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Improving Pedestrian Safety in Bangladesh: Insights from Behaviour Change Models and Co-Design Interventions

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

Acknowledgements

I dedicate this thesis to the memory of my deceased father. No one would be happier and prouder of my accomplishments if he were alive today. I offer my heartfelt prayers to almighty Allah for the eternal peace of my father.

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Abstract

In Bangladesh, pedestrians, particularly students and workers, frequently face the challenge of crossing medium-to-high speed roads during their daily commute. Pedestrians' low rate of crossing use necessitates the application of a relevant behaviour change model, 'COM-B', to diagnose the behavioural problem and investigate factors in enhancing pedestrian safety and promoting safe crossing behaviour in Bangladesh. Three studies were conducted on two national highways of Bangladesh using mixed methods to identify factors and strategies for promoting pedestrian safety.

Study 1 presents a conceptual model for predicting pedestrians' safe use of crossings, examining the complex interplay between Capability, Opportunity, and Motivation in promoting safe crossing practices. The findings highlight influential factors in pedestrians' crossing-use decisions, including avoiding lapses and aggressions. Study 2 further promotes pedestrian safety by investigating drivers' yielding behaviour and identifying key pedestrian factors and contextual elements in pedestrian-driver interactions. Study 2 used a conceptual thematic coding framework and explored barriers and facilitators to safe crossing practices amidst the conflicting interests of drivers' reluctance to yield to pedestrians. The theoretical domains framework (TDF) was utilised to map the behavioural model constructs in studies 1 and 2.

Study 3 involves students and workers in intervention design, with and without applying the selected behavioural model for solutions. The evaluation suggests that the co-design approach and the behaviour change model address conventional design flaws in promoting the safe use of crossings. Stakeholders' consultations address blaming culture among pedestrians, drivers, and authorities for promoting the safety of vulnerable road users.

The combined findings of these studies provide valuable insights and recommendations for policymakers, road authorities, and stakeholders involved in pedestrian safety. The suggested intervention development strategies emphasise the social and physical opportunity element by optimising the use of limited resources and encouraging authorities to assume collective responsibility by fostering collaboration among all stakeholders.

Conferences and publications

Conference/ Journal	Title	Comments
Traffic Safety Research	Motivations of pedestrians for safe use of highway crossing: An application of the behaviour change model 'COM-B' in Bangladesh	Manuscript* is accepted subject to revision. Part of Study 1 (Chapter 4)
Traffic Injury Prevention	Promoting pedestrian safety in Bangladesh: Identifying factors for drivers' yielding behaviour at designated crossings using behaviour change theories	Manuscript* under review. Part of Study 2 (Chapter 5)
55th UTSG Annual Conference 2023, Cardiff, UK	Intervention Design for Vulnerable Road Users: Applying Co-Design and Behaviour Change Model in Bangladesh	Abstract accepted, full paper* under review. Part of Study 3 (Chapter 6)
WRDTP 11th Annual Conference 2022, University of Sheffield, UK	Why are pedestrians not using road crossings in Bangladesh? An analysis with a behavioural model	The accepted abstract was presented with key findings
International Symposium (online): Transportation in Emerging Countries 2022, IMOB, Hasselt University, Belgium	Pedestrians and contextual factors in motivating safe interactions between drivers and pedestrians at pedestrian crossings: A psychometric study with the "COM-B" model	The accepted abstract was presented with key findings

* The researcher served as the lead author, responsible for preparing the entire manuscript/paper with guidance from the supervisors. The supervisors reviewed the manuscripts, including the research conceptualisation and methodology, and occasionally assisted with editorial tasks.

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Abbreviations

ARI	Accident Research Institute
AADT	Annual Average Daily Traffic
BRTA	Bangladesh Road Transport Authority
BCTs	Behaviour Change Techniques
BCW	Behaviour Change Wheel
COM-B	Capability, Opportunity, Motivation, and Behaviour
DOT	Department of Transportation
DBQ	Driver Behaviour Questionnaire
FHWA	Federal Highway Administration
HBM	Health Belief Model
HICs	High-Income Countries
IBM	Integrated Behavioural Model
ILO	International Labour Organisation
iRAP	International Road Assessment Programme
LMICs	Low-and Middle-Income Countries
NRSC	National Road Safety Council
PBQ	Pedestrian Behaviour Questionnaire
PMT	Protection Motivation Theory
PWM	Prototype Willingness Model
RRFB	Rectangular Rapid-Flashing Beacons
RTHD	Road Transport and Highway Division
RHD	Roads and Highways Department
SCT	Social Cognitive Theory
SEM	Structural Equation Modelling
SDG	Sustainable Development Goal
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TDF	Theoretical Domains Framework
TTM	Transtheoretical Model
VRUs	Vulnerable Road Users
WHO	World Health Organization

Chapter 1
Introduction

This chapter sets the stage for this study by addressing the critical issue of pedestrian safety on a global scale. It highlights the specific challenges faced in developing countries, focusing primarily on the pedestrian safety problem in Bangladesh. The problem statement further elucidates the urgency of improving pedestrian safety in the country. The research aim and objectives are then presented, outlining the purpose and direction of this study. The rationale and significance of the research are emphasised, indicating its potential impact on informing policies and interventions. Finally, the chapter provides a concise thesis outline, offering a roadmap for the subsequent chapters.

1.1 Global pedestrian safety problem

Safe and sustainable mobility is fundamental for road users in any society. Unfortunately, the consequences of unsafe mobility have become a global tragedy, with an increasing trend of road crashes (WHO, 2018). Every year, road traffic accidents cause around 1.3 million fatalities, resulting in 20-50 million non-fatal injuries. Vulnerable Road Users (VRUs), including pedestrians, motorcyclists, and bicyclists, represent more than half of the global deaths due to road traffic accidents (WHO, 2021). Road traffic crashes have emerged as the eighth leading cause of death for all age groups globally, and it is the leading cause of death for children and young adults aged 5 to 29 years (WHO, 2021). Road users who are most vulnerable to collisions are pedestrians, as they lack protection against vehicles. Most pedestrian collisions occur while crossing the road, and there is a high risk of being killed or seriously injured while crossing the street (Bartolomeos et al., 2013; Department for Transport, 2015).

Data indicates that road traffic injuries are the leading cause of death among all 5–19-year-olds, particularly in 15–19-year-old males (Liu et al., 2022). Within this age group, children aged 10 to 19 are particularly affected by road traffic injuries (Peden et al., 2009). Furthermore, child pedestrian injuries significantly increase on school days, especially during school start and end times (Newbury et al., 2008). Similarly, young adults aged 15 to 29 years, the economically productive population, represent half of the global road deaths and injuries (WHO, 2015). Commuting accidents could cause 158,000 deaths yearly (ILO, 2005), and workers are also vastly victimised due to commuting accidents (Rusli Bin, 2014). The safety of students and economically productive workers needs more attention than other groups in reducing road traffic accidents.

Education and employment rates are essential indicators of a country's growth. Child pedestrians need to travel to educational institutions, but their exposure to motorised vehicles often results in injury or death. In the same way, employees in developing nations depend on walking as their primary means of transportation to their job sites. Poverty in developing countries hits the young pedestrian group hard, as casualties usually originate from the poverty-stricken parts of the community (Christie, 1995).

The International Road Assessment Programme (iRAP) star rating is an assessment tool to evaluate the safety standard of a road, measuring the level of safety for road users. iRAP surveyed 54 countries globally and found that pedestrians remain the most vulnerable road users, with 88% of them travelling on one or two-star roads (WHO, 2018). The iRAP star rating standard measures infrastructure safety facilities on a 1-5 scale, with a higher star rating indicating a safer route (Highways England, 2019). The United Nations Sustainable Development Goal (SDG) has specific road fatality reduction goals, action plans, and strategies being taken to find evidence-based solutions.

1.2 Pedestrian safety problem in developing countries

According to the world health observatory, Low-and Middle-Income Countries (LMICs) have high road traffic fatality rates, with 21.5 and 19.5 per 100,000 population, respectively (Global health observatory, 2020). The World Bank (2019) states that 93% of the world's road fatalities occur in LMICs (WHO, 2021), where Vulnerable Road Users (VRUs) groups disproportionately share significant parts of road crash casualties. Traffic accidents have become a growing concern for growth in motorisation in developing countries (Dıaz, 2002). Unlike High-Income Countries (HICs), student and worker numbers are rising in LMICs, and the conflicts between pedestrian and vehicular traffic on high-speed roads are also increasing (Tiwari, 2020).

Developing countries usually focus on education and creating employment to fulfil the needs for economic growth. Governments prioritise education in producing an educated and skilled workforce. As a result, there has been a rise in the number of schools, and more importance is placed on ensuring that every child receives an education. However, child fatalities in developing countries are approximately two and a half times higher than in industrialised countries (Mahmud et al., 2014). Study shows that children have a high chance of getting injured if they go out without adults before developing good road sense (Department of the Environment Transport and the Regions, 2000).

Like many industrialised countries, developing nations prioritise rapid industrial growth to create widespread employment opportunities. Therefore, many industries (including garments, textiles, ceramics, toys, and steel) are located close to roads due to the cost and time savings associated with transportation. Apart from that formal employment, the International Labour Organisation (ILO) report also shows that 2 billion people work informally in developing countries, around 50 to 60 per cent of total employment (ILO, 2020). They primarily work in rural areas such as farms, markets (bazaars), and small business shops. Such informal employment accounts for 41 per cent of the gross national income (Chambwera et al., 2011). Studies show that most pedestrians in developing countries come from the economically challenged section of society, and their relative risk factor is high (Azetsop, 2010; Cubbin and Smith, 2002; Marcin et al., 2003).

Compared to developed countries, the behavioural patterns of road users are substantially different due to the differences in the road traffic environment (Mahmud et al., 2018). Lack of adherence to traffic regulations is also one of the vital attributes prevailing in developing countries (Hamed, 2001). Study shows that pedestrian violation behaviour is higher at the uncontrolled mid-block locations of the road. Such behaviour is concentrated mainly among young groups (Kadali and Vedagiri, 2013). Shi et al. (2007) found that most pedestrians in developing countries lack sufficient knowledge of traffic rules and whose behaviours are unpredictable. Pedestrians are particularly vulnerable in pedestrian and driver interactions, as drivers in developing countries usually do not want to give the right of way to pedestrians crossing the road (Muley et al., 2017).

In LMICs, inappropriate pedestrian infrastructures are often blamed for the unpredictable behaviours of drivers and pedestrians. Additionally, the culture of car-centric roads and victim-blaming of pedestrians (Job, 2012), fragmented institutional responsibilities and less priority in comparison to competing interests (Shuey, 2013), institutional weakness with lack of funding and expertise (Wegman, 2017; Turner et al., 2020), and lack of voice of road users, especially pedestrians in road safety policy decisions (Job, 2012) are some of the key barriers to promoting the safety of road users in LMICs.

1.3 Problem statement: Pedestrian safety in Bangladesh

Bangladesh is a middle-income country in Southeast Asia, with a total area of 147,500 square kilometres and a per capita income of USD 1,909 as of June 2019 (Bangladesh News, 2019). Unfortunately, this region has shown the highest increase in road fatalities compared with other parts of the world (WHO, 2018). In Bangladesh, the road traffic fatality rate is 102.1 per 10,000 vehicles and 13.6 per 100,000 populations (The World Bank, 2020), and pedestrians are the largest single victim group, accounting for 65% of road accidents (Ahmed et al., 2014). This issue is of great concern as road crashes in Bangladesh cost the country nearly 2% of the Gross Domestic Product (GDP) (Hoque et al., 2008).

More attention needs to be given to the safety of pedestrians, who are often overlooked compared to motorists (Mahmud et al., 2018). In Bangladesh, the national highways are the highest road network category, with eight major national highways (N1 to N8) and some highway links of the same standard (RHD, 2001). Eight (8) major national highways (N1 to N8) with some highway links of the same highway category in Bangladesh. However, historical crash data from 2006 to 2010 shows that pedestrian crashes occur on national highways (38%) (Raihan et al., 2018), with more than 72% of crashes occurring in places without traffic controls and 90% of pedestrian crash victims getting run over.

Furthermore, Accident Research Institute (ARI) data from 2006 to 2015 revealed that pedestrian casualties in Bangladesh happen more while crossing (42%), followed by along the roadside/shoulder (29%), no activity or standing position (19%), and others (10%). According to a study by Gururaj et al. (2004), most deaths occur while business or service workers and students are on the road. iRAP (2013) found that 97% of the major road network in Bangladesh has one or two-star safety standards for pedestrians, indicating inadequate pedestrian infrastructure.

Certain land use types, such as educational, industrial, and commercial activities adjacent to roads, create the highest pedestrian road crossing flow, posing considerable risks to students and workers who primarily rely on walking as a mode of mobility to study or work in such areas. There are 20,465 schools in Bangladesh, with a relatively high number of secondary or high schools (16,186) (statistics, 2018). A study conducted in Bangladesh found that schools located near highways with high-speed traffic pose the most unsafe conditions (Sadeek et al., 2018). In addition, the garment industry, which has over 4 million workers, has 54% of its locations near the right of way of primary roads (Hoque et al., 2006). Female workers, who represent 85% of the total workforce in this industry, face considerable risks of accidents while crossing highways to reach their workplaces (Chowdhury, 2018; PPRC, 2014).

In Bangladesh, informal employment has a higher share (89%) of the total number of jobs in the labour market, particularly in rural areas (ADB, 2012). Roadside marketplaces, locally known as “hats” or “bazaars”, are typical informal workplaces in Bangladesh. However, many of these marketplaces are located along highways and often become pedestrian hotspots, leading to accidents involving fast-moving vehicles. PPRC (2014) found that over 28% of accidents occur in road segments with marketplaces on major national highways in Bangladesh.

To aid pedestrians in crossing roads, the road agencies in Bangladesh have provided various at-grade facilities such as speed humps and rumble strips, zebra crossings, and expensive grade-separated pedestrian footbridges. However, despite these efforts, pedestrian usage of these facilities remains inadequate in Bangladesh. A study showed that pedestrians opt for the shortest distance, often ignoring footbridges (iRAP, 2013). Research on pedestrians’ behaviour based on road crossing facilities is scarce in Bangladesh (Pasha et al., 2015). A study on vulnerable road users of highway intersections revealed that even pedestrians who have received formal education tend not to use the available pedestrian crossing facilities (RHD, 2019). That study recommended exploring alternative ways to educate people about the importance of following traffic rules.

Unsafe driver behaviours are common in Bangladesh, but enforcement against them is scarce (Bandyopadhyay et al., 2020). According to PPRC (2014), bus drivers, particularly those driving long-distance buses, are involved in the most accidents (49%) in the country, followed by minibus/truck drivers (23%) and heavy truck drivers (22%). Many drivers ignore pedestrian crossings and overtake other vehicles, disregarding pedestrians. Moreover, drivers often fail to give pedestrians the right of way and aggressively honk their horns to force pedestrians out of their way (Bhattacharjee et al., 2022).

Blame-shifting, where one shifts the responsibility for their mistakes or failures onto someone else, is a significant barrier to taking appropriate action, and it is common in many countries dealing with complex issues such as road safety (Lozano and Laurent, 2019). In Bangladesh, blame-shifting is prevalent among drivers, pedestrians, and authorities. Pedestrians are often blamed (victim blaming) for accidents, even when they are not at fault. According to Job (2012), pedestrians have little say in transport and road safety policies compared to vehicle owners in LMICs. Blame-shifting can also result in a lack of accountability, ultimately hindering the ability to take appropriate actions.

Poor crossing facilities in Bangladesh, as in other developing countries, is a crucial concern for pedestrians' safety. Many pedestrian crossings are unmarked and lack traffic signals, making it difficult for drivers to identify them, resulting in drivers ignoring pedestrians. After a tragic accident involving garment workers, vehicles were damaged, and roads were blocked until the workers' anger subsided. Road traffic accidents have become a critical issue in Bangladesh, causing significant loss of life, injuries, and property damage on personal, social, and economic levels (Hoque et al., 2007). In 2018, school students demonstrated massive protests after two high-school students were killed due to a road crash (Podder et al., 2019). They demanded stricter rules and fines against drivers and better road infrastructure facilities. In response, the government passed the Road Transport Act 2018 in the parliament on 19

September 2018, increasing fines and imprisonment for violating traffic rules. However, the outcome is not yet visible due to increased pedestrian casualties. Pragmatic solutions are needed to improve pedestrian safety in Bangladesh, including addressing the unyielding behaviour of drivers and pedestrian decision-making in complex interactions between drivers and pedestrians (Zafri et al., 2022; Debnath et al., 2021).

1.4 Research aim and objectives

The study is based in Bangladesh and primarily focuses on the most vulnerable pedestrian target groups, i.e., students and workers (formal and informal). The uses of designated crossings by pedestrians are low in Bangladesh. Additionally, the drivers’ unyielding behaviour towards pedestrians demotivates their crossing use. Such practices (behaviour) of pedestrians result from either design flaws or constraints of an individual’s behaviour of pedestrians and drivers. A significant disparity exists between people’s perceptions, attitudes, and behaviour in Bangladesh. While many individuals possess appropriate feelings, understanding, and beliefs, their actions may not align with these values (Bhattacharjee et al., 2022). This discrepancy can be attributed to two underlying problems: one relating to behavioural issues and the other to infrastructure-related issues. It is debatable whether the poor design of facilities or violation of traffic rules by road users is the leading cause of pedestrian injuries and deaths. Professionals, pedestrians and drivers tend to blame each other. There is a need for effective strategies to improve pedestrian safety in Bangladesh, particularly in using designated crossings. This research aims to contribute to developing effective strategies for improving pedestrian safety using a behaviour change model and co-design approach in intervention designing for the designated crossings in Bangladesh. The research problem is significant because of the high number of pedestrian fatalities and injuries, especially among students and workers, in the country. The research findings will have implications for policy and practice in road safety.

Table 1.1 represents the research questions and objectives framed to fulfil the aim of the study.

Table 1.1 Research questions and objectives

No.	**Research questions**	**Objectives**
1	What factors influence pedestrians' decisions to use designated crossings in Bangladesh?	To identify factors that motivate pedestrians to use a designated crossing.
2	What pedestrian attributes or environmental factors of crossing sites influence driver yielding to pedestrians, and how do these factors impact pedestrians' safe crossing use?	To establish the factors that could promote drivers' yielding behaviour with a consensus among drivers and pedestrians for enhancing pedestrian safety.
3	Do pedestrians and drivers share a common perception of problems at crossings, and what are the effects on intervention designing strategies? How can the benefit of intervention be optimised?	To recommend an intervention design strategy for the pedestrian and driver to meet the respective target behaviours of drivers' yielding and pedestrians' safe crossing use.
4	What are the design flaws in the conventional design for pedestrian crossings in Bangladesh, and how could those flaws be addressed with co-design and usage be encouraged by applying a behaviour change model?	To improve the design of interventions for the safety of vulnerable road users.
5	How can the shared responsibilities of authorities be improved for the safety of vulnerable road users?	To address the blaming culture among pedestrians-drivers-authorities by suggesting a solution to the authorities.

1.5 Rationale and significance of the study

The rationale of the research is to address the issue of pedestrian safety in Bangladesh, particularly concerning the use of designated crossings. Ensuring pedestrian safety is a crucial concern in Bangladesh, as frequent road accidents involve pedestrians. Pedestrians in Bangladesh are highly vulnerable due to the country's high rate of road traffic fatalities. Despite being involved in nearly 50% of all fatal collisions, pedestrians in Bangladesh have been the most overlooked road user group in terms of safety measures and research (Debnath et al., 2021). Designated crossings are an essential safety measure for pedestrians.

However, the efficiency of measures can be impacted by road users' non-compliance, design flaws, and lack of enforcement.

The lack of pedestrian infrastructure is often blamed for the unpredictable behaviour of road users in developing countries. However, due to the present reality and unrealistic expectations of a very robust pedestrian facility in developing countries with limited resources, overlooking behavioural issues and solely dependent on infrastructure could not be a pragmatic approach to solving pedestrian injuries and fatalities. Focusing more on alternative but proven practical strategies to address behavioural limitations could help adapt to the available or improvised pedestrian facilities. Studies have shown that even in-expensive engineering measures could significantly reduce crashes if education campaigns and other actions were added (Ellis and Van Houten, 2009), incredibly close to the targeted area (Zhang et al., 2013). When it comes to socio-technical design, meta-design can be employed to develop a more collaborative and participatory design process allowing all stakeholders to have a say in the design of a system or organisation. Meta-design, based on socio-technical design, advocates' loose fit' or under-design at design time instead of overdesign to incorporate emergent design behaviour or accommodate unexpected issues in use time (Fischer and Herrmann, 2015). Co-design could be a practical approach for involving vulnerable road users, who often have unique perspectives and needs when designing transportation-related interventions. Such an approach could stimulate pedestrians' behaviour so that they could motivate or adapt their behaviour as per the prevailing context by using appropriate tools, methods, and processes that enable designers to design collaboratively with users and stakeholders within the meta-design process.

Ineffective road safety strategies contribute to the rising number of fatalities in LMICs, including Bangladesh (Khan and Rahman, 2016). Previous studies on pedestrian safety in Bangladesh have mainly focused on identifying the contributing factors, with limited attention paid to developing effective strategies using behaviour change theories and a co-design approach. The significance lies in its potential to develop effective strategies to improve pedestrian safety and motivate them to use crossings in Bangladesh. Therefore, the research aims to identify the factors that influence pedestrian decision-making regarding the use of designated crossings and to establish the factors that could promote driver yielding to pedestrians, with a consensus among drivers and pedestrians for enhancing pedestrian safety. The research also recommends an intervention design strategy for promoting safe crossing use and addressing the blaming culture among pedestrians, drivers, and authorities. Additionally, the research aims to improve the design of designated crossings for the safety of vulnerable road users. The investigation's findings hold immense value for policymakers, highway designers, and other concerned stakeholders who aim to boost pedestrian safety and minimise traffic accidents in Bangladesh.

1.6 Thesis outline

Chapter 1 introduces the global pedestrian safety problem, specifically in developing countries, and presents the problem statement and research objectives. Chapter 2 offers a literature review on the factors influencing road traffic injuries, safety models and approaches to road safety, including co-design and behaviour change theories. Chapter 3 describes the research framework and methodology, including data collection, experiments, and ethical considerations. Chapter 4 to Chapter 6 investigates the five research questions to meet the research goal and objectives.

Chapter 4 investigates the motivations for safe crossing behaviours among pedestrians. Chapter 5 investigates drivers' yielding behaviours for pedestrian' safety and examines shared perceptions of pedestrians and drivers regarding pedestrian safety. And Chapter 6 presents the experiments of co-design and behaviour change models in promoting pedestrian safety, including an investigation on shared responsibility among stakeholders.

Chapter 7 summarises findings, interpretation, limitations, and future research directions. Finally, chapter 8 includes conclusions, contributions, implications, recommendations for practitioners and designers, and future research.

Chapter 2
Literature review

This literature review explores the factors affecting road traffic injuries at crossing areas, including pedestrian behaviour, safety and driver yielding to pedestrians. It also introduces safety models and approaches to road safety, including the Safe System approach to pedestrian safety with various safety pieces of evidence of pedestrian safety measures in designated crossings. The applicability of co-design in road safety and the challenges in developing countries are also discussed. Finally, the review discusses several behaviour change theories and models with their uses in road safety, followed by the selection and rationale for choosing a behavioural model for the application in this study.

2.1 Factors in road traffic injuries at crossing areas

Research shows road crossing is a significant source of risk for traffic injuries (Ward et al., 1994). Several factors contribute to such injuries. One of the most critical factors is vehicle speed, which increases the risk of pedestrian fatalities (Ditcharoen et al., 2018). Road infrastructure and traffic engineering also play a crucial role in preventing road traffic injuries. Poorly designed crossing areas, lack of proper signage, and inadequate traffic enforcement can all contribute to injuries (WHO, 2021). In developing countries where the road network is expanding, efforts to meet safety standards through safety audits during the planning, designing, and operation stages are insufficient (Gebru, 2017). Therefore, physical road environmental factors are crucial for pedestrian safety, especially in developing countries. Although vehicle safety features are a significant concern in developing countries, human and environmental factors contribute more to road traffic injuries (Pakgohar et al., 2011).

2.1.1 Factors in pedestrian behaviour and safety

Pedestrian safety is critical in transportation planning and management (Rankavat and Tiwari, 2016a). Amado et al. (2020) conducted a systematic review of pedestrian-vehicle interaction at unsignalised crosswalks and identified several influential factors related to pedestrians and safety, including roadside characteristics. In areas where educational institutions are nearby, influential safety factors included the number of pedestrians waiting, pedestrians' age, waiting time, assertiveness, approach speed, hesitation, distance, and position. In commercial or business areas, influential safety factors included pedestrian speed, attitude, pedestrian group, pedestrian race, the position of pedestrians, and pedestrian assertiveness. In Ghana, the lack of zebra crossings on streets with numerous educational facilities led to many pedestrian accidents, and the lack of crossings in marketplaces and commercial streets forces people to cross roads randomly (William et al., 2021).

Rasouli and Tsotsos (2019) analysed classical pedestrian behavioural studies from the early 1950s and identified key environmental (n=20) and pedestrian-related factors (n=17) influencing pedestrians' behaviour in crossing a road. Environmental factors included the right of way, location, time of day, road conditions, lighting, street width, signal, zebra crossing, weather, road structure, gap acceptance, waiting time, vehicle speed, vehicle distance, traffic flow, traffic volume, vehicle size and type, communication, and law enforcement. Similarly, pedestrian factors included age, gender, walking pattern, pedestrian speed, attention, trajectory, group size, social norms, pedestrian flow, imitation, social status, law compliance, culture, experience, faith, and the estimation of vehicle distance and speed.

Pedestrians' intentional violations and unintentional lapses, which are predominant in Bangladesh, pose significant risks while crossing a road. A study on pedestrians' self-reported behaviour in Bangladesh showed that the mean score of violations, aggression, and lapses measured on a 6-point scale were more than 3, about 1.5, and about 2, respectively (McIlroy et al., 2019). Such behaviours depend on various factors. The trade-off between safety and convenience (Rankavat and Tiwari, 2016b; Sharples and Fletcher, 2000), stresses or psychological states (Papadimitriou et al., 2009; Rastogi et al., 2011), crossing strategy of rolling type (Kadali and Vedagiri, 2019; Zhang et al., 2019), and distractions (Damsere-Derry et al., 2010; Hatfield and Murphy, 2007; Nasar et al., 2008; Thompson et al., 2013) are some critical pedestrian factors contributing to unsafe behaviour. Research in pedestrian safety has consistently identified various intrinsic and extrinsic motivational factors, two types of motivation used in road safety (Milder et al., 2013), influencing pedestrians' behaviour.

Intrinsic motivational factors, for example, habits, play a significant role in children's safety and shaping pedestrians' motivation and decision-making when crossing streets (Tiwari et al., 2021; Fujii and Gärling, 2005). A study in New Zealand focused on pedestrian motivation and found that habit was the main driver of pedestrians' intention to cross roads at mid-block sections (Soathong et al., 2021). Furthermore, crossing footbridges and roads can become habitual behaviours for pedestrians, with convenience and proximity being more influential than perceived crossing time (Oviedo-Trespalacios and Scott-Parker, 2017). In addition to habits, other motivational factors significantly influence pedestrians' behaviour when crossing roads. Emotional responses play a role in shaping pedestrians' motivation, with positive feelings while crossing or guilt for not using nearby crossings influencing their intention to engage in road crossing behaviour, especially among adolescents (Evans and Norman, 2003). Safety priority is another crucial motivational factor, as pedestrians prioritise their well-being and take precautions to ensure their safety. Studies conducted in Bangladesh indicate that safety is considered the main factor in road crossing decisions (Saha et al., 2013). Pedestrians have greater flexibility in choosing their path and adjusting their behaviour than other road users, which can influence their motivation to use a specific crossing path. This freedom enables them to carefully select safer crossing locations, time to cross a road, and adapt their strategies to suit particular situations (de Lavalette et al., 2009).

While focusing on extrinsic motivational factors, the availability of various physical opportunities in the traffic infrastructure significantly promotes safe crossing behaviour. Research has shown that factors such as pavement maintenance, over- and underpasses, well-functioning traffic lights, and separate pedestrian roads are associated with a decrease in risky pedestrian behaviours (Şimşekoğlu, 2015). It is also crucial to investigate factors that affect pedestrian safety in LMICs to address the significant differences in road user behaviour between LMICs and high-income countries attributed to culture and compliance with traffic laws.

