Crossing trajectory and Crossing and journey context and were in interaction with other factors on the Pedestrian and the Equipment and surroundings levels. More than half of them concerned a reported likelihood to commit a violation (52%) than past experience. These interactions described violations motivated by a fear of missing a train to (to work/school), unwillingness to wait for the lights at a nearby road traffic intersection, time pressure or impatience (e.g., shortcuts, diagonal). They were associated with various aspects of the LC and the larger urban environment, with rail traffic characteristics and with time and weather conditions. For example violations were associated with crossing after shopping, at any time of the day or out of peak
hours, in the presence of a stopped train at station, or else when it’s raining. Interactions with other factors on the Pedestrian level described goal directed behaviour underpinned by positive attitudes (e.g., “pushing the pedestrian [entry] gate open is quicker and more efficient”). Violations reported for the cognitive precursors corresponding to factors within the Past experience and knowledge, Attitudes and Expectations categories. These behaviours seemed to be influenced by other factors on the Organisational and the Equipment and surroundings levels. Logically they were more associated with past (71%) than hypothetical experience. For example, violations were related to: awareness of the absence of locks on pedestrian entry gates, poor knowledge about the existence of pedestrian lights; awareness of second train arrival; familiarity with the platform, the larger area and with more than one LC. The large majority of the violations associated with low perception of risk (71%) interacted with other factors of the Equipment and surroundings level (e.g., presence of stopped train, distance of approaching train, prior to closure of the pedestrian entry gate).

Various cognitive and motivational precursors were associated with violations reported as other pedestrians’ observed or hypothetical behaviour, and were logically interacting with other factors of the Social environment level. These interactions described the perception of high risk groups of pedestrians. For example, they were associated with negative Attitudes (e.g., people are stupid, crossing for a dare is useless) or else, with a decreased Perception of risk compared to others’ crossing behaviour (e.g., younger are unaware of the risk, younger are more at risk crossing for a dare, elderly with disabilities are more at risk, confident and people wearing high heels are more at risk). Contrary to participants’ own behaviour, their perception of others’ goal directed behaviour was associated with social influences and more specifically with sensation seeking tendencies (i.e., for a dare, to show up).

6.5.4 AcciMaps of two case studies illustrating interactions between factors on different system levels

Two crossing scenarios in which pedestrians reported violations at Wynnum Central LC were chosen because they involved a large number and different nature of factors from multiple system levels and were therefore considered as suitable to illustrate the potential use of the PULC.
6.5.4.1 Case study 1

The first case study identifies the risk contributing factors resulting in a violation against a closed pedestrian entry gate. AcciMap 1 (Figure 31) shows the interaction between these factors playing a role in the decision, whilst being aware that an approaching train has been announced to pass through the LC.

This particular crossing experience was reported by one participant – a 30-year-old female. She was on her way to Wynnum Central train station to catch a train home after shopping for groceries at a nearby supermarket. Evidence from the focus groups reveals that this is a commonly adopted trajectory by pedestrians, the LC being connected to a main road giving access to a nearby shopping centre, whereas an overpass is provided at the opposite LC and main road side end of the platform. Issues associated with the planning of the LC and overpass access points can therefore be inferred. According to the participant, her main reason for engaging in the particular crossing behaviour was the presence of a train already stopped at station. Crossing with her child, grocery bags, “school bag”, “university bag”, the participant ran to the platform, following the pedestrian path, she was unwilling to wait for the next train. As reported, she regularly crosses in identical situations (“I do it all the time...”).

Such repetitive behaviour could be attributed to a low perception of risk or deterrence. Indeed, although not reported in relation to this particular crossing situation, the participant showed a low perception of risk associated with her familiarity with the LC environment: “I know the platform really well so if it was somewhere I haven’t been before I couldn’t gauge how far it was if I didn’t know how long the platform was” or with her (self-reported) “risk-taking” tendencies (“I’m a risk taker”). A link was also established with pedestrians’ reported lack of previous experience with sanctions: “see I do it all the time and I never got caught”. This could be influenced by failures on the higher system levels to adequately plan or implement enforcement strategies (e.g., inadequate or limited enforcement staff presence or schedules). Queensland Rail – “QR” (Technical and organisational management level) for example shares the responsibility to provide enforcement with the State Police (State policy and budgeting level). Budgetary issues could impede on the appropriate implementation of enforcement strategies and procedures on both levels.
Participant’s perception of risk can be also attributed to issues related to the design of the station platforms and the larger station environment (i.e., access to the platform through the LC). Moreover, the participant expressed positive attitudes related to the ease of pushing the pedestrian gates open (i.e., absence of locks):

“It’s quicker and it’s more efficient just to push through the gates and run . . . its faster”.

Thus, the technical properties of the automatic controls might enhance pedestrians’ intentions to violate. However, the implementation of new and more intricate controls would be con-strained by the budget on the Technical and operational management level as well as on the State government level.

LTA – less than adequate

Figure 31. AcciMap 1 – illustration of crossing context where a pedestrian commits a violation on their way home after shopping
6.5.4.2 Case study 2

The second AcciMap (Figure 32) represents a violation at the same Wynnum Central LC, which resulted in legal consequences for the participant. In this crossing situation, the pedestrian—a 55-year-old woman pushed the entry pedestrian gate open to catch a train on her way to work. The choice of trajectory (crossing the LC instead of taking the overpass) was here again a matter of the shortest path. However in this case, the pedestrian parked her car closer to the LC avoiding a car park (giving access to the overpass) where she had previously observed aggressive behaviour and therefore considered as unsafe location.

During the violation, she was issued a fine together with a young man crossing at the same time from the opposite side of the LC. Both pedestrians received the fines from undercover QR officers (transit officers). The main reported reason for crossing was the lack of locking mechanism on the pedestrian gates: “it’s easy to open they don’t lock the gate – it’s easy to push and go”. Here again, the technical configuration of the pedestrian gates was explicitly associated with increased likelihood to violate. The woman refers to pedestrian gates providing access to a different train station (Lota) which lock and cannot be opened, enhancing safe crossing. In addition to the ease of pushing the gate, the crossing decision in this situation could be linked to the expressed strong perception of control (e.g., “but I had time, see this is the danger, people are pushing the gate - so Lota they have a locking mechanism”). Similarly to Case study 1, the perception of control in this situation could be explained by a low perception of risk or deterrence. However, in this case the pedestrian demonstrated a good knowledge about the regular presence of QR officers and associated this violation with a failure to recall this information (e.g., “I know, at 7.30 they are always there every 3 months . . . and I forgot that they are here . . . I haven’t see them for a long time”), noting that the pedestrian recalled the exact time of when she was issued the fine (7.30 am).
In addition to exploring cognitive and motivational precursors of behaviour, Fig. 7 provides the opportunity to explore the extent to which they are influenced by the negative consequences of the action (i.e., receiving a fine). Specifically, the self-reported data post violation provides information on the effects of enforcement measures. The pedestrian reported a reinforced perception of deterrence (e.g., “I’ll never do it again, I look at the station make sure they . . . I’ll never do it again”), but also a maintained perception of control over the situation. In fact, according to QR policies, in addition to the sanction for illegal crossing transit officers are informing pedestrians on the risks of such behaviour. After having this discussion with enforcement officers, the pedestrian seemed to maintain a stronger perception of control than of deterrence.

“yes they told me that I shouldn’t be doing this, you know, and it’s dangerous, you know and, that I could be, you know killed and all that, but old people got killed cause they are slow-walking, or they can’t hear. There was one lady she couldn’t hear so the gate is very important it should be locked”
Arguably her perception of control was associated with a greater perception of risk for others than for herself in a similar situation (i.e., activated controls). She mentioned a specific past fatal occurrence at Wynnum Central train station 6 years prior to the focus group discussion. This collision was well known among multiple participants across focus groups, being widely covered by local media and discussed among community members (as indicated by participants). It appeared to have generated a lasting perception that elderly pedestrians are a high-risk group of LC users, due to their limited motor, visual or hearing capacities. It is worth noting that the exact reasons for this past occurrence are unknown. Nevertheless, participants in the focus groups tended to explain the “old lady’s fatality” in terms of impairments rather than statements or opinions as to whether she was aware or not of the risk she had taken (i.e., following a group of younger pedestrians pushing through the closed pedestrian gates). This is why it can be argued that this tragic past experience had more weight on the formation of crossing decisions than the educative discussion provided by enforcement officers.

6.6 DISCUSSION

The conducted literature review on pedestrian crossing behaviour at LCs highlighted significant gaps in knowledge about the cognitive and motivational precursors of unsafe crossing and the associated multiple risk-contributing factors. To address these gaps, a system-based model called PULC (Pedestrian Unsafe Level Crossing framework) is proposed for the investigation of errors and violations at active LCs.

This framework presents an extended view of various components of the system linked to cognitive and motivational precursors of behaviour (safe crossing, errors and violations). The PULC was applied to the analysis of qualitative data obtained from focus group discussions culminating in a detailed classification of factors derived from the descriptions of participants' safe and unsafe crossing. The classification facilitated the description of interactions between factors across system levels and moreover the examination of their role in the emergence of errors and

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1 To our knowledge there is not an official report of the investigation in the ATSB (Australian Transport Safety Bureau) database.
violations. To our knowledge, this is the first study to provide an indication on the importance of groups of interacting factors according to their association with past and hypothetical violations reported for the self and for others.

Among the twelve focus groups participants, three had previously committed errors, five reported violations and the remaining four only declared safe crossing behaviour. Independently of the small number of participants, the broad discussions allowed information to be recorded relating to the observed crossing behaviour of others. The results presented here presented are used as an illustration of the application of the framework and cannot be considered as representative of the general population.

The analysis of the results on the interacting factors showed that factors on the Equipment and surroundings level are the most associated with each of the three types of crossing behaviour. Factors on the Organisational level were least associated with errors, whereas factors on the Social environment were least associated with safe crossing.

Safe crossing was more commonly adopted by older participants and infrequent users of LCs. It appeared to be predominantly associated with knowledge about previous near-miss or fatal occurrences. Safe crossing was also associated with cues in the environment impeding on the emergence of error-prone conditions (e.g., audible alarms) or influencing safe crossing decisions (e.g., train position, angle of visibility, tracks and platform characteristics). These results suggest that participants tend to perceive themselves as unlikely to commit errors, and moreover that their crossing decisions are rather associated with a perception of risk than with legal constraints. These results are consistent with previous findings, suggesting that pedestrians rely on the audible alarms to gauge a train's approach (i.e., controls' activation), but on the contrary – judge whether to cross according to the visibility of the approaching train (Beanland et al., 2013).

The identified errors were distributed evenly across all three age groups of participants. A similar number of factors were associated with errors referring to participants' own behaviour and to the behaviour of others. The small number of factors associated with errors is not surprising given that pedestrians might not be aware of their previous errors. Nevertheless, the findings allowed for the identification of potential failures of the system likely to create error-prone
conditions. An identified rule-based error was associated with a participant pushing an opening entry gate to enter the LC after a train had passed not being aware of the illegal nature of such behaviour. In fact, according to information from pre-observations at this particular crossing site (Wynnum Central) and other LCs in Queensland, the precise opening moment and time required for the entry gate to fully open could vary among pedestrian gates at different LC angles. These technical characteristics of the automatic mechanisms might create conditions for rule-based errors, and influence pedestrians’ perception of risk in a long term (i.e., expectations that the gate would take longer to start opening after a train had passed and thus pushing it open when it is still closed). Moreover, their trust in the equipment might be altered, especially at middle islands where pedestrian crossing is regulated separately on both sides of the island. They could also induce confusion and misinterpretation of the road rules if crossing seem to be prohibited at one LC angle and not at others due to discrepancies in the opening times. This result raises a question about the availability and the clarity of information about road rules for pedestrians. It underlines the importance of the homogeneity of the technical properties between active controls in the same geographical region. It also demonstrates the need for future similar and more in depth research specifically targeting the understanding of factors which lead to errors. In fact, most of the factors associated with errors reported for the self (rule/knowledge based) interacted with similar factors related to the technical and physical characteristics of active and passive controls and with familiarity with the LC environment. Therefore, arguably greater effort needs to be channelled towards improving the LC environment in a way that more information towards safe crossing is provided to users. In particular, more information about the purpose and the safe use of pedestrian gate systems (especially at LCs including middle islands) and presented in a more succinct manner (i.e., avoid abundance of passive signs) targeting the particular population of pedestrians (i.e., avoid confusions with road rules for motorists) would be likely to contribute to the reduction of errors. Finally, this result underlines the utility of the system approach to the detection of issues resulting from the dynamics of the LC system. Further research, should consider focusing on the investigation of the precursors of different types of errors.
Violations were most common with frequent LC users who were either younger or middle aged. The reported violations and likelihood of engaging in such behaviour were to a large extent associated with goal directed behaviour and were closely related to characteristics of the LC environment. A larger percentage of the violations associated with goal directed behaviour referred to hypothetical crossing, which could explain future risk-taking intentions (e.g., “I would cross if the train is far away”). Thus, risk-taking intentions appeared to be underpinned by previous unsafe experience associated with positive outcomes, and to be highly dependent on the perception of key elements in the physical environment.

The importance of aspects of the environment to the decision to violate was also illustrated in both case studies (AcciMaps). Specifically, the absence of locking mechanism on pedestrian gates could be a decisive element contributing to violations. While in past research, pedestrian gates were found to reduce unsafe crossing to a greater extent compared to other safety controls, it seems that the technical properties of such measures could play a crucial role to safety (Metaxatos and Sriraj, 2013). Arguably, there is a need to be sensitive to contextual differences across jurisdictions when interpreting other research. In relation to this, the Applied PULC framework controls for a rather exhaustive list of factors if the same behaviour is to be compared between two different populations and/or territories.

In addition to goal directed behaviour, reports of one's own violations were also associated with attitudes, knowledge and expectations related to different aspects of organisational factors such as safety campaigns or enforcement procedures. Such interacting factors were often related to knowledge about others’ behaviour associated with low perception of risk with regards to own behaviour (e.g., “younger pedestrians only receive warning”, so I am not at risk) as illustrated in the second case study (AcciMap 2). Thus, violations underpinned by precursors of rule/knowledge based errors and based on the observation of others' behaviour could potentially be mitigated through actions at the Organisational level targeting the improvement of various procedures, and strategies (i.e., changes in enforcement procedures, rail staff training, and safety campaigns targeting specific age groups of pedestrians).

The presence and behaviour of other pedestrians was not associated with self-reported violations. However, in line with past research, crossing among others was
associated with decreased safety checks. Violations among a large number of pedestrians could be explained by an increased distraction or by a “diffusion of responsibility” – a psychological phenomenon rooted in the theories of social influences describing the delegation of responsibility in the presence of others executing the same task. Explaining taking risks in road safety, the diffusion of responsibility has been demonstrated by Harrell (1991) who found that pedestrians' cautiousness is reduced in the presence of others crossing on the opposite road side. In this relation, a clear intention to violate in the presence of others in order to avoid being issued a fine was reported by one of the participants. Similarly, as illustrated in the second case study (AcciMap 2), the presence of another pedestrian crossing at the same moment might have influenced the crossing decision, provided that the participant expressed a perception of control after the infringement. Moreover, the participant expressed future intentions to look for enforcement officers before crossing, such statement being likely to explain a strategy to avoid violations only in the presence of enforcement officers. This finding highlights a potential need to adopt strategies towards the improvement of the working schedules of enforcement staff (i.e., avoiding repetitive appearance).

Considering factors associated with the perception of the crossing behaviour of others, it could be argued that the large majority are influenced by a low perception of risk for the self, compared to others. Unlike the reported errors in participants’ own behaviour, the perception of others’ likelihood to commit errors was associated with social influences (e.g., “following others blindly”). Similarly, the observed violations of other pedestrians were associated with negative attitudes and a perception of more at risk groups of users than the self, independently of whether it corresponded to their own age group or not. Such phenomenon in social psychology is known as “illusion of invulnerability” (i.e., comparative optimism, optimistic bias, unrealistic optimism) and refers to people’s tendency to perceive themselves as less likely to experience negative events than others (Harris & Middleton, 1994). Illusion of invulnerability could be explained by the perception of control and low perception of risk and has been associated with various types of risk-taking (i.e., smoking, health checks). Thus, to reduce such bias in the perception of the risk of crossing, the origins of the bias need to be further investigated in order to develop more effective safety measures.
6.7 CONCLUSION, LIMITS AND PERSPECTIVES

This analysis and the results confirmed that focus group transcripts can be used to identify contributory factors of behaviour and in particular are a rich source of data pertaining to the lower system levels, which could be used to infer failures or necessary actions towards safety improvement to be taken on higher system levels. It is possible that the lack of higher level factors is an artefact of the focus group participants being non-rail expert end users of the LC. Future studies may wish to consider applying a similar technique to focus group discussions with rail employees and experts from influential organisations at the higher system levels.

The factors associated with violations might be subject to a social desirability bias, omissions or a poor recall of the exact conditions under which the behaviour took place or the motivations that underpinned it. Even though in this data set participants logically reported factors influencing their recent or future behaviour, such evidence cannot be considered as describing the “current” state of the system because of its permanently changing and dynamic nature. However, such limitations are to a point compensated by the benefits of looking into multiple factors’ contribution to crossing behaviour, a hardly attainable objective by traditional methods such as crash investigation for example.

In addition, the presentation of two case studies of unsafe crossing behaviour demonstrated how factors from different levels of the system interact to influence pedestrian crossing behaviour. This novel application of the AcciMap technique (Rasmussen, 1997) provided new insights into potential areas of weakness within the system which facilitate unsafe behaviour. For example, pedestrians’ decision to access the station from the LC seemed to be potentially correlated to inadequate planning of the station design considering the larger urban environment (i.e., location of overpass; security issues or convenience with regards to journey context). Future efforts could be concentrated on the redesign of the station environment and particularly to solutions providing pedestrians with direct (path of least resistance) access points to the LC.

In addition, the use of AcciMaps demonstrated wider applications for this technique beyond traditional accident analysis. As shown by the current analysis, the same behaviour is likely to be underpinned by various precursors requiring different remedial measures. Therefore, AcciMaps linking cognitive and motivational
precursors of behaviour to actions and decisions of frontline actors or higher level
decision-makers would allow more specific description of (potential) issues and
failures within the system and thus facilitate the identification of more specific
actions towards safety improvement.

The PULC could be further applied to the analysis of larger data sources
allowing specialists from a wider range of areas (e.g., experts in social, engineering,
marketing sciences) to collaborate towards the prevention of future incidents and the
prediction of future problems. For example, this may be achieved by the
development of simulation studies with the aim to predict and test the efficacy and/or
potential issues of new safety measures taking into consideration the identified and
inferred risk contributing factors.

In conclusion, the current study provides evidence that pedestrian crossing
behaviour at LCs is influenced by a wide range of factors from across the rail LC
system. This cross system level influence on behaviour is in line with previous
research at rail LCs (Read et al., 2013) and wider accident analysis (J. Rasmussen,
1997; Reason, 2008). The presented PULC framework provides new insight into
explaining why unsafe acts are undertaken by pedestrians at LCs and can be used to
propose more integrative future interventions to mitigate unsafe crossing behaviour.
Chapter 7: **Key factors explaining self-reported transgressions and risk-taking likelihood in different level crossing scenarios – an Australian study**

7.1 **INTRODUCTORY NOTES ON THE PUBLICATION**

This chapter comprises Paper 3 as taken from:

Stefanova, T., Oviedo-Trespalacios, O., Freeman, J., Burkhardt, J.-M., Wullems, C., Rakotonirainy, A., & Delhomme, P. Key factors explaining self-reported transgressions and risk-taking likelihood in different level crossing scenarios – an Australian study. *Accident Analysis & Prevention* (under review)

Paper 3 was submitted in a peer reviewed international journal: Accident analysis and prevention. After a first review suggesting major revisions, the article was rejected. The reviewers found the article very interesting and contributing to important knowledge. However, they suggest that the amount of information exceeds the acceptable length of a journal article. Therefore, two separate papers, now under preparation will present the results from this study. The first one will present the results relevant to pedestrians’ past experiences at level crossings. The second one will present the results associated with pedestrians’ responses to the 5 video scenarios.

The candidate was responsible for all aspects of the manuscript preparation, including reviewing the literature, formulating the research question, conducting data collection, analysing and interpreting the results and writing and submitting the final manuscript. All co-authors meet the criteria for authorship and take responsibility for their role in delivering the publication. The second co-author conducted a cluster analysis identifying the high profile of pedestrians. All other co-authors of this paper are members of the candidate’s supervisory team and their contribution to this paper was mainly supervisory in nature. Written permission was provided from each to
include the publication as part of this thesis and its publication on the QUT ePrints database (Appendix N).

The study in this paper was the only study conducted in the second, empirical stage of research. A survey was administrated to a larger sample of pedestrians (N = 222) who were usual users of LCs on all metropolitan rail lines in Brisbane. The survey measured the influence on self-reported unsafe behaviour of precursors identified in the exploratory stage, such as status of the active controls, train position, social influences, motivations, familiarity with LC designs and active and passive controls, precautionary behaviour etc. In addition, the impact of these precursors was measured on the reported transgression likelihood accounting for differences in the crossing context in terms of the status of the controls and the rail traffic characteristics (i.e., different stages of controls’ activation, absence or presence of different numbers and types of trains). The results provided for the first time empirical evidence on the association between different risk-contributing factors (e.g., presence of other pedestrians, rail staff, vigilance etc.) and precursors of behaviour (e.g., perception of risk, comparative optimism and pessimism, motivations). Given the lack of existing empirical evidence on the precursors of unsafe behaviour at LCs, conclusions from this study present a valuable basis for future research directions.
7.2 ABSTRACT

Both within Australia as well as other countries, level crossing collisions involving pedestrians have remained stable or even increased in recent years, while vehicle-train crashes have declined. There is a lack of research specifically investigating the origins of pedestrians’ behaviour at level crossings. This study reports on an innovative method used to examine the risk perceptions and risk-taking likelihood of a wide sample of pedestrians from Queensland (Australia), featuring footages of five “real world” crossing scenarios. An online survey was developed to measure a wide range of factors potentially explaining previous unsafe behaviour and risk-taking intentions, reported for the scenarios, in which two main variables were manipulated—status of controls and train position. In total, 222 pedestrians aged 16 years and over completed the survey. The results allowed to distinguish pedestrians transgressing regularly and the best predictors of such behaviour. Comparing the reported transgression likelihood in different crossing situations, pedestrians perceived the lowest risk, and reported the most risk-taking likelihood for crossing after the pedestrian lights are active but before the pedestrian gates have started moving. Furthermore, binary regression analyses identified the best predictors of transgression likelihood for each scenario among factors related to pedestrians’ familiarity with the crossing context, previous experience at LCs and the perceived risk for other pedestrians. The results emphasised the important role of factors, such as being in a hurry to catch a train, the presence of other pedestrians crossing, and the expression of comparative optimism, on decision-making. Limitations and future implications are discussed.
7.3 INTRODUCTION

Worldwide, the number of pedestrians being struck by trains at level crossings (LCs) remains stable compared to the number of crashes with vehicles which continues to decrease (ATSB, 2012; Evans, 2011a; Metaxatos & Sriraj, 2013b). In Australia there is an increasing trend of pedestrian-train collisions (ATSB, 2012). Most of the LCs in Brisbane’s suburbs (Queensland) are active with automatic controls designed specifically for pedestrians, as opposed to passive LCs, where the crossing decision pertains uniquely to the judgement of road users. At active LCs pedestrian lights, audible alarms and pedestrian gates regulate traffic independently of the controls of vehicles (i.e., red flashing lights, barriers). Crossing while the controls are active is illegal and is here referred to “transgression” and the moment from the onset until the cessation of the active controls is called “closure”. Transgressions are commonly associated with different levels of risk according to the number of controls already activated when the pedestrian engages in unsafe crossing. Transgressions of the activated pedestrian lights and audible alarms (“Transgression of light and sound”) are associated with the least risk taken as the person crosses soon after the activation of the controls. Transgressions while the pedestrian gates are closing (“Transgression of a closing gate”) are associated with “beating the gates tendencies” explained by the perception of low risk or of having enough time to cross as long as the gate is not fully closed (Richards & Heathington, 1990). Finally, transgressions after the pedestrian gates are fully closed (“Transgressions of a closed gate”) are associated with a high risk because crossing occurs shortly before the train arrives or in front of a second train (i.e., if one train has already passed through). Thus, transgressions according to the status of the controls could be associated with different cognitive and motivational precursors related to the risk assessment of the situation (e.g., perceived ability to cross safely, perception of having enough time, expectations about the type of arriving train etc.) and the perceived value of crossing (e.g., avoid missing the next train).