Haghani et al. (2022) compiled essential studies on pedestrian safety in LMICs. For instance, a study conducted in Serbia found that young people were more prone to violating traffic laws than older individuals due to fatigue from long-distance walking (Antić et al., 2016). In Ghana, adolescents were more likely to take risks due to lower risk perception and inadequate assessment of consequences (Nordfjærn et al., 2011). Additionally, accidents were less severe in clear weather and mainly occurred during off-peak periods, especially at night (Amoh-Gyimah et al., 2017). Male pedestrians were found to be more involved in accidents than female pedestrians in Iran (Sheykhfard et al., 2020). However, a study found that females, especially garment workers who are mostly victimised on the road, have less time and opportunity to gain traffic safety knowledge in Bangladesh (Chowdhury, 2022).

In Malaysia, mobile phone use was the leading cause of distraction among pedestrians, followed by smoking and talking (Mohd Syazwan et al., 2017). In Ethiopia, pedestrian rule violations increased when drivers failed to yield at pedestrian crossings (Tulu et al., 2013). In Turkey, pedestrians felt more secure crossing when the vehicle speed was moderate (Demiroz et al., 2015). Studies conducted in China revealed that pedestrian refuges positively impacted pedestrian safety (Zhang et al., 2017), and pedestrians tended to use crosswalks when others did (Zhou et al., 2009). However, negative factors such as high vehicle speed, high traffic volume, rolling gap crossing pattern, larger pedestrian platoon, traffic rule violations, and poor judgment were also identified (Zhang et al., 2017; Zhou et al., 2016). In India, police enforcement positively affected pedestrian safety (Mukherjee and Mitra, 2020). Another study on school students aged 12-15 years showed that nurturing good street-crossing habits increased children's safety (Tiwari et al., 2021). However, other studies identified negative factors, including inaccessible pedestrian crosswalks, absence of pedestrian signals, presence of wider carriageways, occupying footpaths, and restricted visibility (Mukherjee and Mitra, 2020).

2.1.2 Factors in driver yielding to pedestrians

A study by Bella and Nobili (2020) revealed that drivers have lower average yield rates and higher deceleration rates when interacting with pedestrians outside of zebra crossings compared to those at designated crossings. However, a study by Koepsell et al. (2002) found that marked crosswalks are often riskier than unmarked ones, especially when pedestrians believe they have priority in a marked crosswalk, but drivers refuse to yield to them. It points to the importance of driver behaviour in interacting with pedestrians. Moreover, drivers in some countries, such as Malaysia (Ibrahim et al., 2005), do not wish to yield to pedestrians.

Some mainstream treatments include traffic signs, advanced yield marking, and overhead flashing beacons to ensure driver yielding. Stapleton et al. (2017) conducted a study in the USA and found that crosswalk markings significantly improved yielding compliance. The study also revealed that the highest compliance rates were achieved when an additional enhancement was added. In addition to engineering measures, educating drivers about pedestrian right-of-way laws is essential to improve pedestrian safety at zebra crossings, as Wirach (2016) observed in Thailand.

However, a review of earlier studies by Varhelyi (1998) found that drivers are generally unwilling to yield to pedestrians at zebra crossings, and the presence of pedestrians has little impact on reducing vehicle speed. The study highlighted the need to improve driver behaviour at these crossings to ensure pedestrian safety. Driver attitudes and behaviours significantly differ between countries with varying road traffic fatality rates. Studies show that drivers living in countries with fewer road traffic fatalities report more positive attitudes towards complying with speed limits and spend a larger proportion of their time complying with speed limits than those living in countries with higher road traffic fatalities (Warner et al., 2009). Interestingly, the existence of a legal framework has been found to have little impact on compliance with traffic rules. In Bangladesh, for instance, the Road Transport Rules 2022 stipulate that drivers must yield to pedestrians in designated crossing places where mandatory traffic signs and road markings such as zebra crossings are installed (Bangladesh Gazette, 2022).

Pedestrians can use ‘assertion’ and ‘direct request’ compliance-gaining techniques that change behaviour via social influence, as shown by Kellermann and Cole (1994). For instance, waiting in the roadway rather than on the kerb (Harrell, 1993), going swiftly toward the crossing (Schroeder, 2008), and extending an arm in the direction of crossing (Crowley-Koch et al., 2011) are examples of pedestrian assertiveness that can influence driver yielding behaviour. Crowley-Koch et al. (2011) found that a raised hand and an extended arm are two effective prompts for pedestrians to use on motorists at uncontrolled crosswalks. In China, Zhuang and Wu (2014) found that using such gestures is effective in driver yielding for visibility, clarity, and familiarity. However, another study shows that many pedestrians hesitate to assert their right to cross because they lack trust in drivers to yield (Schneider et al., 2017).

Several other pedestrian attributes and environmental factors can significantly influence drivers' yielding behaviour, such as the pedestrian's distance from the curb (Himanen and Kulmala, 1988; Harrell, 1993), the number of pedestrians waiting to cross (Sun et al., 2003), higher pedestrian volumes (Stapleton et al., 2017), pedestrians wearing brighter clothing (Harrell, 1993), and looking behaviour (Haupt et al., 2015). Zafri et al. (2022) found that several pedestrian attributes and situations positively influenced the yielding behaviour of drivers in Bangladesh, including the pedestrian's gender (favouring females over males), crossing in a group, carrying baggage, not using a mobile device, making a hand gesture to the driver, or using the "rolling gap" crossing strategy with assertiveness.

Anciaes et al. (2020) analysed past studies and identified several environmental and pedestrian-associated factors that positively influence drivers' behaviour at marked unsignalised crossings (zebras). Environmental factors include crossing width, staggered crossing, speed humps, traffic signals, kerb extensions, high-visibility signs and markings, advanced yield marking, in-street signs, junction, morning time (vs afternoon), buses and cars, and other vehicle yield in an adjacent lane. Pedestrian factors include the presence of vulnerable groups (such as children, disabled, or older people), same age group as a driver, ethnic minority, number of pedestrians, conspicuity, assertiveness, friendliness, crossing from far side pavement, and second stage of crossing at a staggered crossing.

2.2 Safety models and approaches to road safety

Hughes et al. (2015) conducted a comprehensive review of various models relevant to road safety, including those related to intervention, sequence, mathematical, process, systems theory, and safety management systems. They found that the component model is the most commonly used for road safety strategy development. It takes a holistic view of safety and encompasses the four E’s: engineering, enforcement, education, and encouragement.

Safarpour et al. (2020) conducted a study on successful road safety approaches employed by countries worldwide to identify common approaches and potential areas for safety improvement. The study identified three main approaches to road safety. The first is the traditional approach, which mainly focuses on human errors. The second is the systemic approach, which places responsibility on both road users and designers. Lastly, the Vision Zero approach aims to achieve zero fatalities and severe injuries on the road network. However, the choice of approach depends on each nation’s ideology, interests, and infrastructure when choosing and implementing road safety measures.

There has been a longstanding debate between the use of “active” (behavioural) and “passive” (structural) strategies in injury prevention and control. Passive strategies aim to make products or environments safer for all, regardless of individual behaviour, while active strategies require individuals to protect themselves actively. Larsson and Tingvall (2013) suggest that road safety approaches can be viewed as person-based and system-based approaches from the perspectives of the two central “axiom” or human factors principles: human capability and system approach.

2.2.1 Person and system-based approaches

Pedestrian safety can be improved through two distinct approaches: person-based and system-based interventions. The person-based approach focuses on changing pedestrian behaviour through education and enforcement. In contrast, the system-based approach involves manipulating external factors such as road traffic environment to the needs of pedestrians.

Reason (1990) proposed a taxonomy of human error comprising two main categories: unintentional and intentional. Slips and lapses are unintentional errors arising from failures in executing planned actions, with slips being performance errors and lapses involving memory failures. Mistakes and violations, on the other hand, are intentional actions deviating from established rules or norms. Mistakes result from incorrect understanding or mental models, while violations involve conscious deviations driven by personal motivations or conflicting priorities. The person-based approach to road safety places the primary responsibility for road accidents on human error, considering individual road users solely accountable for crashes. This perspective is supported by studies, e.g., Sabey and Taylor (1980), indicating that road-user factors contribute to approximately 95% of accidents. It is crucial for all individuals who use the road to follow safety regulations to prevent any accidents from occurring. In the event of an accident, the legal system may hold the person responsible for the incident. Pedestrian violations can pose a significant safety threat, particularly in LMICs. In developing countries, the person-based approach is helpful, especially in dealing with violation behaviour (Batool, 2012).

However, regulating human behaviour and making individuals accountable for accidents limit unintentional errors (Dekker, 2002), as it only impacts intentional violations (Svensson, 2008). Nevertheless, these violations and errors need to be addressed because they may reduce the effects of the system design. Therefore, design solutions and regulations must be evidence-based and integrated with a systems approach to change human behaviour (Larsson and Tingvall, 2013). A study emphasises the importance of a systems approach, which involves a holistic understanding of the road safety system, including the road network's design, road users' behaviour, and their interactions (Hughes et al., 2016).

Some argue that focusing on individual behaviour can be seen as blaming the victim, but empowering individuals can also lead to political or social action to bring about structural changes (Gielen and Sleet, 2003). Injury reduction typically requires behaviour change to some extent, even when implementing structural interventions. While structural interventions are essential to creating safer environments, addressing intentional violations and non-compliance is crucial to ensure effective injury reduction. The environmental changes may require humans to adapt their behaviour. Therefore, the importance of both person-based and system-based approaches in road safety is still essential in developing countries, supported by Batool (2012). Non-compliance with traffic laws is commonly observed among road users in LMICs. For example, in Iran, a study highlights the importance of adopting a comprehensive system approach to prevent road traffic injuries (Khorasani-Zavareh et al., 2009). This approach is also commonly used in HICs. However, the person-based approach can also effectively promote desirable road user behaviour. A study focusing on mature driver behaviour in countries like the USA, Sweden, Denmark, and the Netherlands demonstrates that community-based approaches and social marketing can effectively address road safety concerns (Waldock, 2008).

2.2.2 The Safe System approach and pedestrian safety

The Safe System approach acknowledges that road safety results from a complex and dynamic interaction among multiple components. These components collectively form a system that influences people's travel choices and behaviour on the roads, ultimately determining their exposure to collision risks (Welle et al., 2018).

The Safe System approach evolved from Sweden's Vision Zero approach (iRAP, 2010). Vision Zero was adopted by Sweden in 1997, which states that "*the long-term goal for Swedish road safety policy is that nobody should be killed or seriously injured in the transport system*". This vision inspired policymakers and road designers to strive towards a traffic system without fatalities or serious injuries (Johansson, 2009). The Vision Zero approach emphasises shared responsibility for road safety, where the designers, administrators, and road users all have a role to play (Larsson et al., 2010). The designers are ultimately responsible for the system's safety level, road users must adhere to the set rules, and if violations occur or injuries happen, the system designers are obligated to take appropriate measures to prevent fatalities and serious injuries.

Most developed and developing nations support the Safe System approach to improving road safety, and treated as the foundation for the UN Decade of Action for Road Safety (Turner et al., 2015). The need for system-based road safety solutions in developing countries is becoming increasingly important, as the built environment in these countries can be dangerous for drivers. The Safe System approach effectively reduced traffic fatalities and severe injuries more than traditional approaches (Johansson, 2009; Weijermars and Wegman, 2011). Moreover, countries across all income levels can embrace and implement the Safe System approach to promote sustainability (Welle et al., 2018). On 21 October 2021, the second ‘Decade of Action for road safety’ was initiated with the release of the global plan for the decade of action for road safety 2021–2030 by the World Health Organization (WHO). In alignment to reduce road deaths and injuries by 50% by 2030, the plan urged governments and partners to adopt and implement an integrated Safe System approach (Stipdonk et al., 2022).

The Safe System approach acknowledges that accidents will occur and aims to reduce their impact, helping to prevent victim-blaming by recognising that human error is not the only cause of a road crash; instead, a failure within the road system itself (Salmon et al., 2010). The Safe System approach consists of key elements crucial to improving pedestrian safety, including safer roads, safer vehicles, safer road users, and a safe speed limit. It promotes a safe transport system that considers human error and pedestrians’ vulnerability through policy measures such as infrastructure, vehicle and speed regulations, education, and enforcement (Davis, 2001). While predominantly used in HICs, the Safe System approach applies to countries with varying income levels, including LMICs. This approach is particularly relevant to many LMICs with challenges such as insufficient road infrastructure and inadequate planning for vulnerable road users such as pedestrians (Lockard et al., 2018).

In the context of LMICs, the World Bank’s Guide for Road Safety Interventions provides evidence-based recommendations for effective road safety interventions (Turner et al., 2020). The guide emphasises the importance of the Safe System approach, which focuses on creating a forgiving road system that accommodates human error and minimises the risk of severe injury or death. The guide also highlights the importance of behaviour change interventions as a vital component of a comprehensive road safety strategy and recommends using evidence-based approaches to design and implement effective behaviour change programs.

However, the Safe System approach faces significant challenges in improving pedestrian safety, especially for vulnerable road users exposed to traffic with speeds above the lower limit (Job, 2012). The Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) in the USA have released vulnerable road users’ safety assessment guidance, highlighting many engineering and operational efforts that agencies can take to improve safety for pedestrians (FHWA, 2022). While the Safe System approach aims to prevent injuries through a comprehensive approach, much more work is needed to ensure the safety of vulnerable road users.

2.3 Designated crossings and other pedestrian safety measures

2.3.1 Safety evidence of designated crossings

Pedestrian crossings can be categorised into at-grade crossings and grade-separated crossings. At-grade crossings are typically installed at road sections where pedestrians are prioritised in reaching the other side of the road. Controlled crossings give pedestrians the right of way and a sense of security when crossing, which can be classified into signalised or unsignalised zebra crossings. On the other hand, uncontrolled crossings have no signal system and only a painted crosswalk. Pedestrians do not have the right of way in uncontrolled crossings and are at higher risk. Mid-block crossings require visible pedestrian signs and guard rails that only open at the crossing.

High-visibility markings, a low-cost treatment (iRAP, 2010), can increase the conspicuity of pedestrian crossings for pedestrians and motorists and provide safety benefits such as crash reductions and early motorist detection (Fitzpatrick et al., 2011; Pulugurtha et al., 2012). The Federal Highway Administration (FHWA) recommends that marked crosswalks alone should not be used for roads with high Annual Average Daily Traffic (AADT) and speed limits. Conspicuity-enhancement measures positively affect pedestrian safety, especially among students (Forjuoh and Guohua, 1996). To improve pedestrian conspicuity, raised crossings or crosswalks are one option (González-Gómez and Castro, 2019). Raised crosswalks are ramped speed tables spanning the entire width of the roadway, designed for speeds of 40 to 50 km/h. Such measures could reduce pedestrian crashes by around 40% (Elvik et al., 2009) and are recommended for arterial roads (WHO, 2010).

Overhead pedestrian crossing signs are suitable where roadside signs are not noticeable, and overhead positioning is also appropriate in certain conditions, such as on roads with buses with stops, more lanes, roadside signs, or assembly beyond the driver's cone of vision (Fitzpatrick et al., 2016). Research shows that high-visibility crosswalk markings and illuminated overhead crossing signs have significantly higher driver-yielding rates during the day (Nitzburg and Knoblauch, 2001). These overhead crossing signs could be supplemented with Rectangular Rapid-Flashing Beacons (RRFB), which use the brightness of an eye-catching flashing device to draw drivers' attention to the device and the area around it (Fitzpatrick et al., 2016). The installation of RRFB can reduce pedestrian crashes by 47% (Zegeer et al., 2017) and has a positive effect on motorist awareness (Dougald, 2016), especially among drivers who rarely yield to pedestrians (Zaworski and Mueller, 2012). To increase pedestrian visibility, various proven measures, such as street lighting, reflective clothing, and pedestrian crossings with flashing lights, can also contribute to vulnerable road users' safety, as the World Bank guide suggested.

Grade-separated facilities involve high-cost investment; however, they can reduce crashes by 60% or more (iRAP, 2010). The main benefit of such facilities is environmental modification, as they can separate pedestrians from traffic and potentially improve road users' behaviour (Thompson et al., 2013). However, pedestrians generally do not prefer grade-separated facilities, especially women and older pedestrians (Anciaes and Jones, 2018). A study on garment workers in the capital city of Bangladesh, showed that such facilities should match the desired travel path and be supplemented with median barriers and footpath fencing to make them self-enforcing (Hoque et al., 2006). Similarly, a study in Barranquilla, Colombia, with high traffic volume, found that one-third of participants never or rarely used the footbridge to cross the highway (Oviedo-Trespalacios and Scott-Parker, 2017). The probability of using an underpass is also low for women and older people who cross the road daily but are infrequent users (Anciaes and Jones, 2018). Furthermore, underpasses are not suitable for areas susceptible to flooding and require routine maintenance (iRAP, 2010).

2.3.2 Safety evidence of other facilities and measures

Several on-road and offsite facilities are effective in improving pedestrian safety. For example, a pedestrian crossing island or refuge area is a raised platform separating pedestrians from motor vehicles. Studies have found that this type of facility can reduce pedestrian crashes by 46% (Bahar et al., 2007), increase motorist yielding, and reduce motorist speeds (Kamyab et al., 2003;

Pulugurtha et al., 2012). According to iRAP (2010), the cost of a pedestrian refuge island can vary from low to medium.

Installing raised medians or pedestrian refuge areas at marked crosswalks could lead to a 46% reduction in pedestrian crashes (FHA, 2013). Constructed medians are more effective than painted medians, with a 50% decrease in crashes compared to a 15% reduction in collisions (Turner et al., 2012). The Federal Highway Administration recommends that medians be at least 1.2 m wide. Narrowing lanes can provide a pedestrian refuge island or median space in a narrow median, such as a New Jersey Barrier (NJB). The Asian highway guideline incorporates the NJB at a median area in the standard road cross-section (Asian Highway, 2017). The National Highways Authority of India considering NJB to replace low-height medians (Mysuru, 2019).

Well-designed traffic calming measures can provide significant safety advantages, particularly for pedestrians and other vulnerable road users, with a 70% reduction in fatal and severe pedestrian injuries (Elvik et al., 2009; Jensen, 1999; Makwasha and Turner, 2017). Road narrowing and speed signs are especially beneficial in preventing fatal and severe injuries to vulnerable road users, with a feasible reduction of 40% (Makwasha and Turner, 2013; Forbes, 2011; Wheeler et al., 1993). Rumble strips, which increase driver alertness for reducing vehicle speed, are often used as a vertical deflection type of engineering measure. Such transverse markers can potentially minimise collisions by 20-30% (Bahar et al., 2007; Elvik et al., 2009), with a study in China finding that transverse rumble strips may reduce the expected crash frequency at pedestrian crosswalks by 25% (Liu et al., 2011). Zig-zag pavement marking lines have a sustained positive effect on speed reduction, increase awareness, and improve drivers' yielding behaviour with a relatively high Benefit-Cost Ratio (BCR) of such measure (Dougald, 2010). Other road markings, such as advanced stop line markings, a low-cost treatment, are suitable at multi-lane uncontrolled crossing locations where a motorist's view of a pedestrian in the crossing is obscured by motor vehicles (Thomas et al., 2016; Zegeer et al., 2017). They positively impact crash reductions, varying from 14% to 36%, and show behaviour improvements (Zegeer et al., 2017).

Pedestrian crashes can be prevented by separating them from the road using footpaths, which have been shown to save up to 60% on transportation costs (iRAP, 2010; Elvik et al., 2009; Jensen, 1999). Fencing is another effective and low-cost measure that physically separates pedestrians from the road and helps direct them towards formal crossing points while discouraging dangerous crossing movements. In rural areas, footpaths and fencing are often provided instead of footbridges.

Effective communication can persuade people to adopt safe behaviours, especially when using a peer-to-peer approach among young people (Shiwakoti et al., 2018; Henderson, 1991). Delhomme et al. (2009) how that outdoor billboard posters, including small and banner options, are effective on-site communication techniques. Crimmins and Callahan (2003) find that outdoor advertising effectively delivers road safety messages, particularly to young, mobile populations. Posters can incorporate pictures and words (Shiwakoti et al., 2019) and are a cost-effective intervention in LMICs (WHO, 2016).

Enforcement, particularly in speed management, is vital to road safety despite weak enforcement records and fewer law-enforcement personnel per population in developing countries (McIlvenny, 2006; King, 2005). Roadside cameras are an effective measure for enforcing traffic regulations, as seen in the Australian state of New South Wales, where 28-speed cameras resulted in a 71% drop in speeding and an 89% reduction in fatalities at treated sites (Job and Sakashita, 2016). Other research has found consistent but modest decreases in trauma (Wilson et al., 2010). Stricter penalties for drivers' traffic rules violations contribute to vulnerable road users' safety (Avenoso and Beckmann, 2005).

While evidence for the effectiveness of educational strategies may be less abundant compared to engineering and enforcement measures, education and awareness campaigns aimed at pedestrians can still have a significant impact in promoting safe behaviours, such as using crosswalks, exercising caution while crossing, and avoiding distractions like mobile phones (Turner et al., 2020). More importantly, Özkan and Lajunen (2007) proposed adding the 'Economy' as the fourth 'E' to the traditional three E's (Engineering, Enforcement, and Education) in injury prevention, especially in the context of

LMICs. In these countries, limited resources and economic instability are significant concerns that affect road safety efforts. Therefore, there is a need to focus on cost-effective interventions, including low-cost behavioural strategies and safety initiatives targeted at Vulnerable Road Users (VRUs).

2.4 Co-design fundamentals and methods

“Co-design” refers to a participatory approach to designing solutions. Collaborative innovation practices have existed for almost 50 years (Sanders and Stappers, 2008). Scandinavians were the first to use participatory design. It began as a design approach in the early 1970s in Norway when computer experts and union officials sought to give employees more control over computer systems (Winograd et al., 1996). Participatory design is an umbrella term that includes various methods for involving stakeholders in the design process. Co-design is a subset of participatory design that involves collaboration and equal participation between designers and stakeholders throughout the design process. Co-design, in a broader sense, refers to the creativity of designers and users not trained in design working together in designing interventions (Sanders and Stappers, 2008). The design ideas emerge from collaborative efforts where designers should spend time with users in their contexts, and decisions are taken democratically (Sanoff, 2007).

The role of users, designers and researchers is crucial in the design process. However, their roles are changing from the traditional disperse roles to the merging roles in the co-design premises. The traditional user-centred design process involves the user as a passive subject of study, where the researcher brings knowledge from theories and observation. The designer then incorporates this knowledge with technology and creativity to develop ideas. In contrast, co-design involves the user as an “expert of his/her experience” and actively engaged in knowledge development, idea generation, and concept development. Users are empowered as co-designers at design time to propose and generate design alternatives at use time. Researchers provide tools for ideation and expression, while the designer and researcher collaborate on creating these tools. Figure 2.1 shows the roles of users, researchers, and designers in classical and co-design settings.

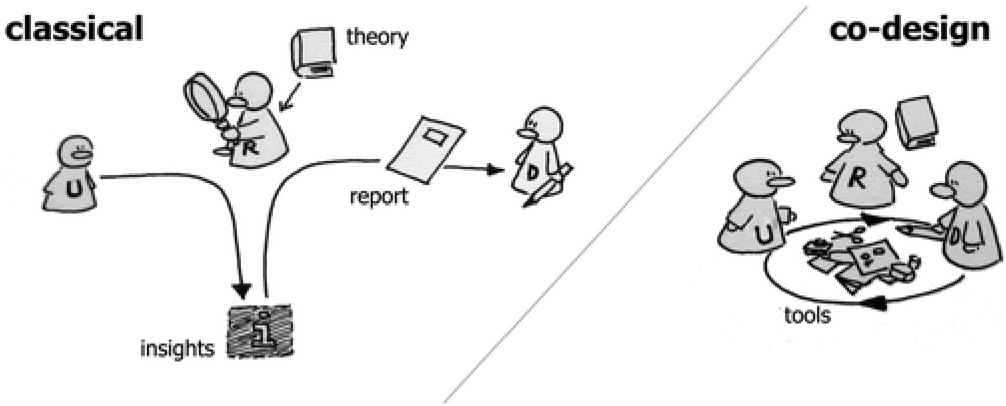


Figure 2.1 Roles of users, researchers, and designers (Sanders and Stappers, 2008)

Participation, the foundation of co-design, is a critical component of successful development initiatives (Brouwer et al., 2016). Bottom-up design projects actively include individuals and groups directly affected by a particular problem, opposite to the traditional practice of top-down design initiatives taken by decision-makers, institutions, or political activists (Murray et al., 2010; Manzini, 2015). However, the level of user involvement in design is essential, which could be done in three ways. The methods of Informative involvement include the interview, questionnaire, focus group discussion or observation, and consultative involvement could use those same techniques with usability testing. Participatory involvement includes various techniques such as prototyping (De Looze et al., 2001; Dinka and Lundberg, 2006), paper prototyping (Demirbilek and Demirkan, 2004), and pilot projects (Béguin, 2003). Among low-fidelity prototyping Techniques, sketches are straightforward and user-friendly (Coyette et al., 2007). It is quicker and cheaper to use paper-and-pencil forms at the early stages (brainstorming). Designers can extract functions from perception in sketches by using them to highlight perceptual characteristics and intrinsically non-visual functional linkages.

In a co-design approach, workshops are rated highly as teaching and design tools. Workshops could play a key role by allowing participants to “propose, depict, interrogate, and remark on diverse parts of the emerging design continuously throughout the process” (Simonsen and Robertson, 2012). In a workshop setting, participants must follow some basic steps in prototype design, from exploring the problem to the solution derived (Figure 2.2) following the double diamond strategy, saving the design process time (Saad et al., 2020).

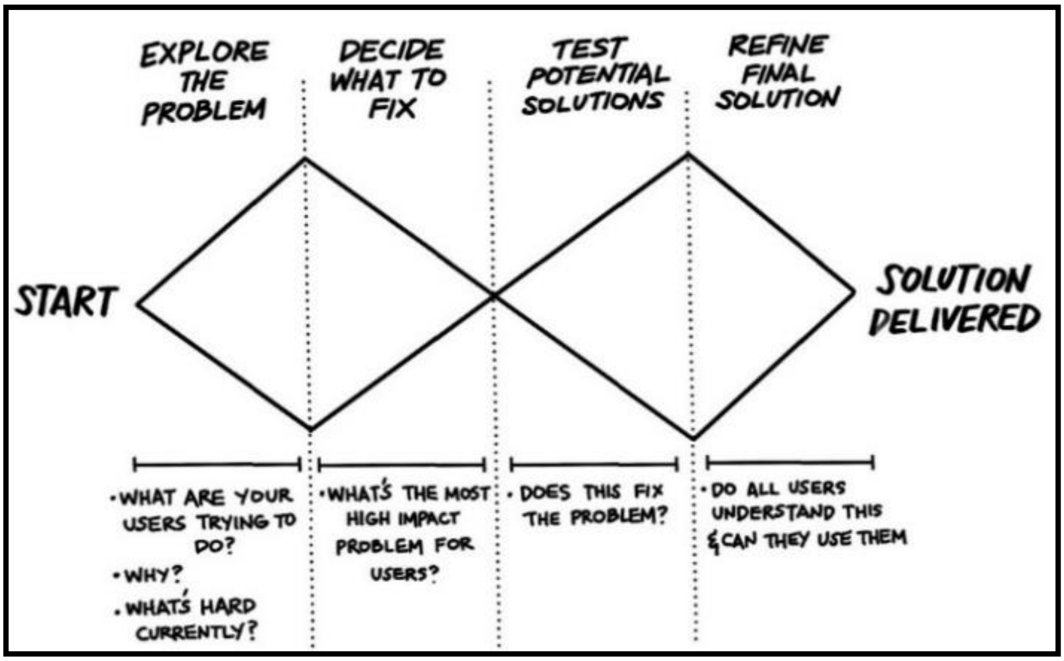


Figure 2.2 Prototype design steps in co-design (Aethelyon, 2022)

2.4.1 Applicability of co-design in road safety

Co-design has had great success and has demonstrated clear benefits in various fields, such as information systems and physical ergonomics (François et al., 2017). In a study on intervention design for changing drivers' attitudes and behaviour, this design approach showed a positive outcome (de Jong, 2009). Co-design also benefits pedestrians in the sustainable travel context as it promotes idea generation and a more holistic perspective on the problem and potential solutions (Mitchell et al., 2016). There are some examples of co-design in pedestrian safety. In Italy, a neighbourhood in Milan called Dergano used co-design to create safer and more accessible pedestrian streets (Moro, 2022). In New York City, the Department of Transportation (DOT) used co-design to create safer pedestrian streets by adding crosswalks, bike lanes, and other features (Baig et al., 2020).