At LCs adjacent to train stations, pedestrian traffic is typically operated separately on both sides of the middle island comprising one or two of the platforms. This separation of pedestrian traffic implies that pedestrian crossing can be permitted on one side of the island and not on the other (i.e., crossing can be permitted through one or the other rail track), while vehicular traffic is prohibited on both
Factors shaping pedestrians’ unsafe behaviour at actively protected level crossings

(i.e., pedestrian lights can be green while red flashing lights are red). Thus, LC contexts for pedestrians in Queensland are different from one LC to another according to the presence or absence of a middle island (i.e., train station), the number of pedestrian corridors provided or the operation mode of the active controls. Environmental characteristics of the area or social factors such as vegetation, angle of visibility, traffic density, presence of rail staff also add to the variability of the crossing contexts. Thus, to better understand pedestrian behaviour in this complex environment, a large number of factors potentially influencing crossing decisions are to be taken into consideration. This paper presents the results from an online survey measuring on one hand previous transgressions and the associated cognitive and motivational precursors, and on the other hand, transgression likelihood reported for five “real world” crossing scenarios recorded at three LCs in Brisbane (QLD, Australia). The survey was completed by a broad sample of pedestrians from Queensland, users of more than 50 different LCs across all metropolitan rail lines.

7.3.1 State of art

To date, evidence on the trends in pedestrian unsafe behaviour at LCs has been obtained from studies based on existing crash data, observations or questionnaires (i.e., self-reported data) (Stefanova, Burkhardt, Filtness, et al., 2015). Most publications concern the examination of factors contributing to illegal crossing behaviour (transgressions), and a smaller amount of publication examine the precursors of deliberate (violations) versus erroneous (errors) unsafe behaviour. The frequency of observed or reported transgressions are often measured in the presence or absence of automatic controls (passive vs. active LCs, different types of controls), according to the demographic characteristics of pedestrians or to temporal characteristics of the situation (am/pm) (Clancy et al., 2007; Khattak & Luo, 2011; Stewart et al., 2004). Pedestrian gates were found to reduce the reported and observed unsafe crossing behaviour of pedestrians in the U.S.A., but were also associated with transgressions behind an outgoing train potentially hiding the risk of crossing in front of a second train (Metaxatos & Sriraj, 2013b). According to demographic characteristics, males and younger adults were pointed out as high risk groups of LC users based on self-reported data or observations (Clancy et al., 2007; Edquist et al., 2011; Freeman & Rakotonirainy, 2015). However, such studies have not included measures of exposure (i.e., total number of pedestrians crossing from...
each demographic group) or of characteristics of the population, making the conclusions questionable. In addition, only a few authors have provided empirical evidence attempting to explain the behaviour of specific groups of pedestrians. Specifically, only one observational study provided empirical evidence that groups with children are more likely to transgress than pedestrians alone (Khattak & Luo, 2011). Physical impairments, distractions or sensation seeking were also discussed as potential explanations associated with the behaviour of specific demographic groups of users (Clancy et al., 2006; Davis Associated Limited, 2005; Searle et al., 2011). However, only Freeman and Rakotonirainy (2015) have recently provided empirical evidence on the association between the transgressions of minors at LCs and sensation seeking tendencies, while Edquist et al. (2011) did not observe pedestrians transgressing to be distracted. Finally, it has been suggested that transgressions predominantly occur in morning and afternoon peak hours (Clancy et al., 2007; Edquist et al., 2011), although after the observations of pedestrian compliant and unsafe behaviour Metaxatos and Sriraj (2013b) concluded that the number of transgressions reflect the density of pedestrian traffic throughout the day, and therefore could not be explained by time pressure specifically in peak hours. Moreover, the same authors showed that pedestrians in larger groups are more likely to transgress than pedestrians crossing alone or in groups of two independently of the time of the day. Thus, it appears that unsafe behaviour is rather associated with the presence of others than with specific times of the day.

In summary, the predominant existing research informs on factors potentially associated with an increased number of transgressions, such as absence of visible or presence of stopped train, presence of others etc., but provides limited knowledge on the origins of unsafe crossing behaviour. How and in which conditions such factors decrease the perceived risk or increase the perceived value of unsafe crossing? Moreover, to date studies have rarely investigated the interactions between multiple risk contributing factors, while recently this type of analysis has been suggested as most advantageous among researchers in the LC domain (Iorio et al., 2012; Read et al., 2013; Werkman et al., 2012). In terms of the intentionality of unsafe behaviour, according to most recent studies conducted in Brisbane, pedestrians seem to be more likely to deliberately transgress the crossing rules rather than to commit errors at LCs (Freeman & Rakotonirainy, 2015; Stefanova, Burkhardt, Filtness, et al., 2015).
Deliberate transgressions are found to be mostly associated with “goal directed behaviour” which refers to motivations such as avoid missing the next train or save time, and which are likely to be associated with the accomplishment of higher level goals such as be at work on time (Clancy et al., 2007; Stefanova, Burkhardt, Filtness, et al., 2015).

More recently observational and focus groups studies conducted in Brisbane (QLD, Australia), revealed that pedestrians’ unsafe behaviour seems to be strongly influenced by the interactions of factors never or rarely investigated before. A system-based analysis of the precursors of crossing decisions at LCs suggested that violations, and specifically violations underpinned by goal directed behaviour (e.g., avoid missing the next train), are likely to be much dependant on factors in the environment informing on the risk associated with the crossing situation, such as the status of the controls and the train’s position (Stefanova, Burkhardt, Filtness, et al., 2015). This was confirmed in an exploratory observational study, again conducted in Brisbane, revealing a significant relationship between the status of controls and the train’s position, even though the majority of the transgressions were occurring visibly on the way to catch a train. The predominant transgressions of the lights and sound were associated with crossing in front of an oncoming train, while the rarer transgressions of closed gates were associated with crossing after a train has already passed through the LC. Thus, transgressions motivated by the need to catch a train do not occur independently of the crossing situation. Moreover, transgressions of the lights and sound, transgressions of the closing gate and transgressions of the closed gates were associated with different LC sites, different demographic groups of pedestrians and with different times of the day. Therefore, it can be argued that unsafe behaviour is perceived differently by different demographic groups of users and according to the environmental characteristics of the crossing context. To better understand transgressions, it is important to investigate in depth the cognitive and motivational precursors shaping behaviour in different crossing situations.

Here the precursors of behaviour associated with the perceived ability to carry out an action are called “cognitive precursors” and those associated with the willingness or the perceived benefits of carrying out an action are called “motivational precursors”. The perceived ability to carry out an action can be associated with the generic term of perceived control, which is analogous to
Bandura’s concept of self-efficacy defined as “the judgement of how well one can execute courses of actions required to deal with prospective situations” (Bandura, 1982, p. 122). The perceived control is directly associated with the assessment of risk and the required skills to carry out an action in a given situation. In contrast, motivations explain personal goals and the efforts one is ready to make to achieve these goals, a concept which is elsewhere defined as “goal striving” (Mann et al., 2013). This study examines a broad range of cognitive and motivational precursors potentially associated with unsafe crossing behaviour as informed to a large extent by the conclusions from the previously conducted exploratory focus groups and observations in Brisbane (Stefanova, Burkhardt, Filtness, et al., 2015; Stefanova, Burkhardt, Wullems, et al., 2015).

The cognitive precursors of crossing are to a large extent associated with previous experience at LCs, contributing to the perception of familiarity with the LC’s performance and use. The term “familiarity” is rather generic and can refer to the period and frequency of LC use, to knowledge and experience with safety measures (e.g., existing controls and their purpose), with safety procedures (e.g., knowledge about sanctions) or with rail traffic characteristics (e.g., familiarity with train timetables). In familiar situations crossing behaviour becomes largely automatic, while in unusual or novel situations the pedestrian applies rules and knowledge from previous experience to select an appropriate crossing decision. Thus, familiarity contributes to the formation of attitudes and expectations about crossing and is essential to the crossing decision. Attitudes are defined by (Ajzen, 1991, p. 188) as “the extent to which a person has a favourable or unfavourable evaluation or appraisal of the behaviour in question”.

Stefanova, Burkhardt, Filtness, et al. (2015) found that pedestrians who committed violations at LCs demonstrate poor awareness of the existence of pedestrian lights, which could potentially explain the largest number of transgressions of the lights and sound observed in Brisbane area (Stefanova, Burkhardt, Wullems, et al., 2015). However, more empirical evidence is required to confirm whether this control is associated with a low perception of risk compared to the active pedestrian gates, with salience issues or with general misunderstanding of its purpose. The study reported here measures for the first time pedestrians’
awareness of the existence of different active and passive controls at LCs in Brisbane area and the reported familiarity with their purpose.

Furthermore, Stefanova, Burkhardt, Filtness, et al. (2015) found that pedestrians’ unsafe crossing decisions might be influenced by expectations and attitudes based on their own (lack of) experience with sanctions (e.g., see I do it all the time and I never got caught”, p. 179) or on knowledge about others’ experience with sanctions (i.e., “younger pedestrians only receive warnings”, p. 181). To date, no study has investigated the effect of past experience with sanctions on the perceived deterrence. This study examines not only the associations between past experience with sanctions and unsafe behaviour but how people perceive others’ likelihood of being issued a sanction and whether such perceptions could indeed enhance unsafe crossing decisions (Stefanova, Burkhardt, Filtness, et al., 2015). In a similar fashion, Stefanova, Burkhardt, Filtness, et al. (2015) found that pedestrians perceive other pedestrians as more likely to transgress compared to themselves, and as more likely to experience fatal consequences of such crossing. The low perception of risk was associated with younger and elderly explaining their behaviour with respectively crossing “for a dare” or because of impairments. However, the small sample in this study did not allow to make generalisable conclusions.

In fact, perception of others’ likelihood to experience a negative event as higher than the likelihood attributed to the self describes a psychological phenomenon known as: illusion of invulnerability, unrealistic optimism, optimistic bias or else comparative optimism (Harris & Middleton, 1994; Perloff, 1983; Perloff & Fetzer, 1986; Weinstein, 1980; Weinstein & Klein, 1996). We will here refer to “comparative optimism” (CO). In road safety domain, the frequent expression of CO has been clearly demonstrated among drivers (Delhomme, 1991; Delhomme, Verlhac, et al., 2009). Comparative optimism has been found to enhance risk-taking and decrease safe behaviour(Deery, 1999; Harré, Foster, & O’Neill, 2005; McKenna, Stanier, & Lewis, 1991). However, expressing similar comparative judgements or higher perceived likelihood for the self to experience negative events (i.e., comparative pessimism “CP”) is also possible (Delhomme, Verlhac, et al., 2009). Series of studies have demonstrated the important impact of perceived control on the expression of CO (Kos & Clarke, 2001; McKenna, 1993). In fact, people are likely to believe that they are more skilled than the average other only in high control
situations (i.e., when they are in control over the events: driver versus passenger). Inversely, people tend to express similar risk judgements for the self and for others, if they perceive themselves as being less in control. However the emergence of CO in the LC domain has not yet been examined. Stefanova, Burkhardt, Filtness, et al. (2015). Therefore, the presented here study is the first to examine how pedestrians perceive the risk of specific others’ of being hit by a train and whether they express potentially biased comparative judgements.

The motivational precursors underpinning unsafe crossing decisions are associated with the accomplishment of a given valued objective (e.g., be on time, be part of the group) and depend on rather situation-related factors such as journey context (e.g., going to work, shopping, exercise, catching a train or just crossing) or the presence of others. As already mentioned, being in a hurry to catch a train has been widely suggested and confirmed in the literature as an important influencing factor to crossing decisions (Clancy et al., 2007; Searle et al., 2011). However, as suggested by pedestrians from Brisbane participating in a focus groups study, unsafe crossing may also occur for reasons as banal as “raining” (Stefanova, Burkhardt, Filtness, et al., 2015, p. 177). Stefanova, Burkhardt, Filtness, et al. (2015) found that goal directed behaviour is to a large extent related to factors in the LC physical environment. Specifically, pedestrians tend to judge the distance to train arrival according to their familiarity with the length of the platform and the pedestrian corridor. Consistently, Stefanova, Burkhardt, Wullems, et al. (2015) observed that pedestrians tend to transgress more at LCs with middle islands, which could be explained by a lower perception of risk while crossing a smaller number of tracks to reach the platform. To examine the influence of the environment on crossing decisions and motivations, in the present study the perceived risk and reported transgression likelihood were examined according to various characteristics of the LC design, such as different number of rail tracks to be crossed and crossing through pedestrian corridors giving access/or not to a train station.

Furthermore, while it has been found that transgressions are more likely to occur in groups (Metaxatos & Sriraj, 2013b), no study has previously investigated the effect of crossing among random or known others. Imitating the behaviour of others crossing at the same time (random) can be explained by descriptive norms which imply “doing what others do”. In contrast, behaving according what is
considered or perceived as a socially accepted and valued conduct is explained by *injunctive norms* (Cialdini et al., 1990). Thus, both types of social influences are to be mitigated differently (i.e., by promoting new descriptive or injunctive norms).

This paper is the first to go beyond reporting the frequency of unsafe behaviour, by examining to what extent factors that influence crossing decisions vary across different crossing situations. The comparison between crossing situations only at active LCs is also innovative as it emphasises the number of different factors from one situation to another that may potentially influence behaviour, as opposed to the typically employed methods comparing behaviour at LCs with active versus passive controls.

### 7.3.2 Aims

The first aim of this research was to measure the self-reported transgressions among a state-wide sample of pedestrians from Queensland, and to examine the cognitive and motivational precursors associated with such behaviour, related to different aspects of familiarity with LCs, with motivations to transgress or with social influences.

The second aim of this study was threefold. First, it was to measure and compare the participants’ reported transgression likelihood in five recorded crossing situations. Second, it was to assess participants’ comparative judgments about perceived risk and transgression likelihood reported for other pedestrians in the five scenarios. Third, it was to identify and compare the predictors of transgression likelihood across the scenarios, among the measured cognitive and motivational precursors of crossing decision and including the assessed comparative judgements.

### 7.4 METHOD

#### 7.4.1 Participants

A total of 222 participants successfully completed the survey (i.e., 11 were excluded due to technical issues encountered). More than half were female (58%). The mean age of participants was 32.3 (SD = 12.9) ranging between 16 and 67 years with the median age of 29. For data analysis participants were grouped in 3 age groups: under 25 years old, between 26 and 55 years old and 56 years old and over.
Participants were asked to list between one and three of their most frequented LC sites. Their responses were analysed to inform on the representativeness of the sample. Participants listed a similar number of LCs across all seven rail lines in Brisbane metropolitan area, accounting for the total number of LCs on each line. Therefore, although no information is publicly available on the size of the population of LC users in Brisbane, the sample could be considered as representative as made of users of each rail line.

In total, 50 different LCs were listed 338 times. Half of the participants listed only one frequented LC (51.3%). The most frequently listed LC accounted for 9.5% of all mentioned LCs, meaning that less than 10% of the participants were users of the same LC site.

All of the listed LCs had between one and four rail tracks, with almost half (48%) of them having two rail tracks and 34% having three. More than half of the participants (54.5%) usually crossed two rail tracks and a smaller percentage (21.9%)–three. Among all LCs, 72% had two pedestrian corridors allowing crossing on both sides of the road. An adjacent train station or its platforms were accessible directly through the LC at only 30% of the listed crossing sites. Nevertheless a large number of the LCs were in close proximity to train stations. Almost all (92%) of the listed frequented LCs were equipped with pedestrian lights and with pedestrian automatic gates, suggesting that participants should be familiar with active protections, noting that pedestrian gates are equipped with locking mechanism only at some LC sites.

7.4.2 Procedure

Multiple recruitment methods were undertaken. Posters were displayed at central and suburban train stations in Brisbane (QLD, Australia). Recruitment flyers were distributed at some of the suburban train stations in close proximity to LCs. Participation was also sought through university and regional social media channels (i.e., local radio stations, newspapers and university twitter and Facebook). Given that recruitment took a long a period of time, and new methods were undertaken, no information can be provided on the number of participants recruited from each source.
The survey was administrated through the online “Key survey tool”. To enter the survey, participants were screened for: LC use as a pedestrian, age (16 and over years old), and current Queensland residency. The survey started with general questions about LC use, knowledge and past experience, and ended with questions related to the five recorded crossing scenarios which were visualised by all participants in a random order, in a YouTube video format. The survey took approximately 20 min to complete. After completion, pedestrians were invited to participate in a prize draw. This study’s procedure was approved by the university’s ethics committee.

7.4.3 Material

The survey comprised three large parts. The first part sought to examine factors related to participants’ habitual crossing behaviour and knowledge about controls (familiarity). The second part included questions measuring the previous unsafe crossing behaviour reported by the participants and their experience with sanctions. The last part consisted of questions related to the five video scenarios.

7.4.3.1 Measuring the cognitive and motivational precursors having a potential impact on crossing behaviour at LCs

7.4.3.1.1 Habitual crossing context

A group of multiple-choice and open ended questions assessed participants’ habitual crossing trajectory (i.e., accessing a train station vs. just crossing) and journey context of crossing. Despite that less than half of the listed frequented LCs were not giving direct access to a train station, three quarters of the participants reported mainly crossing on their way to a train station (76.3%) and the remainder were mostly crossing just to go to the other side of the road. Among those who access train stations, the majority were crossing both - on their way to catch a train and after disembarking a train (64.8%).

The reported journey contexts for those mainly catching a train were classified in 10 categories \(M = 1.96, SD = 0.91\), and for those just crossing the road – in eight categories \(M = 1.59, SD = 0.83\). Globally, the journey context of those catching a train was associated with professional activities (e.g., going to work), while the journey context of those just crossing were associated predominantly with recreational activities (e.g., sport/exercise, meeting with friends, shopping).
The frequency of LC use was assessed through five questions measuring the reported LC use at five different times of the day on a 6-point Likert scale (Table 13) (Cronbach $\alpha = .72$). Pedestrians demonstrated significant differences in their habitual crossing in the five time slots, $\chi^2 (20, N=1100) = 127.49, p<.000, V^2 = 0.02$, such that according to the RDs the most regular users (i.e., once, twice per day or more) were crossing in morning peak hours (6am-9am) and in the afternoon peak hours (3pm-6pm) and those rarely using LCs were crossing out of peak hours.

<table>
<thead>
<tr>
<th>Likert scale</th>
<th>6am-9am</th>
<th>9am-12pm</th>
<th>12pm-3pm</th>
<th>3pm-6pm</th>
<th>after 6pm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>1. Never</td>
<td>58</td>
<td>25.9</td>
<td>84</td>
<td>37.5</td>
<td>76</td>
</tr>
<tr>
<td>2. Once per fortnight or less</td>
<td>68</td>
<td>30.4</td>
<td>91</td>
<td>40.6</td>
<td>95</td>
</tr>
<tr>
<td>3. Once per week</td>
<td>14</td>
<td>6.3</td>
<td>15</td>
<td>6.7</td>
<td>14</td>
</tr>
<tr>
<td>4. Twice or more per week</td>
<td>21</td>
<td>9.4</td>
<td>22</td>
<td>9.8</td>
<td>29</td>
</tr>
<tr>
<td>5. Once per day</td>
<td>49</td>
<td>21.9</td>
<td>6</td>
<td>2.7</td>
<td>6</td>
</tr>
<tr>
<td>6. Twice or more per day</td>
<td>12</td>
<td>5.4</td>
<td>4</td>
<td>1.8</td>
<td>2</td>
</tr>
</tbody>
</table>

Participants reported crossing at the LC site/s for a minimum of a year or less and a maximum of 59 years ($M = 8, SD = 8.65, Median = 5$).

A group of open ended and yes-no questions assessed in detail different properties of the crossing context (e.g., earphones use, crossing with family members, children). The largest number of participants reported usually crossing alone (36%) and the smallest (9.9%)– crossing with known others. Of all participants, 32.8% reported regularly crossing with earphones. More than half of them (56.1%) admitted doing so without interrupting their activity (i.e., listening to music, having a conversation).

7.4.3.1.2 Familiarity with controls

Respondents’ awareness of the existence and the purposes of five common controls were measured using two separate scales. Each scale was made of five photograph items of the following controls: red flashing lights for vehicles, pedestrian lights, pedestrian gate, a U.K. red flashing light design and a passive warning sign on the rail track (“Stay off the tracks or get a fine, injury or worse”).
The U.K. red flashing light was included as a foreign active control to detect biases in responses.

In the first scale, participants were asked whether they recalled having seen each of the five different warning signals/systems at the level crossing/s that they cross as a pedestrian. They provided their responses on a 3-point ordinal scale: 1 - “No” (“not at the LC/s that I cross”), 2 – “At places” (“not at all LCs that I cross”) and 3 – “Everywhere” (“at all LCs that I cross”). After data collection, a new variable was computed for each item to verify whether the different types of controls were correctly recalled. The U.K. flashing light was not included in this analysis because, as expected, only a few participants suggested recalling this signal and this could be due to experience with crossing in other countries. The new variable “Recall” was coded as follows: “correct recall” (i.e., if the presence or the absence of the control was correctly recalled) versus “incorrect recall” (i.e., if the presence or the absence of the control was incorrectly recalled) versus “unsure” if pedestrians reported having seen the control at some LC sites without listing the LCs which are not equipped with the control. Provided that automatic controls were installed at a large number of the frequented LCs, in most cases pedestrians correctly recalled the presence of the controls (not the absence). Only 0.9% did not correctly recall the red flashing lights for vehicles, 2.3% did not correctly recall the pedestrian gates and the largest 14.4% did not correctly recall the pedestrian lights.

In the second scale, participants were asked: “How familiar are you with the purpose of each warning signal/system?” and responded on a 5-point Likert scale from 1- “Not at all” to 5 – “Extremely”. Internal consistency analysis confirmed that the measure associated with familiarity with the purpose of the U.K. red flashing light did not correspond to the rest of the items. After the item was removed, the internal consistency of the scale was good (Cronbach $\alpha = .77$). The large majority of the participants responded being well aware of the purpose of the different controls. Over 78% reported being “extremely familiar” with each. Those who assessed themselves as being less familiar with the purpose of the gates were also less familiar with the purpose of the pedestrian lights and vice versa, apart from a small number of pedestrians (3-4) who reported being more familiar with one or the other control (Fisher, $p< .000$, $V^2= 0.15$).

7.4.3.1.3 Familiarity and past experience with enforcement procedures
One question assessed the perceived likelihood for pedestrians in general to be issued a fine if crossing during activated controls on a 5-point Likert scale from 1 - “Not at all” to 5 – “Extremely”. Three other questions measured previous experience with different sanctions on a 5-point Likert scale form 1 - “Never” to 5 - “Almost all the time”. The items concerned previously received a LC fine, a LC warning or other rail sanction (Cronbach $\alpha = .79$).

A large number of the participants (20.1%) perceived the sanctions for illegal crossing at LCs as unlikely to occur. The largest number of the participants responded that it was “slightly likely”(40%) or “somewhat likely” (22.1%), while the smallest number perceived it “fairly” (7.2%) and “extremely likely” (4.5%). Regarding participants’ previous experience with sanctions, only 6% of the respondents have ever been issued a LC fine, 6.4% have been issued a LC warning and 8.6% have been issued other type of rail sanction.

7.4.3.1.4 Precautionary behaviour

Two questions measured the visibility of the active controls (e.g., “In general, is it easy for you to see the activation of the automatic warnings?”) and the reported vigilance for their activation (e.g., “In general do you consider yourself vigilant for the activation of the automatic warnings?”). A little over half of the participants (57.7%) considered the activation of the automatic controls as “extremely easy” to notice and only 0.5% reported that the activation is “not at all easy to see”. A similar number of pedestrians considered themselves “extremely” vigilant for the activation of the controls against 0.9% who reported being “not at all vigilant”.