Although the co-design practices in road safety are minimal, the positive outcome of successful practices in various fields could support co-designs efficacy in road safety. For example, Sundin et al. (2004) conducted a participatory ergonomics project to develop an assembly line for a new chassis design in a bus manufacturing company. The objectives were to achieve shorter assembly times and early discovery of problems before full deployment, and the outcome successfully achieved these goals. Weng et al. (2007) found that trust between designers and users builds in intervention development, which is pertinent in building trust between drivers, pedestrians, and designers in road safety. Hess et al. (2004) found that an iterative design process could help designers modify the prototype before implementation, saving costs and lives on the road. Using local knowledge could find a better solution, as proven in a big coastal management project (Fontalvo-Herazo et al., 2007). Loisel et al. (2001) found that the co-design approach could achieve many cost-effective solutions quickly. Stakeholders could quickly adopt rapidly adopted participatory solutions, enhance the chance of success, and foster a sense of ownership (Thursky and Mahemoff, 2007). Pehkonen et al. (2009) found that the co-design approach can generate multiple solutions with small budgets, which is much more relevant to authorities with limited budgets.

The Safe Systems approach recognises that many factors influence road safety and underscores the importance of shared responsibility among stakeholders to prevent fatal and severe injury collisions. An essential part of this approach is figuring out how to implement road safety efforts into a system of shared responsibility. Combining “top-down” policy leadership and “bottom-up” public demand could tackle those challenges. The World Bank guide emphasises that road safety is everyone’s responsibility, including the government, civil society, private sector, and road users. In the context of LMICs, that guide recommends a collaborative approach that engages all stakeholders in designing and implementing road safety interventions (Turner et al., 2020).

The Safety System principle also emphasises the authorities’ role in providing facilities for road users and is often used to guide interventions to improve pedestrian safety. It highlights the authorities’ responsibility to provide safe facilities. However, little attention has been given to understanding the users’ safety priorities and the willingness to behavioural changes with the available crossing facilities. Using behavioural models in co-design could also be a powerful approach to promoting sustainable behaviour change in each community or organisation. A study in healthcare shows that the combined use of co-design and behaviour change constitutes a promising strategy in formulating a shared vision of challenges and thus helps to find potential solution routes with quality outcomes (Carvalho et al., 2017).

2.4.2 Co-design practice and challenges in developing countries

Co-design has been used in underdeveloped nations for over three decades (Simonsen and Robertson, 2012). It has gained popularity among contemporary designers in developing country settings, especially in community contexts (DiSalvo et al., 2012). Most of the literature on participatory design in developing countries is from Information System design (Hussain et al., 2012). This study identified some successful practices in various fields that could be relevant to the local context for improving pedestrian safety. For example, involving the local community can achieve an integrated solution from multiple fragmented solutions (Byrne and Sahay, 2007). In Uganda, Ssozi-Mugarura et al. (2017) found that co-design can promote transparency, accountability, and confidence among the parties involved in the design process. Cambodian experiences showed that a co-design approach could create an opportunity to meet the users' needs with the psychological empowerment of the participants, including vulnerable groups (Hussain et al., 2012). In India, Sharma et al. (2008) found that participatory design methodology helps to find a viable solution swiftly. Bank (2004) evaluated a few small-scale projects in Bangladesh, showing that a bottom-up approach in a participatory process finds a win-win outcome among the competing parties involved.

However, Hussain et al. (2012) identified various factors that can impact participatory design processes in developing countries. These factors include human aspects, such as the relationship between designers and participants, access to users and stakeholders, participants' capacity to participate, language barriers, and appropriate methods of rewarding participants. Social, cultural, and religious aspects ensure equal participation and accommodate customs and religious beliefs. Financial aspects include providing transportation and workshop resources, allocating time for participants, and building trust. Organisational factors include recognising the importance of the process, allocating resources, and considering organisational hierarchy.

In developing countries, the above challenges can broadly be divided into two dimensions: the conceptual dimension and the technological dimension. Fischer (2004) demonstrates how to transform such challenges into possibilities. The conceptual dimension challenge is bringing stakeholders from different areas together, which can be addressed using “boundary objects”. For example, a product prototype can be a boundary object facilitating communication and coordination between stakeholders from different areas. Boundary objects can include diagrams, models, specifications, and other documentation forms that can help clarify and align the understanding and expectations of stakeholders from different areas. In tackling technological challenges, training can help to familiarise stakeholders with technological tools and best practices for using them. Trial sessions and establishing protocols can help ensure consistent and efficient technology use while preventing technological misuse.

2.5 Behaviour change theories and models

Various theories are employed in road transport safety to inform safety measures. Causal theories analyse identifiable accident causes, while epidemiologic theories examine underlying relationships influencing accident outcomes. Systemic theories identify dependencies and factors impacting accidents, aiding in developing safety measures and monitoring systems. Behavioural theories assess individual behaviour’s impact on accidents and facilitate public and political support for effective programs (Jamroz, 2008). However, no single road safety theory can fully explain the complex causes of accidents. Even system theories, considering various factors, do not offer a complete and comprehensive explanation. Fishbein (2000) has highlighted the importance of understanding the theoretical variables that determine behaviour to develop effective interventions.

2.5.1 Overview of behaviour change theories and models

Behaviour change theory encompasses a wide range of models and approaches. Darnton (2008) reviewed 60 social-psychological models of behaviour and categorised them into those that focus on the individual, context, or the middle ground. Some of the Individualistic rational choice models include the Theory of Planned Behaviour (TPB), the Health Belief Model (HBM), and the Transtheoretical Model (TTM). These models place agency with the individual, emphasising their ability to make rational choices and act accordingly. While these models acknowledge some contextual factors, such as subjective norms in TPB and perceived barriers in HBM, their primary focus is on individual-level variables. The context is typically considered to a limited extent, and the models do not extensively address the broader social, cultural, or environmental influences on behaviour change. Purely contextual models, such as the Choice Architecture Model, focus on contextual effects on decision-making behaviour. This framework suggests how choices are presented or framed can significantly influence decision-making. However, ethical concerns arise when government programs use this approach, as it may raise concerns about individual rights, control, and responsibility. In contrast, the middle-ground models explicitly consider the interplay between individual-level factors and contextual influences in understanding behaviour change. However, the individualistic rational choice model of behaviour change has been a dominant perspective in the behavioural sciences (Niedderer et al., 2014).

The prominent individual-focused model, Theory of Planned Behaviour (TPB), posits that attitudes, subjective norms, and perceived behavioural control are the immediate predictors of behaviour. The model extends the Theory of Reasoned Action (TRA), which explains an individual’s values, beliefs, and attitudes (Figure 2.3). Both theories share the fundamental premise that intentions influence behaviour, which is determined by attitudes and subjective norms. The TPB adds perceived behavioural control as a factor that strongly influences behavioural intentions (Ulleberg et al., 2009). According to Ajzen (1991), intentions are assumed to capture the motivational factors that influence behaviour. Volitional measures, including planning, self-efficacy, and action control, have been found to mediate the relationship between intention and behaviour, bridging the gap between them (Sniehotta et al., 2005). Researchers have also attempted to enhance TPB by incorporating additional variables influencing behavioural intentions, including perceived moral obligation, past behaviour, and self-identity (Werner and Mendelsson, 2001; Norman et al., 2000; Armitage and Conner, 2001). Although intention is an important factor in predicting behaviour, it may not always be accurate due to other intervening factors. TPB primarily considers cognitive factors, such as attitudes, beliefs, and intentions.

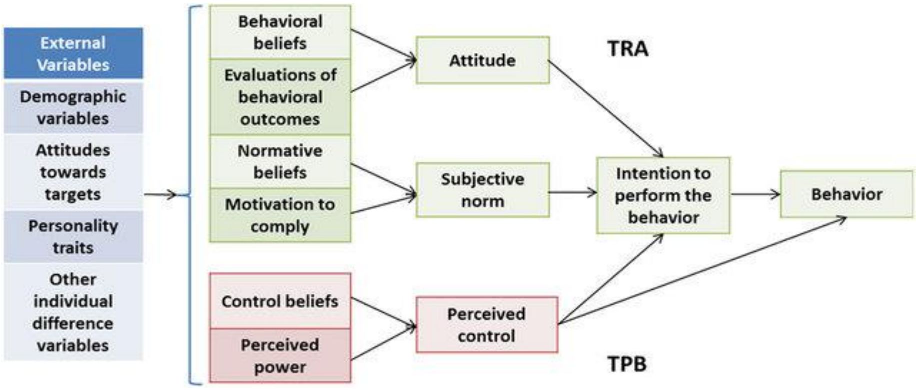


Figure 2.3 TRA and TPB (DeNicola et al., 2016)

The Prototype Willingness Model (PWM) is another popular theory for understanding risky behaviours. PWM focuses on the social-reactive component, as pedestrian violations happen mostly through willingness rather than intention, as conceptualised in TPB (Figure 2.4). According to PWM, individuals who strongly identify with the prototype of someone who engages in a specific behaviour are more likely to be willing to engage in that behaviour themselves. PWM incorporates additional factors, such as prototypes and willingness, to explain behaviour better. Prototype perceptions and willingness are the most critical determinants of violations. A study found that reactive pathways were more predictive of willingness to engage in risky online behaviour in adolescents than adults, suggesting that reactive processes play a more significant role in adolescent risk-taking (Branley and Covey, 2018).

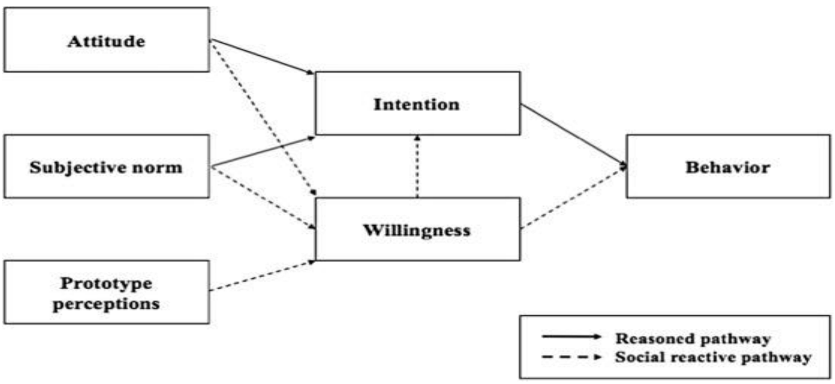


Figure 2.4 Prototype Willingness Model (Demir et al., 2019)

The Health Belief Model (HBM) proposes that behaviour change messages are most effective when they address perceived barriers, benefits, self-efficacy, and threats. Despite its potential as an ideal framework for communication research, the HBM's theoretical limitations have restricted its widespread use (Jones et al., 2015). A combined psychological model was developed by borrowing elements from different models highlighting the 'barriers or facilitators' and the emotion to adopt a behaviour change strategy and bridge this intention-behaviour gap (Fylan, 2017). This model (Figure 2.5), represents an extended version of the TPB, employing a Dual-Process approach of PWM.

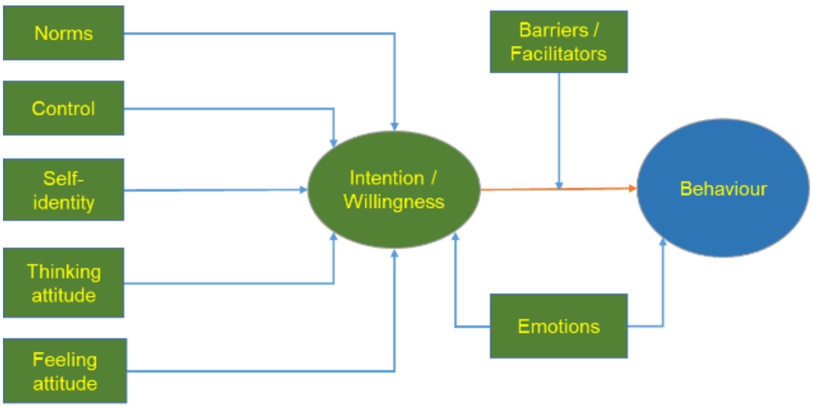


Figure 2.5 Combined Model from Fylan (2017)

The Integrated Behavioural Model (IBM) arose from efforts to combine TRA and TPB components with additional variables such as demographic factors, environmental influences, habit, and capability. IBM is a theory that explains and predicts human behaviour based on the intention or decision to perform the behaviour (Glanz et al., 2008). IBM adds or modifies some factors influencing intention, such as experiential attitude, descriptive norm, personal agency, and self-efficacy (Figure 2.6). The model assumes that people are rational and have the knowledge and skills to act on their intention. IBM can predict how individuals behave regarding their health, the environment, and risk-taking. However, the model does not consider other factors influencing an individual's health habits and status, such as race, financial position, education, and emotional state.

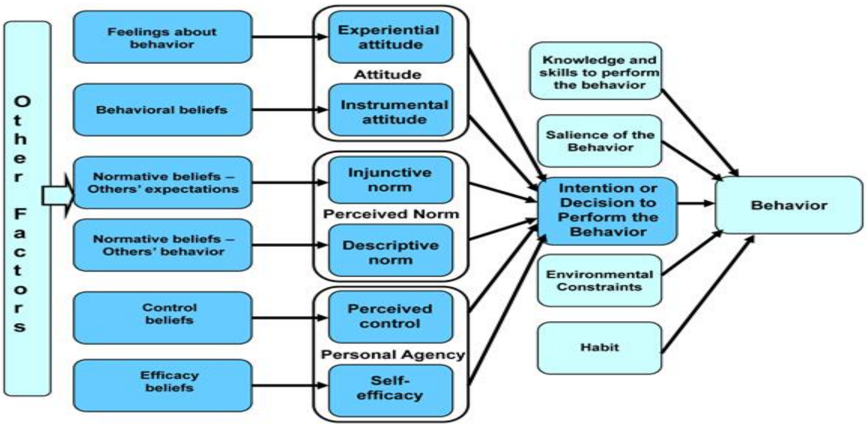


Figure 2.6 Integrated Behavioural Model (Glanz et al., 2008)

Bandura's Social Cognitive Theory (SCT) emphasises the importance of observational learning, self-efficacy, and reciprocal determinism in shaping human behaviour. Bandura promoted self-efficacy in frameworks that analyse fearful and avoidant behaviour, derived initially from Hovland's Theory of Fear Appeals and referred to as "belief in the effectiveness of coping responses". Protection Motivation Theory (PMT) describes how people process information and make decisions regarding protective behaviours in response to perceived threats or dangers (Maddux and Rogers, 1983) (Figure 2.7). The "protection motivation" construct is the mediating variable between attitudes and the end behaviour (in place of intention in TRA). PMT proposes that people's decision to engage in a health-protective behaviour is influenced by two cognitive processes: threat appraisal and coping appraisal. When people feel threatened, they tend to take protective measures if they think these actions can effectively minimise the threat and if they have the skills and resources required to carry out the defensive behaviour.

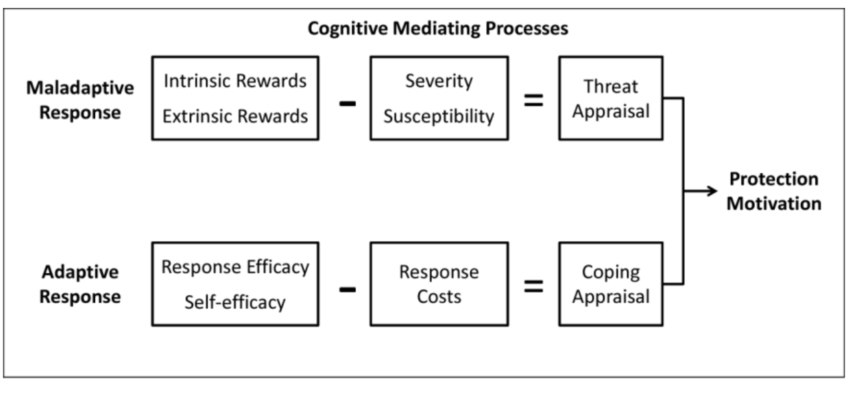


Figure 2.7 Protection Motivation Theory (Menard, 2014)

Transtheoretical Model (TTM) is another approach that views behaviour change as a deliberate process that occurs over time and involves progressing through six stages of change (Figure 2.8). TTM is unique in combining stage-of-change and process-of-change constructs, making it helpful in defining and managing interventions. However, TTM does have limitations, such as not considering the social context of change and assuming that individuals make logical plans in their decision-making process (Whysall et al., 2004).

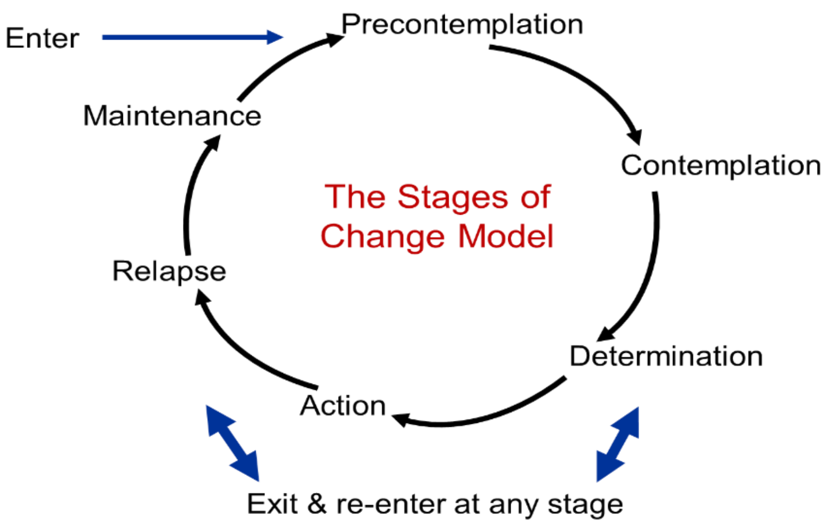


Figure 2.8 Transtheoretical Model (TTM) (LaMorte, 2022)

Behaviour change theory is often limited by focusing solely on behavioural models rather than change theories (Darnton, 2008). Distinguishing between these approaches can highlight different ways of utilising evidence when planning interventions. One practical cue-based approach is Gollwitzer's Implementation Intentions, which uses an "if…then…" process to change habits. While many models offer helpful frameworks for understanding the factors that influence health behaviour, they do not address the practical steps or strategies that can be taken to change health behaviours. Witte (1998) identified a few factors common in many behaviour-change models, as listed in Table 2.1, along with the strategies to change behaviour.

Table 2.1 Factors in behaviour-change models

No.	Key factors	Recommended strategies
1	Threat	Awareness of the existence of the threats while emphasising their severity and susceptibility.
2	Fear	Channel emotional arousal from perceiving threats appropriately for effective response and management.
3	Outcome expectations	Informing individuals about the effectiveness of recommended responses in preventing specific threats.
4	Self-efficacy	Boost individuals' self-assurance in their ability to react and ensure they can stop the threat.
5	Barriers	Be mindful of any potential cultural or physical barriers and make an effort to overcome them.
6	Benefits	Positive outcome or the benefits of taking the advised action.
7	Subjective norms	Recognise those with whom people are more likely to comply.
8	Attitude	Before attempting to alter attitudes, evaluate them.
9	Intentions	Identify whether intentions are sincere or only a cover for actual action.
10	Cues to action	Communicate in a way that could persuade people to take or trigger decision-making actions.

Source: (Witte, 1998; World Bank, 2010)

A middle-ground model, the behavioural wheel model, relies on responsible design with intent. Lockton et al. (2010) define 'Design with Intent' as designed to influence or result in particular user behaviour. The method starts with a system where user behaviour is essential, and the design process aims to modify or redesign the system to achieve a target behaviour. Another approach is "mindful" design within behavioural safety, where road users take responsibility for their safety and that of others. These approaches are instrumental in social contexts (Niedderer, 2013).

2.5.2 Application of theories and models in road safety

In a review of a few individual or cognitive models, such as the Health Belief Model (HBM), the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour (TPB) and the Trans-Theoretical Model (TTM), Taylor et al. (2006) found that the Theory of Planned Behaviour (TPB) is used more than others.

However, according to Delhomme et al. (2009), there is a lack of consensus regarding the efficacy of different approaches for achieving lasting change in road user behaviour. Helman et al. (2011) also note that relatively few interventions in this field are evidence-based or theory-led. Some interventions use theories and models such as the TPB, HBM, PWM, IBM, and PMT.

Various cognitive models are applied to predict pedestrians' behaviour (Holland and Hill, 2007), jaywalking (Xu et al., 2013), and distraction behaviour (Barton et al., 2016). In Malaysia, Sundararajan et al. (2020) used TPB to investigate factors affecting pedestrians' use of crossing facilities and safe crossing behaviour. TPB could explain explaining social behaviour beyond decision-making. A study conducted in China found that TPB-based models accounted for road-crossing intentions, demonstrating TPB's utility in understanding social behaviour (Zhou et al., 2009).

The HBM can provide valuable insights into the motivation of pedestrians engaging in risky behaviours, such as crossing on red, not looking around while crossing, and engaging in distracted crossing (Bendak et al., 2021). Demir et al. (2019) found that it could predict pedestrian violations better than TPB. PWM has been used to predict drivers' speeding behaviour (Elliott et al., 2017). In Vietnam, IBM was used to study individual risky behaviours such as driving after drinking, illegally changing lanes, and speeding (Trinh and Vo, 2016).

Regarding road safety, PMT has been applied, especially when crossing roads (Darnton, 2008), and fear-based communication is commonly used in this area (Lewis et al., 2007). Fear-arousing messages can be persuasive when the audience perceives high self-efficacy and response efficacy (Wundersitz et al., 2010). However, fear appeals may also be counterproductive, resulting in defensive and maladaptive behaviour (Elliott, 2003). Thus, it may be necessary to consider cultural differences and tailor the type of threat used in road safety interventions to the target audience. In some countries, such as Australia, New Zealand, the United States, and Great Britain, explicit pictures of crashes, casualties, injuries, blood, and grief of traffic victims are common (Hoekstra and Wegman, 2011).

However, such models often fail to meet the objective of the interventions. For example, many researchers are sceptical about recommending TPB for developing and planning interventions (Taylor et al., 2006; Webb et al., 2010), because of the inherent weaknesses of TPB, such as the emotional component being absent and the intention-behaviour gap.

2.5.3 Selection and rationale of the behavioural model

According to Fylan (2017), most behavioural models have limitations in changing behaviour as they predict intentions better than actual behaviour. Davidson et al. (2018) found that few interventions have been designed and empirically tested that focus on behavioural change techniques (Davidson et al., 2018). The success of behaviour change also depends on the completeness or success of the motivational process before starting with the implementation process (Steinmetz et al., 2016). Niedderer et al. (2014) suggest that a dominant focus on individual cognitive processes and decisions may underestimate the impact of social contexts. The Capability, Opportunity, Motivation, and Behaviour (COM-B) model mediates between individual agency and contextual approaches in behaviour change. This model has widespread uses in intervention development (Barker et al., 2016), and predicting behaviour in various domains (Michail et al., 2021; Gibson Miller, Jilly et al., 2020).

Theoretical Domains Framework (TDF) consists of 14 domains that include knowledge, skills, social/professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, reinforcement, intentions, goals, memory, attention and decision processes, environmental context and resources, social influences, emotions, and behavioural regulation. TDF helps to formulate measuring instruments as it can readily be mapped to the COM-B and covers a range of behavioural determinants (Cane et al., 2012).

The study employs the behaviour change model “COM-B” (Figure 2.9), which lies at the heart of the Behaviour Change Wheel (BCW) framework, performing as an overarching model of different behaviour models (Michie et al., 2014; Michie et al., 2011), including TPB, HBM, SCT, PMT, and TTM as described in section 2.5.1. The COM-B model is widely regarded as the only all-encompassing model that meets the criteria of comprehensiveness, coherence, and interconnectedness (Michie et al., 2011). The COM-B model encompasses three primary components: capability, opportunity, and motivation. Each component further consists of specific subcomponents. Physical capability refers to an individual's physical ability or skills for behaviour performance, while psychological capability pertains to knowledge, understanding, and cognitive skills necessary for behaviour change. Physical opportunity relates to external factors or environmental conditions that facilitate or hinder behaviour change. In contrast, social opportunity encompasses social and cultural factors influencing behaviour change, including social norms, support, influence, and expectations. Motivation includes reflective motivation, driven by conscious and deliberative processes, and automatic motivation, influenced by subconscious processes.

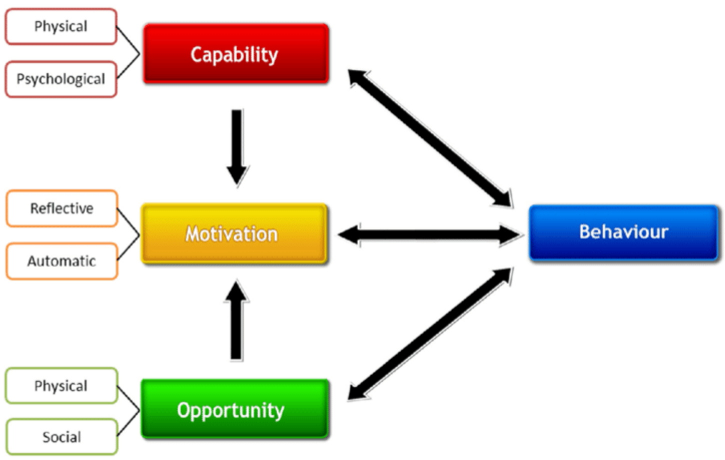


Figure 2.9 COM-B Model (Michie et al., 2014)

The COM-B model provides a foundation for understanding the factors that influence behaviour, while the BCW provides a roadmap for designing and implementing interventions to change behaviour. The BCW includes nine intervention functions that can be used to address deficits in capability, opportunity, or motivation. Around the BCW are seven categories of policy that can enable these interventions to occur. COM-B is a behaviour change model that helps understand human behaviour before choosing appropriate intervention functions such as education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement. Those intervention functions were discovered after synthesising the 19 frameworks and thereby used in BCW. BCW also guides the intervention selection process by a few criteria, such as affordability, practicality, effectiveness and cost-effectiveness, acceptability, side-effects/safety, and equity, known as APEASE criteria (Michie et al., 2014).

The predictive component of the COM-B could be comparable with TPB components. The three components of the TPB, attitudes, subjective norms, and perceived behavioural control, were found to be significant predictors of pedestrians' road crossing intention, where perceived behavioural control (comparable with the capability and physical opportunity component of COM-B) emerged as the strongest predictor (Evans and Norman, 2003; Evans and Norman, 1998). However, a study in China showed that instrumental attitude (comparable with the motivation component of COM-B), as well as conformity tendency & descriptive norms (comparable with the social opportunity component of COM-B), were found significant in predicting pedestrians' violation (Zhou et al., 2016). The TPB has also been criticised for its cultural limitations, as it was developed in Western contexts and may not apply to other cultural settings. Despite its success in explaining behaviour in Asian high-income countries like Taiwan, the TPB has faced criticism for its cultural limitations and limited effectiveness in LMICs (Hung et al., 2019; Hendriks et al., 2019; Hendricks and Moghaddam, 2020). One example of cultural limitation is the assumption of individualistic values in the TPB, which may not be applicable to collectivistic cultures. In individualistic cultures, such as those in Western countries, people tend to prioritise personal goals and autonomy. The TPB, which focuses on individual attitudes, subjective norms, and perceived behavioural control, aligns well with these cultural values. However, in collectivistic cultures, such as many Asian and African countries, people prioritise group harmony and social relationships over individual goals. The TPB's emphasis on individual factors may not fully capture the complexity of behaviour in these cultural settings (Morren and Grinstein, 2021).

Various studies recognised that the COM-B component could predict the behaviour in respective research (Michail et al., 2021; Gibson Miller, J. et al., 2020). A study in the health domain found that the capability, opportunity, and motivation construct of COM-B explained 47% of the variation in opportunistic behaviour change intervention delivery and 35% of the variation in time spent providing treatments. In contrast, meta-analyses of rivalling behaviour change models show up to 37% of the variance in behaviour (Keyworth et al., 2020).