Two other questions measured the reported checks for train respectively if the automatic controls are active or not on a 5-point Likert scale from 1 – “Never” to 5 - “All the time” (e.g., “Normally, before you cross, do you visually check for an approaching train if the automatic warnings are/not active?”). An additional 6th point - “Doesn’t apply” was included in the second scale, for those who did not report transgressions (Cronbach $\alpha = .66$).

A larger number of participants reported checking for a train before crossing if the controls are active (57.7%), than if they are not (44.1%). Globally, the largest percentage of pedestrians (69.8%) suggested “all the time” checking for trains if crossing during activated controls and only two reported never doing so.
7.4.3.2 Measuring the self-reported unsafe crossing behaviour and the associated motivations

Three questions measured the reported frequency of previous unsafe crossing on a 5-point Likert scale from 1 - “Never” to 5 – “Almost all the time”, respectively: during any moment of the activation of the controls, while the pedestrian gate was closing, and after the pedestrian gate had already closed (Cronbach $\alpha = .64$).

Seven items measured different explanations for transgression on a 5-point Likert scale 1 – “Not at all likely” to 5 – “Extremely likely”. Participants were asked: “Based on your past experience, how likely are you to cross at a level crossing when at least one of the automatic warnings has activated because …”: of error (failed to notice the controls’ activation); being in a hurry to catch a train; being in a hurry to cross; could make it (i.e., perception of control); others crossing at the same time; if it was raining; if it was too hot (Cronbach $\alpha = .87$).

7.4.3.3 Measuring the contextual perception of risk and transgression likelihood across five recorded “real world” crossing scenarios

The last part of the survey was made of questions related to the recorded LC scenarios. This method was chosen to enable participants to consider a multitude of factors in the crossing situation while reporting their behavioral intentions and perceived risk. Although, the main aim was to detect differences in the measured variables according to the status of the active controls and trains’ position, other variables, such as various number of LC tracks, crossing corridors not giving to station platforms, presence of another pedestrian crossing, were included. After multiple recording trials and pre-test of the survey, an optimal number of five scenarios were retained (to avoid making the survey too long). The scenarios were recorded at three different LCs with two and three rail tracks, which is the most common design of LCs in Brisbane (Figure 33).
Figure 33. Plans of the three LC sites where the scenarios were recorded

Scenario 1 ("Pedestrian lights and sound") starts with the activation of the red flashing lights for vehicles and the pedestrian lights and ends when the pedestrian gate starts to close, there is no train visibly approaching from either side. In Scenario 2 ("Closing gate") the entry pedestrian gate starts to close in the beginning of the video and as soon as it is fully closed, the video ends with no visible train approaching. In Scenario 3 ("Stopped train") the entry pedestrian gate is already closed at the beginning of the video, and a train coming from the left side stops at the station on rail track 2. In Scenario 4 ("Express train and safe crossing") the entry pedestrian gate is already closed in the beginning of the video and an express train (i.e., not stopping at station) arrives on rail track 1 shortly after its horn can be heard. As soon as the train is visible, a pedestrian (legally) crosses tracks 2 and 3. The video ends before the train has crossed the LC. In Scenario 5 ("Two trains"), a train stops on track 1, coming on the left side of the pedestrian corridor in question. After the train has stopped, the controls continue to be active and the video ends with another train visibly approaching on track 2 from the opposite direction (i.e., on the right side of the pedestrian corridor in question). The closed pedestrian gates in Scenarios 3, 4, and 5 were not visible in the videos but acknowledged in the questions. The audible alarms for both vehicles and pedestrians can be heard on all videos. Table 14 presents a summary of the manipulated variables in each scenario.
### Table 14. Summary of the modalities of the variables included in each scenario.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent variables</td>
<td>PED. LIGHTS &amp; SOUND</td>
<td>CLOSING GATE</td>
<td>STOPPING TRAIN</td>
<td>EXPRESS TRAIN &amp; SAFE CROSSING</td>
<td>2 TRAINS</td>
</tr>
<tr>
<td>Train presence</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Train position</td>
<td>Na</td>
<td>Na</td>
<td>Stopped</td>
<td>Visibly Approaching</td>
<td>Stopped and visibly approaching</td>
</tr>
<tr>
<td>Train type</td>
<td>Na</td>
<td>Na</td>
<td>Stationary</td>
<td>Express</td>
<td>Stationary</td>
</tr>
<tr>
<td>Red FL</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
</tr>
<tr>
<td>Ped. lights</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
</tr>
<tr>
<td>Ped. gates</td>
<td>Inactive</td>
<td>Closing</td>
<td>Closed</td>
<td>Closed</td>
<td>Closed</td>
</tr>
</tbody>
</table>

Two cameras, each covering one side of the pedestrian corridor (left and right), were used to record the scenarios, which lasted between 4 to 27 sec (Figure 34)

*Figure 34.* Screenshot of the video of scenario 5 (Sunshine level crossing)

Prior to responding to the questions, a wide angle photograph was presented to participants to familiarise them with the crossing context, and which indicated clearly the crossing trajectory (yellow flesh) concerned by the questions (Figure 35).
For each scenario participants were asked to report their: transgression likelihood (Cronbach $\alpha = .72$), perceived risk of being sanctioned (Cronbach $\alpha = .90$), and perceived risk of being hit by a train (Cronbach $\alpha = .84$). After having responded for the self, participants were asked to respond to the same questions for others of different gender (i.e., male vs. female) and age groups (i.e., under 25 years old vs. 26-55 years old vs. 56-75 years old vs. over 76 years old). Thus, participants responded to a total of 27 questions associated with each scenario:

\[ 3 \text{Questions self} + 3 \text{Questions others} \times (\text{Gender 2 x Age Groups 4}) \times 5 \text{Scenarios} \]

All 27 questions for each scenario appeared on the same page under the video, which could be replayed as many times as required and the photograph was visible at all times.

### 7.4.4 Data analysis

Chi-square tests ($\chi^2$) examined the significance effect between two discrete variables. Fisher’s exact test was reported for contingency tables with small expected values (<5) in more than 20% of the cells. Cramer’s $V^2$ was used to assess the strength of associations between discrete variables. Relative deviations (RDs) were reported for associations of higher than 0.10 between the modalities of discrete variables. Repeated measures analysis of variance (ANOVAs) were performed to compare the responses to different questions by the same participants. Greenhouse Geisser correction was applied for ANOVAs with violated assumption of sphericity (Mauchly’s Test of Sphericity). Post-hoc test using Bonferroni correction was utilised for every ANOVA with significant effect to examine the significance of the relationship between the modalities of the variables. Binary logistic regressions with stepwise method (forward Wald) were conducted to identify the best predictors of transgression likelihood in each scenario. The fitness of the model was assessed using the Nagelkerke $R^2$ statistic, which ranges from 0 for models that provide no
predictive information to 1 for models that predict accurately (Buelvas, Oviedo-Trespalacios, & Amaya, 2015; Holgado et al., 2014). A maximum of 22 predictor variables were included in each analysis satisfying the minimum requirement of 10 participants per IV. All of the dependent variables in the regressions were transformed to dichotomous (positive vs. negative transgression likelihood).

7.5 RESULTS

Results are organised in three sections. The first section presents results on the self-reported unsafe behaviour and the best predictors of regular unsafe behaviour (Section 7.5.1.). The second section (7.5.2.) presents results on the reported transgression likelihood and risk perceptions across the five video scenarios, as reported for the self and in comparison with those perceived for others. The final section (7.5.3.) presents the identified factors explaining transgression likelihood for each scenario.

7.5.1 Reported previous unsafe crossing and factors associated with unsafe crossing

Less than half of all participants (37.5%) reported having crossed unsafely while at least one automatic control was activated, 16% reported having crossed while the gates were in the process of closing and 12% - after the gates had already closed, noting that only 10 participants reported transgressions of closing gate (6 participants) and of closed gates (4 participants), but not transgressions of the active controls in general. No significant differences were found in the reported transgressions between male and female and between participants of different age groups (Fisher, ns.)

Based on their past experience, the majority of the participants explained their likelihood to cross during controls’ activation with being in a hurry to catch a train (42%). Both, committing an error and crossing among other pedestrians were the next most suggested explanations by participants (35% each). A similar number of participants reported the perceived control over the situation (could make it) (25.9%) and raining (24%) as potential explanations of unsafe crossing. A smaller percentage of the participants reported being likely to cross if in a hurry to cross the intersection (18%) and the least number reported being likely to cross because of too hot weather (1%).
7.5.1.1 Assessing regular transgressors – a cluster analysis

To identify the estimated risk associated with the frequency of crossing, the participants were clustered accounting for exposure (Frequency of crossing at different time slots / the number of trains passing in the corresponding time slot) and self-reported unsafe crossing during activated controls. This technique is an inductive multivariate statistical method useful for establishing homogenous groups in a population (Westlake & Boyle, 2012) and was performed on a two-step procedure. First, a Ward’s hierarchical cluster analysis with squared Euclidean distance was used to determine the number of clusters. This method assigns participants to a cluster by minimizing the within-cluster variance and maximizing between-cluster variance (Oviedo-Trespalacios, Haque, King, & Washington, 2015). The optimal number of clusters was determined by plotting the possible number of clusters on the x-axis (starting with the one-cluster solution at the very left) and their proximity measures on the y-axis (Lu, Chang, & Hsieh, 2006). Proximity is defined as the increase in the squared error that results when two clusters are merged. Using this plot (Figure 36) the total number of clusters was selected by the “elbow method” that determines the number of clusters based on a distinctive break in the changes of proximity measure. Following this procedure, it was clear that the sample could be divided into two clusters.

![Figure 36. Variations in proximity coefficients versus number of clusters](image)

In the second step, the non-hierarchical algorithm was executed using the K-mean method. A non-hierarchical method identified homogeneous groups of cases based on selected variables and indicated the number of clusters to be formed. The values of the input parameters were the same of the Ward’s hierarchical cluster and the expected number of cluster was two. The software realised a non-hierarchical
clustering of observations, evaluating each observation by identifying the nearest cluster with the smallest Euclidean distance between the observation and the centroid of the cluster and treating the missing values with list-wise criteria (Macchion et al., 2015). The clustering of exposure and transgression produced two clusters. Post-hoc tests showed that transgression during active controls was the only significantly different variable between cluster ($F(1,220) = 687.178, p< 0.000$) while the exposure did not differentiate the groups ($F(1,220) = 2.498, p = \text{n.s.}$), (Figure 37). In terms of labelling these clusters, it would appear that participants in Cluster 1 ($N = 43$) could be classified as “regular transgressors” according to the reported “occasional” and “quite frequent” transgressions compared to participants in Cluster 2 ($N = 179$).

![Figure 37. Representation of each participant in the risk space based on cluster membership](image)

7.5.1.2 Assessing the predictors of regular transgressions

A series of Chi-square tests were performed to identify the variables significantly associated with regular transgressors’ profile among the measured cognitive and motivational precursors and previous unsafe experience. In total, 12 variables were included in a stepwise binary regression model to predict the profile of regular transgressors (Appendix E).

The model was significant and included four variables which best predict participants’ classification in the regular transgressors’ group, $\chi^2(4, N=222) = 125.75, p< .000$(Table 15). The model predicted 62% of the variance between the two profiles of users and successfully classified 85.7 %, while only 18.6% could be randomly classified before the inclusion of the predictors.

Table 15. Predictors of regular transgressors’ profile
The included predictors suggest that pedestrians transgressing regularly are more often male than female, and are more likely to be those who reported previous transgressions of a closing gate and transgressions motivated by the perception of control (i.e., could make it on time), and those who considered themselves less familiar with the purpose of the pedestrian lights.

7.5.2 Contextual differences in the reported transgression likelihood and risk perceptions across the five scenarios

7.5.2.1 Self-reported transgression likelihood and risk perceptions in the five scenarios

Significant differences were found in the self-reported transgression likelihood and risk perception between the five scenarios (Table 16).

Table 16. Descriptive statistics on the reported transgression likelihood and risk perceptions for the self across the five scenarios.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Ped.lights and sound</th>
<th>Closing gate</th>
<th>Stopped train</th>
<th>Express train and safe crossing</th>
<th>Two trains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transgression likelihood</td>
<td>M</td>
<td>2</td>
<td>1.36</td>
<td>1.32</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.36</td>
<td>.83</td>
<td>.81</td>
<td>.89</td>
</tr>
<tr>
<td>Likelihood of being issued a fine</td>
<td>M</td>
<td>2.02</td>
<td>2.29</td>
<td>2.56</td>
<td>2.41</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.16</td>
<td>1.36</td>
<td>1.37</td>
<td>1.35</td>
</tr>
<tr>
<td>Likelihood of being hit by a train</td>
<td>M</td>
<td>2.21</td>
<td>2.62</td>
<td>2.83</td>
<td>2.85</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.29</td>
<td>1.4</td>
<td>1.34</td>
<td>1.41</td>
</tr>
</tbody>
</table>

A repeated measures ANOVA with Greenhouse-Geisser ($\varepsilon = .65$) correction determined a significant difference between the reported crossing likelihood across the five scenarios, $F (2.62, 578.10) = 32.66$, $p < .000$, $\eta^2 = .129$, such that the transgression likelihood in the first scenario was significantly higher compared to the transgression likelihood reported for all other scenarios, $p < .000$. There was no other significant difference between the scenarios. Only 12 (5.4%) of all participants reported transgression likelihood in all 5 scenarios. The second highest percentage of
participants reporting transgression likelihood for the same scenarios (i.e., Scenario 1: lights and sound and Scenario 4: express train and safe crossing) was 4.5% (N =10), after those who reported transgression likelihood only in the first scenario with lights and sound (18.5%)

A repeated measures ANOVA determined a significant difference between the perceived likelihood of being issued a fine across the five scenarios, $F (4, 884) = 15.26, p< .000, \eta^2 = .065$, such that the least likelihood was reported for the first scenario compared to Scenario 2 ($p< .01$), Scenario 3 ($p< .000$), Scenario 4 ($p< .000$) and Scenario 5 ($p< .000$). The highest likelihood to receive a fine was reported for the scenario with the stopped train (Scenario 3), where the crossing corridor was adjacent to a station platform. This perceived likelihood was significantly higher compared to scenarios 1 and 2 ($p<.001$) but not compared to Scenarios 4 and 5, associated with an express train approaching while a pedestrian crosses compliantly and with two approaching trains, respectively

A repeated measures ANOVA with Greenhouse-Geisser ($\varepsilon =.95$) correction determined a significant difference between the self-reported likelihood of being hit by a train across the five scenarios, $F (3.82, 845.87) = 18.45, p< .000, \eta^2 = .077$. Pairwise comparisons showed that the lowest level of perceived risk of being hit by a train was reported for the first scenario (only lights and sound) compared to all other scenarios ($p< .000$). The only significant difference between the remaining scenarios was the perceived lower likelihood of being hit by a train in the scenario with a closing gate (Scenario 2) compared to the scenario with two approaching trains (Scenario 5), $p< .05$.

Finally, a significant difference in the reported transgression likelihood as a dichotomous variable between participants of the three age groups was found only for the second scenario with a closing gate, $\chi^2(2, N=222) = 8.14, p< .05, V^2 =.03$. According to the RDs the youngest group of participants (under 25 y.o.) were most associated with transgression likelihood. Gender of the participants did not produce any significant effect for the three dependent variables measured for the self across the five scenarios.
7.5.2.2 Comparative judgments about transgression likelihood and risk perceptions in the five scenarios

Repeated measures ANOVAs were conducted to compare the transgression likelihood and risk perceptions reported for the self with those reported for others. Such analysis corresponds to the indirect measure of comparative risk judgments used to detect the expression of comparative optimism (CO) or pessimism (CP), as opposed to the direct measure, consisting of asking participants to directly evaluate the risk for the self and for others in the same question (Helweg-Larsen & Shepperd, 2001).

The results related to each question (i.e., transgression likelihood, likelihood of being issued a fine, likelihood of being hit by a train) are summarised in a tabular format in the following sections, illustrating the absence or presence of significant differences and the respective direction of the effect: an expression of comparative optimism (CO) or comparative pessimism (CP). The absence of a significant relationship translates to an equally perceived transgression likelihood or perceived risk for the self compared to others. Additionally, it is indicated whether the effect was found for all scenarios (ALL) or only some (i.e., listing the number of scenarios). Descriptive statistics for each test are presented in Appendices G to K.

7.5.2.2.1 Comparison of the reported transgression likelihood for the self and for others

As illustrated in Table 17, all participants perceived youth (under 25 years old) and middle aged adults (between 26 and 55) as much more likely to engage in unsafe crossing behaviours compared to the self (Appendices G to I). Other older pedestrians (between 56 and 75) were perceived as more likely to transgress mainly by male participants, and only in some scenarios. Female between 26 and 55 were the only participants to express CP for elderly adults, perceiving them as less likely to transgress in the first scenario (Appendix H). Males under 55 years old also systematically expressed significantly different perceptions for other males versus females of the same age (Appendix G). Specifically other males were perceived as more likely to transgress than other females.
Table 17. Comparative judgements of transgression likelihood across all scenarios

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>-25 years old</th>
<th>26 - 55 years old</th>
<th>56 - 75 years old</th>
<th>76 + years old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>-25 years old</td>
<td>Male</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>n.s.</td>
</tr>
<tr>
<td>26 - 55 years old</td>
<td>Male</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
</tr>
<tr>
<td>56 + years old</td>
<td>Male &amp;</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
<td>CO ALL</td>
</tr>
</tbody>
</table>

Note. CO – comparative optimism (i.e., the perceived transgression likelihood for others is significantly higher compared to the transgression likelihood reported for the self); CP – comparative pessimism (i.e., the perceived transgression likelihood for others is significantly lower compared to the reported transgression likelihood for the self); ALL- significant differences were found for all scenarios; CO/P: “n” – significant differences were found only for some scenarios. Highlighted cells correspond to judgements about the same demographic groups of others (as the participants’ group).

7.5.2.2.2 Comparison of the reported likelihood of being issued a fine for the self and for others

As illustrated in Table 18, the likelihood of being issued a fine was again perceived as higher for the younger groups of other pedestrians, as reported by the youngest groups of participants (Appendix J). The only significant difference in the perceived likelihood between other males and females of the same age group was reported by male participants under 25 years old for others of their age group in Scenario 4 (express train approaching). Again, only female participants between 26 and 55 perceived older and elderly pedestrians as less likely to be issued a fine compared to the self in Scenario 3 (stopped train at station).
Table 18. Comparative judgements on the likelihood of being issued a fine across all scenarios

<table>
<thead>
<tr>
<th>Age</th>
<th>Reported likelihood of being issued a fine by participants of:</th>
<th>Perceived likelihood of being issued a fine for other pedestrians:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
<td>-25 years old</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>-25 years old</td>
<td>Male (N=44)</td>
<td>CO 1,2,4</td>
</tr>
<tr>
<td></td>
<td>Female (N=42)</td>
<td>CO 1,2,3,5</td>
</tr>
<tr>
<td>26 -55 years old</td>
<td>Male (N=61)</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Female (N=55)</td>
<td>n.s.</td>
</tr>
<tr>
<td>56 + years old</td>
<td>Male &amp; Female (N=20)</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Note. CO – comparative optimism (i.e., the perceived transgression likelihood for others is significantly higher compared to the transgression likelihood reported for the self); CP – comparative pessimism (i.e., the perceived transgression likelihood for others is significantly lower compared to the reported transgression likelihood for the self); ALL- significant differences were found for all scenarios; CO/P: “n” – significant differences were found only for some scenarios. Highlighted cells correspond to judgements about the same demographic groups of others (as the participants’ group).

7.5.2.2.3 Comparison of the reported likelihood of being hit by a train for the self and for others

As illustrated in Table 19, the perceived likelihood of being hit by a train was perceived as equal or higher to the one reported for the self. Other elderly pedestrians were perceived as more likely to be hit by a train by almost all demographic groups of participants (Appendices I, K). Globally the youngest female group of participants perceived others as more likely to be hit by a train compared to the self. No significant differences were found in the perceived likelihood for males and females of the same age group across all scenarios.
Table 19. Comparative judgements on the likelihood of being hit by a train across all scenarios.

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>-25 years old</th>
<th>26 - 55 years old</th>
<th>56 - 75 years old</th>
<th>76 + years old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>-25 yrs</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>CO</td>
</tr>
<tr>
<td>years old</td>
<td>(N=44)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>CO</td>
<td>5</td>
<td>CO</td>
<td>CO</td>
</tr>
<tr>
<td></td>
<td>(N=42)</td>
<td></td>
<td>5</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>26 - 55 yrs</td>
<td>Male</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>years old</td>
<td>(N=61)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>(N=55)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56 + yrs</td>
<td>Male &amp;</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>years old</td>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(N=20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.5.2.3 Assessing the predictors of transgression likelihood in each scenario

For each scenario a binary regression was conducted to identify the factors that best predict transgression likelihood among all measured variables. A series of chi-square tests were conducted to identify the best potential predictors (Appendices E, F).

7.5.2.3.1 Scenario 1: Crossing in the presence of active pedestrian lights and sound with no visible train approaching

In total, 20 independent variables were considered for the regression. Using a forward stepwise method, the predictor variables were identified in 5 steps. The full model was statistically significant, $\chi^2(5, N=222) = 104.22, p<.000$. The model explained 50% of the variance and correctly classified 79.7% of the cases against an initial classification of 46.4% of the cases without the predictors.

Five predictor variables were retained in the final model (Table 20). The more participants perceived other female pedestrians between 26 and 55 years old as likely to transgress in this situation, the more they expressed transgression likelihood. The more participants reported being likely to transgress if in a hurry to catch a train, the more likely they were to report a crossing likelihood in this scenario. The more participants reported checking for train while the controls are inactive, and the more they perceived that in general people are very likely to receive sanctions for illegal crossing, the less they were likely to report transgression likelihood in this situation.
Finally, the more participants perceived the risk of being hit by a train, the less likely they were to express transgression likelihood.

### Table 20. Predictors of transgression likelihood in Scenario 1 – only lights and sound

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.D</th>
<th>Wald $\chi^2$</th>
<th>df</th>
<th>Sig</th>
<th>Exp(B) - OR</th>
<th>95% CI for Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurrytrain</td>
<td>.87</td>
<td>.19</td>
<td>19,42</td>
<td>1</td>
<td>.000</td>
<td>2.39</td>
<td>1.62 to 3.53</td>
</tr>
<tr>
<td>Traincheck(IN)</td>
<td>-.36</td>
<td>.12</td>
<td>8.58</td>
<td>1</td>
<td>.003</td>
<td>.69</td>
<td>.54 to .88</td>
</tr>
<tr>
<td>Sanction likelihood</td>
<td>-.42</td>
<td>.17</td>
<td>5.70</td>
<td>1</td>
<td>.017</td>
<td>.65</td>
<td>.46 to .92</td>
</tr>
<tr>
<td>Being hit by a train</td>
<td>-.65</td>
<td>.15</td>
<td>18.34</td>
<td>1</td>
<td>.000</td>
<td>.52</td>
<td>.38 to .7</td>
</tr>
<tr>
<td>Trans.Female26-55</td>
<td>.80</td>
<td>.14</td>
<td>28.75</td>
<td>1</td>
<td>.000</td>
<td>2.22</td>
<td>1.66 to 2.98</td>
</tr>
</tbody>
</table>

Note. Nagelkerke $R^2=.50$, -2 Log Likelihood = 203.52

### 7.5.2.3.2 Scenario 2: Crossing in the presence of closing pedestrian gates

In total, 22 independent variables were considered for the regression. Using a forward stepwise method, the predictor variables were identified in 7 steps. The full model was statistically significant, $\chi^2 (4, N=222) = 204.08, p<.000$. The model explained 80% of the variance and correctly classified 91% of the cases against an initial classification of 20.7% of the cases without the predictors.

Four predictor variables were retained in the final model (Table 21). Similarly to the previous model, the perception of other females’ likelihood (26-55) to cross unsafely and previous transgressions explained by being in a hurry to catch a train augmented the odds of reporting transgression likelihood. For every additional score participants attributed to the visibility of the controls in general, the reported transgression likelihood decreased. Finally, the more participants perceived the risk of being hit by a train, the less they were likely to express transgression likelihood.