The COM-B model has found applications across various aspects of the transport domain. It has primarily been applied in the UK, such as in the development of public transport messaging to provide crowding information (Krusche et al., 2022), changes in commuting behaviours in response to the COVID-19 pandemic (Harrington and Hadjiconstantinou, 2022), encouraging children’s active travel in their journey to school (Michail et al., 2021), and the design of street space schemes for short local journeys (Lunetto et al., 2023). However, it has also been utilised outside the UK, notably in understanding child car restraint use in South Africa (Hunter et al., 2020).

However, the COM-B model and intervention functions or behavioural change techniques targeting pedestrian behaviour are still absent or rare in the research community. This study is among the first instance that used COM-B for pedestrians’ safety, especially for vulnerable road users, through a co-design process for the intervention development. The COM-B model can guide the co-design process by providing a comprehensive framework for understanding behaviour and identifying the specific components that need to be addressed to change behaviour.

The COM-B model is not based on a single theoretical framework, which can make it difficult to apply in practice. One practical limitation is that the model is complex and has ill-defined constructs. This can make it difficult to apply the model in practice and to develop clear and useful guidelines for behaviour change interventions, including challenges faced in applying and testing the model (Willmott et al., 2021). Some studies suggest that the COM-B model does not adequately address the motivational determinants of risky behaviours such as culture, age, ethnicity, religion, gender, or other contextual factors (Whittal et al., 2021; Marks, 2020). Despite its limitations, the COM-B model is still a useful tool for understanding and promoting behaviour change.

Chapter 3
Research framework and methodology

This chapter presents the research framework and methodology for investigating pedestrian safety issues in Bangladesh. It starts with an overview of the research motivation and framework, followed by a description of the study area and the scope and limitations of the study. The chapter then outlines the overview of the research methodology, including data collection methods, analysis procedures, and ethical approval for the data collection. Finally, an outline of the following investigation chapters is incorporated at the end.

3.1 Research motivation and framework

The research motivation for this study is the high number of pedestrian accidents and fatalities, particularly among vulnerable groups such as students and workers in Bangladesh. Significant concerns are the low use of designated crossings and unyielding driver behaviour towards pedestrians. The study aims to develop effective pedestrian safety interventions in the country using a framework based on the Safe System approach, behavioural theories, and co-design methods. The research objectives are to identify factors influencing pedestrian decisions to use designated crossings, promote driver yielding to pedestrians, and recommend intervention design strategies to improve shared responsibilities among pedestrians, drivers, and authorities.

3.1.1 Overview of the research motivation and its significance

The lack of pedestrian infrastructure is often blamed for the unpredictable behaviour of road users in developing countries. However, ignoring behavioural issues and solely depending on infrastructure is not a viable pragmatic approach to solving pedestrian injuries and fatalities. Stakeholders often debate whether design flaws or individual behaviour factors are the leading cause of pedestrian injuries and deaths. As a result, professionals, pedestrians, and drivers tend to blame each other, leading to a blaming culture, which ultimately creates a danger to pedestrians. Existing pedestrian safety studies in Bangladesh prioritise identifying factors but often overlook applying behaviour change theories and a co-design approach for effective strategies.

The study aims to contribute to developing effective strategies for improving pedestrian safety using behaviour change and co-design interventions at designated crossings in Bangladesh. The research objectives are framed to fulfil the study's aim by identifying the factors influencing pedestrians' decisions to use designated crossings and establishing the factors that could promote driver yielding to pedestrians. The study also aims to recommend intervention design strategies that address shared problems among pedestrians, drivers, and authorities and to suggest ways to improve the shared responsibilities of authorities for the safety of vulnerable road users.

The proposed research's overall goal is to contribute to developing effective and sustainable pedestrian safety interventions by considering the perceptions and behaviours of pedestrians and drivers. By using a behaviour change model and reaching a consensus among competing road users, the research aims to recommend intervention strategies that meet the individual target behaviours of drivers and pedestrians, ultimately enhancing pedestrian safety. The research's significance lies in its potential to improve pedestrian safety and reduce pedestrian fatalities and injuries in Bangladesh. The study findings will have implications for policy and practice in road safety, enabling the development of effective strategies for improving pedestrian safety using behaviour change and co-design interventions. The study's focus on the most vulnerable pedestrian groups, i.e., students and workers, is particularly significant, as they are most at risk of pedestrian accidents in Bangladesh. By addressing the blaming culture among pedestrians, drivers, and authorities and suggesting ways to improve designated crossing design, the study will contribute to improving pedestrian safety in Bangladesh.

3.1.2 Brief on the conceptual framework used in the research

Objective 1 To identify factors that motivate pedestrians to use a designated crossing.

Conceptual framework: The application of behaviour change models will lead to more effective interventions. The person-based approach generally employs a cognitive behavioural model, while the system-based approach can apply cognitive and contextual behavioural models. The cognitive model describes how people process information and make decisions based on the idea that people use mental processes such as perception, attention, memory, and reasoning to understand and interact with the world around them (Busemeyer and Diederich, 2010). On the other hand, contextual models focus on how their environment influences people's behaviour and establish the relationship between individuals and their physical, cognitive, and social worlds. The Safe System principle is one of the promising system base approaches in developing countries, where both person- and system-based approaches are recommended (Batool, 2012). This study applied a middle-ground model COM-B, which lies between the cognitive and contextual levels, suitable for application in developing countries.

However, behavioural models are often criticised for the intention-behaviour gap when they apply to change the behaviour of individuals. An implementation intention is one of the key strategies to provoke behaviour modification by connecting a given behaviour to a particular circumstance with the simple cause-effect statement "If X occurs, then I will do Y". It can be used to develop new habits and has proven helpful in various circumstances (Adriaanse et al., 2011; Gollwitzer, 1999). Fylan's combined model (Fylan, 2017) emphasises the importance of identifying barriers and facilitators to a target behaviour to fill the gap between intention and behaviour. Motivation, the most influential element in the COM-B model, could act as a vehicle to break the barriers in achieving target behaviour. Personality traits and psychological needs influence motivation, where emotions (as included in the combined model) serve as motives to change behaviour. There are several other factors proven to affect individuals' motivations, including persuasive and motivational messages (Anderson, 2011), praise (Robins, 2012), action planning (Mistry et al., 2015), copying others or social identity function (Meltzoff and Moore, 2002), good street crossing habits (Fujii and Gärling, 2005) and moral stance on good or bad (Kroll and Egan, 2004). Intervention design with a simple premise will not bring about an anticipated change in the risk-taker group, where motivation is needed to alter their behaviour. While motivation is key to behaviour change, more research is needed to understand the motivational factors in the safety of crossings.

Objective 2 To establish the factors that could promote driver yielding with a consensus among drivers and pedestrians for enhancing pedestrian safety.

Conceptual framework: In Bangladesh, there is a significant risk to pedestrian safety due to drivers failing to yield at designated crossings, discouraging their use (Bhattacharjee et al., 2022). Designers often deliver interventions that are found to be ineffective in achieving goals when it involves competing requirements by road users (Michie et al., 2014; Wittink, 2001). This problem is even more pronounced in low- and middle-income countries, where institutional weaknesses hinder effective intervention design (Bhalla and Shotten, 2019). Evidence suggests that there are significant disparities between the communication needs of drivers and pedestrians and that drivers' behaviour is influenced by various factors, such as road structure, which can impact pedestrian expectations (Sucha et al., 2017; Björklund and Åberg, 2005). Neglecting the effect of drivers' unyielding behaviour on pedestrians' expectations could pose a safety risk to pedestrians. To manage users' expectations, it is crucial to agree on the intervention type(s) and the degree of behaviour change that can be expected from the design (Nag et al., 2020). In such complex situations where the behaviours of drivers and pedestrians are interdependent, the use of behaviour change theories may be more appropriate. While many studies have identified factors that affect drivers' yielding behaviour, few have attempted to apply behaviour change theories to explore and validate these factors, and to reach a consensus among competing road users. The objective aims to reach a consensus among drivers and pedestrians on intervention types and the expected degree of behaviour change, utilising behaviour change theories to address the interdependent behaviours of drivers and pedestrians.

Objective 3 To recommend an intervention design strategy for the pedestrian and driver to meet the respective target behaviours of drivers' yielding and pedestrians' safe crossing use.

Conceptual framework: Zebra crossings are the most commonly used pedestrian crossing facilities due to the high cost and impracticality of installing grade-separated facilities frequently over highways. However, pedestrians' safety is endangered when drivers fail to yield to them, discouraging them from using designated crossings. In developing nations such as Ethiopia (Tulu et al., 2013), Malaysia (Ibrahim et al., 2005), and India (Pawar and Patil, 2015), drivers' failure to yield is more prevalent than in other parts of the world.

Marked crosswalks can be risky, especially when pedestrians assume priority in a marked crosswalk but cars refuse to yield to them (Koepsell et al., 2002). The difference in behaviour and perceptions between competitive road users, such as pedestrians and drivers, can affect the safety design aspect of interventions. Research on road users' preferences and perceptions of pedestrian crossing facilities is limited compared to studies on crash investigation and safety evaluation (Guo et al., 2014). Therefore, it is crucial to consider how users perceive the available pedestrian crossing facilities (Sisiopiku and Akin, 2003).

When designing interventions, it is essential to agree on the type(s) of intervention and the degree of behavioural change it can cause (Nag et al., 2020). However, very few interventions that focus on behavioural change techniques have been designed and empirically tested (Davidson et al., 2018). A relevant behaviour change model could help understand road users' perceptions, which were inadequately understood in earlier studies (Akgün-Tanbay et al., 2022).

Decision-making in designing interventions remains a primary concern in almost all countries. Despite pedestrians bearing the brunt of road traffic injuries and deaths, they rarely participate in safety intervention decisions (Salmon et al., 2016). Most evidence on effective interventions comes from high-income nations and mainly focuses on the benefits for vehicle passengers (Ameratunga et al., 2006). Relying on such interventions could unwisely use the limited resources of developing countries and threaten vulnerable road users.

In pedestrian-vehicle collisions, pedestrians and environmental factors contribute equally to pedestrian negotiation and decision-making (Amini et al., 2019). Therefore, exploring the factors that affect drivers' yielding for safe interactions between drivers and pedestrians is essential. While motivation is the key driver of behaviour change, there is minimal information in road safety research to understand the effect of pedestrians' attributes and contextual factors on the motivation of road users in their respective target behaviours.

Objective 4 To improve the intervention design for the safety of vulnerable road users; and

Objective 5 To address the blaming culture among pedestrians-drivers-authorities by suggesting a solution to the authorities.

Conceptual framework: Improving pedestrian safety for vulnerable road users remains a significant challenge for the Safe System approach. Pedestrian violations in crossing use, especially among vulnerable road users, are a pervasive traffic safety problem highlighting the need for improved intervention design (FHWA, 2022; National Transportation Safety Board, 2022). While the Safe System emphasises the responsibilities of authorities in providing safe facilities for road users, the blaming culture among pedestrians, drivers, and authorities can hinder the success of safety interventions (Elvik, 2013). The complex relationship between human factors and the environment affects road user behaviour, and violations of traffic laws can be attributed to a combination of factors, including infrastructure, enforcement, user needs, and organisational factors. Therefore, blaming specific road user groups for these violations is inappropriate, and governmental interventions should also be considered when investigating accidents (Nikolaou and Dimitriou, 2018; Newnam and Goode, 2015).

In developing countries, the design may not be robust due to a lack of expertise or resources, so the designers must offer the best possible choices of facilities to alter the road user's behaviour. Here, users' involvement in the design process (co-design) should change their behaviour when using these infrastructures because they are partly responsible for the design. However, little attention has been given to understanding the users' safety priorities. To overcome the blaming culture, authorities should adopt a co-design approach that involves vulnerable road users in the intervention design process (Sanders et al., 2010). Co-design effectively promotes shared responsibility and user satisfaction while incorporating local actors' needs and priorities in intervention design (Turan et al., 2016). Additionally, using a behaviour change model in the co-design could improve the design intervention quality and thus lead to a sustainable behaviour change (Carvalho et al., 2017).

3.2 Study area, scope, and limitations

3.2.1 Description of the study area with justification

This study focuses on two national highways in Bangladesh, Dhaka-Sylhet Highway (N2) and Nabinagar-DEPZ-Kaliakoir (Chandra) Highway, identified for data collection and research. N2 is known for its high accident rate, with the second-highest average death rate per km among national highways (0.55), while N540 has a high pedestrian death rate (0.56). N2 has a length of 287 km with an Annual Average Daily Traffic (AADT) of 15536, while N540 has a length of 16 km with an AADT of 13650. The road layout of N2 is mostly a two-lane undivided rural highway, but market segments have expanded road lanes by adding a New Jersey Barrier in the median. N540, on the other hand, is a four-lane divided bidirectional semi-urban highway with a median, and many industries and educational institutions are located near it. Research locations for N2 are in the Norshingdi district, where some roadside marketplaces have been identified as high-risk locations for accidents. Figure 3.1 shows the research roads on the highway network in Bangladesh.

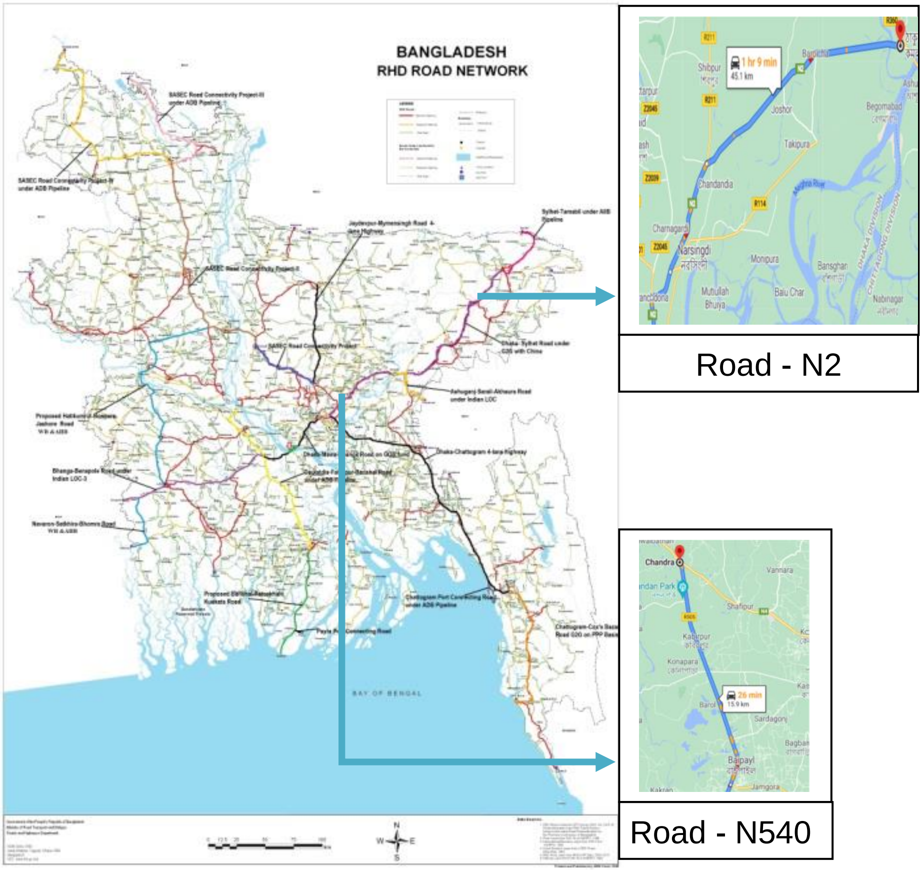


Figure 3.1 Research roads on highway network in Bangladesh

The justification for selecting these two highways for the study is their high accident rate and significant traffic flow. Dhaka-Sylhet Highway (N2) has been identified as one of the most dangerous roads in Bangladesh, with a high average death rate per kilometre (iRAP, 2013). The road is also characterized by various roadside marketplaces (bazaars) along the rural highway segment, which are hotspots for accidents and casualties. On the other hand, the Nabinagar-DEPZ-Kaliakoir (Chandra) Highway has a high average pedestrian death rate per kilometre according to the available ARI crash data from 2006 to 2015 before starting this research work. This road is also characterized by the presence of numerous industries and educational institutions close to the semi-urban road, which generate many students and workers. The Annual Average Daily Traffic (AADT) is reported using the Roads and Highways Department (RHD) database. Both roads have a maximum speed limit of 80 km/hour, but in areas with commercial, educational, or industrial establishments, posted speed limits of 40 km/h are enforced following the traffic sign-manual guidelines of Bangladesh. By focusing on these two highways, this study aims to provide valuable insights into the factors contributing to high road accident rates in Bangladesh and identify potential measures to improve road safety.

This research aim is to improve pedestrians' safety. In Bangladesh, students and workers, vulnerable pedestrians, face significant risks crossing highways to reach their institutions or workplaces. It is also a fact that the low uses of designated crossings raise questions on the design flaws or the blaming culture among stakeholders around road users' violations behaviour. Typically, there are four types of highway crossings available in Bangladesh. They are pedestrian priority zebra crossing, crossing without priority type, footbridge, and underpass. Considering those factors and nearby institutions or marketplaces that generate students or workers, four research sites were selected for this study (Figure 3.2). These include the zebra crossing site (location 1) at Dendabor, the footbridge and underpass site (location 2) at Bipyl on the N540 highway, the Narshingdi Abdul Kader Mollah School zebra crossing site (location 3), and the Morjal zebra crossing site (location 4) on the N2 highway.

Site 1 is a zebra crossing on a four-lane divided highway in a semi-urban area in front of a school, with traffic signs, road markings, and a spacious median refuge area. Site 2, also in a semi-urban area, is situated 500 meters away and includes an underpass and a footbridge. The underpass has a dedicated lane for non-motorised vehicles and a separate pedestrian footpath, with traffic signs at the entrance. The footbridge is designed with a height clearance of 5.7 meters above the road level, following the Roads and Highways Department (RHD) standards. There are several nearby garment industries near sites 1 and 2. Site 3 is located on a rural highway and consists of a zebra crossing with traffic signs in front of a college. Another zebra crossing is also positioned within a 200-meter-long widened 4-lane highway segment in a marketplace area on the same rural highway.

Location 1 on N540 (Zebra crossing, 4-lane divided with wide divider)

Location 2 on N540 (Footbridge in bottom-right & Underpass in top-left)

Location 3 on N2 (Zebra crossing, 2-lane undivided)

Location 4 on N2 (Zebra crossing, 4-lane divided with narrow divider)

Figure 3.2 Research sites

3.2.2 Research scope and limitations

This study was conducted in Bangladesh at four crossing sites on two national highways known for their high fatality rates. While acknowledging the dual roles of individuals as both drivers and pedestrians in pedestrian behaviour and safety, it is important to clarify that the research did not primarily focus on this dual role for two key reasons. Firstly, the study's target group of female garment workers and students had limited involvement as drivers. Identifying drivers was impractical as they often used longer routes not covered by the study. Nonetheless, the study enriched its insights by including drivers in focus group discussions, allowing them to share experiences related to pedestrian behaviour from both driver and pedestrian perspectives, all within the research's defined scope.

It is important to note that the study has certain limitations. Firstly, the sample size was constrained by time and resource constraints. Secondly, the study's findings may not apply to the entire country of Bangladesh. This is because the research focuses on specific locations, and the factors contributing to pedestrian accidents may vary in different regions of the country. Lastly, other factors could impact the research findings, such as the COVID-19 situation-related stress, which could affect the respondents' ability to recall their pre-COVID behaviour and attitudes accurately. Additionally, there may be inadequate physical opportunities on the research highway routes upon which the respondents gave their opinions in the questionnaire survey.

3.3 Overview of methodology

This methodology overview includes the theoretical foundations of reach design, the method used in data collection, and the analysis strategy according to the research's different objectives (1–5). The data collection and analysis details are stated in chapters 4–6.

3.3.1 Research methodology design

According to Bryman (2016), research strategy determines the tactical decisions on how the study will be carried out and the data analysed. The multiphase design offers several advantages, including the flexibility to incorporate mixed methods to address related research questions, the ability for researchers to publish individual study results while contributing to an overall evaluation or research program, and suitability for program evaluation and development approaches (Creswell and Plano Clark, 2011).

In this study, the researcher approached the research applying a mixed method approach, where quantitative (e.g., survey, experiments) and qualitative (e.g., focus group discussion) data were collected to understand reality in a way that might not be possible with any single strand alone.

3.3.2 Data collection and experiments

This study employs quantitative and qualitative methods, including experiments, to address the research problems and objectives. Quantitative research systematically gathers data to quantify study participants' attributes using various forms such as experimental, quasi-experimental, correlational, and survey research. Self-report methods have been proven effective for multiple analyses such as attitudes, opinions, beliefs, emotions, cognitive processes, and behaviours (Lajunen and Özkan, 2011). A self-report questionnaire is also helpful in case of under-reporting, to find answers to research questions from the target group, and where there is a need for faster evaluation of traffic safety measures (Polders and Brijs, 2018). Qualitative research, on the other hand, aims to provide a contextualised picture of a social or educational issue. Focus group is an excellent approach and a highly efficient way to gather in-depth attitudes, beliefs, behaviours and anecdotal data from a large group simultaneously (Boulanger et al., 2009).

Table 3.1 shows the linkage of TDF domains and associated pedestrian factors to operationalise the key components of COM-B with the pedestrians' self-reported attitude and behaviour. The items and/or statement selections for measuring the concepts and/or domains were based on a previously validated questionnaire and established causal link between factors and COM-B components with the proven 'if then' strategy, which were described in the following investigation chapters (Chapter 4 and Chapter 5).

Table 3.1 TDF mapping with factors within COM-B components

COM-B components	TDF domains (positive factors)
Physical capability	Skills (e.g., ability to walk or use stairs, gestural or eye contact, and fatigue management)
Psychological capability	Memory, attention and decision process; and knowledge, memory, and behavioural regulations (e.g., estimating vehicle speed/distance, controlling mood, and crossing with attention, knowing traffic rules, fines, and users' priority)
Physical opportunity	Environmental restructuring and resources (e.g., short crossing time, convenient location, easy access and weather friendliness, traffic signs/road marking, enforcement, barrier, right of way, visibility, refuge area, and speed reducer)
Social opportunity	Social influences (e.g., support from family/institution, many known users, parental reminder on safety, group crossing, and influential persons)
Reflective motivation	Social/professional role and identity; beliefs about capabilities; optimism; beliefs about consequences; intentions; and goals (e.g., planning, confidence, satisfaction, safety priority / benefit, persuasion, praise/gift, and imitation)
Automatic motivation	Reinforcement; and emotions (e.g., habit, good feelings, self-protection for beloved one, divine faith, and fear of injury/death)
Target behaviour	Safe use of crossings (e.g., avoiding violations, aggressions, and lapses)

A survey was conducted with pedestrian and driver questionnaires to capture the behaviour and attitudinal data of pedestrians and drivers. Appendix A and Appendix B incorporate the COM-B Pedestrian and Drivers Questionnaire with Bengali versions. Focus group discussions with pedestrians and drivers, and in-depth interviews with relevant stakeholders were conducted to explore the road users' behaviour and stakeholders' views, respectively.

This study also investigates the effect of co-design on the quality of outcome (intervention 1). Further, it explores the additional improvement achieved by applying a behaviour change model in the co-design process (intervention 2) compared to the current design practice in Bangladesh. The experimental Study was conducted through design workshops, including interviews with the key informants of design authorities.

3.3.3 Data Analysis

Descriptive statistics, structural equation modelling, and regression analysis were used in studies 1 and 2 to analyse quantitative data and identify factors influencing pedestrians' motivation in crossing use and driver yielding to pedestrians. On the other hand, qualitative data were analysed deductively using a thematic framework based on the behaviour change framework in Study 2 and deductive content analysis based on research questions was conducted in Study 3.

3.3.4 Ethical considerations

Incorporating ethical considerations is a crucial aspect when involving participants in social research. To ensure meaningful and voluntary participant involvement, it is deemed ethically acceptable to provide incentives that encourage and acknowledge their participation (Seymour, 2012).

Various ethical issues may arise during the data collection, particularly in interviews or focus groups, where coercion is strictly prohibited (Boulanger et al., 2009). This study obtained informed consent from participants, ensured confidentiality, and minimised potential harm or discomfort. Collecting behavioural data in road safety is not ethically questionable, primarily when anonymity is maintained. The survey data in this study was collected anonymously.

While adopting strategies to encourage and recognise participants' involvement in the focus group discussion, cash payments have been identified as essential incentives. Research indicates that cash payments help reduce the exclusion of low-income families from research (Seymour, 2012), which is particularly relevant to the socioeconomic context of Bangladesh. However, some participants may choose to participate because they believe the research will benefit them, help others, or view it as their social duty to participate (Williams et al., 2008). Recognition or visual motivational sayings can also be key factors in encouraging the participation of young people.

The University of Leeds Research Ethics Committee has approved this study for ethics (Ref: AREA 20-103). All ethical protocols, including the Participant Information Sheet (Appendix C for the survey and Appendix D for the workshop) and Consent Form (Appendix E), were followed in capturing data from the participants during this research.

3.4 Thesis investigation chapters

Following Chapter 4 to Chapter 6 describes three studies with specific purposes:

Study 1 (Chapter 4) investigates the motivation factors for safe crossing behaviours among pedestrians. Study 2 (Chapter 5) investigates drivers' yielding behaviours for pedestrian' safety and examines shared perceptions of pedestrians and drivers regarding pedestrian safety to establish the factors that could promote drivers' yielding behaviour with a consensus among drivers and pedestrians for enhancing pedestrian safety. Study 1 based on pedestrians' self-reported survey data. At the same time, Study 2 employs drivers' self-reported survey focus group study to investigate the pedestrians and drivers' competing interests for safe crossing use and unyielding behaviour, respectively. Study 3 (Chapter 6) presents the experiments of co-design and behaviour change models in promoting pedestrian safety, including an investigation of the existing blaming culture to enhance shared responsibility among stakeholders.

Chapter 4
Study 1: Pedestrians’ motivation in safe uses of crossing

4.1 Introduction

4.1.1 Background

The Safe System principles to reduce pedestrian fatalities may not work as expected in developing countries because of the prevalence of intentional violations and other non-intentional errors. The key objective of this study is to identify factors that motivate pedestrians to use a designated crossing.

In this study, the target behaviour of pedestrians is the safe use of crossings which needs to be measured with a validated scale. The Pedestrian Behaviour Scale (PBS) was initially developed as a comprehensive questionnaire to assess pedestrian behaviour across various age groups. It encompasses five dimensions: violations, errors, lapses, aggressive behaviours, and positive behaviours. The development of the PBS drew inspiration from several questionnaires and scales, with the principal conceptual framework being the Driver Behaviour Questionnaire (DBQ).

The original DBQ was created in the United Kingdom and consisted of three factors: violations, dangerous errors, and lapses. Özkan et al. (2006) successfully implemented a 19-item version of the DBQ in six countries across Europe and Asia. This revised version included three factors: errors, ordinary violations, and aggressive violations. However, the study revealed that the three-factor structure of the DBQ was not consistently stable across different countries, indicating that factors like aggressive violations were influenced by social context. Nonetheless, the two-factor structure of the DBQ, focusing on errors and violations, demonstrated validity and stability across various cultures and over time.

Reason et al. (1990) defined the key constructs used in the Pedestrian Behaviour Scale (PBS). ‘Violation’ refers to intentionally disregarding social norms without intending to cause harm or damage. ‘Errors’ relates to deficiencies in knowledge of traffic rules or errors in decision-making. ‘Lapses’ were defined as unintentional deviations from safe practices due to carelessness or a lack of concentration.

The PBS incorporated the Aggressive Driver Behaviours Scale (Lawton et al., 1997), which defines ‘aggressive behaviour’ as misinterpreting the actions of other road users, resulting in the intention to annoy or endanger them. Additionally, the Positive Driver Behaviours Scale (Özkan and Lajunen, 2005) was included, which defines ‘positive behaviour’ as actions that aim to prevent violations or errors and promote compliance with traffic rules.

Granié et al. (2013) validated the PBS for assessing injury risk behaviours in pedestrians of all age groups. Their study defined’ aggression’ as aggressive actions directed towards other road users. Deb et al. (2017) utilised the 43-item PBS to develop and validate a shorter version called the Pedestrian Behaviour Questionnaire (PBQ), consisting of 20 items tailored to the US population. The PBQ was subsequently applied in studies conducted worldwide.