### Table 21. Predictors of transgression likelihood in Scenario 2 – closing pedestrian gate

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.D</th>
<th>Wald $\chi^2$</th>
<th>df</th>
<th>Sig</th>
<th>Exp(B) - OR</th>
<th>95% CI for Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurrytrain</td>
<td>1.79</td>
<td>.35</td>
<td>26.53</td>
<td>1</td>
<td>.000</td>
<td>5.98</td>
<td>3.03 to 11.82</td>
</tr>
<tr>
<td>Visibility active ctrls</td>
<td>-1.10</td>
<td>.27</td>
<td>16.69</td>
<td>1</td>
<td>.000</td>
<td>.33</td>
<td>.20 to .57</td>
</tr>
<tr>
<td>Being hit by a train</td>
<td>-1.06</td>
<td>.26</td>
<td>16.34</td>
<td>1</td>
<td>.000</td>
<td>.35</td>
<td>.21 to .58</td>
</tr>
<tr>
<td>Trans.Female26-55</td>
<td>1.20</td>
<td>.26</td>
<td>20.94</td>
<td>1</td>
<td>.000</td>
<td>3.33</td>
<td>1.99 to 5.57</td>
</tr>
<tr>
<td>Train checks (AC) not at all</td>
<td>7.23</td>
<td>3</td>
<td>.065</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train checks (AC) fairly</td>
<td>-2.22</td>
<td>1.27</td>
<td>3.06</td>
<td>1</td>
<td>.080</td>
<td>.11</td>
<td>.01 to 1.31</td>
</tr>
<tr>
<td>Train checks (AC) extremely</td>
<td>-2.29</td>
<td>1.21</td>
<td>.06</td>
<td>1</td>
<td>.813</td>
<td>.75</td>
<td>.07 to 8.01</td>
</tr>
</tbody>
</table>

Note. Nagelkerke $R^2=.50$, -2 Log Likelihood = 103.67
7.5.2.3.3 Scenario 3: Crossing in the presence of stopped train at station

In total, 22 independent variables were considered for the regression. Using a forward stepwise method, the predictor variables were identified in 8 steps. The full model was statistically significant, $\chi^2 (6, N=222) = 205.84, p< .000$. The model explained 80% of the variance and correctly classified 91.4% of the cases against an initial classification of 18% of the cases without the predictors.

Six predictor variables were retained in the final model (Table 22). In this scenario, the more participants perceived other female pedestrians between 56 and 75 years old as likely to transgress in this situation, the more they expressed transgression likelihood. A strong reported likelihood to transgress if in a hurry to catch a train, and reported previous transgressions of a closing gate augmented the odds of reporting transgression likelihood. The more participants felt familiar with the purpose of the pedestrian lights, the less they were likely to report transgression likelihood. The more pedestrians reported being likely to transgress if they felt they could make it on time, the less they reported transgression likelihood for this scenario. Finally, the more participants perceived the risk of other elderly male pedestrians (over 76 y.o.) to be hit by a train, the less they were likely to express transgression likelihood.

Table 22. Predictors of transgression likelihood in Scenario 3 – stopped train

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.D</th>
<th>Wald $\chi^2$</th>
<th>df</th>
<th>Sig</th>
<th>Exp($B$) - OR</th>
<th>95% CI for Exp($B$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could make it</td>
<td>-.83</td>
<td>.33</td>
<td>6.24</td>
<td>1</td>
<td>.012</td>
<td>.43</td>
<td>.23</td>
</tr>
<tr>
<td>Trans. Closing Gate</td>
<td>.80</td>
<td>.35</td>
<td>5.26</td>
<td>1</td>
<td>.022</td>
<td>2.23</td>
<td>1.12</td>
</tr>
<tr>
<td>Hurry train</td>
<td>1.39</td>
<td>.30</td>
<td>21.63</td>
<td>1</td>
<td>.000</td>
<td>4.03</td>
<td>2.24</td>
</tr>
<tr>
<td>Trans. Female 56-75</td>
<td>1.69</td>
<td>.32</td>
<td>27.96</td>
<td>1</td>
<td>.000</td>
<td>5.43</td>
<td>2.90</td>
</tr>
<tr>
<td>Purp. Ped. Lights</td>
<td>-1.14</td>
<td>.21</td>
<td>29.22</td>
<td>1</td>
<td>.000</td>
<td>.32</td>
<td>.21</td>
</tr>
<tr>
<td>Hit by a train. Male 76+</td>
<td>-.75</td>
<td>.23</td>
<td>10.53</td>
<td>1</td>
<td>.001</td>
<td>.47</td>
<td>.30</td>
</tr>
</tbody>
</table>

*Note.* Nagelkerke $R^2=.80$, -2 Log Likelihood = 101.91

7.5.2.3.4 Scenario 4: Crossing in the presence of express train and a pedestrian passing

In total, 21 independent variables were considered for the regression. Using a forward stepwise method, the predictor variables were identified in 7 steps. The full model was statistically significant, $\chi^2 (10, N=222) = 175.46, p< .000$. The model explained 75% of the variance and correctly classified 89.5% of the cases against an initial classification of 21.9% of the cases without the predictors.
Seven predictor variables were retained in the final model (Table 23). In this scenario, the more participants perceived other female pedestrians between 56 and 75 years old as likely to transgress in this situation, the more they expressed transgression likelihood. A strong reported likelihood to transgress if in a hurry to cross, or if others were crossing at the same time, augmented the odds of reporting transgression. The more participants reported being vigilant for the activation of the controls, the less they were likely to report transgression likelihood. Those who incorrectly recalled the pedestrian light at their frequented LC/s (or the recall was “unsure”) were more likely to report transgressions than those who correctly recalled the existence of the control. Those who reported being fairly likely to check for trains during active controls were less likely to report transgression likelihood in this scenario compared to those who were not likely to perform train checks. Finally, the more participants perceived the risk of other elderly male pedestrians (over 76 y.o.) being hit by a train, the less they were likely to express transgression likelihood.

Table 23. Predictors of transgression likelihood in Scenario 4 – express train and pedestrian crossing safely

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.D</th>
<th>Wald</th>
<th>df</th>
<th>Sig</th>
<th>Exp(B)</th>
<th>95% CI for Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Influences</td>
<td>.72</td>
<td>.23</td>
<td>9.80</td>
<td>1</td>
<td>.002</td>
<td>2.06</td>
<td>1.31 3.22</td>
</tr>
<tr>
<td>Vigilance</td>
<td>-.98</td>
<td>.26</td>
<td>14.57</td>
<td>1</td>
<td>.000</td>
<td>.38</td>
<td>.23 .62</td>
</tr>
<tr>
<td>Hurry crossing</td>
<td>.82</td>
<td>.33</td>
<td>6.10</td>
<td>1</td>
<td>.013</td>
<td>2.28</td>
<td>1.19 4.37</td>
</tr>
<tr>
<td>Train checks (AC) not at all</td>
<td>-3.3</td>
<td>1.36</td>
<td>5.90</td>
<td>1</td>
<td>.015</td>
<td>.04</td>
<td>.00 .53</td>
</tr>
<tr>
<td>Train checks (AC) fairly</td>
<td>-.52</td>
<td>1.15</td>
<td>.21</td>
<td>1</td>
<td>.650</td>
<td>.59</td>
<td>.06 .56</td>
</tr>
<tr>
<td>Train checks (AC) extremely</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recall.Ped.Light (correct)</td>
<td>1.33</td>
<td>.64</td>
<td>4.30</td>
<td>1</td>
<td>.038</td>
<td>3.79</td>
<td>1.08 13.36</td>
</tr>
<tr>
<td>Recall.Ped.Light (unsure)</td>
<td>1.30</td>
<td>.63</td>
<td>4.23</td>
<td>1</td>
<td>.040</td>
<td>3.66</td>
<td>1.06 12.58</td>
</tr>
<tr>
<td>Recall.Ped.Light (incorrect)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trans.Female56-75</td>
<td>1.25</td>
<td>.27</td>
<td>21.68</td>
<td>1</td>
<td>.000</td>
<td>3.49</td>
<td>2.06 5.91</td>
</tr>
<tr>
<td>Hit by a train.Male76+</td>
<td>-.50</td>
<td>.17</td>
<td>8.38</td>
<td>1</td>
<td>.004</td>
<td>.61</td>
<td>.43 .85</td>
</tr>
</tbody>
</table>

Note. Nagelkerke $R^2$=.75, -2 Log Likelihood = 115.35

7.5.2.3.5 Scenario 5: Crossing in the presence of stopping and express trains passing at station

In total, 22 independent variables were considered for the regression. Using a forward stepwise method, the predictor variables were identified in 7 steps. The full model was statistically significant, $\chi^2 (7, N=222) = 196.20, p < .000$. The model explained 78% of the variance and correctly classified 90.5% of the cases against an initial classification of 17.6% of the cases without the predictors.
Seven predictor variables were retained in the final model (Table 24). In this scenario, the more participants perceived other male and female pedestrians between 56-75 years old and younger females (under 25 y.o.) as likely to transgress, the more they expressed transgression likelihood. A strong reported likelihood to transgress if in a hurry to catch a train augmented the odds of reporting transgression likelihood in this scenario as well. The more participants reported being vigilant for the activation of the controls and for an approaching train while the controls are not active, the less they were likely to report transgression likelihood. Finally, the more participants perceived the risk of being hit by a train, the less they were likely to express transgression likelihood.

Table 24. Predictors of transgression likelihood in Scenario 5 – two trains passing from opposite directions

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.D</th>
<th>Wald</th>
<th>df</th>
<th>Sig</th>
<th>Exp(B) - OR</th>
<th>95% CI for Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vigilance</td>
<td>-.67</td>
<td>.23</td>
<td>8.57</td>
<td>1</td>
<td>.003</td>
<td>.51</td>
<td>.33, .80</td>
</tr>
<tr>
<td>Hurry train</td>
<td>.88</td>
<td>.22</td>
<td>15.48</td>
<td>1</td>
<td>.000</td>
<td>2.42</td>
<td>1.56, 3.75</td>
</tr>
<tr>
<td>Being hit by a train</td>
<td>-.85</td>
<td>.24</td>
<td>12.71</td>
<td>1</td>
<td>.000</td>
<td>.43</td>
<td>.27, .68</td>
</tr>
<tr>
<td>Trans.Male56-75</td>
<td>1.14</td>
<td>.61</td>
<td>3.56</td>
<td>1</td>
<td>.059</td>
<td>.32</td>
<td>.10, 1.04</td>
</tr>
<tr>
<td>Trans.Female.Under25</td>
<td>.97</td>
<td>.28</td>
<td>11.71</td>
<td>1</td>
<td>.001</td>
<td>2.65</td>
<td>1.52, 4.62</td>
</tr>
<tr>
<td>Trans.Female56-75</td>
<td>2.05</td>
<td>.61</td>
<td>11.25</td>
<td>1</td>
<td>.001</td>
<td>7.77</td>
<td>2.34, 25.72</td>
</tr>
<tr>
<td>Traincheck(IN)</td>
<td>-.71</td>
<td>.24</td>
<td>8.60</td>
<td>1</td>
<td>.003</td>
<td>.49</td>
<td>.31, .79</td>
</tr>
</tbody>
</table>

Note. Nagelkerke R²=.78, -2 Log Likelihood = 111.55

7.6 DISCUSSION

This paper presented the results from a survey measuring a wide range of factors potentially contributing to transgressions in the specific context of LCs in Queensland (Australia). The majority of the participants within the sample were regular users of LCs for at least two years, mainly crossing to catch (and disembark from) a train, even though a train station was directly accessible (through the LC) at only a small percentage of the listed most frequented LCs. Among this sample of regular LC users, the precursors of regular unsafe behaviour and of transgression likelihood in various crossing situations were identified accounting for pedestrians’ habitual crossing behaviour, previous unsafe experience at LCs and perceptions about other pedestrians’ behaviour and the associated risk.
7.6.1 Identified characteristics of regular transgressors and precursors of such behaviour

A cluster analysis was conducted for the first time in a LC context, to identify homogenous groups of LC users according to their reported unsafe behaviour and exposure to risk. The analysis distinguished participants only according to their frequency of transgressions. Participants having committed transgressions more than once or twice were classified in the same group of “regular transgressors” (N = 43), which allowed to investigate the precursors of such behaviour. The results were somehow contradictory to previous findings suggesting that, while male and female pedestrians are equally likely to commit transgressions, males are more likely to do so on a more regular basis (Freeman & Rakotonirainy, 2015). Regular transgressors were also associated with previous transgressions of a closing gate, with poor understanding of the purpose of the pedestrian lights and with perception of control over the risks (could make it). If, arguably, more frequent transgressions are intentional, risk-taking could be explained as underpinned to a large extent by the assessment of the risk in the given situation (perception of control) which is rather related to previous experience than dependent on the signals given by the controls.

On the contrary, the predictors of regular transgressions are also consistent with “beating the gates tendencies” (Richards & Heathington, 1990), explained by a strong perception of control as long as the gate is not closed. It is possible that the perception of control grows with previous unsafe crossing experience and thus reduces the effectiveness of pedestrian gates demonstrated so far (Metaxatos & Sriraj, 2013b). Given that the large majority of participants were using LCs for at least two years, and that the cluster did not distinguish groups according to exposure, it is possible that familiarity and perceived control enhancing unsafe behaviour are to a large extent influenced by factors other than the frequency of crossing at (activated) LCs, such as knowledge about train timetables, sanctions procedures etc. Nevertheless, future research could experimentally test the effects of frequent exposure to different controls on crossing decisions, which could be achieved in naturalistic studies.
7.6.2 Identified predictors of transgression likelihood accounting for differences in the crossing context

7.6.2.1 Predominant likelihood of transgressions of the lights and sound could be associated with low perception of risk or potentially less than adequate information about the purpose of the pedestrian lights

The transgression likelihood reported in the first scenario, involving only activated lights and sound, was significantly higher compared to the likelihood reported for all other situations, which confirms that people tend to cross as soon as they detect the activation of controls as shown in Stefanova, Burkhardt, Wullems, et al. (2015) and before the gates have started moving (Metaxatos & Sriraj, 2013b). Inversely, the least perceived risk of being hit by a train was reported in the first scenario and was significantly different to the rest of the scenarios, confirming that crossing during activated pedestrian lights is not perceived as likely to result in a crash.

On the other hand, provided that the poor understanding of the purpose of the pedestrian lights was a predictor of regular transgressions and that the largest number of participants failed to recall this control, it is likely that, as found by Stefanova, Burkhardt, Filtness, et al. (2015), the salience and the available information about the purpose of this control is not adequately provided to pedestrians. Thus, the increased transgressions of this control and the low perception of risk may be due to confusions. On the contrary, it is also possible that pedestrians in general pay less attention to pedestrian lights in the presence of pedestrian gates, as the latter provide a more “obstructive” physical barrier to unsafe crossing.

Furthermore, the poor visibility of the active controls only appeared as a predictor of transgression likelihood in the scenario with a closing gate (Scenario 2). In this video the red FLs for vehicles were easily visible, along with the descending barriers for vehicles. Therefore, it could be assumed that those who perceived it difficult to notice the activated controls were more inclined to cross, confused by the simultaneous “dynamic” (i.e., falling barriers and closing gates) activation of the controls for vehicles and for pedestrians. In other words, the perception that active controls are difficult to notice could be associated with confusion due to the different active controls for pedestrians and vehicles, rather than with poor salience of the pedestrian lights or gates. Arguably, closures might be perceived as generating an overload of audible, visual and physical. It is well known among traffic
psychologists that the excessive information in the environment is a potential source of errors (Cavallo & Cohen, 2001).

7.6.2.2 **Beating the gates and train tendencies are rather associated with regular transgressors and potentially increase the likelihood of transgressions in the presence of a stopped train**

While beating the gate tendencies could be associated with participants who reported regular transgressions, the larger sample of participants expressed as much transgression likelihood in the situation with a closing gate (Scenario 2), as in the situation with a closed gate (Scenario 3). However, previous transgressions of a closing gate predicted transgression likelihood of closed gate and in the presence of a stopped train (Scenario 3). Consequently, crossing while the gates are closing could be associated specifically with regular transgressors and is likely to enhance transgression of closed gates in the presence of a stopped train. This confirms that, the more pedestrians cross unsafely, the more they are likely to gain confidence in their abilities, and engage in riskier crossing. As shown by Stefanova, Burkhardt, Wullems, et al. (2015) transgressions in the presence of a stopped train are rather rare occurrences but are associated with a high risk of crossing in front of a second train.

7.6.2.3 **The perception of deterrence is potentially increased in close proximity to train stations, rail staff and in the presence of a stopped train and could have more impact on decision-making than the perception of control**

The strongest perception of the risk of being issued a fine was reported for transgressions in the presence of a stopped train (Scenario 3), which was the only scenario with a crossing corridor adjacent to a train station and a visible stopping train. A lower likelihood of being issued a fine was reported if the crossing was to take place before a train was visible independently of the location of the corridor (Scenarios 1,2), and an equally high - if the crossing was to take place on the opposite - station side corridor and in the presence of a visibly approaching train (Scenarios 4,5). Therefore, it can be argued that the perception of deterrence is directly associated with the presence of a train, independently of the number or types of trains. Pedestrians might associate a stopped or an approaching train with the presence of more rail staff at train stations and at the LC environment, with the presence of more rail staff potentially explaining a fear of sanctions.

Furthermore, the results revealed for the first time that, contrary to the above (Section 7.6.2.2.), the expressed control with regards to previous transgressions was
negatively associated only with transgression likelihood in the presence of a stopped train. In other words, even pedestrians who reported a general perception of control during transgressions expressed less transgression likelihood in the presence of a stopped train. Thus, it is possible that in the presence of a stopped train, the perception of deterrence had more impact on decision-making than the perception of control. Future research should investigate the effectiveness of sanctions of different forms (i.e., presence of rail staff, cameras) or amounts (i.e., severity) in reducing pedestrians’ perception of control and over-confidence in unsafe behaviour. The global perception of deterrence of participants was quite low, therefore reinforced enforcement measures especially at pedestrian crossings not adjacent to train stations (i.e., with no or less rail staff) need to be considered.

7.6.2.4 Equal risk of being hit by a train was perceived in the presence of a visible train independently of their types, number or position

The reported perception of risk of being hit by a train was higher for the scenario with two trains compared to the scenario with a closing gate and no visible train. Moreover, there was no difference in the perceived risk between the scenarios with one train and the last scenario with two approaching trains. This result suggests that once the pedestrian gate has started closing a higher risk is perceived only in the presence of more than one train. On one hand, this finding shows for the first time that while the trains’ position (i.e., presence of a stopped train) might increase unsafe crossing decisions, especially among familiar transgressors (i.e., to catch a train) as found by Stefanova, Burkhardt, Wullems, et al. (2015) and discussed in Section 7.6.2.2., it is unlikely to be associated with an increased perceived risk of being hit by a train compared to situations with an approaching train. On the other hand, it also shows that people are likely to underestimate the risk of a second approaching train, perceiving an equal risk of occurrence in the presence of one or more trains. It should be noted that the train’s visibility in the recorded scenarios is subject to biased answers because of different screen resolutions or according to the type of utilised device. Therefore, these results are to be interpreted with caution. More research on the perception of risk associated with visible trains of different types and in different positions is needed to validate these results. Objective measures of the visible train’s distance could provide further valuable information on the factors influencing the perception of risk of being hit by a train. Nevertheless, it is clear that education campaigns should specifically target pedestrian awareness of the risk of express
trains and of a second train arriving, especially when crossing at sites with multiple rail tracks as suggested by Stefanova, Burkhardt, Wullems, et al. (2015).

7.6.2.5 Evidence of the expression of comparative optimism about transgression likelihood

With regards to the measured comparative risk judgements, the results of this study revealed for the first time that pedestrians in a LC context perceive others as more likely to engage in unsafe behaviour than themselves (CO). Participants of all age groups perceived the younger (under 25 y.o.), and middle aged other pedestrians (between 26 and 55 y.o.) as more likely to engage in transgressions compared to the self across all five scenarios. Consequently, younger pedestrians perceive their own age groups as particularly at risk, without considering their own behaviour as such. Considering the broad literature on the expression of comparative optimism, such judgements are likely to be biased (Chambers, Windschitl, & Suls, 2003), even though realistic comparative judgements are also possible (Radcliffe & Klein, 2002). Moreover, such potentially biased comparative judgments were found to have a strong impact on crossing decisions, given that the perceived higher likelihood for others, especially females, to transgress explained the increased self-reported transgression likelihood in all five scenarios.

Pedestrians were asked to base their estimations about others’ likelihood to transgress according to the previously observed behaviour of other pedestrians. Therefore arguably, the obtained results reflect a perception that in general, younger and middle aged adults commonly transgress at LCs. As a predictor of transgression likelihood, such perception can be explained by descriptive norms explaining behaviour as an imitation of other’s behaviour (Cialdini et al., 1990), and not by injunctive norms, as all participants stated that other pedestrians of their age and gender are more likely to transgress than themselves. However, those who were used to crossing with or among others did not report more previous transgressions or more transgression likelihood in the scenarios than those usually crossing alone. Thus, transgression likelihood is not necessarily explained by the direct presence of others, but by the belief (attitude) that unsafe crossing is a common behaviour among the larger population of pedestrians. Similarly, the reported transgression likelihood for other younger and older adults in the fifth scenario was a strong predictor of transgression likelihood. Therefore, in this high risk situation with two trains
passing, those who reported transgression likelihood were also those who believed others of various demographic groups are likely to transgress as well.

In contrast, the results also showed that participants who reported being likely to transgress in the presence of others also reported higher transgression likelihood for the scenario with an express train approaching and a pedestrian crossing compliantly. Therefore, undeniably, and consistent with previous research, the presence of others crossing at the same time is an important risk-factor enhancing unsafe behaviour explained by descriptive norms (Metaxatos & Sriraj, 2013b).

7.6.2.6 Evidence of the expression of biased comparative judgements about the likelihood to be issued a sanction

It was only the youngest participants who perceived others as more likely to receive a fine compared to the self. This result is consistent with previous findings suggesting that young pedestrians believe that they often receive only warnings instead of fines (Stefanova, Burkhardt, Filtness, et al., 2015). Such attitudes based on previous experience raise the question of the deterrent effect of this form of sanctions. It is likely that less than adequate enforcement procedures on the organisational level have contributed to the formation of positive expectations towards enforcement (e.g., “It will never happen to me”). Such issues require attention from rail operators.

Curiously, middle aged female participants perceived other older pedestrians as less likely to receive a fine if crossing in the presence of a stopped train. This could be explained by the strong perception of deterrence associated with this particular scenario or by the perception than older pedestrians are less likely to transgress in this situation. However, the same participants also perceived other older adults as more likely to cross in this scenario compared to the self. This suggests that the expressed comparative judgements are biased and consequently, it can be argued that older and elderly adults are perceived as more likely “to get away” with sanctions. This again suggests that pedestrians perceive enforcement procedures as concerning some age groups of pedestrians more than others.

7.6.2.7 Evidence of the expression of comparative optimism about the perceived risk (of being hit by a train)

A perception of more risk for others to be victims of negative events (i.e., being hit by a train) compared to the self, was for the first time shown in the LC
context. Curiously, the youngest male participants perceived other elderly to be more at risk, which could be justified given the differences in the physical conditions between youth and elderly. However, the youngest female participants perceived other pedestrians of all age groups as more vulnerable compared to the self. Thus, it would appear that female pedestrians consider themselves as more able to cross safely and avoid crashes. If female participants, and especially those under 25 years old, were not associated with frequent transgressions, they could be considered more confident transgressors, especially when crossing in high risk situations, provided that they expressed CO related to crossing in Scenario 5, with the two trains approaching.

Furthermore, the perceived risk of being hit by a train explained a decrease in the reported transgression likelihood in all scenarios. Curiously, the reported risk for the self was associated with a decreased transgression likelihood in the riskiest scenario - with two trains, but also in the least risky scenarios (1, 2) before the gates were closed. Consequently, the perception of risk has a positive impact on crossing decisions in more or less risky crossing situations. Moreover, the reported risk for other elderly pedestrians was associated with a decreased transgression likelihood in the scenarios with a stopped and an expressed train. Thus, the belief that others (i.e., elderly) are much at risk of being hit by a train could also significantly influence risk-taking intentions, however in the opposite direction to what was expected. Given that participants expressed the most CO towards elderly in the largest number of scenarios, it can be argued that even of the perception of more risk for others than for the self is likely to decrease risky behaviour contrary to findings in the literature suggesting that CO increases risky behaviour (Delhomme, Verlhiac, et al., 2009; Harré et al., 2005; Milhabet et al., 2002). Education campaigns should therefore consider not only reinforcing the perception of risk for the self, but also the perception of risk for the general population of pedestrians. Safety improvement could be increased if more information is provided to pedestrians about the extent to which crossing behaviour is subject to social influences and the importance of crossing in an exemplary manner.
7.6.2.8 Lack of precautionary behaviour is associated with transgression likelihood across various crossing situations and is likely to enhance crossing in the presence of others

Poor vigilance towards the active controls’ activation appeared as a predictor of transgression likelihood only in the last two scenarios, suggesting that transgression likelihood, in these risky situations with visibly approaching trains, is reported by pedestrians relying on factors other than the alerts provided by the active controls.

In addition, the lack of checks for trains before the controls are active explained increased transgression likelihood in more or less risky situations, with a visible train (Scenario 1), or without a visible train (Scenario 5). In contrast, the absence of train checks during active controls only appeared as a predictor of transgression likelihood in the scenario with an express train and another pedestrian crossing at the same time (Scenario 4). Thus, arguably those who do not check for trains when the controls are active are more likely to engage in transgressions in the presence of others. Descriptive norms, or rather “diffusion of responsibility” (Darley & Latane, 1968; Harrell, 1991), might explain unsafe behaviour and reduced precautionary measures while crossing among others.

In fact, in this forth scenario the predictors of transgression likelihood were quite different compared to the other scenarios. The emergence of five predictors uniquely in this scenario (i.e., low recall of pedestrian lights, self-reported transgression likelihood in the presence of others and while in a hurry just to cross a road, poor vigilance for active controls, and fewer train checks even during active controls) could explain a unique pattern of transgressions. It appears that the presence of others crossing enhances transgression likelihood not motivated by the need to catch a train (i.e., just crossing the road), and for those who are likely to rely on others’ judgement than on the available safety controls (i.e., pedestrian lights). This emphasises the importance of the previously discussed effect of social influences on unsafe behaviour.

7.6.3 Limitations and future perspectives

A number of limitations exist in the collected data and survey design. The sample included only a small number of pedestrians aged over 56 years old (N=20). It is likely that this demographic group might experience difficulties completing the
electronic survey. Therefore, other forms of investigation of the behaviour of this group of users are recommended. The use of self-reported measures of previous behaviour and transgression likelihood could be a source of biased responses, as people are likely to respond in a socially desirable manner. However the private setting of data collection could have diminished the effect of such biases (Lajunen & Summala, 2003). Although the results should be interpreted with a certain degree of caution, they could be considered generalizable to the larger population of pedestrians in Queensland as the recruited participants were users of all rail lines and over 50 different LCs. Nevertheless, a study with a similar design and a larger sample would most certainly provide a finer-grained understanding of the different transgression patterns of the different demographic groups of pedestrians. Contrary to what might be expected, given that the recruited sample of participants were used to crossing at many variable LC sites, factors related to their habitual crossing context (e.g., trajectory, crossing with others, with earphones, usual number of tracks to cross) did not have an impact on the reported previous transgressions or on the transgression likelihood associated with the scenarios. This could be because the limitation of the number of recorded scenarios did not allow a comparison between intersections with a more variable number of rail tracks, or between intersections not providing direct access to train stations. Simulated scenarios with control groups could be developed on the basis of the current results and would provide further more in depth analysis on the potential effect of such variables on transgression likelihood. More variables related to social influences at LCs should be investigated, such as crossing among a larger number of compliant and/or non-compliant users. Factors influencing the perceptions that others are more risk inclined compared to the self, and more likely to avoid sanctions compared to the self are also to be investigated. A better understanding of such potentially biased judgements would certainly be beneficial to the development of educational safety programs.

7.7 CONCLUSION

Examining a broad range of potential risk-contributing factors to unsafe behaviour at LCs, the findings from this study provide for the first time empirical evidence on the factors explaining regular transgressions and on the factors potentially participating in decision-making accounting for differences in the crossing situations.
It was found that while some factors are likely to contribute to unsafe crossing decisions independently of the situations, others are triggered by specific context-related characteristics of the situation. On one hand, being in a hurry to catch a train explained transgression likelihood in all Scenarios except for one. The perception of others (female) as being likely to transgress was also a significant predictor of transgression likelihood in all scenarios. On the other hand, the predictors of transgression likelihood in the scenario with an express train and a person crossing compliantly were quite different compared to the other scenarios, emphasising the important role of social influences on pedestrian behaviour at LCs.

Finally, although certain limitation are to be considered in interpreting the results, the identified variables as predictors of unsafe behaviour are an important addition to the current state of art, but also raise questions and provide opportunities for future more in depth research on certain risk-contributing factors to unsafe crossing behaviour.
Chapter 8: Discussion

This thesis was conducted as part of a larger collaborative CRC project, with the main research aim to contribute to a better understanding of pedestrian behaviour at LCs. After an extended review of the literature and on-site visits at LCs in Brisbane, it was determined that the PhD research program would focus exclusively on the investigation of pedestrian behaviour at active LCs. The large number of active LCs in the Brisbane area and the future plans to update more crossings with such controls justified the in-depth study of pedestrian behaviour at such intersections. In addition, understanding cases of trespass or suicide on the train tracks were excluded from the research program as they are now widely recognised as different to LC occurrences and requiring different safety investigations and measures.

The literature review identified a notable lack in knowledge related to the understanding of the core origins of pedestrian behaviour at LCs. Only a few studies had so far investigated the multiple and interacting factors influencing crossing decisions and how they contribute to errors and violations in the complex LC environment. Three research aims were formulated to address these gaps in two stages of research: exploratory and empirical.

A mixed qualitative and quantitative method approach was adopted to enable a comprehensive investigation of pedestrians’ crossing behaviour at LCs in two research stages. The first exploratory stage of research was critical to this program, given that pedestrian behaviour at LCs is a highly under-researched area. In this stage two different qualitative methods were articulated to provide a detailed baseline list of factors that have an impact on crossing decisions, which were associated with specific cognitive and motivational precursors of behaviour. Direct and systematic observations of pedestrian behaviour at three black spot LCs in Brisbane were first conducted to identify risk-contributing factors at play across a multitude of crossing situations. These exploratory results were complemented by data collected through focus group discussions with pedestrians familiar with the riskiest LC in Brisbane. This type of data provided information on the role of different factors in shaping
crossing decisions and behaviour. The conclusions from the focus group discussions helped to explain how different risk-contributing factors contribute to the formation of cognitive and motivational precursors of unsafe behaviour.

After the completion of this first stage a new systems-based model (Pedestrian Unsafe Level Crossing framework – PULC) was proposed as a tool to help explain pedestrian crossing behaviour at LCs. Linking potential risk-contributing factors across all hierarchical system levels with specific precursors of behaviour, the framework can be used to identify failures in the system, but it can also be used to propose specific strategies to change unsafe behaviour. Thus, this model was developed to support a comprehensible retroactive investigation of past occurrences, as well as a proactive analysis of risk-prone situations and emerging risk-contributing factors.

The first exploratory stage of research underpinned the next empirical stage, in which a quantitative survey study was conducted to investigate the impact of the previously identified precursors of unsafe crossing in greater depth, among a larger sample of pedestrians and accounting for differences in the crossing context at active LCs. The survey collected information on a broad range of factors potentially influencing unsafe crossing behaviour, and measured their association with self-reported transgressions. Data analysis provided evidence on the best predictors of regular unsafe crossing behaviour. In addition, participants’ reported transgression likelihood was measured and compared across five recorded crossing scenarios with different levels of risk. The predictors of transgression likelihood in each scenario were also identified, illustrating for the first time the plethora of different factors likely to lead to unsafe crossing from one situation to another.

The main findings from each study are discussed in the next sections (8.1., 8.2., 8.3) followed by a general discussion on the strengths and weaknesses of the research program (Sections 8.4-8.7). Lastly, future research perspectives are discussed in Section 8.8.
8.1 STUDY 1: IDENTIFICATION OF A WIDE RANGE OF CONTRIBUTING FACTORS TO UNSAFE PEDESTRIAN CROSSING THROUGH DIRECT OBSERVATIONS AT BLACK SPOT LEVEL CROSSINGS

To address the lack of available descriptive information around the factors involved in LC collisions and occurrences with pedestrians, a direct observations method was adopted in the first exploratory study. Unlike self-reported or occurrence data, observational methods provide opportunities for, qualitative, in addition to quantitative, analysis of pedestrian crossing behaviour, accounting for characteristics of the urban environment and for travel behaviour (e.g., walking speed, route choice, distractions) (Kim, 2015). Data from direct observations is less subject to biases related to social desirability or omissions compared to self-reported data. Pedestrians are unlikely to recall as many of the characteristics in a given crossing situation as an observer can be vigilant for.

Three black spot LC sites were selected after careful consideration involving pre-observations, discussions with rail professionals, and analysis of the available near-misses report for 2011. Given that data could only be collected for a short period of time (45h in total), the selected sites were part of the same rail line, in order to facilitate the comparison of the number and the frequency of observed transgressions. Moreover, such design allowed the proposal of explanations of unsafe behaviour related to other, less studied factors than rail traffic density (Iorio et al., 2012). The comparison in the transgression patterns at sites with different numbers of rail lines and different locations of the platforms, but with similar rail traffic characteristics, increases the validity of the conclusions, despite the small number of selected observation sites.

To satisfy the research aim, multiple factors related to the pedestrians’ characteristics, their crossing trajectory, and their potential journey context were analysed (from a qualitative perspective), in addition to factors related to the status of the controls and the train’s position, which were analysed from a quantitative perspective.

8.1.1 Rail traffic characteristics: The train position and the status of the active controls have important impact on crossing behaviour

Transgressions of different active controls have previously been explained differently. The predominant transgressions of the lights and sound and of closing
gates have been associated with a low perception of risk related to the absence of a visible train or with beating the gate tendencies (Clancy et al., 2007; Edquist et al., 2011). In contrast, transgressions of closed gates have been associated with a low perception of risk after a first train has already passed through the LC (Metaxatos & Sriraj, 2013b; Sposato et al., 2006). However, this rarer type of transgression has also been considered the riskiest, even if a first train has already passed, as it hides the risk of crossing in front of a second approaching train. According to results from an observational study in the U.S.A, pedestrians are more likely to run when engaging in transgressions of closed gates than if transgressing closing gates or lights and sound (Metaxatos & Sriraj, 2013b). Thus, it is likely that pedestrians are well aware of the increased risk associated with crossing once the gates are fully closed, which could explain the rarer occurrence of such behaviour. However, not much research has previously investigated other factors contributing to the three types of transgressions.

Results from the direct and systematic observations addressed this gap by providing an analysis of the crossing patterns associated with each type of transgression: transgressions of the lights and sound, transgressions of closing gates and transgressions of closed gates.

In line with previous findings, at the observed black spot LCs in Brisbane, transgressions of the lights and sound were the most commonly observed type of unsafe behaviour (Edquist et al., 2011; Metaxatos & Sriraj, 2013b). However, during the observations, no evidence was found in relation to beating the gate tendencies. On the contrary, at the selected Brisbane sites, transgressions of closed gates (24%) were more frequently observed than transgressions of closing gates (17.8%). Moreover, the results confirmed that, unlike the two other types, transgressions of closed gates are strongly associated with the train’s visibility. Specifically, the results revealed for the first time that transgressions of closed gates are strongly associated with the presence of a stopped train.

Furthermore, it was found that in most cases, pedestrians engaged in this type of behaviour when the stopped train has already passed through the LC (i.e., transgression behind a stopped train). Such behaviour can be explained by familiarity with rail traffic characteristics. Pedestrians might be more inclined to cross unsafely if they are familiar with the expected train’s direction and with the time to train
departure (i.e., being aware that they can still catch a stopping train entering the train station through the LC). However, it is not clear if familiarity is associated with less objective risk-taking. Pedestrians may be crossing behind or in front of a stopped train only in situations with no real risk of accident (i.e., crossing only the same track behind an outgoing train). Additional innovative analysis of the data was conducted in the form of counting the number of rail tracks crossed during the transgression, distinguishing those on which a train has passed and those on which a train could have potentially arrived. No significant difference was found in the number of crossed tracks where a train could arrive between transgressions of the lights and sound, transgressions of closing gates and transgressions of closed gates. Therefore, pedestrians transgressing in front of a stopped or after an outgoing train were equally likely to cross multiple tracks and take the risk of crossing in front of a second train as those transgressing before the gates are closed. This result emphasises the importance of pedestrians’ perception of familiarity with rail traffic characteristics and previous experience with unsafe crossing. Arguably, with experience, risk-taking can become a rather habitual and to a large extent automatic behaviour. The more pedestrians would appreciate the benefits of transgressing the lights and sound, the more likely they would be to transgress closing or closed gates. With previous unsafe experience, pedestrians learn and form expectations about the trains’ direction, speed, time of arrival and departure. Based on such rules they will be likely to engage in riskier transgressions underestimating the potential changes in the crossing situations. For instance, crossing multiple tracks before the gates are active could be associated with less perceived risk of accident than crossing multiple tracks after the gates are fully closed (i.e., crossing in front of a second train). As already pointed out, pedestrians’ expectations are a key precursor of unsafe behaviour at LCs (Beanland et al., 2013; Salmon et al., 2013). Pedestrians’ expectations could be modified through measures aiming to reduce the over-confidence in knowledge about rail traffic characteristics (Clancy et al., 2006; Davis Associated Limited, 2005). An education-enforcement safety campaign has proven to be particularly effective in reducing transgressions of closed gates at a LC adjacent to a train station in the U.S.A. (Sposato et al., 2006). To raise risk awareness about crossing in front of a second train, more information should be provided to pedestrians about the frequency of rail traffic disruptions which may cause express (i.e., not stopping) trains to pass through the LC instead of stationary ones, and at unusual time frames.
Apart from education campaigns, previous studies have evaluated the effectiveness of second train warning controls. Different types of audible only and audible and visual controls were trialled (Gabree & da Silva, 2015; RSSB, 2008). While it was found that it is difficult for pedestrians to detect the audible warning for a second train, a reduction in unsafe behaviour was noted after installation of both audible and visual warnings (RSSB, 2008). However, it was pointed out that the presence of a stopped train at station is likely to reduce the effectiveness of such measures, inducing confusion in pedestrians about whether the control is active for the present train or another approaching train (RSSB, 2008). As the presence of a stopped train has been here identified as a high-risk situation, the risk of potential contrary effects of second train warnings should be carefully considered before implementation of future interventions.

8.1.2 Level crossing design: the number of the rail tracks and the location of the platforms have an important effect on unsafe crossing behaviour

Only a small number of studies have previously compared the observed transgressions according to the LC design, or specifically, according to the location of the platforms vis-à-vis the rail tracks and the pedestrian corridors providing access to the platforms. Edquist et al. (2011) observed more transgressions at LCs where the platforms surround the rail corridor. The authors associate unsafe behaviour with the need to cross both tracks to access either of the platforms. Arguably, LCs with a middle island hosting both of the platforms of commuter train services should reduce the number of transgressions. However, the results from the conducted observations at Brisbane’s black spot LCs were in contradiction with those previous findings. In fact, the least number of transgressions were observed at the LC where the platforms to commuter services were outside of the rail corridor. In contrast, the largest number of transgressions was observed at the LCs with middle islands, suggesting that the crossing of a small number of rail tracks might be associated with the perception of low risk related to the short distance. However, the largest number of crossed tracks where a train could arrive was also observed at the LC with platforms surrounding the rail tracks. Therefore, it is likely that such LC design (i.e., with platforms surrounding the rail tracks) contributes to, if not more transgressions, then much riskier types of transgressions. Even though Edquist et al. (2011) argued that a change in the platform’s location is too expensive and unlikely to eliminate the risk
of transgression, such a measure can provide a significant reduction in unsafe behaviour, and lower cost solutions should be considered. In relation to this, research on second train warnings conducted in the U.K. revealed that there is a greater risk of second train occurrences at locations with the so called “sandwich platforms”, one platform across from the other, surrounding the rail corridor, compared to sites with “staggered platforms”, with platforms on both sides of the LC zone where the controls deactivate once the train has left the LC zone independently of its direction (RSSB, 2008). Thus, given that middle platforms are associated with more single-track transgressions but less risk of crossing in front of a second train, it is likely that middle island staggered platforms could significantly reduce unsafe crossing. At middle islands with staggered platforms, the active controls would activate only after a stopped train is about to leave the platform and thus cannot be caught. Such platform design creates crossing conditions in which the effect of a number of important risk-factors could be mitigated. Firstly, it would be legal to cross while the train is stopped at station and catch it. Secondly, the activation of the controls could increase risk perception among familiar users as it would be associated with the departure of an already visible train. However, such improvement may cause additional risk to vehicle users given that the time required to clear the road might be reduced. Therefore, more research should be conducted to identify the potential benefits of such or similar solutions for all types of users.

8.1.3 Goal directed behaviour can be explained by characteristics of the larger area

In the literature, being in a hurry to catch a train has been reported as one of the major motivations to cross unsafely the rail tracks (Clancy et al., 2007). However, motivations related to specific journey contexts imposing time pressure or the contextual factors facilitating the effect of such motivations on behaviour have rarely been previously investigated. The exploratory observational study confirmed that the largest number of the transgressions occurred on the way to station platforms, independently of whether the platforms were on a middle island or external to the rail corridor. Of the 129 pedestrians who transgressed during the observed period, 91 visibly caught a train and 66 of them were running or walking faster while accessing the platform. The examined interactions between factors informed on other
One of the LCs (Wynnum Central) was located on the main road, giving access to a large shopping centre, and was also in a close proximity to a nearby road intersection, implying long waiting times to cross from one side of the road to the other. Unlike transgressions at the other observation sites, transgressions at this LC were associated with afternoon peak hours and with the most variable adopted trajectories towards the station from the shopping centre. Transgressions could be explained by the lack of overbridge connecting the main road and the station platforms and by shortcuts taken to avoid waiting at the road intersection. Another LC (Cannon Hill) was associated with more school children crossing alone, particularly in the morning and before the gates are active (i.e., transgressions of the lights and sound). The large number of primary schools in the area could have contributed to increased risk-taking behaviour among peers (observing each others’ behaviour). The third LC (Coorparoo) was associated with group transgressions and with older and elderly transgressors. At this LC the crossing trajectories corresponded to crossing on the way to a car park or crossing towards the station platforms.

Thus, at the three observation sites pedestrians adopted quite different transgression trajectories which could be associated with different journey contexts (going to school, work, shopping, to a carpark). The urban environment, land use and the design of crossing facilities play a crucial role in pedestrians’ decision-making (Sisiopiku & Akin, 2003; Yu, Ma, Lo, & Yang, 2015). The same authors found that in road crossing settings, “the most influential factor cited by pedestrians in making a decision to cross at a designated location is the distance of the crosswalk to desired destinations of pedestrians” (Sisiopiku & Akin, 2003, p. 271). Thus, providing more direct paths for faster access to station platforms with regard for adjacent land use (e.g., schools, shopping districts, road intersections) is likely to significantly reduce unsafe behaviour. This raises the question of the utility of overpasses provided at inadequate locations. Specialists from different domains (i.e., civil engineers, urban planners, psychologists, other human factors specialists, risk assessment specialists) should combine efforts to find new low cost solutions to improve the utility of the existing access points to train station platforms.
8.1.4 Demographic groups of pedestrians: males do not seem to be more at risk than females, but have different transgression patterns

There is no recent information on the high risk groups of LC users that accounts for characteristics of the larger population, as the only available analysis is based on crash data between 1997 and 2002 (ATSB, 2001). Given that the currently available crash data is associated with a number of limitations and does not include information on near-miss occurrences, observational studies should seek to provide a more accurate estimation of the objective risk associated with different demographic groups of LC users. However, the most recently conducted observational study in Australia did not follow a systematic procedure and did not provide evidence on exposure (Edquist et al., 2011). Such limitations of the study methodology are understandable given the collection of data generalisable to the larger population is a time and effort consuming procedure (i.e., stratified sampling across the general population of Australia), while observational studies often have broader objectives than the identification of high risk demographic groups of users. This was the case in the observational study conducted here. The direct observations provided an indication on the percentage of pedestrians involved in transgressions and a rather detailed description of them (i.e., demographics), unlike other existing studies (Metaxatos & Sriraj, 2013b), but more importantly, it identified factors associated with the transgression pattern of different groups of users. To the author’s knowledge, previously only an association between school children or younger pedestrians and group transgressions was found (Khattak & Luo, 2011; Metaxatos & Sriraj, 2013b). In addition to differences in the behaviour according to influences from others, the observations conducted here showed that different demographic groups of pedestrians tend to transgress different types of active controls (e.g., lights and sound, closing and closed gates) and in the times of the day (e.g., morning afternoon peak hours). Specifically, it was found that school children (i.e. 5-15 years old), were associated with transgressions of lights and sound and, contrary to previous findings, with crossing alone. For the first time elderly persons were also associated with crossing alone. On the contrary, group transgressions were not associated with a specific age group of pedestrians. Elderly and older adults (i.e., 30 - 70 years old) were associated with transgressions of closing gate and younger adults (i.e., 16 -30 years old) with transgressions of closed gate. Males were associated with
transgressions in the afternoon peak hours while females tended to transgress in the morning peak hours.

Consequently, in line with previous findings (ATSB, 2001) pedestrians aged between 16 and 30 demonstrated the riskiest transgressions when the gates were closed. Such transgressions in the driving context have been associated with beating the train tendencies and sensation seeking (Witte & Donohue, 2000). While sensation seeking personality was not associated with a specific age group of drivers, Freeman and Rakotonirainy (2015) found that minors expressed the most sensation seeking tendencies among pedestrian users of LCs in Australia. Thus, if more weight was put on the observed than on the self-reported behaviour, it is likely that, among the population of pedestrians in Brisbane, young adults (i.e., 16-30) are more likely to engage in the riskiest type of transgressions, rather than minors.

Young drivers’ sensation seeking has previously been associated with biased, positive judgements about the ability to assess train speed, distance and the time required to cross, and with frustration about waiting times (Witte & Donohue, 2000), The results from the observations suggest that pedestrians’ confidence may increase and then diminish with age, as there was an association between transgressions of lights and sound and school children, transgressions of closed gates and younger adults and transgressions of closing gates and older adults and elderly. Arguably, in advanced age, pedestrians may lose confidence in their ability to assess the exact time of the train’s arrival which may be associated with loss of visual or hearing capacities. Similarly, they might also lose confidence in their ability to cross in time, which may be associated with physical impairments, fatigue or tiredness.

In the present study males were not directly associated with transgressions of closed gates, as suggested by Witte and Donohue (2000), so communication campaigns for this particular form of transgression should target middle aged pedestrians to reduce their high risk behaviour. It would be interesting to conduct research among pedestrians crossing unsafely to measure to what extent their perceptions of the risk are accurate (e.g., estimated time to train arrival, perceived train speed and distance). Such research would provide a valuable basis for successful safety campaigns. While risk awareness is important, the frustration of waiting, characteristic of sensation seekers, is not to be underestimated. As suggested by Lorch et al. (1994) frustration among sensation seekers is likely to be reduced by
providing them with “equally attractive” alternatives to thrill seeking (e.g., exciting activities to occupy their waiting time).

8.2 STUDY 2: IDENTIFICATION OF DIFFERENT PRECURSORS OF BEHAVIOUR FROM FOCUS GROUPS WITH PEDESTRIANS

In the second exploratory study, the second research aim was addressed by conducting focus groups discussions with pedestrians, which shed light on the cognitive and motivational precursors of unsafe behaviour influenced by risk-contributing factors identified in the previous stage. This study was based on the newly proposed framework for the investigation of pedestrian unsafe behaviour at LCs (PULC). The PULC underpinned the development of the study design (discussion protocol) and supported an innovative analysis of the results. The following sections summarise the results on the precursors of safe behaviour, errors and violations.