In a Southeast Asian study conducted by McIlroy et al. (2019), a 20-item version of the Pedestrian Behaviour Questionnaire (PBQ) was tested to validate all its dimensions. Based on their findings, the study recommended a shorter version of the PBQ consisting of 12 items, encompassing three behavioural dimensions: violations, aggressions, and lapses. This 12-item PBQ was found to be valid across six culturally diverse countries, including Bangladesh.

This study incorporated 12 PBQ items used as formative items within the COM-B framework to measure the target behaviour. They were grouped into four categories of typical positive and negative behavioural questions. These categories included items related to the use of a nearby crossing (e.g., violations in using a zebra crossing or footbridge), other violation items (e.g., diagonal crossing), aggression (e.g., expressing anger towards drivers), and lapses (e.g., forgetting the crossing norms).

4.1.2 Research model and hypotheses

This study used original COM-B model framework to understand the hypothetical relationships between COM predictors and the target behaviour. Later, a conceptual model is framed to predict the target behaviour to understand the impact of additional demographic variables and conceptualised path of the modified model suited for the context. This approach was adopted to identify notable differences (i.e., in predictive power) or similarities compared to the original model. Moreover, to predict the target behaviour, the conceptual model was analysed at a lower and a higher order level to understand the contribution of sub-components of each COM-B constructs (i.e., physical and psychological sub-components of capability construct) and the overall contribution of construct (i.e., capability construct), respectively.

4.1.2.1 Original COM-B model

This study used the COM-B model, as introduced in Chapter 2 (section 2.5.3), to predict the target behaviours of pedestrians' safe crossing use model. The applied model included four exogenous latent variables (physical capability, psychological capability, physical opportunity, and social opportunity) to predict two endogenous latent variables (motivation and target behaviour).

The target behaviour of the pedestrians is the safe use of crossings, denoted by 'Safe crossing use' in the original model. Five hypotheses (H-P1 to H-P5) are drawn in the pedestrians' safe crossing use model. The descriptions of each of the hypotheses are stated below:

H-P1. Pedestrians' physical capability (PC) and psychological capability (PsC) will positively influence pedestrians' motivation and safe crossing use.

Explanation: Pedestrians with sufficient physical strength or stamina (physical capability), or who know the traffic rules, or who have other psychological skills (psychological capability), such as estimation of vehicle speed and distances, will be more motivated to use crossings safely.

H-P2. Pedestrians' physical opportunities (PO) and social opportunities (SO) will positively influence pedestrians' motivation and safe crossing use.

Explanation: When pedestrians find physical crossing facilitates (physical opportunity) such as convenient locations, safety devices or other road furniture that facilitate their safe crossings, they will be more likely to use the designated crossings. Favourable social support (social opportunity) from family, institutions, or locals could be stronger reasons to use the crossings. Individuals in a favourable environment (physical and social) will be motivated to use crossings safely.

H-P3. The motivation (of pedestrians) will positively influence safe crossing use.

Explanation: Various extrinsic and intrinsic motivation factors will positively impact on pedestrians' safe crossing use. For example, when pedestrians see the benefits or become satisfied with safe crossings (reflective motivation) or their habits develop (automatic motivation), they could be motivated to perform the target behaviour.

H-P4. Male pedestrians will be motivated more to use crossings than women.

Explanation: Bangladesh is a country with traditional gender roles and expectations, where women are the main workforce in the garment industry. They are often responsible for household and caregiving duties, which can limit their mobility and time to gather knowledge on road safety in using designated crossings. Consequently, they become victims on the road. Additionally, women may face more social and cultural barriers to moving freely in public spaces, which could contribute to their lower motivation to use busy crossings compared to men.

H-P5. Students will be more motivated than workers when they have access to physical opportunities.

Explanation: Students may have different priorities and preferences than workers regarding the physical features of crossing sites. The difference in motivation between students and workers could be attributed to their different contexts and priorities. Students in an educational setting may have more time and freedom to explore and utilise the physical opportunities provided to them, enhancing their motivation. In contrast, workers typically have more structured and demanding schedules, primarily focusing on fulfilling work-related responsibilities and meeting deadlines. They may have limited time and energy to engage in activities outside their work commitments, leading to less motivation to take advantage of available physical opportunities.

4.1.2.2 Modified COM-B model

This study also used an adapted version of the COM-B model as a conceptual research framework (Figure 4.1). The lower-order model consists of seven latent factors. They are physical capability (PC), psychological capability (PsC), physical opportunity (PO), social opportunity (SO), reflective motivation (RM), automatic motivation (AM), and target behaviour (TB). Later, a second-order 4-factor (capability, opportunity, motivation, and target behaviour) model is formed.

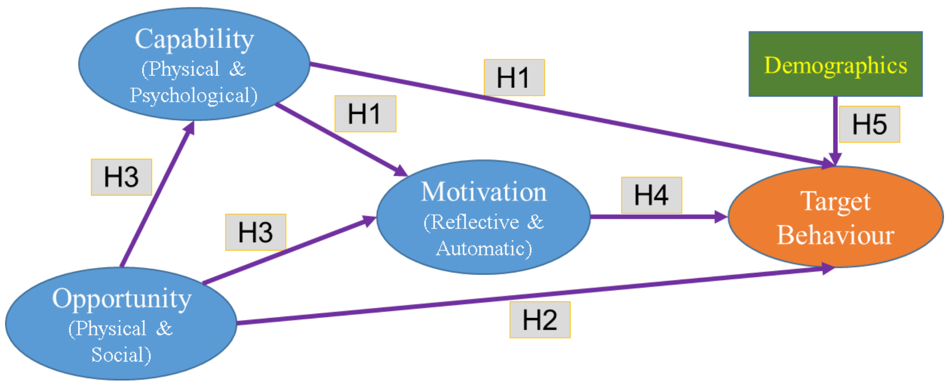


Figure 4.1 Conceptual COM-B (modified) framework

The application of the COM-B model is limited in the health domain. A study in seven countries (Australia, China, India, Indonesia, Saudi Arabia, South Africa, and the United Kingdom) examined the predictive relationships between COM-B components and children's handwashing (Schmidtke and Drinkwater, 2021). For all countries except China, at least one component (maximum of three components in Saudi Arabia) was a significant predictor. In Australia, Indonesia, and South Africa, only Capability was significant. Capability and Opportunity were significant in India, while Capability and Motivation were significant in the UK. In another study in the UK, the motivation component of the COM-B model was found to be the most influential component (Gibson Miller, J. et al., 2020). However, most studies have been performed in developed countries (Lydon et al., 2019). Therefore, the predictive power of COM-B elements in developing countries could be different due to infrastructure and other social and cultural differences. This study conceptualised the original COM-B paths' directions and added a path from opportunity to capability (annotated as H3 in Figure 4.1). This study analyses the data to assess the following hypotheses (H1-H5):

H1. The capability will positively predict the motivation and the target behaviour, similar to the original model.

H2. Unlike the original model, the opportunity will be the strongest positive predictor of the target behaviour compared with the capability and motivation.

H3. The opportunity will positively impact motivation, similar to the original model. Additionally, the opportunity positively impacts capability because individuals in a favourable environment (physical and social) will be more capable and more motivated to use crossings safely. They will walk or use stairs for physical exercise and will be more likely to improve their crossing skills, knowledge about traffic rules, or judgement. However, the contribution of physical or social opportunity to capability could have minimal effect, as the original model did not explicitly acknowledge such effect.

H4. Motivation will positively predict target behaviour and is the most potent mediator of the model. Both capability and opportunity will affect target behaviour strongly using motivation, similar to the original model.

H5. Students and workers are more exposed to the risky environment in LMICs, as they need to travel more to their places of study/work. The age group above 18 are primarily workers. Therefore, among five demographic variables (age, gender, profession, marital condition and parent), age and profession will significantly impact the target behaviour.

4.2 Data collection, procedure and sampling

4.2.1 Questionnaire development

Only a few COM-B questionnaires have been assessed for acceptability, reliability, and validity. Keyworth et al. (2020) conducted a study using a short version of a generic 6-item self-evaluation COM (Capability, Opportunity, and Motivation) questionnaire within the health domain, which was the first to test its predictive validity. In that questionnaire, each construct of COM-B was linked to the target behaviour by providing examples or indicators. For instance, one statement tied the capability construct with the target behaviour: "*I am PHYSICALLY able to Make Every Contact Count.*'' The indicators included statements such as "*I have sufficient physical stamina*," "*I can overcome disability*," and "*I have sufficient physical skills*." To evaluate the questionnaire's applicability, the survey was administered to individuals from a low socioeconomic background. Feedback from individuals with low socioeconomic status indicated that the questionnaire was easily understandable, engaging, and well-balanced.

In the road safety domain, no standardised measurement tool is available for assessing the COM-B constructs. Consequently, it was imperative to develop a measuring instrument using a formative approach, wherein indicators are utilised to predict the underlying construct. This study used the Theoretical

Domains Framework (TDF) to guide the COM-B construct formation. TDF does not establish correlations between domains which is suited for formative construct. In the context of measurement or modelling, a formative construct is one where the observed indicators or items contribute to or form the latent construct. In the case of the TDF, the domains are considered distinct components that collectively influence behaviour rather than being directly interrelated. This allows for a more flexible and nuanced understanding of the factors that shape behaviour change, as it recognises the multifaceted nature of human behaviour and the complex interactions between different domains. Therefore, TDF domains were mapped with the COM-B items, following the validated COM questionnaire structure.

In developing the questionnaire, the emphasis was placed on incorporating adequate and relevant indicators for each construct. A recommended *COM-B questionnaire* structure, as outlined by Michie et al. (2014) was followed, which includes various factors. The questions within the questionnaire were formed by mapping these factors to the corresponding constructs within the COM-B framework. *Sample questions for making a COM-B diagnosis*, as provided by West et al. (2020) were also utilised to inform the formulation of COM statements with the indicators that predict each COM-B construct. These questions help establish a clear cause-and-effect relationship between the constructs and their corresponding indicators. For each questionnaire statement, this study used the tested behavioural modification technique of the ‘If X occurs, then I will perform Y’ cause-and-effect relationship between constructs and indicators. A 5-point Likert scale was employed in the questionnaire to facilitate effective data collection and response quality. This scale was chosen as it has been shown to improve response rates and quality, reduce respondent frustration levels (Buttle, 1996), and is easily understandable to the respondents.

Researchers employ various methods to establish the validity of a measuring instrument, including conducting a thorough literature review, using established measurement tools or scales, gathering expert feedback, and conducting pilot testing. Additionally, correlations between variables can provide additional evidence of validity when they align with expectations and are statistically significant.

In this study, a preliminary questionnaire was pilot tested in two rounds with a small target population of pedestrians. The aim was to incorporate relevant factors for the formative constructs being assessed. The rationale behind this approach was to avoid a lengthy questionnaire that could lead to less reliable responses (Galesic and Bosnjak, 2009). The first round of the pilot study incorporated 36 COM items. After completing the questionnaire, the respondents could be asked to elaborate on their thoughts about each item and its corresponding response. The questionnaire items were then revised based on the results of this pilot testing. The second-round pilot questionnaire incorporated 41 COM items with a 10-point Likert scale. While taking responses from the pilot group, the researcher found some other items were not clearly understood by the respondents, and the majority of respondents preferred a 5-point Likert scale instead of the scale used in the pilot survey. The questionnaire aimed to capture the essential elements required to understand and assess the formative constructs of pedestrians' behaviour.

The COM-B questionnaire items were finalised in consultation with experts, specifically the supervisors of the researcher. The content was checked for consistency and validity during this phase. The researcher used a validated COM questionnaire with validated items in the light of literature and the TDF mapping process. Finally, 37 items were selected for the final version for testing of internal consistency by analysing the data from the pilot study using statistical methods such as Cronbach's alpha. Including the four target behavioural items, the final version of the questionnaire comprised 41 COM-B item statements designed to assess the relevant constructs (Appendix A).

A 5-point Likert frequency scale was used to measure the target behaviour, consisting of four statements. Example: (TB1) statement - "*When I had a chance to use my nearby crossing, I used that*," measured on a 5-point Likert scale (1 = never to 5 = always). The survey instrument included thirty-seven COM items, and respondents provided responses on different COM statements to measure the agreement level on a 5-point bipolar Likert agreement scale (-2 = strongly disagree to +2 = strongly agree). Sample statements of each construct item were:

1. Physical opportunity items (n = 10) started with the statement - “When I had the following physical opportunities, I used the crossing safely,” followed by variables such as “short crossing time” (PO1).
2. Social opportunity items (n = 5) started with the statement - “I had the following social opportunities to use the crossing safely,” followed by variables such as “getting education and support from family/institution” (SO1).
3. Physical capability items (n = 4) started with the statement - “I was physically able to use the crossing safely because I,” followed by variables such as “being able to walk” (PC1).
4. Psychological capability items (n = 5) started with the statement - “I was psychologically able to use the crossing safely because I,” followed by variables such as “estimating vehicle speed/distance correctly” (PsC1).
5. Reflective motivation items (n = 8) started with the statement - “I was motivated to use the crossing safely because I,” followed by variables such as “planning to improve crossing behaviour” (RM1).
6. Automatic motivation items (n = 8) started with the statement - “I was motivated to use the crossing safely because of my,” followed by variables such as “faith in God, which strengthens willingness to use” (AM1).

The COM-B questionnaire also included demographic items such as gender, profession, having children, marital status, and age, accident history including test variables for the target behaviour such as near-accident situation frequency.

4.2.2 Survey procedure, sample with descriptive

The research team actively visited the investigation sites and nearby institutions, encompassing schools, industries, and the marketplace. The researcher distributed the questionnaire to the participants through collaboration with local road agencies and institutional representatives, including school teachers and industry managers. Alongside the questionnaire, a participant information sheet was provided to offer essential details about the study, ensure informed consent, and guarantee the confidentiality of participants’ responses. Data was collected between December 2021 and March 2022 by the research team.

Data collection for the research study focused on capturing the respondents' self-reported behaviour and attitudes of pre-COVID-19 period, specifically before March 2020. This approach was chosen as data collected during the COVID-19 period may not accurately reflect the normal situation due to the impact of the pandemic. Four hundred paper-based questionnaires were distributed to students and garment workers by the research team through institutional representatives such as teachers or managers. Subsequently, the questionnaires were collected by the research team. Additionally, on-the-spot responses were obtained from marketplace workers and other individuals at the research locations. The study encompassed four research locations on two national highways in Bangladesh, specifically N-540 and N-2. Respondents were familiar with at least one of the four crossing facilities available, including zebra crossings, footbridges, underpasses, or non-priority crossings. In sample size estimation, this study used an online sample calculator (http://www.raosoft.com/samplesize.html), where the estimated sample size turned out as 267 with margin of error 5%, confidence level 90%, estimated population size 20000, and response distribution 50%. That calculator used the formula:

$$x = Z\,(c/100)^{\,2} * r * (100 - r)$$

$$\text{The sample size } n = \frac{N * x}{(N-1)^2 + x}$$

$$\text{Margin of error } E = \sqrt{\frac{(N-n) * x}{n * (N-1)}}$$

where, *N* is the population size, *r* is the fraction of responses of interest, and *Z*(*c*/100) is the critical value for the confidence level *c*.

Supplying more questionnaires than your targeted sample size is a common practice in survey research to account for uncertainty and potential non-response. In this study, the number of questionnaires supplied was based on the assumption 1.5 times the estimated sample size of 267, which is approximately 400 questionnaires.

The total sample size with completed responses was 302, and the response rate of the paper questionnaire was 75.5%. Based on the nearby crossings reported by the respondents, there were 156 respondents near at-grade crossings, with 141 near zebra crossings and 15 near non-priority crossings. In contrast, 146 respondents were near grade-separated crossings, with 106 near footbridges and 40 near underpasses. Descriptive statistics for gender, marital status, parent, age, and profession were shown in Table 4.1.

Table 4.1 Descriptives of demographics

Variable	Class/ type	Frequency (N = 302)	Percentage
Gender	Male	163	54.0
	Female	136	45.0
	Others	3	1.0
Marital status	Married	149	49.3
	Unmarried	152	50.3
Parent	Yes	120	39.7
	No	179	59.3
Age	12-18 years	123	40.7
	19-25 years	50	16.6
	26-32 years	75	24.8
	33-39 years	35	11.6
	40 years and above	19	6.3
Profession	Secondary school student	53	17.5
	College/University student	74	24.5
	Industry/Garments worker	99	32.8
	Marketplace worker	46	15.2
	Other	30	9.9

The sample comprised 163 (54%) males and 136 (45%) females. The married and unmarried were almost equal, where 152 were single, and 149 were married. Regarding parental status, most participants had no child (n = 179, 59.3%), while 120 (39.7%) reported having children. The age of the participants ranged from 12–18 years (lowest group) to 40 years and above (highest group), with five groups. Most participants were between 12 and 18 years (n = 123, 40.7%).

A total of 127 students (42%) of school and college, 145 workers (48%) of garment industry and marketplace, and 30 respondents (10%) from other professions filled out the questionnaire. Finally, about accident history, 93 (30.8%) participants reported having been involved in at least one accident in the past, while 196 (64.9%) reported no history of accidents.

4.3 Statistical analysis and model evaluation

Regression analysis is a statistical technique used to determine the correlation between dependent and independent variables. This method can involve various regression models, such as linear and ordinal logistic regression. Partial least squares (PLS) regression is helpful in developing predictive models when dealing with limited observations or highly correlated variables. PLS considers the correlation structure to identify complex relationships in multivariate patterns. PLS regression can be extended to Structural Equation Modelling (SEM) using the PLS-SEM approach, which models relationships between latent variables.

Partial Least Squares Structural Equation Modelling (PLS-SEM) is a second-generation data analysis technique in the family of structural equation modelling. Different from the SEM covariance-based groups, PLS-SEM is a prediction-oriented approach to SEM. PLS-SEM is particularly useful for causal-predictive analysis in situations of high complexity and low theoretical information availability (Vinzi et al., 2005). PLS-SEM approach is suitable with a prediction-oriented objective, abnormal data distribution and accommodates small sample sizes (minimum 30-100) (Chin and Newsted, 1999; Hair et al., 2012; Hair et al., 2017, do Valle and Assaker, 2016). SmartPLS, WarpPLS, PLS-Graph are some of the commonly applied software in PLS-SEM.

PLS-SEM is a multivariate analysis method that focuses on variance analysis. The combination of PLS and SEM enabled the assessment of the formative measurement model of the COM-B and the constructs' predictive validity. Construct formation and directional causality need to be settled before analysing the model. Otherwise, it could lead to incorrect conclusions on the relationships between constructs, support for theories, or implicitly make unjustified causal claims (Freeze and Raschke, 2007). Reviewing relevant literature, Hanafiah (2020) suggests three criteria that can be used to categorise the research constructs into formative or reflective measurement models: (i) the nature of the construct; (ii) the relationship between the latent construct and the indicators in terms of causation; and (iii) the characteristics of the indicators that are used to assess the construct.

PLS-SEM is the preferred approach when formative constructs are included in the structural model (Hair et al., 2019). The first step in evaluating PLS-SEM results involves examining the measurement models. If the measurement models meet all the required criteria, researchers then need to assess the structural model. The assessment procedure-

a) *Formative measurement model assessment:* In formative measurement model, the observable indicators are considered to cause the latent construct. Thus, formative constructs should be assessed based on the statistical significance and size of the indicator weights as well as collinearity among indicators. For the evaluation of the formative measurement model, Hanafiah (2020) suggested three parameters should be examined: (i) multicollinearity; (ii) construct validity; and (iii) indicator reliability. Since the indicators are not essentially inter-changeable, high correlations are not expected between indicators in formative measurement models. In fact, high correlations between two formative indicators are known as collinearity (Hair et al. 2014). In order to test for the construct validity, the estimation of the indicator weights in measuring the contribution of every each of the formative indicators to the variance of the latent variable should be applied (Petter et al., 2007). The significant value for the formative indicator in PLS-SEM can be evaluated through the outer weight (Chin, 1998; Latan & Ghozali, 2012a). Outer weights (λ) are the results of a multiple regression of a construct on its set of indicators. However, Hair et al. (2012) claims that if it is found that the outer weight is non-significant and the outer loading is high (i.e., > 0.5), that indicator is still acceptable.

b) *Formative structural model assessment:* Standard assessment criteria include the coefficient of determination (R^2), the blindfolding-based cross validated redundancy measure (Q^2), and the statistical significance and relevance of the path coefficients (β). The β (beta) value represents the strength and direction of the relationship between variables.

A couple of methodologists have endorsed model fit measures for PLS-SEM (Henseler et al., 2016a). The Standardized Root Mean Square Residual (SRMR) is a measure of model fit that can be used to assess both measurement models and structural models. It is calculated by comparing the observed correlations between the variables in the model to the correlations that are implied by the model. A lower SRMR value indicates a better fit between the model and the data. The SRMR value of 0.08 being the acceptable threshold.

Data cleaning was done before using SmartPLS 4 software, followed by normality checks. Model variables were tested with statistical tests using SPSS, including PLS-SEM and regression analysis using smartPLS for each target variable item. In SmartPLS 4, the default settings of the PLS algorithm were used to obtain the weights for the initial model's outer (i.e., the measurement model) and inner model (i.e., the path model of the constructs). Multicollinearity within the inner and outer model was minimal as the Variance Inflation Factor (VIF) was less than the ideal and most conservative threshold of 3.0 (Becker et al., 2015).

In the original COM-B model framework, the model was established through initial model trimming by removing statistically non-significant (outer model item $p > 0.05$ and outer loading < 0.5) items and insignificant inner model paths ($p > 0.1$) stepwise. Later, a conceptual higher-order model was proposed, which was formed based on the lower model constructs for the modified conceptual COM-B model framework, and a similar procedure was followed as followed in the original model. The p-value was set at 0.05 for interpreting the results, except for interpreting the lower-order conceptual model and multigroup analysis of the original model, where it was set at 0.1.

Assessing Multigroup Analysis (MGA) in partial least squares path modelling (PLSPM) could assist in spotting significant variations in numerous linkages among group-specific outcomes (Schlägel and Sarstedt, 2016). The multigroup analysis was conducted on the trimmed original COM-B model framework. Before multigroup analysis, three steps of the measurement invariance of composite models were followed (Henseler et al., 2016b). These were configural invariance in step-1, compositional invariance in step-2, and equal mean values and variances in step-3. Step-1 was automatically confirmed while performing Measurement Invariance of Composite Models (MICOM) in SmartPLS.

R^2 (R-squared) and Q^2 (Q-squared) are statistical measures used to evaluate regression or predictive models' performance and predictive power. R^2 is often used as a measure of model fit for both reflective and formative models. Q^2 is a particularly useful measure of model fit for formative models; however, it requires large sample size for accuracy. R^2 represents the proportion of the variance in the dependent variable that can be explained by the independent variables in a regression model. It ranges from 0 to 1, with higher values indicating a better fit and a stronger relationship between the variables. Q^2 measures predictive validity in SEM, specifically in PLS regression. Using cross-validation techniques, it assesses the model's ability to predict the dependent variable(s). Q^2 values have a scale from -1 to 1. Positive values mean that the predictive performance is good, while negative values mean that the predictive performance is poor. A Q^2 value above 0 indicates the model has predictive power beyond chance. Both R^2 and Q^2 values are essential in evaluating the quality and usefulness of a model. R^2 assesses how well the model fits the observed data, while Q^2 evaluates its ability to predict new data. These values were used to describe the explanatory power of the conceptual models on the observed data (in-sample explanatory power) and the predictive power on new data (out-of-sample predictive power), respectively.

4.4 Results

4.4.1 Model variables with statistical tests

4.4.1.1 Target variable

The target variable in this study consisted of four items, each measured using a 5-point Likert scale ranging from 1 (never) to 5 (always). The four items and their corresponding labels are as follows:

a) *TB1:* the use of nearby crossing;

b) *TB2:* violation behaviours, such as crossing diagonally or using prohibited crossing paths;

c) *TB3:* aggressive behaviours, such as walking slowly, yelling at drivers, or making rude gestures, and hitting a vehicle; and

d) *TB4:* road safety lapses, such as failing to pay attention or properly look at traffic due to using a mobile phone while crossing or joining someone on the opposite side.

To check additional validity of measuring target behavioural items, the frequency of near-accidental situations was measured as a test variable with a

5-point Likert scale (e.g., 1 = never to 5 = always). The descriptive statistics of the test variable and target behavioural items, including their mean, range, and standard deviation, are presented in Table 4.2.

Table 4.2 Descriptives of the target variable and test variable

Variable (Mean, Std. Deviation & Range)	**Response**	**Frequency (N = 302)**	**Percentage**
Uses of nearby crossing (TB1) Mean (3.78) Standard deviation (0.79) Range (4.0)	Never	1	0.3
	Infrequent	14	4.6
	Sometimes	88	29.1
	Frequent	147	48.7
	Always	52	17.2
Violation behaviour (TB2) Mean (2.16) Standard deviation (0. 78) Range (3.0)	Never	55	18.2
	Infrequent	161	53.3
	Sometimes	69	22.8
	Frequent	17	5.6
	Always	0	0
Aggression (TB3) Mean (1.94) Standard deviation (0.89) Range (4.0)	Never	109	36.1
	Infrequent	120	39.7
	Sometimes	58	19.2
	Frequent	12	4.0
	Always	3	1.0
Lapses (TB4) Mean (2.13) Standard deviation (0.74) Range (3.0)	Never	56	18.5
	Infrequent	162	53.6
	Sometimes	74	24.5
	Frequent	10	3.3
	Always	0	0
Near-accidental situations Mean (2.37) Standard deviation (0.98) Range (4.0)	Never	77	25.5
	Infrequent	68	22.5
	Sometimes	120	39.7
	Frequent	32	10.6
	Always	1	0.3

Range= The difference between the largest and smallest values in a dataset

In the original and conceptual research model, the target behaviour is the safe use of crossings. It is constructed using four indicators: TB1, TB2*, TB3*, and TB4*. It is important to note that TB2, TB3, and TB4 were measured with a reversed scale compared to the original formulation. The reversal of these items allows for a consistent interpretation of the target behaviour as the safe use of crossings.

It is logical to assume a correlation between crossing use (or less violation, aggression, or lapse behaviour) and the test variable of the frequency of near-accident situations. Self-control theory, TPB, and the protection motivation theory could support such correlations. Individuals who exhibit less violation, aggression, or lapse behaviour may have a higher level of self-control (Gottfredson and Hirschi, 1990), positive attitudes toward responsible behaviour (Ajzen, 1991), and a heightened perception of risks (Rogers, 1975) associated with risky behaviours. As a result, they are less likely to have experience near-accident situations while crossing the road.

Therefore, those who report target behaviour (behavioural variables TB1, TB2*, TB3*, and TB4*) more frequently may have a less likelihood of experiencing near-accidental situations when pedestrians cross a road if other factors remain constant. The Spearman correlation between the test variable and the target variable items TB1, TB2*, TB3*, and TB4* was used. The correlation coefficients between the test variable and the behavioural items were found to be statistically significant: TB1 ($r = -0.137$, $p < 0.05$), TB2* ($r = -0.189$, $p < 0.01$), TB3* ($r = -0.367$, $p < 0.01$), and TB4* ($r = -0.203$, $p < 0.01$).

4.4.1.2 Predictors

In the original and conceptual research model, PO is constructed with ten physical opportunity items (PO1–10), SO with five social opportunity items (SO1–5), PC with four physical capability items (PC1–4), PsC with five psychological capability items (PsC1–5). However, motivation is constructed with eight reflective motivation items (RM1–8) and five automatic motivation items (AM1–5) in the original model. In contrast, the conceptual model constructed reflective motivation (RM) and automatic motivation (AM) separately. The descriptives of predictor variables have shown in Appendix F.