8.2.1 Precursors of safe versus unsafe behaviour

In line with findings from the literature (Beanland et al., 2013), pedestrians reported that it is hard to miss the activation of the controls, as the audible alarm can be heard even before the gates are active. It was also confirmed that, independently of their awareness of the activated controls, pedestrians reported basing their crossing decision on whether or not a train was in sight (Beanland et al., 2013) and to a lesser extent on the status of the gates. This result questions previous findings which suggest that the presence of pedestrian gates significantly reduces unsafe crossing (Metaxatos & Sriraj, 2013b). Moreover, it was confirmed that the audible alarm undeniably increases pedestrians’ vigilance but not their perception of risk.

Consistent with the findings from the observations in this study, pedestrians reported that they do not and would not transgress if they were just crossing the road or if catching a train for leisure activities. These results conflict with previous research explaining unsafe crossing behaviour with frustration about waiting times (Witte & Donohue, 2000), but support an explanation of time pressure and avoiding missing the next train (Clancy et al., 2007). As discussed above, improving the access to station platforms may significantly reduce unsafe behaviour. However, such interventions are costly and complicated as it is difficult to find the optimal access point for all types and demographic groups of users. Therefore, safety
communications should target the reduction of violations committed to avoid missing the next train. Given that only self-reported data is currently available about pedestrians’ motivations to violate, future behaviour change strategies would benefit from more experimental research.

The focus groups conducted in this research provided novel information on the extent to which the social environment influences decisions at LCs. Specifically, pedestrians suggested that they adopt more precautionary measures and safe crossing if crossing with children or family. This result is consistent with a large amount of research showing that parents perceive themselves as the main providers of road safety education for their children, and thus adopt safe crossing to provide a good crossing example (Cantillo, Arellana, & Rolong, 2015; Zeedyk & Kelly, 2003). However, it was also found that in a road crossing context parents rarely provide a verbal explanation of safe crossing (Zeedyk & Kelly, 2003). Such research has not yet been conducted in a LC context and deserves a considerable attention, given the higher risk associated with crossing this type of intersection.

8.2.2 Precursors of errors

Pedestrians reported previous errors and the likelihood of committing an error as associated with failures on the rule-knowledge based level of performance. Such errors were related to inadequate (e.g., abundance of passive signs generating confusion) or insufficient (e.g., lack of previous experience) information provided to users. In contrast, the perceived likelihood of others committing an error was explained with suboptimal mental states (e.g., fatigue), physical impairments or the consumption of psychoactive substances. Other pedestrians’ likelihood of committing an error was also associated with crossing in large groups of pedestrians. Thus, others’ errors were generally seen as failures on the skill-based level of performance. While others’ errors were viewed as failures to act appropriately and safely in the LC environment, personal errors were explained as failures of the system to provide adequate safety measures. These results provide information about the (non) effectiveness of specific active and passive controls, and also reveal that pedestrians perceive others as more at risk of committing an error than the self. This evidence emphasised the importance of pedestrians’ over-confidence and should be taken into consideration in the development of strategies to reduce such perceptions.
In terms of the identified issues with the active controls, errors were associated with the misunderstanding of pedestrian lights. They were a (potential) source of confusion at middle islands where multiple sets of lights regulate pedestrian traffic through each crossing corridor. It is likely that the separation of pedestrian traffic on both sides of a middle island hinders the understanding of this control and is associated with ambiguous and contradictory information provided to users (i.e., do not cross on red light, while there might be red and green light flashing at the same time). Previous data from a survey conducted in the U.K. road crossing context reveals that crossing at streets with (refuge) middle islands are perceived by pedestrians as safer than crossing without middle islands, and thus are likely to increase risk-taking behaviour (Hao et al., 2008). Arguably, similarly to road crossing context pedestrians might perceive it safer to cross at middle islands because of a perceived shorter distance, and thus would be likely to pay less attention to active controls. Consequently, it is also possible that pedestrian confusion is explained by poor vigilance at middle islands rather than by less than adequate information on safe crossing.

8.2.3 Precursors of violations

The number of participants was insufficient to identify the high risk groups of pedestrians. Nevertheless, consistent with previous findings from the literature and the observations, younger and middle aged pedestrians were more likely to report unsafe behaviour and violations in particular, compared to the elderly (Clancy et al., 2007; Edquist et al., 2011).

In line with the results from the observations, the absence of a visible train and the estimated distance to train arrival at the LC zone were suggested as the main reasons for violations. Participants confirmed being equally likely to transgress in the presence of a stopped train as when there is no approaching train visible, or when they “can see that the arriving train is far away”. They explained this behaviour by the motivation to catch the train at station, but also with positive attitudes related to the easy access through closed pedestrian gates.

Firstly, these results highlight the risk of perceived familiarity with crossing situations, resulting in potentially biased estimations of the distance to train arrival as was previously demonstrated (Clark et al., 2013). Secondly, the results provide information for the first time on the attitudes associated with the characteristics and
the operation mode of pedestrian gates specific to the Brisbane context. Participants expressed positive attitudes, such as “pushing the pedestrian gate is quicker and more efficient” (Stefanova, Burkhardt, Filtness, et al., 2015, p. 177) enhancing unsafe crossing behaviour. The absence of a locking mechanism on the gates was also associated with positive attitudes and expectations towards violations – “it’s easy to push and go” (Stefanova, Burkhardt, Filtness, et al., 2015, p. 179). Consequently, it was found that the technical properties of the gates are likely to reduce the perception of risk (i.e., easily circumvented, absence of locks) and contribute to violations motivated by the need to catch the next train.

In line with the conclusions from the observations, pedestrians reported different factors motivating transgressions which were indeed associated with the LC design (i.e., access to station) and the larger environment (i.e., nearby road infrastructure). Specifically, pedestrians reported previous violations and likelihood to violate to avoid waiting or because of time pressure (i.e., need to be on time). Pedestrians suggested avoiding waiting at the LC or at nearby road intersections. They also reported being likely to violate if in a hurry to go to work, school or simply to go home. Participants in the focus groups confirmed that they would be equally likely to violate not only in the morning while in a hurry to catch a train and be at work on time, but at anytime of the day, and not necessarily only to catch a train but also just when in a bad mood. Thus, even though catching a train is undeniably closely related to violations, it appears that the widely proposed explanation in the literature “to be on time” does not reflect all potential motivations underpinning violations. In conclusion, although violations are found to be strongly influenced by motivational precursors, it appears that before violating, pedestrians are likely to assess their ability to carry out the action (i.e., push the gates open) and the associated risk (i.e., distance to train arrival). Therefore, it appears that improvements of the physical environment are a potentially successful measure to reduce violations, along with safety communications targeting the reduction of over-confidence and changes in the expectations and attitudes associated with the benefits of unsafe crossing.

Similar to the explanations provided for the likelihood to commit an error, pedestrians explained others’ violations differently compared to self-reported violations. Others’ violations were seen as “reckless” behaviour in the presence of
others (i.e., to show up) or in a search of extreme sensations (for a dare). Such violations were attributed to younger pedestrians. In general, participants considered their own transgressions as “justified” and less risky compared to others’ transgressions (younger and elderly). These judgements corresponded to the expression of comparative optimism associated with a strong perception of control increasing risk-taking (McKenna et al., 1993), rather than with sensation seeking tendencies. In contrast, pedestrians expressed negative attitudes towards violators seeking strong sensations and arousal. Given the small sample of participants, further research is needed to assess the proportion of sensation seekers among the pedestrians violating the active controls “for rational reasons” (i.e., save time).

Finally, it was found that knowledge about past occurrences and existing safety campaigns are likely to reinforce comparative optimism. As illustrated in the second case study, knowledge about a fatal accident with an elderly lady with disabilities seemed to reinforce the participant’s perception of control as she (the participant) could not identify herself with characteristics of the victim. Similarly, a pedestrian who reported transgressing often considered herself as less at risk than a victim of an rail incident (Jonathan Beninca, Section 2.6.), because she would never “just walk on the tracks to save time”, or engage in similar behaviour (result not detailed in Paper 2, Chapter 6). Although not applicable to the general population, such results illustrate the need to carefully consider the targets of safety messages and campaigns and the negative effects of underestimating this requirement (Delhomme, De Dobbeleer et al., 2009).

8.3 STUDY 3: EXAMINING THE EXPLICATIVE FACTORS OF PREVIOUS UNSAFE CROSSING BEHAVIOUR AND TRANSGRESSION LIKELIHOOD.

The empirical stage of research consisted of the third study, addressing the third research aim, which was to examine the impact of cognitive and motivational precursors on unsafe behaviour across different crossing situations. Building upon the results from the first two studies, the survey examined to what extent factors related to pedestrians’ usual crossing (i.e., number of usually crossed tracks, LCs, journey context, familiarity with controls and sanction procedures) explain the self-reported previous transgressions. As per the conclusions from the previous stages, the status of the controls and the gate’s position were manipulated in five crossing
scenarios to examine empirically their impact on transgression likelihood. In addition, following the results from the focus groups, the perception of risk associated with being hit by a train and being issued a sanction was examined for the self, but also for others in relation to the five scenarios. The following sections summarise the main findings from the third study in relation to the results obtained from the exploratory studies.

8.3.1 Identified profile of regular transgressors

For the first time, evidence that helps explain the profile of regular transgressors was provided. They were characterised as males, with a strong perception of control and poor understanding of the purpose of the pedestrian lights, but used to transgressing while the pedestrian gate is closing. As there was no difference in the number of male and female participants who reported previous unsafe behaviour, it can be argued that instead of being more likely to transgress than females (Freeman & Rakotonirainy, 2015), males are more likely to engage in more frequent and riskier crossing behaviour (i.e., transgressions of closing gate). Previous transgressions of closing gates were also associated with transgression likelihood in the presence of a stopped train (Scenario 3), highlighting, the importance of previous experience with unsafe crossing as potentially increasing the perceived control in riskier situations. This result also builds upon previous findings, associating for the first time regular LC transgressors with beating the gates tendencies, which had so far only been demonstrated among drivers in a LC context (Richards & Heathington, 1990).

8.3.2 The most influential factors on risky crossing decisions appear to be the trains’ position and status of the automatic controls

The results from the survey provided empirical evidence for the first time that suggests that pedestrians base their crossing decisions to a large extent on the perceived risk associated with the status of the controls and the train position. Even though motivational factors (e.g., being in a hurry) were predictors of transgression likelihood in all situations, the largest number of participants reported likelihood to transgress only in the first scenario, with only the pedestrian lights and sound active. Thus the results from the self-reported data are consistent with data from the conducted observations (Paper 1) and with evidence from the literature (Metaxatos
suggesting that transgressions of the lights and sound are associated with the least perceived risk and most transgression likelihood.

Although no significant difference in the transgression likelihood between the scenarios with and without visible trains was found, the presence of a stopped train could be associated with regular transgressors. Thus, in line with findings from the observations and other studies based on self-reported data (Clancy et al., 2007), the presence of a stationary train is likely to increase the riskier and rarer transgressions of the gates. Similarly, no difference was found in the risk-perception of being hit by a train across the scenarios with different numbers and positions of trains. However, this absence of a significant result can be related to the fact that there was no scenario with an outgoing train. As found in the observations and other studies (Metaxatos & Sriraj, 2013b), the presence of outgoing train is associated with transgressions of the closed gates. In this line of thinking, it is possible that the conclusions from self-reported and observations data are contradictory because participants watching a video recording are not facing the same motivational (i.e., being in a hurry) and contextual constraints (i.e., fatigue) as participants in a naturalistic crossing context. It is also possible that participants in the survey estimated the distance to train arrival differently due to differences in screen resolution or the devices used to complete the survey. Further research is needed to clarify the extent to which the presence of a stopped and outgoing train influences crossing decisions. A study design including objective measures of train visibility and distance to arrival would be most appropriate.

Moreover, results from the survey provide important implications on the effectiveness of pedestrian gates, associating regular transgressors with beating the gates tendencies and beating the gates tendencies with an increased likelihood of transgressions (of closed gates) in the presence of a stopped train. Although consistent with evidence from the literature, pedestrian gates could be associated with a reduction in unsafe behaviour (Metaxatos & Sriraj, 2013b); the presence of this control could also be associated with risk-taking behaviour in a similar fashion to the countdown timers introduced at road intersections. In the literature, divergent opinions exist on the effects of countdown timers on pedestrian compliance with road rules. A reduction specifically in pedestrian-car crashes was reported by some authors (Hooper, Vencatachellum, & Tse, 2007; Kapoor & Magesan, 2014;
Pulugurtha, Desai, & Pulugurtha, 2010), while others argue that countdown timers have a negative effect on risky crossing behaviour, increasing the number of transgressions right after the onset of the lights and five seconds prior to their cessation (Vujanić, Pešić, Antić, & Smailović, 2014). Such an increase was explained by the adding of extra-confidence in pedestrians’ ability to estimate the remaining time to the arrival of vehicles (i.e., to safe crossing) which increases the probability of the so called “late starters” (Huang & Zegeer, 2000; Paschalidis, Politis, Basbas, & Lambrianidou). Consequently, similarly to countdown timers, pedestrian gates may enhance familiar users’ perception of control and ability to cross safely.

8.3.3 Other risk factors associated with increased transgressions

8.3.3.1 Poor awareness and understanding of the pedestrian lights

Building upon qualitative results from the exploratory studies, the survey verified to what extent variables such as the number of usually crossed tracks, usual crossing trajectory (to station vs. just crossing), journey context (to work, home etc), period of crossing at LCs (in years), and familiarity with controls and sanctions procedures, could explain self-reported transgressions and transgression likelihood. Among those variables, only familiarity with the controls stood out as a significant predictor in the profile of regular transgressors and of the reported transgression likelihood in the scenarios. Consistent with findings from the focus groups, the poor understanding and recall of the pedestrian lights emerged as significant predictors of transgression likelihood in the last two scenarios. Specifically, it appeared that pedestrians who reported poor recall and awareness of the purpose of pedestrian lights reported more transgression likelihood in the scenario with an express train and another pedestrian crossing compliantly (Scenario 4). The already discussed potential issues with this control could therefore enhance transgressions in the presence of others. The delegation of the responsibility to others executing the same task is known as “distribution of responsibility” – a phenomenon so far demonstrated only in the pedestrian road crossing context (and not the rail-road crossing context) (Harrell, 1991). Future experimental studies could investigate further to what extent errors (and/or violations) in the presence of others could be attributed to the poor understanding of the signals by the self (distribution of
responsibility), or to the copying of others’ behaviour explained by descriptive social norms.

### 8.3.3.2 Time pressure

Consistent with results from the observations, the focus groups and the broader literature (Clancy et al., 2007), the results from the survey confirmed that being in hurry to catch a train was a strong predictor of transgression likelihood in four out of five scenarios. It was only in the scenario associated with just crossing the road in the presence of another pedestrian that being in hurry to cross emerged as a strong predictor of transgression likelihood, instead of being in a hurry to catch a train. Consequently, in line with the results from the observations and the focus groups, being in a hurry seems to be mainly associated with accessing a train station and catching a train. Thus in a LC context, transgressions are more often motivated by time pressure and the desire to avoid missing the next train than simply by frustration with the waiting times (Witte & Donohue, 2000). However, the results from the survey revealed for the first time that transgressions not underpinned by pressure to catch a train are enhanced by the presence of others (i.e., as the crossing corridor in this scenario was on the opposite side to the train station LC side). Participants who reported being likely to transgress if just in a hurry to cross were more likely to report transgression likelihood in the presence of another pedestrian than in other scenarios involving just crossing the road without another pedestrian visibly crossing.

### 8.3.3.3 Social influences

In the only crossing scenario where a pedestrian was recorded crossing (compliantly), the predictors of transgressions were quite different to the rest of the scenarios. As mentioned just above, one of them was the likelihood of transgressing if in a hurry to cross a road. Another predictor was the reported lack of checks for trains while crossing during activated controls. In this relation, the survey results were consistent with findings from the focus groups and the broader literature on road safety (Zeedyk & Kelly, 2003), suggesting that pedestrians used to crossing among random others tend to perform fewer precautionary measures. Further, as previously mentioned, transgression likelihood in this scenario was associated with pedestrians who did not recall correctly the presence of pedestrian lights at their most frequented LCs, potentially associated with distribution of responsibility. Moreover,
participants who reported being generally less vigilant for active controls also reported more transgression likelihood in this situation.

Consequently, these results reveal for the first time the important impact of descriptive norms on various precursors of behaviour, such as decreased vigilance, more reliance on others’ decisions, known as “diffusion of responsibility” (Darley and Latane, 1968), more confidence in the ability to cross while in hurry but not needing to catch a train and less precautionary measures. The presence of others seems to have a negative effect on different aspects of pedestrians’ attentional resources during crossing, which could be explained by descriptive norms. The role of descriptive norms in the prediction of road violations has been previously demonstrated, and especially their strong influence in “high risk-prone situations” (i.e., risk of overtaking in a situation of poor visibility) (Forward, 2009). The careful consideration on whether safety communications should privilege the change of descriptive norms or injunctive norms is therefore essential.

8.3.3.4 **Comparative judgements on transgression likelihood and the perceived risk across scenarios**

In line with the latter, the results from the empirical survey showed for the first time that, independent of the context of the crossing situation, pedestrians perceive others and in particular younger and middle aged others as more likely to transgress compared to the self. As comparative optimism has been associated with biased judgements (Windschitl & Suls, 2003), this result underlines the potential perception of pedestrians that transgressions are a common behaviour among the larger population. Moreover, the perception of others’ likelihood to commit more transgressions was also confirmed as a strong predictor of transgression likelihood across all the five scenarios. This effect was particularly evident in the last high risk scenario, as pedestrians’ transgression likelihood was explained as enhanced by transgression likelihood perceived for various demographic groups of others. Thus comparative optimism has an important potential influence on decision-making.

Conclusions from the focus groups suggested that the perception of others’ likelihood to commit both errors and violations was associated with low moral value (i.e., “people are stupid”). It is therefore likely that biased perceptions about the general population are associated with descriptive rather than injunctive norms. Communication campaigns targeting changes in the descriptive norm by promoting
safe behaviour as a normal and widely adopted behaviour, should be considered, as pointed out by Forward (2009). It is also likely that such perceptions are rather influenced by information from media on previous occurrences, as illustrated in the second Case study presented in the focus groups (Paper 2), where pedestrians demonstrated a low perception of risk for the self as compared to what was perceived as the “stereotype” of a LC victim (i.e., an elderly woman). Therefore, it is to be further verified whether the available information around LC occurrences has an impact pedestrians’ perception of control. In a driving context comparative optimism was explained by the perception of being a more skilled driver than the average other (Harré et al., 2005). In a similar fashion and consistent with statements provided by the participant in case study 2 (i.e., the victim could not hear could not see), it is likely that pedestrians express comparative optimism in relation to the perception of being “in a better shape” than the average other. While there is a large amount of literature on the explanations and on the expression of biased comparative judgements, few studies investigate potential measures to reduce the expression of comparative optimism (Perrissol, Smeding, Laumond, & Le Floch, 2011). The most successful measures to reduce this precursor of unsafe behaviour would be those targeting the perceived controllability of the event, the perceived frequency and severity of the outcomes, and excessive self-enhancement, which all are essential factors contributing to the formation of comparative optimism (Harré et al., 2005; Kos & Clarke, 2001).

The results associated with the perceived risk of being issued a fine showed that predominantly younger pedestrians express comparative optimism vis-a-vis other younger or middle aged groups of pedestrians. This was consistent with findings from the focus groups suggesting that in general, pedestrians are likely to consider certain demographic groups of pedestrians as more likely to avoid legal sanctions (i.e., younger and elderly) than others. However, such perceptions did not explain increased transgression likelihood in any of the scenarios. Consequently, the impact of biased perceptions of deterrence towards other groups of users remains to be clarified. Experimental studies examining the perceived risk of sanction for specific others (e.g., male, female, child, minor, younger adult, elderly) in exactly the same situation would be best fit to provide evidence on the extent to which the perception of deterrence is biased and could potentially impact crossing decisions.
Consistent with findings from the focus groups, pedestrians expressed comparative optimism about the likelihood of being hit by a train. However, unexpectedly, these optimistic judgements had a negative effect on the reported transgression likelihood. The more others were perceived as vulnerable, the less participants reported transgression likelihood across different scenarios. Thus, the general perception of risk positively influences behaviour, although such results could be explained by social desirability bias. Participants expressing strong awareness of this risk could consider it socially desirable to report a lower transgression likelihood. Still, the perception of being less at risk than others deserves attention and more research on its impact on behaviour.

8.3.3.5 Perception of deterrence

Contrary to what has been suggested in the focus groups, the presence of another person crossing at the same time (in one of the scenarios) did not have an effect on the perceived likelihood of being issued a fine. The perception of deterrence could therefore depend less on the immediate presence of other offenders, but rather on the belief that people in general cross illegally. In contrast, the strongest perception of deterrence across the scenarios was reported for the situation where a train was about to stop at a station platform adjacent to the pedestrian corridor. This result emphasises the importance of situational factors on assessing the risk of legal sanction. For example, a stronger perception of deterrence could be explained by the presence of a train. In the LC context, pedestrians may associate the likelihood of being issued a fine with the presence of rail staff on the platforms at the approach of a train.

8.4 GENERAL CONTRIBUTIONS TO KNOWLEDGE

The cumulative results from the three studies succeeded in identifying risk-factors contributing to unsafe behaviour and provided a more comprehensible explanation of how they impact the cognitive (i.e., associated with the ability to act) and motivational (i.e., associated with goal directed behaviour) precursors of behaviour. This research program prioritised the study of the effects of interacting and context-specific factors on unsafe behaviour. The main findings building upon the knowledge from the literature are summarised in the following sections.
8.4.1 Interacting risk-contributing factors influencing unsafe behaviour at active level crossings

8.4.1.1 Status of the active controls and train’s position

Results from all three studies, based on data of different natures, support the assumption that pedestrians are likely to base their crossing decisions on information about the status of the active controls and the train’s position. Consistent results from the observations and the video survey support the idea that transgressions are most likely to occur before the pedestrian gates have started moving and in the absence of a visible train. However, evidence from the three studies also suggests that transgressions of closed gates are likely to be committed by regular transgressors and are associated with the presence of a stopped train. Although rarer, such transgressions deserve attention, as data from the observations also showed that pedestrians were equally likely to take the risk of crossing in front of a second train (i.e., multiple tracks) in the presence of active lights and sound and after the pedestrian gates were closed.

8.4.1.2 Location of the platforms and access to a train station

Descriptive data from the focus groups and the observations revealed different transgression trajectories according to the placement of the pedestrian corridors in relation to land use (e.g., schools, shopping districts) and other pedestrian facilities (e.g., road crossings, overpass, carpark). An innovative analysis of the results from the observations revealed that LCs with a lower number of transgressions accounting for exposure could be associated with riskier transgression patterns (i.e., taking more risk of crossing in front of a second train by crossing more rail tracks).

8.4.1.3 Vigilance and precautionary measures

Results from all three studies confirmed that pedestrians are most likely to transgress the activated lights and sound. However, self-reported data from the focus groups revealed potential issues with the salience and the interpretation of the pedestrian lights. This finding was confirmed by the self-reported data from the survey which was conducted with a larger sample of pedestrians, and therefore deserves attention from researchers and rail professionals. Specifically, this control was associated with the lowest recall among other signals. The poor recall of this signal was associated with increased transgression likelihood in the presence of others. Moreover, the poor understanding of the purpose of the pedestrian lights was
suggested to induce confusions at LCs with two corridors separated by middle islands and operated independently.

Further, participants’ lack of vigilance for the active controls was associated with high reported transgression likelihood in high risk situations with express trains and two trains approaching, suggesting that the increasing of vigilance for the active controls might need to be further targeted by safety communication campaigns. Similarly the absence of precautionary checks for trains explained increased transgression likelihood in the presence of others suggesting that the influence of descriptive norms on pedestrian behaviour is an important factor to be considered for further improvement.

8.4.1.4 Comparative judgements

The focus groups revealed the expression of comparative optimism with regards to the perception of risk of being hit by a train, as well as with regards to the perception of deterrence. These findings were confirmed in the survey which showed a stable tendency of the expression of comparative optimism among the larger sample of pedestrians. In addition, the survey showed that the expression of comparative optimism was a constant predictor of transgression likelihood in different crossing situations. Curiously, comparative optimism about others’ likelihood to be hit by a train predicted less reported transgression likelihood, which provides an interesting path to explore in search of effective measures for the reduction of unsafe behaviour. In addition, arguably the expression of comparative optimism was a reflection of the perception that transgressions are a common behaviour within the population of pedestrians at LCs, the reduction of which should be targeted by future safety measures.

8.4.1.5 Perception of deterrence

This is one of the first research programs to investigate to a certain extent the perception of deterrence at LCs. Self-reported data from the focus groups revealed that the perception of deterrence is likely to be reduced in the presence of other pedestrians. This result was not confirmed by the self-reported data from the survey. Instead, higher perception of deterrence was associated with crossing near a train station and with the presence of rail staff. This is an important result to be considered in future attempts to improve the effectiveness of deterrent measures, considering
that pedestrians from both the focus groups and the survey reported low perceived risk of sanctions.

8.4.1.6 Time pressure and frustration with waiting times

The results from the focus groups showed that pedestrians are likely to transgress during different journey contexts, and not only when they need to catch a train. Such results are consistent with the explanation of transgressions underpinned by frustration with waiting times. Conversely, results from the survey suggested that self-reported transgression likelihood is mainly underpinned by the need to catch a train. However, this discrepancy could be attributed to social desirability biases more likely to emerge during the completion of a survey than during discussions. Indeed the focus groups showed that pedestrians tend to generally attribute the behaviour of others (not present) “to reckless behaviour”, and see their own behaviour as justified. Therefore, given that during the discussions participants had the opportunity to hear the illegal experiences of other participants, they may have felt more comfortable sharing the real motivations of their unsafe behaviour than participants completing the survey alone.

8.4.1.7 Social influences

Results from the focus groups revealed that pedestrians are likely to adopt different behaviour according to whether they are surrounded by known or random others. Specifically, more precautionary measures were reported while in the presence of children than if crossing alone. Similarly, as discussed above (Section 8.4.1.3) results from the survey showed that transgression likelihood is likely to be affected by the presence of random others. Being used to transgressing in the presence of others was a significant predictor of transgression likelihood only in the scenario with a pedestrian crossing compliantly. This evidence not only underlines the important role of descriptive norms on crossing decisions, but highlights the potential for committing errors at intersections with separately operated crossing corridors on both sides of middle islands. Such evidence was also found in the focus groups.

8.4.2 Overview of the new PULC framework as an explanatory tool of pedestrian behaviour at LCs.

The PULC is a tool associating system factors with the precursors of behaviour of a critical actor (actor of interest). As such it distinguishes factors proper to the
actor from other system factors and particularly from factors related to the social environment. Unlike the traditional hierarchical system organisation proposed by J. Rasmussen (1997), the inclusion of the separate “Social environment level” in the PULC allows the in depth investigation of the behaviour of a particular type of actor, accounting for influences from the physical, social and organisational system environment. Such micro level analysis is unlikely to be achieved by the modern systems models.

Unlike the modern system models focusing on the detection of direct or latent factors contributing to an accident, the main objective of PULC is to explain how different factors influence decision-making. The cognitive and motivational precursors of behaviour are not necessarily identifiable within the typical chain of events preceding the action. The precursors of pedestrian behaviour at LCs are associated with past experience, perceptions and expectations. Consequently pedestrians are the most reliable source of such information. In the traditional retrospective accident investigation methods, the frontline actors are often the victims of accidents and thus unlikely to provide similar information. While implying the effects of risk factors on behaviour is a common practice, the modern systems-based models should not rely uniquely on such analysis. As already underlined, modern complex systems are dynamic. Systems performance changes and system components adapt differently to such changes. Analysts can only estimate the systems’ performance in terms of probabilities (Dekker et al., 2011). Thus, relying on what could be considered as “foreseeable” based on retrospective analysis is not sufficient or justified for the analysis of modern systems’ performance. In the case of the LC system, knowledge of the effects of diverse risk-contributing factors has been applied from other domains, or has rarely been empirically tested. To address this gap, the PULC framework was created as a tool for the proactive analysis of the system’s performance based on the retrospective analysis of past non-fatal occurrences.

In its first application, the PULC identified factors related to different components of the system which were likely to have a positive or negative impact on pedestrians’ perception of risk or motivations to transgress. Errors and violations were explained as underpinned by factors which are not commonly cited or investigated in the literature. Furthermore, one of the case study analyses
demonstrated the benefits of applying the PULC to the understanding of how people react to the implementation of systems procedures, and thus contributes to conclusions on the potential effect of such procedures (i.e., the effects of the dynamic system performance on decision-making). The influence of factors previously identified in the literature was detected in their interaction with other multiple factors. In other words, the PULC provided evidence on how the same factor could influence behaviour differently in the presence or absence of other personal or contextual factors.

The first application of the framework to the analysis of the qualitative results from the focus groups was motivated by the aim to produce a first classification of a broad range of risk-contributing factors associated with different precursors of behaviour. The understanding of precursors of behaviour requires a detailed description of the situation when a transgression occurs, but also of the physical and mental states of the transgressor, of the surrounding social environment and a good understanding of pedestrians’ crossing history (experience). To address the lack of existing data on precursors of behaviour associated with a broad range of risk-contributing factors collected from the same source, focus group discussions with a small number of participants were conducted. This method enhanced the collection of extensive data on factors related to the individual transgressions and how they influenced crossing decisions. Given that each discussion was lengthy and time consuming, only a limited number of focus groups could be conducted. Therefore, after its first application, the framework should not be considered validated. In addition to the small number of participants for the focus groups, this particular group of participants was unlikely to provide information on factors associated with the higher system levels. To validate the framework further, it could be applied to data from larger and more representative samples of the population and equally to rail staff. Further applications of the framework on larger databases could provide more generalisable conclusions, and thus identify the most critical sources of potential system failures that require immediate action. Various other data sources can be used in a similar proactive manner. Arguably, data sources obtained from specialists in different system domains would provide a most complete and extended illustration of the systems’ performance. For example, QR collects users’ feedback on various aspects of the system performance and under different forms (e.g., safety
discussions, open days, website feedback forms etc.). In addition, the framework can be adapted for research on behaviour at passive LCs, or for research in other domains, and can support various interpretations of the collected data according to the research questions.

In this second study, the research objective was exploratory, and thus various methods were applied to the interpretation of the results. Three illustrations of how the PULC could be applied to generate results of specific interest were presented. First, a detailed classification of factors from all system levels influencing errors and/or violations was proposed. This classification was complementary to the generic PULC, providing a detailed list of system components associated with the emergence of risk-contributing factors. Second, graphical representations of the interacting factors contributing to safe and unsafe behaviour were presented. This analysis allowed identifying different types of factors influencing errors and violations. Moreover, it depicted differences in the explanations of unsafe behaviour if a person was talking about his/her own behaviour or about others’ behaviour. Most importantly, it identified the most common interactions between factors explaining unsafe behaviour. Arguably, these interactions corresponded to the most influential factors to decision making, which would require action or further research. For instance, the PULC identified the status of the controls versus train position as having an important role in decision-making and supported the development of the methodology of study 3 in which these two variables were operationalized in five different crossing scenarios. Third, the PULC supported the analysis of two case studies of unsafe behaviour using AcciMaps. In each case study the precursors of behaviour were identified in addition to the actions and decisions preceding the transgression. Thus, the PULC supported a novel application of the widely used AcciMaps technique. Finally, the selected precursors of unsafe behaviour identified through the PULC for further in depth investigation in Study 3 were to a large extent confirmed, specifically the important role of comparative judgments, not only in relation to transgression likelihood but also in relation to the perception of risk of being hit by a train and of being sanctioned, the low perception of deterrence, the poor recall and understanding of pedestrian lights, and to a smaller extent the abundance of active and passive controls generating confusions.
8.5 GENERAL PRACTICAL CONTRIBUTIONS

The cumulative quantitative and qualitative results from the studies revealed potential flows in the system’s performance requiring attention from authorities and experts in different fields. Considering that the conclusions from any of the qualitative studies cannot be considered as representative of the larger population, two issues were identified as supported by qualitative and quantitative evidence. Additionally, improvements at specific LC sites are suggested based only on qualitative data. In summary they are:

- Poor salience of pedestrian lights, especially when installed at intersections that have a middle island. In the same vein, issues with the information provided about the purpose of the pedestrian lights.

- Poor awareness of the illegal sanctions applied for transgressions at LCs. Moreover, issues with the implementation of sanction procedures, which are likely to be perceived as infrequent events and/or as events occurring only in close proximity to train stations and during closures.

- Inadequate station access at LCs requiring optimization of the location of pedestrian corridors or global redesign of the environment (e.g. Wynnum Central overpass is too far from the main road, Cannon Hill lacks an overpass connecting the middle platform with the nearby carpark and Coorparoo has less than adequate placement of a road intersection crossing, given the characteristics of the population of the, school children who are frequent users).

8.6 BENEFITS OF THE ADOPTED SCIENTIFIC APPROACH AND METHODS

The benefits of using qualitative and quantitative methods in a common system centred approach are reviewed in the following paragraphs. According to the principles of the systems approach, research should examine all aspects of the system performance in order to identify the sources of failure (Salmon & Lenné, 2015; Salmon et al.). In reality it has been recognised that because complex systems are dynamic (adaptive) and have variable performance, a complete description of the system state is never possible and research methods are none the less likely to accurately predict the future system performance (Dekker et al., 2011; Read et al.,
2013). Similarly, according to Wilson (2014, p. 12) even the term “system” often implies “dealing with a number of constituent parts rather than being holistic”. The adopted approach and implemented methods within the scope of this thesis acknowledges the influence of a great number of factors potentially influencing pedestrian behaviour at LCs, and facilitated their investigation.

8.6.1 Benefits of applying a systems based approach combined with theories and methods from the traditional individual centred approach

As stated by Salmon et al. (2013, p. 1287), although systems-based models of accident investigation provide an exhaustive view on the system’s performance and on the failures of specific components, they also “lose the fine grained analysis provided by individual, psychological accounts”. Therefore, the complementary application of systems and individual approaches are recommended, although it is currently a rather common practice in LC safety domain to adopt one or the other approach or to compare them (Salmon et al.). Arguably, systems models tend to overlook the benefits of using traditional individual-centred research methods with regards to the proactive analysis of accidence occurrence and prevention. On the other hand, traditional individual-centred approaches fail to acknowledge and account for changes in behaviour due to multiple causes and their interactions. In completing this PhD programme, it was demonstrated that respecting the principles of both approaches is feasible and in fact defines a framework consistent with the research objectives. Theories of risk perception and risk taking were used to critically evaluate multiple (potential) precursors of unsafe behaviour, related not only to humans’ attributes (e.g., attitudes, expectations) but also to the social and physical environment of the LC context and to the organizational characteristics of the system (e.g., legal sanctions).

8.6.2 Benefits of using Qualitative and Quantitative methods as complementary data collection and analysis methods

The first exploratory stage of research was based on qualitative data which helped to identify a wide range of factors influencing behaviour, as well as relating them to specific precursors of behaviour, thus providing a better understanding of why transgressions occur. Qualitative data made possible a more complete description of risk prone situations defined by different interacting factors. Some of the risk situations could be considered as more frequently occurring (i.e., related to
rail traffic characteristics) than others, associated with rare events such as social events (i.e., influencing the density of pedestrian traffic) or technical failures of the equipment. Thus, qualitative data was suitable to reveal “latent” failures of the systems performance. Information on the various combinations of factors creating conditions for errors or violations is unlikely to be part of official LC accident investigation reports, which are often limited to a generic list of potential risk contributing factors. Used as a first support for the application of the PULC, qualitative data from the focus group discussions has proven to be a valuable source of detailed information on a multitude of aspects of the “current” system performance and thus a suitable basis to conduct a systems-based analysis.

Qualitative data provided an extended database for more in depth empirical research on recurring issues of the systems performance. The exploratory stage of research helped to discern various areas of interest to be investigated together in the next empirical stage of research. Thus in compliance with a systems-based approach, the empirical stage of research examined the influence of various factors on pedestrian behaviour, although the list (of factors) cannot be considered exhaustive.

The articulation of qualitative and quantitative methods in a complementary manner has been pointed to as a highly valuable approach in the domains of behavioural and human sciences (Creswell, Shope, Plano, & Green, 2006). According to the same authors, the frequently criticised qualitative approach provides much needed input on the development of quantitative measures, strengthens the causal relationships between variables, and makes research context globally more explicit.

8.7 LIMITATIONS

A number of limitations related to this research program are to be taken into consideration. First, although direct observations provide a large amount of descriptive data, they are also associated with subjectivity biases. It is possible that the presence of observers influenced pedestrian behaviour even though the least obvious observers’ positions were selected and the observers were as discrete as possible in coding the variables. The direct observations were systematic, but were also conducted in limited timeframes, i.e. only during peak hours. Therefore, they are not a reliable source of information on pedestrian behaviour outside of peak hours.
While the omission of data outside of peak times at these specific LC sites was carefully considered and accepted (i.e., because of the much lower rail traffic and pedestrian traffic density), the inclusion of observations of pedestrian behaviour outside of peak zones is recommended for future observations at busier LC intersections. The observations were also conducted at a limited number of LCs - three black spot LCs. Therefore, the generalizability of the data is questionable, because even though the selected LCs are considered to be representative of the most problematic intersections in Brisbane, this method provides no information on potentially different factors increasing transgressions at “safer” LCs and at LCs with different rail traffic characteristics. Observations at multiple LCs from each rail metropolitan line would be more suitable to provide a more accurate estimation on the prevalence of transgressions in Brisbane area. Finally, because of the limited number of observers that could be involved, the adopted study procedure (i.e., each observer had to code different variables) did not allow for iter-rater reliability scores to be calculated. However, to reduce reliability bias all observers were instructed to note as many variables as possible if the situation allowed (i.e., if they had the time), in order to be able to resolve issues of uncertainty during the coding of the results, which was done immediately after the end each observation and in the presence of all observers (i.e., one dictating, one entering data and one verifying).

Second, the focus groups were based on qualitative data from a small sample of participants. Although rich in content, this data was subject to biases in self-reported measures. People’s responses are often biased with regards to questions of a sensitive nature such as illegal crossing (Kahan, 1997; Maccoby & Maccoby, 1954). Consequently, pedestrians could have provided their responses in accordance with what is considered to be “correct” or socially accepted behaviour. To the author’s knowledge, an attempt to compare results from self-reported data with data from direct observations was made in only one study in the domain of LC safety (Metaxatos & Sriraj, 2013b). The results were consistent and in line with the obtained results in this research program, showing that pedestrian gates have a strong deterring effect on transgressions. However, inconsistencies between some of the conclusions drawn from the observations, the focus groups and the quantitative study were noted. Consequently, data from the exploratory stage of research is to be
regarded and interpreted with caution and could not be considered as generalisable to the larger population.

Although the empirical data from the survey study could also be subject to social desirability bias, the private setting of data collection could have diminished the effect of the bias (Lajunen & Summala, 2003). The survey was completed by a larger sample of pedestrians usually crossing at multiple LC sites on different rail lines. The conclusions can therefore be considered as generalisable to the larger population of pedestrians in Queensland, although this could be further verified with information about the general characteristics of LC users (e.g., average number per LC site, demographic characteristics, frequency of use). Finally, the conclusions associated with the video scenarios are to be interpreted with caution as it is possible that participants perceived or interpreted the recorded situations differently, even though a pre-test was conducted to validate the visibility and the correct understanding of the key variables to be considered.

8.8 FUTURE RESEARCH DIRECTIONS

Although the results from this research program indicated some factors potentially associated with errors (e.g., salience of the controls, less than optimal operation mode of the pedestrian lights at middle islands), more in depth research is to be undertaken on the understanding of the different types of errors and the conditions under which they occur. Research with experimental design could examine the recall of the active controls across different crossing situations.

In terms of deliberate transgressions, contrary to previous evidence, the conclusions from this research program suggest that a stopped train is not necessarily more associated with a lower risk perception than a visibly approaching one. Further research should investigate the distance and the time to train arrival at the LC. This can be achieved experimentally in simulation studies asking pedestrians to directly assess the distance to an approaching train arrival in various contexts (e.g., trains approaching at different speeds, presence of station platform, different distance of crossing corridor or different length of the station platform).

More research is needed to provide a better understanding of pedestrian behaviour in the presence of others. The conclusions from the three studies indicated that the presence of others is not only likely to increase unsafe crossing behaviour,
but reduces the adopted precautionary measures (e.g., vigilance, checks for trains for controls). Moreover, pedestrians act differently in the presence of known and random others, but also in the presence of rail staff. Future studies could examine the simple and cumulative effect of the presence of different others. More precisely, it is important to better understand whether the presence of others has more effect on the perception of deterrence or on the perception of risk.

In addition, it was shown that pedestrians perceive others in general as more likely to transgress and as more likely to be victims of fatal incidents. These perceptions were likely to have both positive and negative effects on unsafe pedestrian behaviour. Bandura’s social learning theory could be an appropriate theoretical framework to underpin future research on that matter, as the model explains the cognitive and motivational precursors of behaviour in a social context (Bandura & McClelland, 1977).

More research is needed to support future education campaigns. Safety campaigns including specific messages about concrete factors in the environment enhancing violations or other personal characteristics could be more successful than existing messages containing generic slogans which often target the larger population (Figure 38). For a safety campaign to be successful, it is recommended that the targeted group or subgroup of users can identify themselves with the actor and the content of the message (Delhomme, De Dobbeleer, et al., 2009). Although behavioural changes targeted by education and safety campaigns can be expensive and time-consuming, safety messages and styles tailored to the targeted demographic groups of pedestrians could be successful in the long term. Future research could examine how different demographic groups of users respond to such measure.
Note. This message is a reference to the 472 white crosses displayed at Post office square (Brisbane) in 2012 as an illustration of the reported number of near-misses at LCs in the previous year.

Figure 38. “Don’t gamble with your life” poster displayed at major train stain station in Brisbane.

8.9 GENERAL CONCLUSION

The need to conduct research in the area of pedestrians’ safety at LCs has been recognised by academics and professionals worldwide (Barker, 2015; Beanland et al., 2013). To date, the investigation of unsafe pedestrian behaviour has suffered from the underestimation of the multitude and the variability of factors likely to shape decision-making across crossing situations. It is important to fully understand how the presence of different factors influences behaviour and to what extent their influence varies from one situation to another.

To achieve that, a detailed description of the current crossing context is essential and imposes a great challenge, given that there are no two identical LCs. Thus, unlike a large part of the existing literature, future research should consider the importance of describing the specific crossing context and focus on the investigation of the precursors of behaviour in a multitude of crossing contexts, rather than listing (potential) risk-factors generalisable to all hypothetical crossing situations. Extended knowledge of the precursors of behaviour under different influences may support the proactive investigation of human reactions to new technical or other changes in the environment, or in rail operations. In addition, proactive research is beneficial to safety improvement as it allows the anticipation of “emerging” risk contributing factors across all system levels.

Addressing both the lack of descriptive information about risk contributing factors and the lack of empirical evidence on how these factors influence behaviour, the adopted research approach and methods in this thesis were innovative for the domain. Considering that there is a small number of existing publications, the
collected and explored data within this thesis adds to both the current academic and professional knowledge pools.

This research program provided evidence for the first time on a number of interacting risk-contributing factors to unsafe behaviour. The conducted observational study included an analysis of transgression patterns according to the LC design in addition to the commonly examined variables associated with the frequency of transgressions. Moreover, the innovative method of data analysis revealed results with important implications for future safety measures. A new theory based model (PULC) was proposed for the investigation of unsafe behaviour, allowing the identification of the precursors of behaviour influenced by specific risk contributing factors. The model supported the illustration of two case-studies published in Stefanova, Burkhardt, Filtness, et al. (2015), highlighting its utility in identifying “current” failures in multiple aspects of LC performance. The final empirical study provided an illustration of how individual-centred research designs could be applied to the in depth investigation of the origins of unsafe behaviour accounting for the influence of multiple risk contributing factors. The results from this study confirmed an important number of results from the exploratory stage of research and provided evidence that can be generalised to the larger population of pedestrians in Queensland. The utility of such methods following exploratory studies (applying the PULC) was confirmed.

Although not generalisable to all LC contexts (i.e., passive LCs, foreign LCs with different designs of controls), the outcomes of this research program provide a basis for further research opportunities in the much wider railway domain. Specifically, the proposed generic PULC framework can be adapted to suit the needs of professionals and researchers facing the challenge of various railway safety issues, be they technical (e.g., detecting inadequacies in the functioning of railway equipment), social (e.g., detecting flows in communication between frontline actors and higher-level staff) or behavioural (e.g., detecting inadequate actions of rail staff or users and the potential causes).

In conclusion, although inadequacies were identified in the systems procedures (e.g., sanctions procedures) and environment (e.g., sub optimal station access points, salience of controls and provided information), the overall results suggest that human error is the origin of unsafe behaviour. As Pope (1749, p. 66) said, “To err is human,
to forgive, divine”. Not only errors, but also violations seem to be underpinned by erroneous expectations and attitudes towards safety at LCs. Therefore, it is the systems’ responsibility not to blame the human for his/her aberrant actions, but to provide adequate measures for reducing them. Safety interventions of any kind will be more effective if supported by theoretical frameworks, preliminary empirical research, and rigorous data collection methods. The studies conducted in this program, illustrate the multiple benefits of the in depth investigation of the origins of unsafe behaviour through different methods, for future research initiatives and practical safety interventions. There is no simple solution for the complex problem of pedestrian behaviour at LCs, but together, academia and industry can work towards improving safety in the long term.
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## Appendices

### Appendix A. Literature review

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<th>Country (Government/Industrial body)</th>
<th>Research type/design (data type)</th>
<th>Considered users (distinction)</th>
<th>Outcome (measured variables)</th>
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<td>2015</td>
<td>Journal article</td>
<td>Australia</td>
<td>Descriptive (survey)</td>
<td>pedestrians</td>
<td>Analysis of risk contributing factors to pedestrian unsafe behaviour</td>
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<td>Journal article</td>
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<td>Descriptive-Correlational (video observations)</td>
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Appendix B. Transgressions observation sheet
### Appendix C. Train times observation sheet

#### Coorparoo - Train Times

**Date:** 15/05/2018  
**Shift:** AM / PM

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<td>Exp</td>
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<td>05</td>
<td>10 / 11</td>
<td>05 / 11 / 12</td>
</tr>
</tbody>
</table>

#### Closures N. 131

<table>
<thead>
<tr>
<th>Closure N.</th>
<th>N</th>
<th>PL</th>
<th>Direction</th>
<th>Type</th>
<th>LC</th>
<th>Station - Stop</th>
<th>Station - Go</th>
</tr>
</thead>
<tbody>
<tr>
<td>112</td>
<td>1</td>
<td>CITY</td>
<td>Exp Stop</td>
<td>-</td>
<td>05</td>
<td>10 / 11</td>
<td>05 / 11 / 12</td>
</tr>
<tr>
<td>120</td>
<td>2</td>
<td>CITY</td>
<td>Exp Stop</td>
<td>-</td>
<td>05</td>
<td>10 / 11</td>
<td>05 / 11 / 12</td>
</tr>
<tr>
<td>119</td>
<td>3</td>
<td>CITY/CLEV</td>
<td>Exp</td>
<td>-</td>
<td>05</td>
<td>10 / 11</td>
<td>05 / 11 / 12</td>
</tr>
</tbody>
</table>
Appendix D. Pre-established categories of variables used for questioning during the Focus groups

<table>
<thead>
<tr>
<th>Themes of questions</th>
<th>Example of questions</th>
<th>Corresponding content in participants’ verbatim</th>
<th>Examples of quote</th>
</tr>
</thead>
</table>
| I. Usual crossing behaviour : Familiarity, Usual crossing trajectory and journey purposes | How often do you cross at level crossings? Which level crossing/s?                                         | Frequency, regularity, time of crossing                                   | “so if we park on the top side than we have to get to there in the afternoon crossing both lines”;
                                                                 | Do you take the train?                                                                                     | Trajectory of crossing (side of crossing, number of tracks, access to platforms, overbridge) | “I have to cross most of the time 3 or 4 times a week including weekend and sometimes 5 times a week because I always catch the train and I’m going there to catch the train or get out from the station”;
                                                                 | Describe your trajectory? Are you using the overpass?                                                     | Crossing with/among others.                                                   |
                                                                 | At what time of the day are you most likely to cross?                                                     | Habitual crossing purpose (to catch a train, to cross the tracks).         |
                                                                 | Do you normally cross alone or with others- with someone you know or are with or with random pedestrians? | Habitual journey purpose (go to work, leisure, school)                     |
| II. Safety checks : Attentional resources, precautionary measures, vigilance during usual crossing     | Is it easy to notice the activation of the automatic warnings?                                             | Salience /Recall of controls (signs, automatic warning devices)            | “I always watch both ways for trains”;                                           |
                                                                 | Are pedestrian light visible enough even with bright sunlight?                                           | Safety checks and perceived reliability of controls                          | “since the accident it doesn’t matter how late they are or not [trains] they all slow down before they come to the crossing”;
                                                                 | Do you check for approaching train if the warnings are not activated?                                     | Internal/External distractions.                                               | “I didn’t know there were lights! ... so obviously It’s hard to see!”;
                                                                 | Is it possible to miss the activation of the warnings if you are distracted by something –external noise, phones, others? | Visual obstacles at the LC site (angle of sight, LC infrastructure, design). |
                                                                 | Is the period between the activation of the warnings and the train arrival long enough?                   | Knowledge about rail traffic characteristics                                |                                                                                   |
III. Unsafe behaviour: Description and argumentation of unsafe behaviour, be it intentional or unintentional

Have you ever crossed the tracks when at least one of the automatic warnings was activated?... tell me more : when, why, what exactly happened?