The PLS-SEM analysis revealed the relative strength of each latent construct in predicting the target behavioural items (TB1, TB2*, TB3*, and TB4*). In the case of TB1, the physical capability construct was supported by three items (PC1–3), while psychological capability was supported by three items (PsC2–4). Additionally, the construct of physical opportunity was represented by seven items (PO1, PO3–5, PO8–10), social opportunity by four items (SO1–3, SO5), reflective motivation by seven items (RM1–3, RM5–8), and automatic motivation by five items (AM1–5). The dominant factors of these constructs can be presented with outer weights (λ). Results showed few dominant factors such as PC1 (λ = 0.642) in PC construct, PsC2 (λ = 0.727) in PsC construct, PO8 (λ = 0.545) in PO construct, SO5 (λ = 0.474) in SO construct, RM2 (λ = 0.578) in RM construct, and AM2 (λ = 0.479) in AM construct. Notably, physical opportunity had the highest total effect (TE = 0.330) on avoiding violations in the use of nearby crossings compared to other constructs. The total effects (TE) ranged from -0.009 for automatic motivation (AM) to 0.181 for reflective motivation (RM). Regression analysis further identified that PO1 (β = 0.132, $p < 0.05$), PO3 (β = 0.157, $p < 0.05$), PO8 (β = 0.216, $p < 0.01$), RM2 (β = 0.268, $p < 0.001$), and PsC3 (β = 0.106, $p < 0.05$) made significant positive contributions, explaining 43.9% variance ($R^2 = 0.439$) in TB1. Notably, significant correlations were observed at the 0.01 level for PO items (excluding PO1 and PO6), SO items, RM items (RM2–5), AM items (excluding AM1), PC items, and PsC items (excluding PsC5).

For TB2*, four items (PC1–4) supported the physical capability construct, while psychological capability was supported by three items (PsC2–4). The construct of physical opportunity was represented by six items (PO2–4, PO6, PO8, PO10), social opportunity by five items (SO1–5), reflective motivation by five items (RM1–3, RM5, RM8), and automatic motivation by five items (AM1–5). The dominant factors of these constructs included PC1 (λ = 0.853), PsC2 (λ = 0.727), PO3 (λ = 0.506), SO3 (λ = 0.366), RM5 (λ = 0.796), and AM3 (λ = 0.385). The total effect of physical capability (TE = 0.197) on avoiding violations other than TB1 was the highest among the constructs. The total effects (TE) ranged from 0.044 for psychological capability (PsC) to 0.230 for reflective motivation (RM). Regression analysis revealed that SO1 (β = 0.159, $p < 0.05$), SO5 (β = 0.139, $p < 0.05$), RM5 (β = 0.197, $p < 0.05$), and PC1 (β = 0.169, $p < 0.05$) made significant positive contributions, explaining 24.3% variance ($R^2 = 0.243$) in TB2*. Significant correlations were observed at the 0.05 level for PO items (PO2, PO4, PO9–10), PO3 and PO8 at the 0.01 level, SO items (except SO4) at the 0.01 level, RM items (RM2–5) at the 0.01 level, and AM3 at the 0.05 level. Additionally, PC items (PC1, PC4) had significant correlations at the 0.01 level, while PC2 had a significant correlation at the 0.05 level. PsC items, except for PsC5, showed significant correlations at the 0.01 level.

Moving on to TB3*, the physical capability construct was supported by four items (PC1–4), psychological capability by three items (PsC2–3, PsC5), physical opportunity by five items (PO4, PO6, PO8–10), social opportunity by four items (SO1, SO3, SO4–5), and reflective motivation by five items (RM1, RM3, RM5, RM7–8). However, no contribution was found from automatic motivation. The dominant factors of these constructs included PC1 ($\lambda = 0.565$), PsC3 ($\lambda = 0.753$), PO4 ($\lambda = 0.704$), SO1 ($\lambda = 0.382$), and RM5 ($\lambda = 0.527$). The total effect of social opportunity (TE = 0.227) on avoiding aggression was the highest compared to other constructs. The total effects (TE) ranged from 0.013 for psychological capability (PsC) to 0.162 for physical opportunity (PO). Regression analysis indicated that PO4 ($\beta = 0.155$, $p < 0.05$), PO6 ($\beta = 0.133$, $p < 0.05$), SO1 ($\beta = 0.188$, $p < 0.05$), and RM3 ($\beta = 0.172$, $p < 0.05$) made significant positive contributions, explaining 27.6% variance ($R^2 = 0.276$) in TB3*. Correlation analysis revealed that PO items (PO1, PO6, PO8–10) showed significant correlations at the 0.05 level, while PO4 had a significant correlation at the 0.01 level. Similarly, SO items (except SO5) had significant correlations at the 0.01 level. RM items (RM3, RM5) showed significant correlations at the 0.01 level, whereas RM7 had a significant correlation at the 0.05 level. Among the AM items, AM2–3 had significant correlations at the 0.05 level. PC items exhibited significant correlations at the 0.01 level, and PsC items (PsC2–3) had significant correlations at the 0.05 level.

Finally, for TB4*, the physical capability construct was supported by four items (PC1–4), psychological capability by four items (PsC2–5), physical opportunity by six items (PO3–5, PO8–10), social opportunity by four items (SO1, SO3, SO4–5), reflective motivation by seven items (RM1–5, RM7–8), and automatic motivation by four items (AM1–4). The dominant factors of these constructs included PC3 ($\lambda = 0.702$), PsC3 ($\lambda = 0.726$), PO4 ($\lambda = 0.486$), SO3 ($\lambda = 0.587$), RM5 ($\lambda = 0.559$), and AM2 ($\lambda = 0.618$). The total effect of social opportunity (TE = 0.179) on avoiding lapses was the highest compared to other constructs. The total effects (TE) ranged from 0.096 for physical opportunity (PO) to 0.139 for psychological capability (PsC). Regression analysis indicated that SO3 ($\beta = 0.152$, $p < 0.05$), AM2 ($\beta = 0.154$, $p < 0.05$), and PsC3 ($\beta = 0.194$, $p < 0.01$) made significant positive contributions, explaining 29.4% variance ($R^2 = 0.294$) in TB4*. Correlation analysis revealed that PO items (PO4–5, PO8–10) showed significant correlations at the 0.01 level, while PO2–3 had significant correlations at the 0.05 level. Similarly, SO items exhibited significant correlations at the 0.01 level. RM items (RM1–5) showed significant correlations at the 0.01 level, whereas RM7–8 had significant correlations at the 0.05 level. All of the AM items except AM1 had significant correlations at the 0.01 level. Except for PC2, PC items exhibited significant correlations at the 0.01 level, and PsC items, except for PsC1 and PsC5, showed significant correlations at the 0.01 level, while PsC1 and PsC5 had significant correlations at the 0.05 level.

However, there could have been significant differences based on the crossing types (e.g., at-grade vs. grade-separated crossings). The Mann-Whitney U test showed a statistically significant difference between the two groups on TB3* ($U = 8223$, $p < 0.001$, $r = -4.441$) and TB4* ($U = 9402$, $p < 0.01$, $r = -2.89$), while others (TB1 & TB2*) were not significant.

4.4.2 Original model and multigroup analysis

After trimming only one unreliable or insignificant ($\beta = 0.178$) inner model path (PsC to Safe crossing use) and statistically non-significant outer model items (PO1–3, PO5–7, PO10, SO2–3, PC2, PC4, PsC1, PsC5, AM1, AM4, RM3–4, RM6–7, and TB2*) from the initial model (Figure 4.2), the prediction model (Figure 4.3) was established with a good model fit (SRMR = 0.045). The trimmed original prediction model displays outer weights (λ) and p-value for the outer model items and beta (β) value (p-value) for each path in the inner model

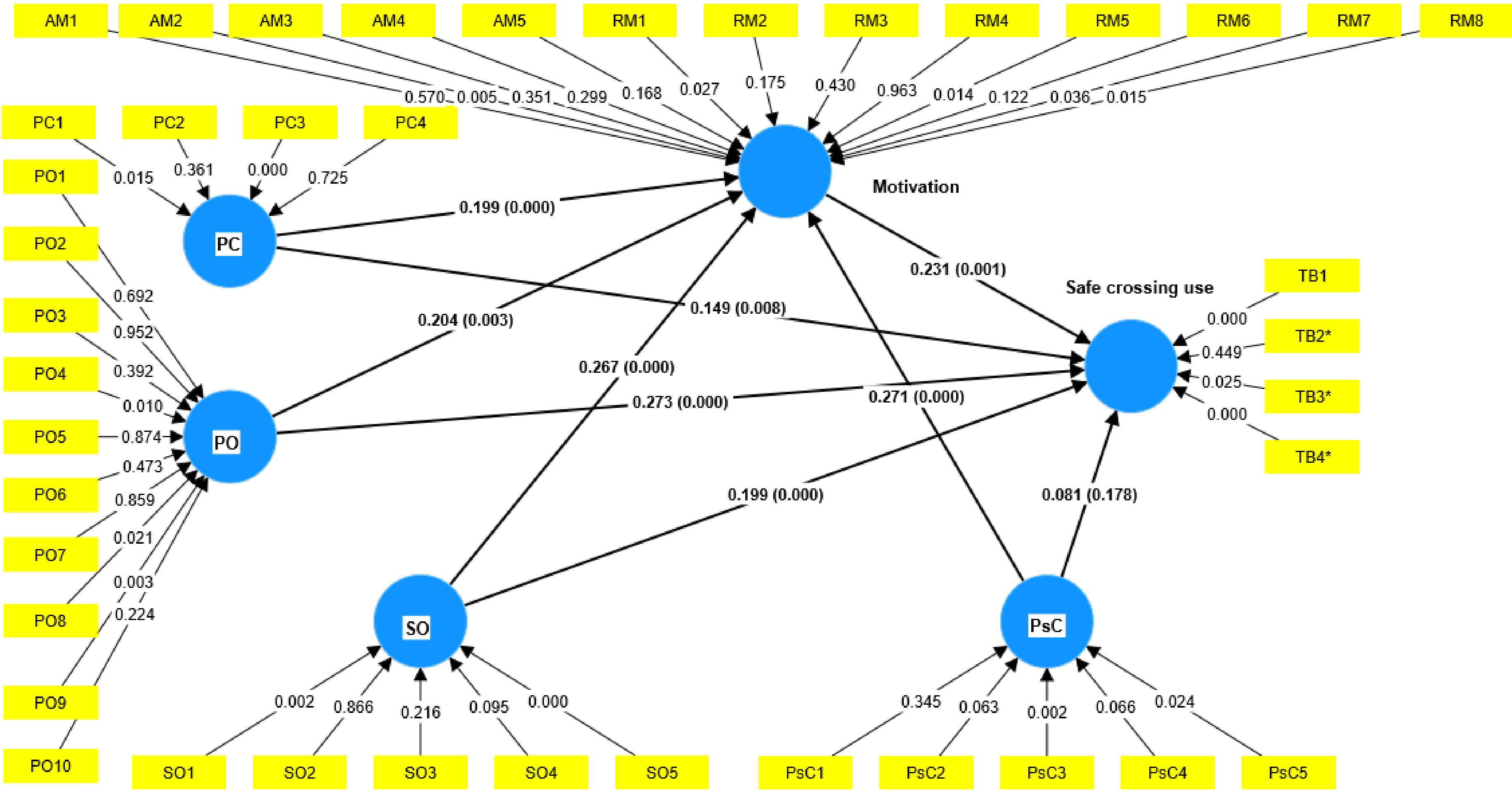


Figure 4.2 The initial original model

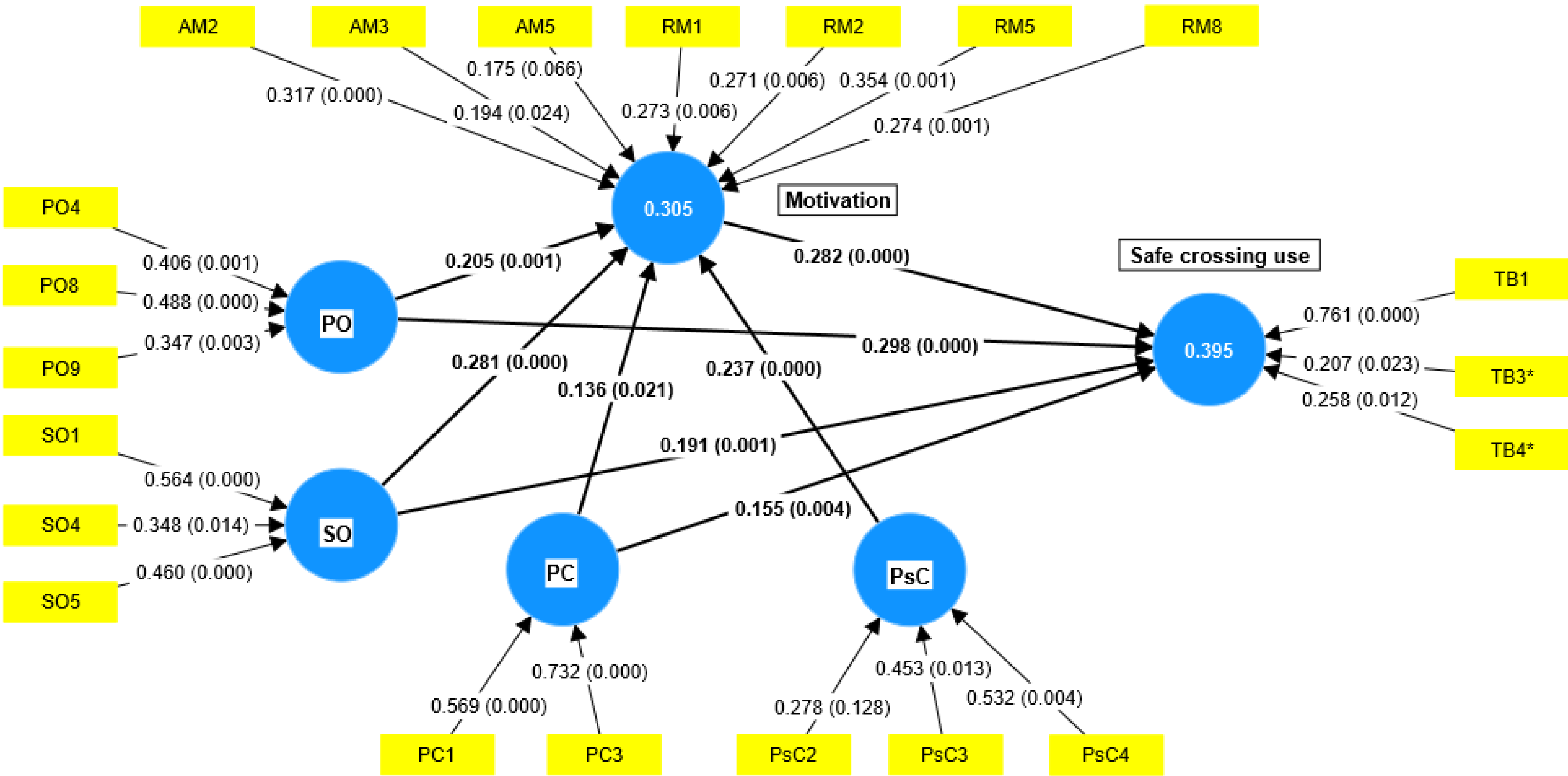


Figure 4.3 The trimmed original prediction model

The 18- factored trimmed model explained motivation with the maximum number ($n = 7$) of factors, followed by physical and social opportunity ($n = 3$, each), psychological capability ($n = 3$), and physical capability ($n = 2$). Multicollinearity was not a problem in the inner and outer models (VIF < 3.3). The model explained 39.5% of the variance in safe crossing use, followed by motivation (30.5%). Social opportunity ($\beta = 0.281$, $p < 0.001$), physical opportunity ($\beta = 0.205$, $p < 0.01$), psychological capability ($\beta = 0.237$, $p < 0.001$), and physical capability ($\beta = 0.136$, $p < 0.05$) significantly predicted motivation. Motivation ($\beta = 0.282$, $p < 0.001$), physical opportunity ($\beta = 0.298$, $p < 0.001$), social opportunity ($\beta = 0.191$, $p < 0.01$), and physical capability ($\beta = 0.155$, $p < 0.05$) significantly predicted the safe crossing use. The most contributory elements in the respective constructs were:

a) *Safe crossing use:* crossing use (TB1) with $\lambda = 0.761$ ($p < 0.001$), avoiding lapses (TB4*) with $\lambda = 0.258$ ($p < 0.05$), and avoiding aggression (TB3*) with $\lambda = 0.207$ ($p < 0.05$);
b) *Physical capability (PC):* strength (PC3) with $\lambda = 0.732$ ($p < 0.001$) and the ability to walk (PC1) with $\lambda = 0.569$ ($p < 0.001$);
c) *Psychological capability (PsC):* knowledge of traffic rules (PsC4) with $\lambda = 0.532$ ($p < 0.01$) and paying attention to traffic (PsC3) with $\lambda = 0.453$ ($p < 0.05$);
d) *Physical opportunity (PO):* visibility to drivers (PO8) with $\lambda = 0.488$ ($p < 0.001$), traffic sign and road marking (PO4) with $\lambda = 0.406$ ($p < 0.01$), and refuge area on a highway (PO9) with $\lambda = 0.347$ ($p < 0.01$);
e) *Social opportunity (SO):* support from family/institution (SO1) with $\lambda = 0.564$ ($p < 0.001$), crossing uses by influential peoples (SO5) with $\lambda = 0.460$ ($p < 0.001$), and group crossing (SO4) with $\lambda = 0.348$ ($p < 0.05$); and
f) *Motivation:* safety priority (RM5) with $\lambda = 0.354$ ($p < 0.01$), habit (AM2) with $\lambda = 0.317$ ($p < 0.001$), imitation (RM8) with $\lambda = 0.274$ ($p < 0.01$), planning (RM1) with $\lambda = 0.273$ ($p < 0.01$), satisfaction in use (RM2) with $\lambda = 0.271$ ($p < 0.01$), and feelings in crossing use (AM3) with $\lambda = 0.194$ ($p < 0.05$).

This study performed permutation through SmartPLS, where the output suggested partial measurement invariance. Therefore, we securely compared the standardised path coefficients between the groups using Multigroup

Analysis (MGA). The outcome of the multigroup analysis between males (n = 162) and females (n = 140) was shown in Appendix G (A), and the multigroup analysis between students (n = 127) and workers (n = 145) was shown in Appendix G (B).

The multigroup analysis revealed that the effect of female motivation (β = 0.135) on safe crossing use was low compared to males (β = 0.403), and workers (β = 0.044) showed less motivation from physical opportunities compared to students (β = 0.326), and this difference was significant ($p < 0.05$). Similarly, the influence of female physical capability (β = 0.039) on safe crossing use was lower than males (β = 0.224), and female physical and social opportunity (β = 0.375 and β = 0.344, respectively) had a stronger impact on safe crossing use compared to males (β = 0.207 and β = 0.164, respectively), and these differences were also significant at a 0.1 level.

4.4.3 The proposed conceptual model

The initial model underwent a refinement process, as followed in the trimming process in the original model (section 4.4.2), where three non-significant inner model paths were removed: from physical opportunity to physical capability and from psychological capability to automatic motivation and target behaviour. Additionally, ten statistically non-significant items were eliminated from the outer model. These items include PC4, PsC1, PO1, PO3, PO5-7, RM3, AM1, and TB2.

The resulting lower-order model demonstrated a strong fit to the data, as indicated by a satisfactory model fit statistic (SRMR = 0.057). The lower-order model, represented in Figure 4.4, illustrates the relationships between variables. The figure includes the outer weights (λ) and p-values for the outer model, providing information about the strength and significance of the relationships between latent constructs. Furthermore, it displays the beta coefficients (β) and associated p-values (in parentheses) for each path of the inner model, indicating the magnitude and significance of the relationships between the latent constructs. All abbreviations in Figure 4.4 are expanded in Appendix F.

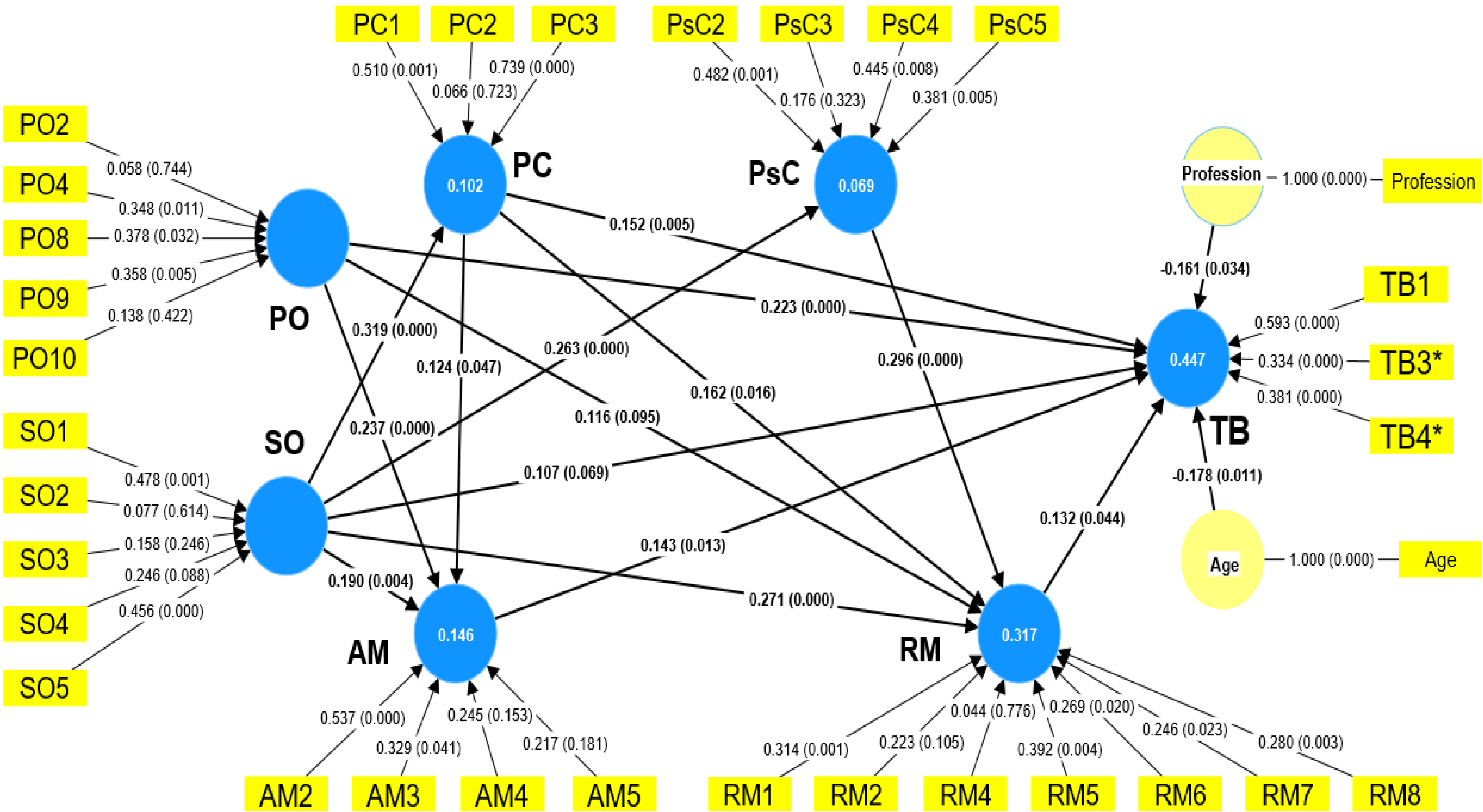


Figure 4.4 Lower-order conceptual model

The trimmed lower-order model confirmed that the strength (PC3), controlling mood (PsC2), visibility to drivers (PO8), support from family or institution (SO1), safety priority (RM5), and habit (AM2) were the most contributory elements in the respective constructs. The cross-loadings check confirmed that each formative indicator was strongly associated with the assigned construct and suggested sufficient discriminant validity.

Multicollinearity was not detected as a concern in either the inner or outer model, as indicated by variance inflation factor (VIF) values below 3. This suggests that there were no significant issues of collinearity among the variables, ensuring the stability of the model.

The model accounted for 44.7% of the variance in the target behaviour, indicating moderate explanatory power. Additionally, all endogenous constructs had Q^2 values greater than zero, signifying their predictive relevance. Notably, the Q^2 value for the target behaviour was 0.336, indicating that the model possesses adequate predictive power for this outcome.

The lower-order conceptual prediction model confirmed that the most contributory elements in the respective constructs were:

a) *Safe crossing use (TB):* crossing use (TB1) with $\lambda = 0.593$ ($p < 0.001$), avoiding lapses (TB4*) with $\lambda = 0.381$ ($p < 0.001$), and avoiding aggression (TB3*) with $\lambda = 0.334$ ($p < 0.001$);
b) *Physical capability (PC):* strength (PC3) with $\lambda = 0.739$ ($p < 0.001$) and the ability to walk (PC1) with $\lambda = 0.510$ ($p < 0.01$);
c) *Psychological capability (PsC):* knowledge of traffic rules (PsC4) with $\lambda = 0.445$ ($p < 0.01$), mood control in assertive crossing (PsC2) with $\lambda = 0.482$ ($p < 0.01$), and knowing the provision of fines for violations (PsC5) with $\lambda = 0.381$ ($p < 0.01$);
d) *Physical opportunity (PO):* visibility to drivers (PO8) with $\lambda = 0.378$ ($p < 0.05$), refuge area on a highway (PO9) with $\lambda = 0.358$ ($p < 0.01$), and traffic sign and road marking (PO4) with $\lambda = 0.348$ ($p < 0.05$);
e) *Social opportunity (SO):* support from family/institution (SO1) with $\lambda = 0.478$ ($p < 0.01$), crossing uses by influential peoples (SO5) with $\lambda = 0.456$ ($p < 0.001$), and group crossing (SO4) with $\lambda = 0.246$ ($p < 0.1$);

f) *Reflective motivation (RM):* safety priority (RM5) with λ = 0.392 ($p < 0.01$), planning (RM1) with λ = 0.314 ($p < 0.01$), imitation (RM8) with λ = 0.280 ($p < 0.01$), persuasion from awareness campaign (RM6) with λ = 0.269 ($p < 0.01$), and reward/praise for using the crossing (RM7) with λ = 0.246 ($p < 0.01$); and

g) *Automatic motivation (AM):* habit (AM2) with λ = 0.537 ($p < 0.001$), feelings in crossing use (AM3) with λ = 0.329 ($p < 0.05$).

The path analysis conducted on the lower-order model revealed significant contributions of various exogenous latent constructs in predicting the endogenous latent constructs (AM, RM, PC, PsC, and TB), including the influence of demographic variables on the target behaviour. The findings are as follows:

1. Physical opportunity (β = 0.237, $p < 0.001$), social opportunity (β = 0.190, $p < 0.01$), and physical capability (β = 0.124, $p < 0.05$) significantly predicted automatic motivation with 14.6% explained variance.
2. Social opportunity (β = 0.271, $p < 0.001$), psychological capability (β = 0.296, $p < 0.001$), and physical capability (β = 0.162, $p < 0.05$) significantly predicted reflective motivation with 31.7% explained variance.
3. Social opportunity (β = 0.319, $p < 0.001$; β = 0.263, $p < 0.001$) significantly predicted physical and psychological capability with 10.2% and 6.9% explained variance, respectively.
4. Physical capability (β = 0.152, $p < 0.01$), physical opportunity (β = 0.223, $p < 0.001$), social opportunity (β = 0.107, $p < 0.1$), automatic motivation (β = 0.143, $p < 0.05$), reflective motivation (β = 0.132, $p < 0.05$), and demographic variables (age: β = -0.178, $p < 0.05$; and profession: β = -0.161, $p < 0.05$) significantly predicted the target behaviour with 44.7% explained variance.

Mediation analysis of lower-order model paths has been shown in Table 4.3.

Table 4.3 Mediation analysis of lower-order model paths

Path	Total effect β(p) & 95% CI	Path, Indirect effect β(p) & 95% CI	Direct effect β(p) & 95%CI
PC->TB	0.191(< 0.01) & (0.084 to 0.298)	RM 0.021 (> 0.1) & (0 to 0.057) AM 0.018 (> 0.1) & (0 to 0.044)	0.152 (< 0.01) & (0.044 to 0.254)
PsC->TB	0.039 (< 0.1) & (0.004 to 0.088)	RM 0.039 (< 0.1) & (0.004 to 0.088) ----	---
PO->TB	0.273 (< 0.001) & (0.169 to 0.380)	RM 0.015 (> 0.1) & (- 0.002 to 0.052) AM 0.034 (< 0.05) & (0.006 to 0.071)	0.223 (< 0.001) & (0.120 to 0.327)
SO->TB	0.240 (< 0.001) & (0.136 to 0.349)	RM 0.036 (< 0.1) & (0.005 to 0.083) AM 0.027 (< 0.1) & (0.004 to 0.060) PC 0.048 (< 0.05) & (0.014 to 0.090) PsC 0.027 (< 0.1) & (0.004 to 0.060) PC & RM 0.007 (> 0.1) & (0.000 to 0.019) PsC & RM 0.010 (> 0.1) & (0.001 to 0.027)	0.107 (< 0.1) & (- 0.014 to 0.216)

The mediation analysis results revealed the following relationships between the latent constructs:

1. Physical capability (PC) did not mediate to the target behaviour (TB) through automatic motivation ($\beta = 0.018$, $p > 0.1$) and reflective motivation ($\beta = 0.021$, $p > 0.1$). Instead, a direct relationship was established between physical capability and the target behaviour, with $\beta = 0.152$ ($p < 0.01$).
2. Psychological capability (PsC) fully mediated to the target behaviour through reflective motivation ($\beta = 0.039$, $p < 0.1$). The paths PsC-TB and PsC-AM were removed from the model due to their insignificant contributions.
3. Physical opportunity (PO) did not mediate to the target behaviour through reflective motivation ($\beta = 0.015$, $p > 0.1$). However, there was partial mediation through automatic motivation, with $\beta = 0.034$ ($p < 0.05$).