Were you confident that you can make it before the train arrives?

Could you see the train coming? Have you crossed when the train was visibly approaching?

Were the gates already closed? Have you done that when they were?

Do you often see others crossing during the automatic warnings’ activation?

Is there a particular risk group?

Describe what have you seen: do you remember the time, the trajectory?

IV. Sanctions: Knowledge about sanctions' amount procedure and staff. Deterrence effect

Have you ever been fined for crossing while automatic warnings activated?

Did you know that such fine exists?

Do you know someone who has been fined?

Do you know who can apprehend you, the amount?

Have you been fined for other rail infringements?

How likely do you think are people to be fined if they cross illegally at LCs?

Frequency, Regularity, Time (day), Moment (in relation to the activation of the controls) of reported unsafe crossing. Weather conditions

Trajectory (pedestrian path/road lane, diagonal), Crossing with/among others.

Crossing purpose (catch a train; cross), Journey purpose (time pressure: going to work)

Perception of risk (Estimations of train speed, train position and visibility).

“for me it’s a normal day, and I’m just running late- it took a little bit longer in the supermarket and I’m running running and running and for me it would be the middle if the day not a peak hour and its just if you are running late if you need an extra 30 seconds to get to there”;

“if you are like 40 meters away that’s – you still have a couple of seconds”;

“I got caught , and I got penalized I didn’t see the guard … Ill never do it again , but I had time”

V. Safety campaigns

Have you ever been informed about the safe use of LCs?

How?

What do you think

Reported past apprehension for illegal crossing at LC or for other type of rail infringement (on train, at station, as a driver).

Knowledge and attitudes about the amount of penalty, the procedure (issuing and paying), and the authorised staff to apprehend pedestrians.

Perception of risk (deterrence)

“I think there is not enough campaign I think you need to bring it to the public because the actual photos they have – I don’t think
<table>
<thead>
<tr>
<th>VI. Past occurrences at LCs</th>
<th>Have you ever experienced false alerts?</th>
<th>Knowledge/opinions in relation to past occurrences (false alerts, past collisions with pedestrians, vehicles, LC infrastructure)</th>
<th>Perceived likelihood of occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>“the old lady she couldn’t hear it she pushed the gate – she got killed at Wynnum Central”</td>
<td></td>
</tr>
</tbody>
</table>
Variables selected for each regression analysis in Study 3, based on Chi-square tests between the variables related to candidate cognitive and motivational precursors of unsafe behaviour, previous self-reported unsafe behaviour and the dependent variable in each regression respectively: the profile of frequent transgressors (Regression 1) and transgression likelihood for each scenario (Regression 2-6).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression 1 Regular transgressors profile</th>
<th>Regression 2 Predictors of transgressions of lights and sound</th>
<th>Regression 3 Predictors of transgressions of closing gate</th>
<th>Regression 4 Predictors of transgressions in the presence of stopped train</th>
<th>Regression 5 Predictors of transgressions in the presence of express train approaching and safe crossing pedestrian</th>
<th>Regression 6 Predictors of transgressions in the presence of two trains approaching from opposite directions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>Fisher = 11.11, p&lt; .016, V^2 = .05</td>
<td>Fisher = 13.49, p&lt; .004, V^2 = .06</td>
<td>Fisher = 58.29, p&lt; .000, V^2 = .28</td>
<td>Fisher = 55.49, p&lt; .000, V^2 = .29</td>
<td>Fisher = 27.91, p&lt; .000, V^2 = .13</td>
<td>Fisher = 14.6, p&lt; .003, V^2 = .07</td>
</tr>
<tr>
<td>Hurry crossing</td>
<td>Fisher = 12.51, p&lt; .007, V^2 = .06</td>
<td>Fisher = 17.22, p&lt; .000, V^2 = .07</td>
<td>Fisher = 36.07, p&lt; .010, V^2 = .05</td>
<td>Fisher = 11.7, p&lt; .010, V^2 = .05</td>
<td>Fisher = 30.55, p&lt; .000, V^2 = .16</td>
<td>Fisher = 17.16, p&lt; .001, V^2 = .08</td>
</tr>
<tr>
<td>Could make it</td>
<td>Fisher = 28.27, p&lt; .000, V^2 = .15</td>
<td>Fisher = 18.95, p&lt; .004, V^2 = .08</td>
<td>Fisher = 23.63, p&lt; .006, V^2 = .05</td>
<td>Fisher = 13, p&lt; .006, V^2 = .05</td>
<td>Fisher = 33.07, p&lt; .000, V^2 = .16</td>
<td>Fisher = 17.15, p&lt; .001, V^2 = .07</td>
</tr>
<tr>
<td>Others crossing</td>
<td>Fisher = 22.31, p&lt; .000, V^2 = .11</td>
<td>Fisher = 17.42, p&lt; .001, V^2 = .07</td>
<td>Fisher = 28.91, p&lt; .002, V^2 = .06</td>
<td>Fisher = 15.3, p&lt; .002, V^2 = .06</td>
<td>Fisher = 43.25, p&lt; .000, V^2 = .21</td>
<td></td>
</tr>
<tr>
<td>Raining</td>
<td>Fisher = 14.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Visibility controls

| Visibility controls | \( \chi^2(2, N=222) = 6.56, p< .037, V^2 = .03 \) | Fisher = 15.12, p< .002, V^2 = .06 | Fisher = 15.57, p< .002, V^2 = .07 | Fisher = 11.98, p< .010, V^2 = .05 |

### Recall Ped.lights

| Recall Ped.lights | \( \chi^2(2, N=222) = 5.59, p< .062, V^2 = .02 \) | Fisher = 15.12, p< .002, V^2 = .06 | Fisher = 15.57, p< .002, V^2 = .07 | Fisher = 11.98, p< .010, V^2 = .05 |

### Purp. Ped.light


### Purp. Ped gate


### Sanction Likelihood

| Sanction Likelihood | \( \chi^2(4, N=222) = 13.63, p< .007, V^2 = .06 \) | Fisher = 16.08, p< .001, V^2 = .01 | Fisher = 12.68, p< .006, V^2 = .06 | Fisher = 24.85, p< .000, V^2 = .12 |

### Vigilance

| Vigilance | \( \chi^2(4, N=222) = 11.61, p< .014, V^2 = .05 \) | Fisher = 29.11, p< .000, V^2 = .12 | Fisher = 34.55, p< .000, V^2 = .15 | Fisher = 22.94, p< .000, V^2 = .1 |

### Train check (IN)


### Train check(AC)

| Train check(AC) | Fisher = 34.48, p< .000, V^2 = .2 | Fisher = 24.45, p< .000, V^2 = .12 | Fisher = 29.46, p< .000, V^2 = .16 | Fisher = 10.83, p< .000, V^2 = .05 |

### Trans. Closing gate

| Trans. Closing gate | Fisher = 34.48, p< .000, V^2 = .2 | Fisher = 24.45, p< .000, V^2 = .12 | Fisher = 29.46, p< .000, V^2 = .16 | Fisher = 10.83, p< .000, V^2 = .05 |

### Trans. Closed gate


*Note.* Only the variables where the result from the Chi-square test is presented in the table were selected.
Appendix F. Variables selected for each regression analysis in Study 3 related to the reported perception of risk for the self and for others and the perceived transgression likelihood for others in each scenario.

The selection is based on significant differences in the comparative judgements.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression 2 Predictors of transgressions of lights and sound</th>
<th>Regression 3 Predictors of transgressions of closing gate</th>
<th>Regression 4 Predictors of transgressions in the presence of stopped train</th>
<th>Regression 5 Predictors of transgressions in the presence of express train approaching and safe crossing pedestrian</th>
<th>Regression 6 Predictors of transgressions in the presence of two trains approaching from opposite directions</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the Self</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiving a fine</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Being hit by a train</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>For Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trans.Male.Under 25</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Trans.Male26-55</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Trans.Male56-75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Trans.Female.Under 25</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Category</td>
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<td>75+</td>
<td>76+</td>
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<tr>
<td>--------------------------------</td>
<td>---------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>Trans.Female 56-75</td>
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<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Fine.Male.Under 25</td>
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<td>✓</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fine.Male 76+</td>
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<td>✓</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Fine.Female.Under 25</td>
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<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit by train.Male 56-75</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit by train.Male 76+</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit by train.Female 56-75</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit by train.Female 76+</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
Appendix G. Descriptive statistics on comparative judgements about transgression likelihood reported by male under 55 years old (y.o.)

Descriptive statistics on the significant results from the repeated measures ANOVAs comparing the reported transgression likelihood by male participants under 25 years old and between 26 and 55 years old, with the transgression likelihood they perceived for other pedestrians of different demographic groups.

<table>
<thead>
<tr>
<th>Perceived likelihood for the SELF</th>
<th>Perceived likelihood for others</th>
<th>-25y.o.</th>
<th>26-55y.o.</th>
<th>56-75y.o.</th>
<th>76+ y.o.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender  Age  N  SC  M  SD</td>
<td></td>
<td>male</td>
<td>female</td>
<td>male</td>
<td>female</td>
</tr>
<tr>
<td>male -25  44</td>
<td></td>
<td>1.91</td>
<td>3.55***</td>
<td>3.32***</td>
<td>3.20***</td>
</tr>
<tr>
<td>p&lt;.01  p&lt;.000  p&lt;.01</td>
<td></td>
<td>1.41</td>
<td>3.02***</td>
<td>2.66***</td>
<td>2.59***</td>
</tr>
<tr>
<td>1.91</td>
<td></td>
<td>.98</td>
<td>1.15</td>
<td>1.07</td>
<td>1.12</td>
</tr>
<tr>
<td>p&lt;.01  p&lt;.01</td>
<td></td>
<td>1.36</td>
<td>2.86***</td>
<td>2.61***</td>
<td>2.48***</td>
</tr>
<tr>
<td>.91</td>
<td></td>
<td>.94</td>
<td>1.23</td>
<td>1.12</td>
<td>1.21</td>
</tr>
<tr>
<td>p&lt;.05  p&lt;.05</td>
<td></td>
<td>1.5</td>
<td>3.2***</td>
<td>2.93***</td>
<td>2.82***</td>
</tr>
<tr>
<td>1.08</td>
<td></td>
<td>.94</td>
<td>1.28</td>
<td>1.16</td>
<td>1.13</td>
</tr>
<tr>
<td>p&lt;.01  p&lt;.05</td>
<td></td>
<td>1.39</td>
<td>3.02***</td>
<td>2.66***</td>
<td>2.5***</td>
</tr>
</tbody>
</table>

| male 26-55  61 |                                | 2.74*** | 3.48***   | 3.21***   | 2.85***   | 2.46***  | 2.23     | 2.05     | 1.95     |
| p<.000  p<.000  p<.01           |                                | 1.26    | 3.08***   | 2.67***   | 2.38***   | 2.11***  | 1.59*    | 1.48     | 1.36     | 1.3      |
| 1.39   |                                | .72     | 1.21      | 1.17      | 1.18      | 1.08     | .97      | .89      | .81      | .66      |
| p<.001  p<.01            |                                | 1.3     | 2.95***   | 2.69***   | 2.44***   | 2.2***   | 1.8***   | 1.66**   | 1.49     | 1.44     |
| .8     |                                | .8      | 1.25      | 1.16      | 1.19      | 1.01     | 1.06     | .91      | .9       | .8       |
| p<.001  p<.01            |                                | 1.23    | 3.13***   | 2.64***   | 2.39***   | 2.07***  | 1.66**   | 1.48*    | 1.36     | 1.28     |
| .69    |                                | 1.19    | 1.09      | 1.13      | .96       | .85      | .69      | .73      | .73      | .52      |
Note.

SC – Scenario number. A significant difference between the reported scores for the self versus others is marked with stars: * $p<.05$, ** $p<.01$, ***$p<.000$. A significant difference in the perceived crossing likelihood for other males versus females of the same age group is directly reported under the corresponding cells ($p<$.)

<table>
<thead>
<tr>
<th></th>
<th>$p&lt;.000$</th>
<th>$p&lt;.001$</th>
<th>$p&lt;.05$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.18</td>
<td>3.02***</td>
<td>2.69***</td>
</tr>
<tr>
<td></td>
<td>.64</td>
<td>1.13</td>
<td>1.14</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>1.28</td>
<td>.74</td>
<td>.74</td>
</tr>
</tbody>
</table>
Appendix H. Descriptive statistics on comparative judgements about transgression likelihood reported by female under 55 years old (y.o.)

Descriptive statistics on the significant results from the repeated measures ANOVAs comparing the reported transgression likelihood by female participants under 25 and between 26 and 55 years old, with the transgression likelihood they perceived for other pedestrians of different demographic groups.

<table>
<thead>
<tr>
<th>Perceived likelihood for the SELF</th>
<th>Perceived likelihood for others</th>
<th>25y.o.</th>
<th>26-55y.o.</th>
<th>56-75y.o.</th>
<th>76+y.o.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender Age</td>
<td>N</td>
<td>SC</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>female -25</td>
<td>42</td>
<td></td>
<td>2.02</td>
<td>3.29***</td>
<td>3.17***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.42</td>
<td>1.43</td>
<td>1.41</td>
</tr>
<tr>
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<td>1.48</td>
<td>2.9***</td>
<td>2.86***</td>
</tr>
<tr>
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<td>.77</td>
<td>1.32</td>
<td>1.2</td>
</tr>
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<td></td>
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<td>1.43</td>
<td>2.81***</td>
<td>2.60***</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>.8</td>
<td>1.23</td>
<td>1.27</td>
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<tr>
<td></td>
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<td></td>
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<td>1.34</td>
<td>1.19</td>
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</tr>
<tr>
<td>female 26-55</td>
<td>55</td>
<td></td>
<td>2.24</td>
<td>3.55***</td>
<td>3.33***</td>
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<tr>
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<td>3.04***</td>
<td>2.82***</td>
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<td>.99</td>
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<tr>
<td>female 76+y.o.</td>
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</table>

Note. SC – Scenario number. A significant difference between the reported scores for the self versus others is marked with stars: * p<.05, ** p< .01, *** p< .000. A significant difference in the perceived crossing likelihood for other males versus females of the same age group is directly reported under the corresponding cells (p<)
Appendix I. Descriptive statistics on comparative judgements about transgression likelihood and risk perception reported by male and female over 56 years old (y.o.)

Descriptive statistics on the significant results from the repeated measures ANOVAs comparing the reported transgression likelihood and perception of risk by participants over 56 years old (N=20), with the likelihood they perceived for other pedestrians of different demographic groups

<table>
<thead>
<tr>
<th>Transgression likelihood</th>
<th>SC</th>
<th>M (SD)</th>
<th>Perceived likelihood for the SELF</th>
<th>Perceived likelihood for others</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td></td>
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<td></td>
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</tr>
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<td>3.2***</td>
<td>3.05***</td>
<td>2.75***</td>
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<td>2.15***</td>
<td>1.65*</td>
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</tr>
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<td>2.6***</td>
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<td>2.55***</td>
<td>2.25**</td>
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<td>5</td>
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<table>
<thead>
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<th>Likelihood of being hit by a train</th>
<th>SC</th>
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<th>Perceived likelihood for the SELF</th>
<th>Perceived likelihood for others</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>-25y.o. 26-55y.o. 56-75y.o. 76+y.o.</td>
<td>male female male female male female</td>
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</table>

Note. SC – Scenario number. A significant difference between the reported scores for the self versus others is marked with stars: * p<.05, ** p< .01, ***p<.000
Appendix J. Descriptive statistics on comparative judgements about the likelihood of being issued a fine by all participants

Descriptive statistics on the significant results from the repeated measures ANOVAs comparing the reported likelihood of being issued a fine by male and female participants under 25 and between 26 and 55 years old, with the likelihood they perceived for other pedestrians of different demographic groups.

<table>
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<th>Sc</th>
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<th>M</th>
<th>SD</th>
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<th>Perceived risk for others</th>
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<td>2.32</td>
<td>1.36</td>
<td>2.32**</td>
<td>2.82**</td>
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Note. SC = Scenario number. A significant difference between the reported scores for the self versus others is marked with stars: * p<.05, ** p<.01, *** p<.000. A significant difference in the perceived crossing likelihood for other males versus females of the same age group is directly reported under the corresponding cells (p<)
Appendix K. Descriptive statistics on comparative judgements about the likelihood of being hit by a train by all participants

Descriptive statistics of the significant results from the repeated measures ANOVA comparing the reported likelihood of being hit by a train by participants of all age and gender groups, with the likelihood they perceived for other pedestrians of different demographic groups

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<tr>
<th>Gender</th>
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<th>N</th>
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<th>M</th>
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<th>Perceived likelihood for the SELF</th>
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<td>76+y.o.</td>
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Note. SC – Scenario number. A significant difference between the reported scores for the self versus others is marked with stars: * p<.05, ** p<.01, ***p<.000.
Appendix L. Statement of contribution of co-authors for Paper 1

The following is the format for the required declaration provided at the start of any thesis chapter which includes a co-authored publication.

The authors listed below have certified that:
1. they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
2. they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. there are no other authors of the publication according to these criteria;
4. potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit, and
5. they agree to the use of the publication in the student's thesis and its publication on the QUT ePrints database consistent with any limitations set by publisher requirements.

In the case of the chapter:
*Direct Observations of Pedestrian Vehicular Crossing at Urban Australian Level Crossing. Urban Rail Transit, 6(19) doi 10.1007/s12574-015-0021-9*

<table>
<thead>
<tr>
<th>Contributor</th>
<th>Statement of contribution*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Jean-Marie Duchêne†</td>
<td>Supervision and editing</td>
</tr>
<tr>
<td>Dr. Christian Wallner*</td>
<td>Added data collection method. Supervision and editing</td>
</tr>
<tr>
<td>Achraf Jassim Frenczen*</td>
<td>Supervision and editing</td>
</tr>
<tr>
<td>Prof. Andy Rakotonirina*</td>
<td>Supervision and editing</td>
</tr>
<tr>
<td>Prof. Patrick Gahovance*</td>
<td>Added research design, aims and data collection method. Supervision and editing</td>
</tr>
</tbody>
</table>
Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

A. Redstorm

9 Nov 2015

Name: ___________________________ Signature: ___________________________ Date: ___________________________

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Appendix M. Statement of contribution of co-authors for Paper 2

### Statement of Contribution of Co-Authors for Thesis by Published Paper

The following is the format for the required declaration provided at the start of any thesis chapter which includes a co-authored publication.

The authors listed below have certified that:

1. they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, or at least that part of the publication in the field of expertise;
2. they take public responsibility for that part of the publication, except for the corresponding author who accepts overall responsibility for the publication;
3. there are no other authors of the publication according to these criteria;
4. potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
5. they agree to the use of the publication in the student's thesis and its publication on the QUT eTheses database consistent with any limitations set by publisher requirements.

In the case of this chapter:

System based approach to investigate pedestrian behaviors at level crossings:

<table>
<thead>
<tr>
<th>Contributor</th>
<th>Statement of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tedora Sentance</td>
<td>Conducted literature review, research design and aims. Conducted data collection (focus groups), data analysis and interpretation. Provided the first drafts of the work, comments (major changes required) in the peer review process.</td>
</tr>
<tr>
<td>Signature</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Prof. Jean-Marc Balthazard</td>
<td>Added data analysis and interpretation. Supervision and editing.</td>
</tr>
<tr>
<td>Dr. Althein Filsells</td>
<td>Actively participated in writing the theoretical framework (PULC), Actively participated in data analysis (ArcMap) and interpretation.</td>
</tr>
<tr>
<td>Dr. Christian Paulsen</td>
<td>Actively participated and supervised the writing of the theoretical framework (PULC), Actively participated and supervised data analysis (ArcMap) and interpretation.</td>
</tr>
<tr>
<td>Prof. Andy Reinhard</td>
<td>Supervision and editing.</td>
</tr>
<tr>
<td>Prof. Frances Ollinghary</td>
<td>Added data analysis and interpretation. Supervision and editing.</td>
</tr>
</tbody>
</table>
Practitioner Supervisor Confirmation

I have signed all or other correspondence from all Co-authors confirming their authorship.

A. Relationship

[Signature]

8 Nov 2015

Name ____________________________ Signature ____________________________ Date ____________________________
Appendix N. Statement of contribution of co-authors for Paper 3

**Statement of Contribution of Co-Authors for Thesis by Published Paper**

The following is the format for the required declaration provided at the start of any thesis chapter which includes a co-authored publication.

The authors listed below have certified that:

1. they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation of at least that part of the publication in their field of expertise;
2. they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. there are no other authors of the publication according to these criteria;
4. potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit, and
5. they agree to the use of the publication in the student’s thesis and its publication on the QUT ePrints database consistent with any limitations set by publisher requirements.

In the case of this chapter:

Key factors explaining self-reported transgressions and risk-taking likelihood in different level crossing scenarios – an Australian study. *Accident Analysis & Prevention* (under review)

<table>
<thead>
<tr>
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<th>Statement of contribution*</th>
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</thead>
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<tr>
<td>Teodora Stefanova</td>
<td>Research design and aims. Conducted and supervised data collection (direct observations). Conducted data analysis and interpretation. Wrote the manuscript. Addressed reviewers’ comments</td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Oscar Ovidio-</td>
<td>Conducted one part of the data analysis (cluster analysis). Editing</td>
</tr>
<tr>
<td>Trespalacios (PhD</td>
<td></td>
</tr>
<tr>
<td>student)*</td>
<td></td>
</tr>
<tr>
<td>A/Prof. James</td>
<td>Supervision and editing</td>
</tr>
<tr>
<td>Freeman*</td>
<td></td>
</tr>
<tr>
<td>Prof. Jean-Marie</td>
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<tr>
<td>Burkhardt*</td>
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<td>Dr. Christian</td>
<td>Supervision and editing</td>
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<tr>
<td>Wullems*</td>
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<td>Prof. Andry</td>
<td>Supervision and editing</td>
</tr>
<tr>
<td>Rakonczenvari*</td>
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<tr>
<td>Prof. Patrick Cobham*</td>
<td>Advisor research design, data handling and data collection method. Supervision and editing</td>
</tr>
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</table>

Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

A. Pakistaniany

9 Nov 2015

Name: ______________________  Signature: ______________________  Date: ______________________