4. Social opportunity (SO) partially mediated to the target behaviour through automatic motivation ($\beta = 0.027$, $p < 0.1$), reflective motivation ($\beta = 0.036$, $p < 0.1$), and physical capability ($\beta = 0.048$, $p < 0.05$). However, no mediation was established through the routes SO-PC-AM-TB, SO-PC-RM-TB, and SO-PsC-RM-TB, as PC-AM, PC-RM, and PsC-RM had insignificant contributions to the mediation with $\beta = 0.007$ ($p > 0.1$), $\beta = 0.007$ ($p > 0.1$), and $\beta = 0.010$ ($p > 0.1$), respectively.

The second-order model was constructed by transforming the latent constructs of the lower-order model into indicators using SmartPLS (Figure 4.5). The respective indicators were added formatively to the higher-order constructs. The cross-loadings of the indicators reaffirmed their strong associations with the second-order constructs, indicating sufficient discriminant validity. Multicollinearity was not a concern in the inner and outer models, as indicated by VIF values below 3.

The second-order model accounted for 42% of the variance in the target behaviour, with motivation explaining 34.5% and capability explaining 13.3% of the variance. The model demonstrated a good fit, as evidenced by an SRMR value of 0.043. Moreover, the Q^2 value of 0.349 for the target behaviour indicated that the model had adequate predictive power.

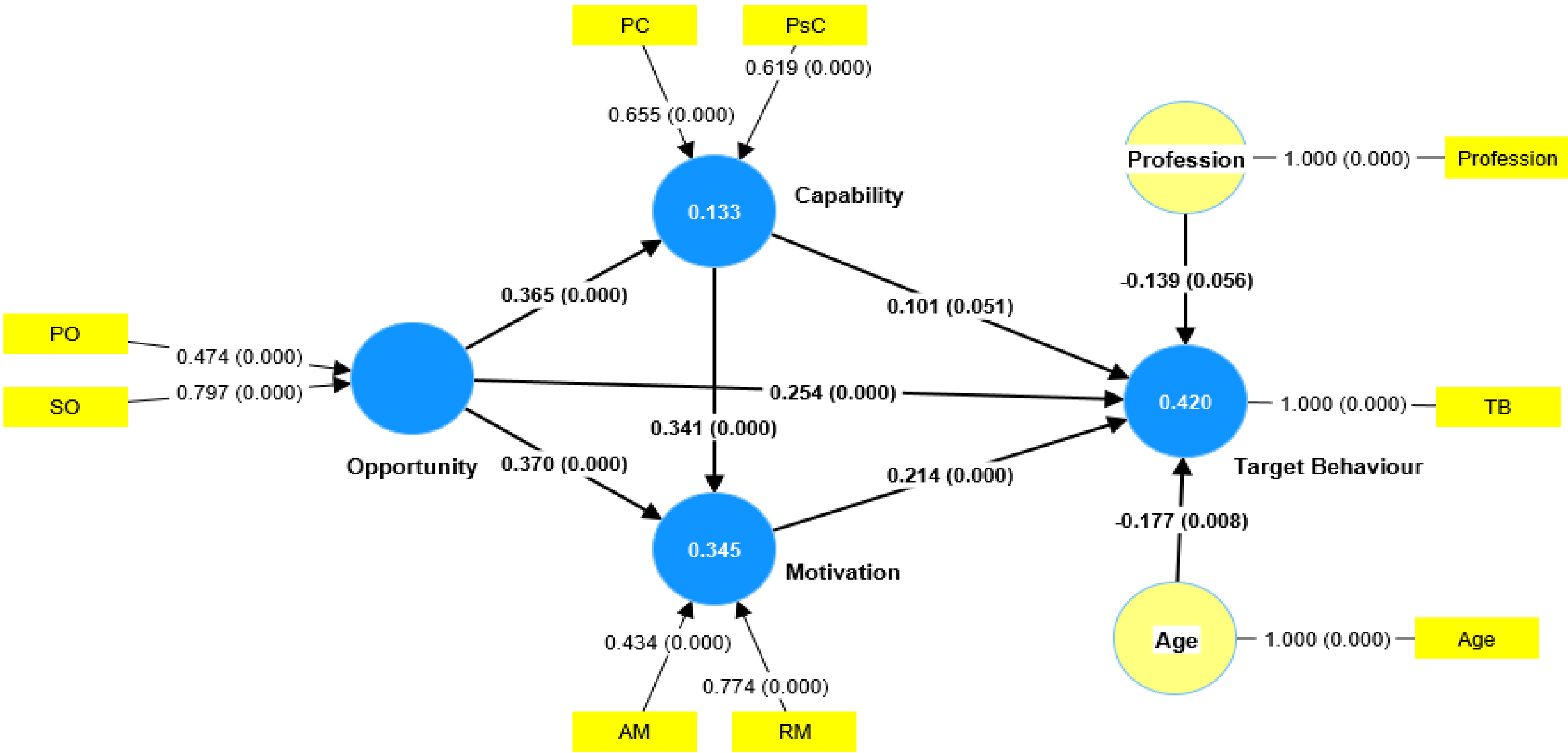


Figure 4.5 Second-order conceptual model

The higher-order model path analysis revealed significant relationships between the exogenous and endogenous higher-order constructs, including the influence of age and profession on the target behaviour. The following relationships were found:

1. Opportunity (β = 0.365, p < 0.001) significantly predicted capability with 13.3% explained variance.
2. Capability (β = 0.341, p < 0.001) and opportunity (β = 0.370, p < 0.001) significantly predicted motivation with 34.5% explained variance.
3. Opportunity (β = 0.254, p < 0.001), Motivation (β = 0.214, p < 0.001), and demographic variable Age (β = - 0.177, p < 0.01) significantly predicted Target Behaviour with 42% explained variance.

The mediation analysis of the higher-order model paths presented in Table 4.4 revealed that capability fully mediated the target behaviour through motivation (β = 0.073, p < 0.01), while the direct effect of capability on the target behaviour was not significant (β = 0.101, p > 0.05). On the other hand, opportunity partially mediated the target behaviour through both motivation (β = 0.079, p < 0.01) and the capability-motivation path (β = 0.027, p < 0.01). However, the indirect effect of opportunity on the target behaviour through capability (β = 0.037, p > 0.05) remained insignificant.

Table 4.4 Mediation analysis of higher-order model path

Path	Total effect (TE) & 95% CI	Mediator with Indirect effect & 95% CI	Direct effect & 95%CI
Capability ->Target Behaviour	β = 0.174 (p < 0.01) (0.073 to 0.275)	Motivation β = 0.073 (p < 0.01) (0.033 to 0.120)	β = 0.101 (p > 0.05) (0.001 to 0.205)
Opportunity ->Target Behaviour	β = 0.397 (p < 0.001) (0.289 to 0.501)	Capability β = 0.037 (p > 0.05) (0.001-0.080) Motivation β = 0.079 (p < 0.01) (0.038 to 0.128) Capability- Motivation β = 0.027 (p < 0.01) (0.012 to 0.047)	β = 0.254 (p < 0.001) to 0.373)

According to Sarstedt et al. (2021), the total effect (TE) represents the combined influence of both direct and indirect effects between exogenous and endogenous latent variables in a path model. In relation to the target behaviour, opportunity exhibited the highest total effect (TE = 0.397), followed by motivation (TE = 0.214), and capability (TE = 0.174). Similarly, regarding motivation, opportunity (TE = 0.494) had a higher total effect than capability (TE = 0.341).

4.4.4 Hypothesis testing

4.4.4.1 Original model: Hypothesis (H-P1 to H-P5)

(1) Physical capability significantly predicted motivation ($p < 0.05$) and safe crossing use ($p < 0.01$). In contrast, psychological capability significantly contributed to motivation ($p < 0.001$). Although the path from the psychological capability (PsC) to the safe crossing was excluded in the final model due to the insignificant influence of psychological capability (PsC) on safe crossing use ($p > 0.1$), the PsC had a marginally positive effect on the safe crossing use in the initial model. Hence hypothesis H-P1 is confirmed.

(2) Physical opportunities significantly predicted motivation ($p < 0.01$) and safe crossing use ($p < 0.001$). The social opportunities also significantly predicted motivation ($p < 0.001$) and safe crossing use ($p < 0.01$). Hence hypothesis H-P2 is confirmed.

(3) Motivation significantly predicted safe crossing use ($p < 0.001$). Hence hypothesis H-P3 is confirmed.

(4) The multigroup analysis found that the motivation had influenced males more in using crossings than females, and the difference was significant ($p < 0.05$). Hence hypothesis H-P4 is confirmed.

(5) The multigroup analysis revealed that students exhibited higher motivation from the available physical opportunity compared to workers, and this difference was statistically significant ($p < 0.05$). Hence hypothesis H-P5 is confirmed.

4.4.4.2 Conceptual model: Hypothesis (H1 to H5)

Based on the results of the lower and higher-order model, the following observations are made on the five hypotheses:

(1) Physical capability significantly predicted motivation and target behaviour at 0.05 and 0.01 significance levels, respectively. In contrast, psychological capability ($p < 0.001$) significantly contributed to the reflective motivation, but there was an insignificant direct contribution to the target behaviour. However, overall, the Capability ($\beta = 0.101$, $p < 0.1$) positively contributed to the Target Behaviour. Hence hypothesis H1 is confirmed.

(2) Physical and social opportunities significantly contributed to the target behaviour at 0.001 and 0.1 significance levels, respectively. The opportunity has the highest total effect (TE = 0.397) on the target behaviour compared to other constructs (TE ranges from 0.174 to 0.214). Hence hypothesis H2 is confirmed.

(3) Opportunity significantly predicted both capability and motivation at a 0.001 significance level. There was no significant relationship between physical opportunity and capability (physical or psychological); however, social opportunity ($p < 0.001$) had a significant contribution to physical and psychological capability. Hence, hypothesis H3 is confirmed.

(4) Reflective and automatic motivation significantly contributed to the target behaviour at the 0.05 level. The overall contribution of motivation ($p < 0.001$) to the target behaviour is significant. Capability had full mediation on the target behaviour through motivation. On the other hand, opportunity partially mediates the target behaviour through motivation and capability–motivation. The model explained target behaviour (42%), with 13.3% explaining variance in capability and 34.5% explaining variance in motivation. Hence, hypothesis H4 is confirmed.

(5) Among the demographic factors (gender, profession, parent, marital status, age), age significantly affected the target behaviour at the 0.01 significance level. Hence hypothesis H5 is confirmed.

4.4.5 Factors in the behavioural components of safe crossing use

From the model findings, the safe crossing use encompasses three components: avoiding violations in the use of nearby crossings (TB1), avoiding aggression (TB3*), and avoiding road safety lapses (TB4*). This study revealed several factors from each construct which have shown significant correlation with the behavioural components of safe crossing use.

Motivation factors: The study revealed significant correlations between motivational factors and behavioural components related to safe crossing use. Specifically, satisfaction for crossing use exhibited a positive correlation with TB1 ($r = 0.360$, $p < 0.001$) and TB4* ($r = 0.159$, $p < 0.01$). Safety priority over convenience was positively correlated with TB1 ($r = 0.283$, $p < 0.001$), TB3* ($r = 0.204$, $p < 0.001$), and TB4* ($r = 0.243$, $p < 0.001$). Habit demonstrated a positive correlation with TB1 ($r = 0.295$, $p < 0.001$), TB3* ($r = 0.121$, $p < 0.05$), and TB4* ($r = 0.242$, $p < 0.001$). Guilty or good feelings showed a positive correlation with TB1 ($r = 0.272$, $p < 0.001$), TB3* ($r = 0.128$, $p < 0.05$), and TB4* ($r = 0.162$, $p < 0.01$). Furthermore, consideration of the benefit of avoiding risky crossings was positively correlated with TB1 ($r = 0.263$, $p < 0.001$), TB3* ($r = 0.184$, $p < 0.01$), and TB4* ($r = 0.158$, $p < 0.01$). Finally, planning for improving behaviour exhibited a positive correlation with TB1 ($r = 0.199$, $p < 0.01$) and TB4* ($r = 0.235$, $p < 0.001$). Regression results indicated that satisfaction with crossing use (for TB1), consideration of the benefit of avoiding risky crossings (for TB3*), and habit formation (for TB4*) directly and significantly impacted their respective behaviours.

Physical capability factors: Among the physical capability factors, the ability to walk showed a positive correlation with TB1 ($r = 0.245$, $p < 0.001$), TB3* ($r = 0.176$, $p< 0.01$), and TB4* ($r = 0.208$, $p < 0.001$). Similarly, strength exhibited a positive correlation with TB1 ($r = 0.202$, $p < 0.001$), TB3* ($r = 0.166$, $p < 0.01$), and TB4* ($r = 0.277$, $p < 0.001$).

Psychological capability factors: As psychological capability factors, mood control in assertive crossing showed a positive correlation with TB1 ($r = 0.162$, $p < 0.01$), TB3* ($r = 0.162$, $p < 0.01$), and TB4* ($r = 0.136$, $p < 0.05$). Similarly, paying attention or thinking before crossing exhibited a positive correlation with TB1 ($r = 0.264$, $p < 0.001$), TB3* ($r = 0.136$, $p < 0.05$), and TB4* ($r = 0.299$, $p < 0.001$). The knowledge of traffic rules had positive corelation with TB1 ($r = 0.244$, $p < 0.001$) and TB4* ($r = 0.182$, $p < 0.01$). Lastly the knowing the provision of fines for violations had positive correlation with TB4* ($r = 0.141$, $p < 0.05$).

Physical opportunity factors: Various physical opportunities such as the visibility of drivers showed a positive correlation with TB1 ($r = 0.365$, $p < 0.001$), TB3* (r

= 0.139, $p < 0.05$), and TB4* ($r = 0.159$, $p < 0.01$). Similarly, short crossing time had a positive correlation with TB1 ($r = 0.159$, $p < 0.01$) but a negative correlation with TB3* ($r = -0.116$, $p < 0.05$). Easy access and usability in all weather conditions were positively correlated with TB1 ($r = 0.332$, $p < 0.001$) and TB4* ($r = 0.166$, $p < 0.01$). The presence of traffic signs and road markings showed a positive correlation with TB1 ($r = 0.295$, $p < 0.001$), TB3* ($r = 0.182$, $p < 0.01$), and TB4* ($r = 0.214$, $p < 0.001$). The availability of waiting areas in the middle or at the side of the road exhibited a positive correlation with TB1 ($r= 0.318$, $p < 0.001$), TB3* ($r= 0.138$, $p < 0.05$), and TB4* ($r = 0.195$, $p < 0.01$). Pedestrian fences on footpaths or medians positively correlated with TB3* ($r = 0.122$, $p < 0.05$). Lastly, the convenient location also had significant correlations with TB1 ($r = 0.286$, $p < 0.001$) and TB4* ($r= 0.131$, $p < 0.05$).

Social opportunity factors: The presence and influence of influential people in crossing use showed a positive correlation with TB1 ($r = 0.208$, $p < 0.001$), TB3* ($r = 0.144$, $p < 0.05$), and TB4* ($r = 0.157$, $p < 0.01$). Similarly, education and support from family/institutions exhibited a positive correlation with TB1 ($r = 0.308$, $p < 0.001$), TB3* ($r= 0.299$, $p < 0.001$), and TB4* ($r = 0.265$, $p< 0.01$). The parental safety alert reminders exhibited a positive correlation with TB1 ($r = 0.260$, $p < 0.001$), TB3* ($r = 0.263$, $p<0.001$), and TB4* ($r = 0.323$, $p < 0.001$). The presence of many users in crossing or group crossings at specific times showed a positive correlation with TB1 ($r = 0.226$, $p < 0.001$), TB3* ($r = 0.302$, $p < 0.001$), and TB4* ($r = 0.242$, $p < 0.001$). Lastly, many known users using the crossing also had significant correlation with TB1, ($r = 0.233$, $p < 0.001$), TB3* ($r = 0.233$, $p < 0.001$) and TB4* ($r = 0.177$, $p < 0.01$).

4.5 Discussion

This study presented two prediction models for pedestrians’ safe crossing. For the first time, this study looked at the three COM-B components and assessed their ability to predict the target behaviour in the road safety domain. In the original and conceptual model, the target behaviour was safe crossing use, which was well represented by three essential contributory compliances of crossing behaviour: not committing a violation (use of a nearby crossing), aggressions, and lapses.

4.5.1 Original prediction model

The original model shows the explanatory power of 39.5% variance. Regarding model explanatory power, R^2 should be ≥ 0.10 to be deemed adequate (Falk and Miller, 1992). In contrast, others suggest 0.26 as substantial (Cohen et al., 2014). Therefore, the proposed 18-factored pedestrians' crossing use model has substantial explanatory power in predicting the target behaviour of the pedestrians. In the model, the motivation construct explained 30.5% with the predictors, which also shows substantial explanatory power in the model.

In the original model, 'motivation' was represented by the seven factors: planning, satisfaction, safety priority, imitation, habit, guilting/good feelings, and fear of injury/death; that well covered the suggestive TDF domains (social/professional role and identity; beliefs about capabilities; optimism; beliefs about consequences; reinforcement; intentions; goals; emotions) of motivation. Multigroup analysis shows that motivation has more influence on male pedestrians for safe crossing use than females, and that difference is significant.

Walking and overcoming fatigue are the two factors that represent the skills domain under the physical capability in TDF. The controlling mood is assertiveness, crossing with attention, and knowing traffic rules and users' priority are the three factors that represent knowledge; memory, attention and decision process; and behavioural regulations domains under the psychological capability in TDF. Model path analysis shows that physical capability has more influence on safe crossing use; in contrast, psychological capability has more influence on motivation.

Similarly, traffic signs/road marking, visibility, and refuge area are the three factors that represent environmental restructuring and resources domain under the opportunity; and support from family/institution, group crossing, and influential persons are the three factors that represent social influences domain under the opportunity in TDF. Model path analysis also showed that physical opportunity had more influence on safe crossing use, whereas social opportunity had more influence on motivation. The multigroup analysis also shows that physical opportunity has more influence on students than workers to motivate them for safe crossing use, and that difference is significant.

4.5.2 Conceptual prediction model

This study also aimed to validate the constructs of the hypothetical or conceptual COM-B model concerning safe uses of pedestrian crossings. The conceptual model is analysed at a lower and higher level to understand the contribution of each model's variables to the target behaviour. The model output showed that opportunity was the most crucial driver of the target behaviour, followed by motivation. Demographic variable, age (older aged group) also negatively influenced the target behaviour significantly.

The key indicators of capability in the original and conceptual model, namely walking, overcoming fatigue or tiredness, and knowledge of traffic rules and users' priority, effectively covered the suggested TDF domains of knowledge, skills, memory, attention and decision process, and behavioural regulations. These indicators were found to be the most influential factors. Similarly, the dominant indicators of opportunity included traffic signs/marking, visibility, refuge/waiting area, social support from family/institution, and role models by influential persons, which adequately represented the suggested TDF domains of environmental restructuring and resources, and social influences. These indicators also emerged as the most significant contributors. Lastly, the reflective motivation indicators of planning, safety priority, persuasion, praise, and imitation, along with the automatic motivation indicators of habits and guilty or good feelings, comprehensively addressed the suggested TDF domains of social/professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, reinforcement, intentions, goals, and emotions. Planning, safety priority, imitation, habit, and guilty or good feelings were identified as the primary factors in the original and conceptual model.

The COM-B model is used mainly in developed countries with more opportunities (e.g., physical infrastructure). According to the *drive theory of motivation,* all behaviour results from primary physiological demand or fulfilment of basic needs following *Maslow's hierarchy of needs*. Designers in developing countries need to balance the actual demand and available resources to make a cost-effective solution to motivate pedestrians. For example, a simple, low-cost safety message that reflects parental expectations could bring more motivation than investing in costly infrastructure, such as putting barriers on the road. The direct contribution of physical opportunity to the target behaviour was more than the social opportunity. However, the total indirect contribution of social opportunity to the target behaviour was more than the physical opportunity and could be cost-effective. Similar to the original model, the conceptual model shows that the physical opportunities significantly predicted the target behaviour, whereas the social opportunities also significantly predicted motivation. The social opportunity significantly contributed to physical and psychological capability and new insight into the conceptual model.

Compared with the original model prediction, the R^2 value of the proposed conceptual model's prediction in target behaviour (42%) and motivation (34.5%) confirms better substantial in-sample explanatory power. The Q^2 value further supports the models' predictive power beyond the current study sample, indicating their ability to forecast the target behaviour and motivation using data from other samples. This suggests that the models have generalisability and can be applied to different populations or contexts.

4.5.3 Model factors

Before analysing the model, the target behavioural items were tested using a near-accident situation test variable. The correlation between those items and the test variable was significant. The interpretation is that the individuals who exhibit higher levels of crossing use and avoidance of violation, aggression, and lapse behaviour while crossing the road are more likely to experience a lower frequency of near-accident situations in pedestrian-driver interactions. The model suggested three essential items, including crossing use, avoidance of aggression, and avoidance of lapse construct the target behaviour of safe crossing use. This study found various influential factors in motivating pedestrians to use crossings safely. They are-

Demographic factors: Gender, profession, and age were the most contributory demographic in model prediction. This study concluded that motivation has significantly more influence on male pedestrians for safe crossing use than females, and physical opportunity significantly influences students more than workers to motivate them for safe crossing use. This study also found that the older aged group of pedestrians (mostly, workers in this study) negatively influences safe crossing use compared with students less than 18. A study in China showed that most school students demonstrated safe crossing behaviour, especially older children (Wang et al., 2018). Students are expected to display more safe crossing behaviour than workers, as many have no formal education.

Capability factors: Five pedestrians-oriented factors (ability to walk, strength, controlling mood, attention to traffic, and knowledge of traffic rules) significantly contributed to the model prediction. Evidence suggests that participants (older population) with reduced physical (and cognitive function) made more unsafe crossing decisions (Butler et al., 2016). As the research population was younger, they expected to have enough physical strength to overcome the physical barrier to enact target behaviour. A Serbian study also shows that walk-related fatigue increases the possibility of pedestrians' behavioural deviations, as mentioned in Chapter 2. Assertive crossing is quite common where drivers' yielding is rare. Here, controlling mood, in other words, remaining calm and taking a decision, is the key to creating a win-win situation with a mutual agreement between the interacting parties involved, supported by the Dual concern model (Pruitt, 1986). The informal approach of drawing attention to the driver is quite common in developing countries due to the lack of a light signal system in a designated zebra crossing for efficiency or cost reasons. Raising a hand is quite common in Bangladesh to draw attention to drivers for safe crossing. Pedestrians' attention toward drivers through eye contact also positively impacts drivers' yield (Ren et al., 2016). Knowledge shows a precursor of safe crossing practice in many cases. As a large portion of respondents were students, it can be assumed that they got an education (through an education curriculum and taking part in a national safety campaign). Workers, especially female workers, also get institutional support (e.g., a flagman with a red flag during the crossing) for safe crossing.

Opportunity factors: Six environmental or contextual factors (visibility to drivers, traffic sign and road marking, refuge area on a highway, support from family or institution, group crossing, and crossing uses by influential people) contributed significantly to the model prediction. The literature says that traffic signs and markings are the preconditions of a road to meet the SER (self-explaining road) principle that clarifies users' roles and delineates the crossings clearly, thereby ensuring road users' safety. SER is a design philosophy that uses psychological principles in design. Poor visibility of people and vehicles is a severe issue in low- and middle-income nations. In South Africa (Ribbens, 2003), approximately 40% of road fatalities are pedestrian fatalities, and accident investigations often reveal that pedestrians have not been visible to motorists. Speed is another dynamic factor that significantly threatens pedestrians' safety. The Safe System suggests the road design should be built, keeping the idea that the drivers could be at fault. That fault could be minimised by the safety features of the road, such as a pedestrian's refuge area for the wider road (similar geometry of the research road site) or a speed reducer to counteract drivers' speed behaviour. Social support from family and friends helps reduce the likelihood of young pedestrians breaking the law (Xiao et al., 2021) and enhances their activity levels (Mendonça et al., 2014). In our case, more use of the footbridge means more exercise and physical fitness. Institutional or family support also contributes to knowledge and control or decision-making. Individual pedestrians are subject to some social control depending on the group size. Due to the "safety in numbers" effect, big groups of pedestrians feel safer than individuals (Harrell, 1991). A study (Rosenbloom, 2009) shows that standing alone is more likely to break the law than waiting on the curb with a group of people, where the theory of Social Control explains such obedient behaviour. Study shows that even the supportive role of the manager help workers' mental health (Heaney et al., 1995). The result is expected because children and women (most workers) are more influenced by their families or institutions from where they learn or work. The influences of their teachers or work managers as a role model for them, although there could be other reasons, such as respondents might feel pressure to give responses in a positive direction as these answers might be seen by their authority in any case.

Motivation factors: Eight pedestrians-related factors (habit, feelings in crossing use, safety priority, imitation, planning, persuasion, praise, and satisfaction in use) were the most contributory factors. Among those factors, the influences of habit, feelings or satisfaction in crossing use, planning, praise, persuasion in awareness campaigns, and imitations on the motivation align with the past studies mentioned earlier in Chapter 2. To support the contributory factor of safety priority, the literature suggests that past consequences often influence future behaviour, especially regarding safety (Kouabenan, 2009). As the students and workers are more victimised in Bangladesh, they have ample examples of believing the consequences of undermining safety rules.

4.5.4 Factors in motivation to safe crossing use

Regression results indicated that satisfaction with crossing use, consideration of the benefit of avoiding risky crossings, and habit formation directly and significantly impacted pedestrians' safe crossing use.

Satisfaction for crossing use can help reduce pedestrians' violation behaviour by promoting a positive and enjoyable experience. When pedestrians feel satisfied with their crossing experience, it indicates that their needs and expectations have been met, and they perceive the crossing as safe and convenient. This positive perception of the crossing environment can lead to higher compliance with crossing rules and regulations. Previous studies have shown that pedestrian satisfaction promotes walking behaviour (Ettema et al., 2011) and is correlated with environmental factors such as 'path quality' (Kim et al., 2014). Designing crossings that prioritise pedestrian satisfaction, including clear visibility, comfortable waiting areas, and efficient crossing times, can encourage pedestrians to adhere to crossing rules and reduce the likelihood of violation behaviours.

Promoting a rational and cautious approach to road interactions can help reduce pedestrians' aggression towards drivers. By emphasising the benefits of making safe choices and increasing awareness of mutual responsibility for road safety, designers can influence pedestrians' mindsets and encourage them to adopt a more cooperative and considerate attitude towards drivers. This shift in thinking can reduce aggressive behaviours as pedestrians become more aware of the importance of respectful interactions with drivers. Cultural factors and attitudes towards pedestrian safety also predict pedestrian risk-taking behaviour (Nordfjærn and Zavareh, 2016).

Satisfactory walking experiences are more likely to be chosen again in the future and can become habitual behaviours (Asakura et al., 2022). Past behaviour frequency is a reliable indicator of habit (Triandis, 1977). Habits can occur automatically without conscious effort, significantly impacting behaviour (Bargh et al., 1994). Even when motivation changes, habits tend to persist (Webb and Sheeran, 2006). Designers can contribute to habit formation and reinforce desired behaviours by creating safe and enjoyable crossing experiences, such as clear signage, well-maintained infrastructure, and efficient crossing times. As mentioned in Chapter 2, nurturing good street-crossing habits has been shown to increase children’s safety and can foster a culture of responsible pedestrian behaviour. As these habits become ingrained, they help reduce lapses in road safety and promote a culture of responsible pedestrian behaviour.

This study found that motivation is a key mediator for capability and opportunity in predicting safe crossing use. Capability fully mediated the target behaviour through motivation. A study found that pedestrians who perceive themselves as physically stronger are more likely to accept the detour distance within 100 meters (Guo et al., 2014). Research suggests that pedestrians consider their physical capabilities when making crossing choices, especially crossing on multilane roads (Dommes et al., 2014). Research focusing on older adult pedestrians highlights their heightened vulnerability in road environments due to reduced physical capabilities, including walking speed, strength, hearing, and vision impairments (Lord et al., 2018).

This study revealed the significance of psychological factors in pedestrian behaviour, particularly mood control in assertive crossing and paying attention or thinking before crossing. Regression results indicated that paying attention or thinking before crossing directly impacted avoiding violations and lapses in using nearby crossings. Previous research in low- and middle-income countries (LMICs) has paid limited attention to the psychological precursors of pedestrian behaviours (Nordfjærn and Zavareh, 2016). However, individuals with better mood control and assertiveness in road crossings are more likely to avoid aggressive behaviour (Camara et al., 2020). Interestingly, anger may lead pedestrians to exhibit more assertive behaviour, potentially disregarding traffic rules and safety considerations (Camara et al., 2020). Higher levels of altruism were associated with positive behaviours and fewer lapses, while neuroticism predicted transgressions and lapses in pedestrian behaviour (Zheng et al., 2017; Jovanovic et al., 2011). In pedestrian behaviour research, it has been observed that active attention and engagement in cognitive processes before crossing the road have significant implications. Changes in head orientation, such as looking or glancing at the traffic, strongly indicate crossing intention

(Rasouli et al., 2017b). Violations and lapses in attention or judgment negatively impact crossing time, as pedestrians who engage in such behaviours take longer to cross the road (Deb et al., 2018).

This study found that physical opportunity influences safe crossing use, particularly impacting violations in using crossings and aggression. Physical opportunity factors, such as better visibility of drivers, shorter crossing time, easy access and usability in all weather conditions, presence of traffic signs and road markings, availability of waiting areas, and pedestrian fences, contribute to safer crossing behaviours. These factors guide pedestrians, enhance safety, and provide designated spaces for safe and comfortable crossings. A study found that restricted visibility significantly threatens pedestrian safety (Mukherjee and Mitra, 2020). Inaccessible pedestrian crosswalks have a negative impact on pedestrian crossing use (Mukherjee and Mitra, 2020).

This study found that the short crossing time had a positive correlation with avoiding violation in crossing use but negatively correlated with aggressive behaviour. This result agrees that engaging in violations can increase the time it takes pedestrians to cross the road, as studied by Deb et al. (2018). When pedestrians take more time to cross, there is a decreased tendency for them to be aggressive towards drivers. Taking more time to cross suggests that pedestrians prioritise their safety and actively assess the traffic conditions before proceeding. This mindset of prioritising safety and being aware of their surroundings tends to reduce frustration and impatience, which are often triggers for aggressive behaviours.

Stapleton et al. (2017) found that yielding compliance improved significantly when crosswalk markings were available. Another study found that pedestrians with higher pedestrian-related traffic sign comprehension were less likely to engage in transgressions, lapses, and aggressive behaviours (Tekeş et al., 2021), while being more likely to exhibit positive behaviours. Traffic signs not only remind crossing rules to the pedestrians but also inform drivers in advance of a crossing location.

Pedestrians generally do not prefer grade-separated facilities, especially women and older pedestrians (Anciaes and Jones, 2018). The availability of waiting areas in the middle or at the side of the road also helps pedestrians for safe and comfortable crossings (Zhang et al., 2017). Fencing helps direct pedestrians towards formal crossing points and discourages dangerous crossing movements in unauthorised road segments where drivers do not expect them. Such measures are proven helpful in Bangladesh, as mentioned in Chapter 2. Study shows that the strategic placement of crosswalks concerning nearby land use, considering areas that generate or attract pedestrian traffic, can greatly enhance pedestrian compliance rates (Sisiopiku and Akin, 2003).

This study found that social opportunity influences safe crossing use, predominantly impacting aggressions and lapses. Social opportunity factors, including the presence and influence of influential people, education and support from family/institutions, parental safety alert reminders, and the presence of many users in crossing or group crossings, positively impact safe crossing practices. Study found that when parents or teachers accompany students, they tend to behave more correctly in traffic (Holm et al., 2018). Similarly, when families and institutions provide education and support regarding crossing safety, individuals are more likely to engage in responsible behaviours and avoid aggression and lapses. Regression results suggest the education and support from family/institution and the parental safety alert reminders from time to time significantly impacted avoiding aggressive behaviour and road safety lapses, respectively. Previous research conducted in China (Zhou et al., 2009) found that pedestrians were more likely to cross the road when they observed other pedestrians crossing. Similarly, Koh et al. (2014) discovered that individuals were more likely to violate traffic rules when they were alone compared to when they were accompanied by companions, particularly on wide 4-lane roads with medians.

4.6 Implications for practice and policy

The COM-B model has a high potential to help designers to diagnose behavioural problems. The physical opportunities, such as visibility to drivers, traffic sign and road marking, and refuge area on a highway, significantly impact pedestrians, especially students. Study shows that the students demonstrated a higher level of motivation derived from the available physical opportunity than workers. Therefore, the designers and policy makers need to concentrate more on providing crossing facilities to ease the students while they cross the road to reach their educational institutions.

The study indicates that physical opportunities significantly predict safe crossing use, while social opportunities significantly predict motivation to use pedestrian crossings. These findings have important policy implications, as they suggest that interventions promoting safe crossing use should prioritise creating safe and accessible physical environments. In contrast, interventions aimed at increasing motivation to use pedestrian crossings should focus on enhancing social opportunities, such as support from family or institutions, group crossing, and crossing uses by influential people. Policymakers should consider the importance of providing infrastructure that promotes safe crossing use, such as well-maintained pedestrian crossings and traffic calming measures, as well as creating social environments that foster positive social interactions and promote social norms that prioritise safe crossing use. By doing so, they may be able to effectively promote safe crossing use and reduce the risk of pedestrian accidents.

While the physical opportunity directly and significantly impacts the target behaviour, the social opportunity also plays a vital role in influencing behaviour through indirect pathways. The interventions focusing solely on improving physical opportunities may not be as effective as those addressing social factors such as social norms, peer influence, and social support. Additionally, considering the lower cost associated with addressing social factors, such interventions as billboard messages or posters may be more cost-effective in promoting the desired behaviour.

This study applied a hypothetical relationship from the opportunity to capability, a new insight opened into designing infrastructure for the designers. The proposed model highlights the significant contribution of social opportunity to physical and psychological capability, such as walking, strength, controlling mood, attention to traffic, and knowledge of traffic rules. These findings have important policy implications. They suggest that interventions to improve individuals' capability should focus on creating supportive social environments that facilitate positive social interactions and foster a sense of belonging. Policymakers should consider the importance of providing opportunities for social engagement, building social networks, and promoting social support to enhance physical and psychological capability. By doing so, they may be able to effectively promote behaviour change and improve the overall health and well-being of the population.

The study aimed to predict safe crossing use and its behavioural components (e.g., avoiding—violations in using nearby crossings, aggressions, and lapses) in Bangladesh. The study highlights the complex interplay between Capability, Opportunity, and Motivation factors in shaping safe crossing behaviours, underscoring the need for comprehensive interventions and strategies to improve pedestrian safety.

Designers can utilise the study results to design interventions that maximise benefits while working with limited resources. To encourage safe crossing use, designers should target reflective and automatic motivation factors, as they impact various behavioural components differently. Prioritising specific motivation factors can effectively address violations in using crossings, aggressions, and lapses. Satisfaction for crossing use should be targeted to tackle violations, consideration of the benefit of avoiding risky crossings to avoid aggressions, and habit formation to avoid lapses.

Physical opportunity plays a crucial role in influencing safe crossing use through automatic motivation, particularly impacting violations in using crossings and aggression. Designers can leverage the physical opportunity to enhance safe crossing use by creating environments that encourage automatic motivation and reduce violations in using crossings and aggression. This can be achieved by improving the visibility and accessibility of crossings, implementing clear signage and road markings, and incorporating features that promote safety and convenience. However, it's important to note that footbridges are inherently anti-pedestrian (Soliz and Pérez-López, 2022). Therefore, designers need to focus on incorporating motivational elements during their design. Footbridges can be designed to foster positive emotions related to crossing use, emphasise the advantages of avoiding risky crossings, and provide a convenient and efficient crossing experience.

Creating social opportunities is another effective strategy for designers. By fostering reflective and automatic motivation, mainly targeting the reduction of aggressions and lapses, designers can encourage safe crossing behaviours. This can involve community campaigns, safety education programs, and collaborations with influential individuals or institutions to promote safe crossing practices and create a supportive social environment. Collaborating with parents, caregivers, schools, and institutions to provide education and support related to pedestrian safety can have a positive impact. Implementing strategies such as sensor-based crossing signals, dedicated crossing times for specific groups, and safety alert reminders can further enhance awareness and caution during crossings.

Additionally, designers should address the role of psychological capability in influencing target behaviour, particularly lapses. Designers can promote consistent and safe crossing practices by designing interventions that enhance reflective motivation and address psychological barriers, such as providing safety education, reminders, and creating positive emotional experiences related to crossing use. This can be achieved through educational campaigns that increase knowledge of traffic rules and regulations, incorporating visual cues such as signage and signals to remind pedestrians to stay focused and cautious during crossings, and incorporating mood control techniques such as calming elements or green spaces in crossing areas to facilitate proactive and safe crossing decisions.

Chapter 5
Study 2: Enhancing pedestrian safety through improved communication and design

5.1 Introduction

5.1.1 Background

In Bangladesh, drivers often fail to yield to pedestrians at designated crossings, posing a risk to their safety and discouraging their use of crossings. Behaviour change theories can provide a more appropriate approach to address this issue, given the complex interdependent behaviours of drivers and pedestrians. While many studies have identified factors influencing drivers' yielding behaviour, as Chapter 2 (section 2.1.2) mentions, few have applied behaviour change theories to validate these factors and reach a consensus among road users. This study is among the first to use behaviour change theories in Bangladesh to identify factors that promote drivers' yielding behaviour and establish a consensus between drivers and pedestrians.

The study aimed to identify the factors influencing drivers' yielding behaviour while preserving pedestrians' safe crossings use. The study used self-reported attitudinal data to identify drivers' yield factors and investigated their perceptions of problems at pedestrian crossings on two major highways in Bangladesh. Drivers responded with their perceptions of the pedestrians' attributes and contextual or environmental factors that could affect drivers' yielding and pedestrians' safe crossing use in pedestrian-driver interactions at designated crossings. The study utilised the COM-B model and the TDF to guide the formation of model constructs for predicting drivers' yielding behaviour for pedestrian safety. However, the qualitative data from focus group discussions of pedestrians and drivers were analysed with a conceptual deductive thematic framework to establish a consensus between drivers and pedestrians on their respective interests.

The key objectives of this study are to establish the factors with a comprehensive understanding of the inherent mechanism in drivers' motivation and yielding decisions in pedestrian-driver interactions that could promote drivers' yielding with consensus among drivers and pedestrians, leading to enhanced pedestrian safety, and recommend an intervention design strategy that meets the respective target behaviours of drivers' yielding and pedestrians' safe crossing use. Overall, this study aimed to enhance pedestrian safety through improved communication and design, creating a safer and more accessible environment for pedestrians in Bangladesh.

5.1.2 Research model with hypotheses

This study used the COM-B model as a conceptual research framework to find a contributing set of pedestrian attributes and contextual environment to predict the target behaviour (drivers' yielding behaviour). The target behaviour is denoted by 'Yield' for the drivers' yielding model. The applied model included four exogenous latent variables following the original model components (physical capability, psychological capability, physical opportunity, and social opportunity) to predict two endogenous latent variables (Motivation and Yield). The original model and its components are described in Chapter 2 (section 2.5.3).

The applied model considered four hypotheses (H-1 to H-4). The descriptions of each of the hypotheses are stated below:

H-1. Pedestrians' attributes related to drivers' physical capability (C1) and psychological capability (C2) will significantly positively influence drivers' Motivation and Yield.

Explanation: Pedestrians' actions and attributes will impact drivers' decisions to yield in pedestrian-driver interactions. Drivers' physical capability enables them to perceive pedestrians in the crossing area due to good eyesight, respond to pedestrians' gestures or eye contact by stopping their vehicle, and quickly identify pedestrians who are dressed in unique colours. Similarly, drivers' psychological capability allows them to accurately judge the speed and distance of vehicles as perceived by pedestrians, recall pedestrians' past crossing behaviours, and possess knowledge of traffic signs, road markings, and crossing priority rules that pedestrians adhere to. These capabilities are expected to play a significant role in drivers' motivation for shaping their decisions to yield to pedestrians.

H-2. Drivers' physical opportunities (O1) and social opportunities (O2) related to pedestrians will significantly influence Motivation and Yield.

Explanation: Various physical opportunities at the crossing site could influence the pedestrians' decision in safe crossing use and drivers' decision in yielding to the pedestrians. Such opportunities include short crossing paths and designated waiting areas, traffic signs and advanced road markings, enforcement, pedestrian fences, visibility between drivers and pedestrians, and speed reducers. Similarly, social opportunities include many pedestrians using the crossing, warnings against random crossers, and promoting group crossings at specific times could influence drivers' yielding decisions. These opportunities are expected to play a crucial role in shaping drivers' motivation and their decisions to yield to pedestrians.

H-3. Motivation will significantly influence Yield.

Explanation: Pedestrians' actions and attributes will impact drivers' motivation to yield in pedestrian-driver interactions. Drivers tend to feel more comfortable when pedestrians adhere to designated crossing areas and avoid random crossings. Positive attitudes of drivers can be triggered by pedestrians' good crossing behaviour and their adherence to crossing rules and traffic signs. However, drivers' past experiences with pedestrians' crossing behaviour may also influence their perception of potential risks. Drivers may be automatically motivated to yield to pedestrians who are vulnerable, such as children or women, or who share a similar profession with drivers' family members, invoking a sense of empathy. Pedestrians' assertiveness may also elicit automatic motivation in drivers' yielding decisions toward pedestrians.

H-4. The multigroup path analysis of vehicle types (bus and light vehicles) will find a significantly different impact of COM-B predictors in predicting Motivation and Yield.

Explanation: Bus drivers and drivers of light vehicles may have distinct characteristics and behaviours that could influence their motivation and yielding decisions while interacting with pedestrians. By considering vehicle type as a grouping variable, the multigroup path analysis provides a more nuanced understanding of how the COM-B predictors may operate differently for bus drivers and drivers of light vehicles. This information can be valuable for developing targeted interventions and strategies to improve pedestrian safety and promote responsible driving behaviour for each vehicle type.

5.1.3 Qualitative data analysis with the thematic coding framework

In addition to the research model, a qualitative study supplemented the understanding of the model findings and explored additional factors regarding drivers yielding to pedestrians. Additionally, it helped to know the drivers' views and perceptions of pedestrians' behaviour and attitude. On the other hand, qualitative findings from the pedestrians of the target groups helped to understand their interest in their safe crossing use and to know the agreement level of the drivers' views on the pedestrians' behaviour and yielding attitude towards the pedestrians.

This study utilised a conceptual thematic coding framework that integrated the theoretical domains framework (TDF), and the combined model to analyse data collected from pedestrians and drivers focus group discussions. The theoretical foundations of the combined model and TDF were thoroughly explained, along with the key factors in behaviour change, in Chapter 2 (section 2.5). Within this proposed coding framework, the central theme focused on drivers' yielding behaviour, which was conceptualised as their intention or willingness. For pedestrians' intention or willingness in relation to safe crossing use, the same set of codes were employed in the framework. The applied thematic framework consists of ten (10) codes to capture drivers' and pedestrians' behavioural and attitudinal attributes within the respective theme of the drivers' yielding and pedestrian safe crossing use, respectively (Figure 5.1).

The literature supports that the key factors in behaviour change include perceived threat, fear, outcome expectations, self-efficacy, barriers, benefits, subjective norms, attitude, intentions, and cues to action. The 10 codes used in the conceptual model capture many of these key factors, including Attitude/Belief about consequences, Barriers, Benefit/reinforcement, Capability/Control, Emotions, Environmental restructuring/resources, Facilitators, Social influences, and Social/professional role and identity.

The 10 codes used in the conceptual model were selected based on a review of the literature on behaviour change and a consultation with experts (supervisors of this study) in the field. The selection criteria included relevance to behaviour change, the ability to provide practical and actionable guidance and coverage of key aspects of the intention-behaviour gap. The 10 codes used in the conceptual model that capture key aspects related to behaviour change and the intention-behaviour gap were developed by integrating elements from the Theoretical Domains Framework (TDF) and a psychological model. The TDF is a well-established and widely recognized framework in the field of behaviour change, and it encompasses 14 domains that cover a broad spectrum of factors influencing behaviour. However, such a broad spectrum can make it difficult to identify the specific factors that are most relevant to a particular behaviour or to develop targeted interventions to address those factors.

In contrast, the 10 codes are more focused and specific subset of the TDF domains. They capture the key aspects of behaviour change and the intention-behaviour gap, and they are directly linked to practical and actionable interventions. For example, the code ‘‘Attitudes/Beliefs about consequences’’ can be used to develop interventions to help people develop more positive attitudes towards changing their behaviour or to develop more realistic beliefs about the consequences of behaviour change. Similarly, the code ‘‘Barriers’’ can be used to develop interventions to help people identify and overcome the obstacles preventing them from changing their behaviour.

A deductive thematic approach was employed to analyse the collected data. This approach involved utilising the pre-defined codes derived from the TDF and the combined model as a framework to identify relevant themes and patterns in the data. The codes encompassed a range of domains, including capability and control, social and professional roles and identity, attitudes and beliefs about consequences, benefits and reinforcement, communication and decision-making, environmental restructuring and resources, social influences, emotions, barriers, and facilitators. By applying this approach, the researchers systematically explored and interpreted the data within the framework of relevant theoretical constructs. This enhanced the rigour and comprehensiveness of the analysis, allowing for a deeper understanding of the factors influencing drivers’ yielding behaviour and pedestrians’ safe crossing use.

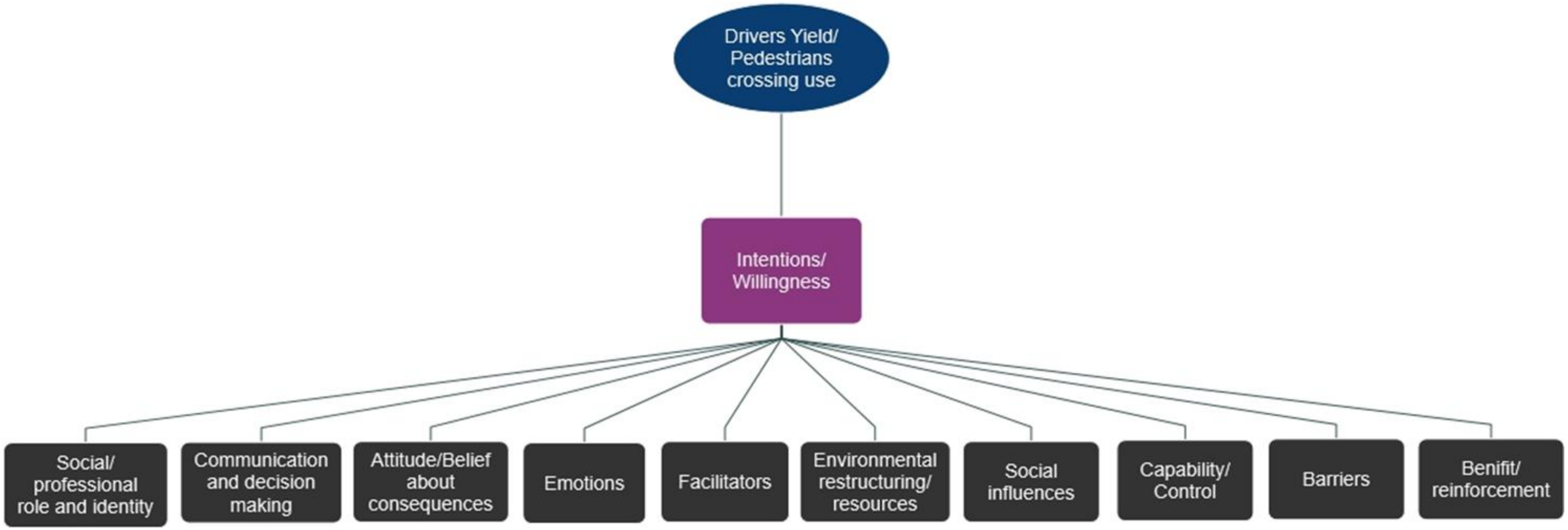


Figure 5.1 Thematic coding framework

5.2 Data collection, procedure and sampling

5.2.1 Drivers focus group

In Bangladesh, participant recruitment for the study involved visiting bus and truck stands commonly used by long-distance bus and truck drivers who regularly drive on the Nabinagar to Chandra highway (N-540) and Dhaka-Sylhet highway (N-2) research routes. The research team collaborated with bus and truck drivers' association offices, local three-wheeler stands, and the local office of road agencies to identify participants from different vehicle categories, including buses, trucks, cars, and three-wheelers.

A total of 19 participants were included in the three focus groups. Each focus group discussion session lasted 30-40 minutes and was audio and video recorded to ensure accurate capturing of the conversations. The discussions began with a general conversation about pedestrians' crossing behaviour around designated crossing facilities, leading to the following question:

Question- From your experiences, what situations decide your willingness or intentions in yielding to pedestrians, whether you will give way or not in or around a designated road crossing?

5.2.2 Pedestrians focus group

The researcher visited educational institutions, marketplaces, and garment factories near the research sites on N2 and N-540 routes to recruit participants. The details of the research sites are stated in Chapter 3. Through collaboration with institutional representatives, participants who regularly cross the research routes and possess valuable experiences regarding designated crossings, such as zebra crossings, were selected. The total number of participants for the four focus groups was 40, consisting of 20 college and school students and 20 marketplace and garment workers.

Each focus group discussion started with a general discussion on pedestrians' crossing behaviour around designated crossing facilities. Later, summary notes of driver focus group discussion sessions were provided to the pedestrians to understand the difference in perceptions between drivers and pedestrians regarding pedestrian behaviour and drivers' yielding behavioural attitude toward pedestrians. The discussion was facilitated using the following questions (Q1 and Q2):

Q1. From your experiences, what situations decide your willingness or intentions to use the designated crossing safely?

Q2. What are the agreements/disagreements on drivers' comments (based on summary notes) on pedestrians' behaviour and drivers' yielding?

The responses to questions Q1 and Q2 were categorised based on the participants' verbal or gestural expressions of agreement or disagreement. Responses indicating a strong consensus or disagreement were classified as major agreement or disagreement, respectively, when most group participants used their voices or gestures to support or contradict the statement. It was considered a general agreement or neutrality if participants remained silent or expressed uncertainty in their opinions. This classification approach allowed for identifying the predominant attitudes and levels of consensus within the focus groups.

5.2.3 Survey questionnaire development for drivers

Similar to the development of the pedestrian COM-B questionnaire, as stated in Chapter 4 (section 4.2.1), the driver questionnaire followed the validated COM (capability, opportunity, and motivation) questionnaire in structuring each questionnaire item using TDF mapping with the COM-B constructs. While mapping items, the pedestrian COM-B questionnaire and driver focus group discussion notes helped identify various aspects of pedestrians' behaviour and attributes in different COM constructs that could have affected the driver's yielding behaviour. This study used the tested behavioural modification technique of the 'if-then plan' cause-effect relationship between constructs and indicators for each questionnaire statement, as Chapter 2 (section 2.5.1) mentioned.

In framing questions related to drivers' self-reported behaviour in response to pedestrians' attributes and contextual or environmental factors, this study used the pedestrian-related factors from the formulated pedestrian questionnaire (Appendix A). This study included twenty-six questionnaire items within the broader theoretical coverage of COM-B (Appendix B).

For measuring the target behaviour ‘Yield’, the frequency of yielding to pedestrians was measured with a 5-point Likert scale (i.e., 1 = never to 5 = always). Then, the respondents were asked to respond on a 5-point bipolar Likert agreement scale (i.e., -2 = strongly disagree to +2 = strongly agree) to measure the agreement level of their yielding to pedestrians on different COM statements. The formulated survey instrument had twenty-five COM items related to physical opportunity (PO), social opportunity (SO), reflective motivation (RM), automatic motivation (AM), physical capability (PC), and psychological capability (PsC). The respondents have given responses on different COM statements. Sample statements of each construct item were:

1. Physical opportunity items (n = 8) started with the statement - “I have yielded to pedestrians while seeing following physical opportunities-” followed by variables such as “short crossing path & designated waiting area for pedestrians” (PO1).
2. Social opportunity items (n = 3) started with the statement - “I have yielded to pedestrians while noticing following social opportunities” followed by variables such as “many pedestrians use the crossing” (SO1).
3. Physical capability items (n = 3) started with the statement - “I was physically able to let pedestrians cross when they” followed by variables such as were at distances but they were visible for my good eyesight” (PC1).
4. Psychological capability items (n = 3) started with the statement - “I was psychologically able to let pedestrians cross when they” followed by variables such as “well-judged my vehicle speed/distance that prompted me to make in-time decision” (PsC1).
5. Reflective motivation items (n = 4) started with the statement - “I was motivated to let pedestrians cross” followed by variables such as when they were in the specified area by avoiding random crossing which was comfortable for me” (RM1).
6. Automatic motivation items (n = 4) started with the statement - “I was motivated to let them cross because of their” followed by variables such as “profession, as I have family members with a similar profession” (AM1).

The questionnaire also included items for gathering drivers' demographic information, their perception of pedestrians' behaviour and their experiences in interaction with pedestrians. The questions related to the drivers' perception of pedestrian behaviour and interactions with pedestrians were framed without altering the descriptions of behaviour stated in the pedestrian questionnaire. For example, in the pedestrian questionnaire, the pedestrians' behavioural item 1 (TB1) statement - “When I had a chance to use my nearby crossing, I used that,” measured on a 5-point Likert scale (1 = never to 5 = always), whereas in driver questionnaire the same statement was stated with “when there was a nearby crossing to them, they used that”, measured on the same 5-point Likert scale (1 = never to 5 = always). Similarly, other pedestrian behavioural items (TB2–4) were stated for the driver.

The questions related to pedestrian-driver interaction included gesture type used for drivers' attention to let them cross and crossing actions when pedestrians started crossing but not completed for some reason. Another question related to near-accident situations in pedestrian-driver interaction was used as a test variable for this study. The literature on traffic safety emphasises the importance of drivers' yield behaviour in reducing the risk of pedestrian-vehicle accidents. When drivers properly yield to pedestrians, it creates a safer environment for pedestrian crossing and reduces the likelihood of near-accidental situations. Adherence to yielding behaviour is expected to decrease the frequency of close calls or potential collisions between pedestrians and drivers. The frequency of near-accident situations is measured with a 5-point Likert scale (1 = never to 5 = always).

A preliminary questionnaire was piloted with two groups of drivers, and the participants (n = 12) were interviewed to understand the questionnaire structure and make necessary modifications.

5.2.4 Survey procedure with sample descriptives

The researcher and his team visited bus and truck stands from where the long-distance bus and truck drivers start and end their journey along the research routes. The research team also visited filling stations or marketplaces where drivers frequently halt their vehicles for fuelling or other purposes. The survey was accomplished with the help of bus and truck drivers' association offices, local drivers from three-wheeler stands and car drivers of the local office of road agencies. In sample size estimation, this study used an online sample calculator (http://www.raosoft.com/samplesize.html), where the estimated sample size turned out as 62 only with margin of error 5%, confidence level 90%, estimated population size 80 based on an average daily traffic flow, and response distribution 50%. However, some researchers recommend a conservative minimum sample size of 200 to run structural equation modelling (SEM) (Kline, 2005; Boomsma and Hoogland, 2001).

Finally, the total driver sample size was 202, with the following distribution by vehicle types: bus/minibus (96), truck/pick up (35), car (56), and three-wheeler/slow-moving type (15). Large portions of respondent groups had primary or high school education (81.2%) and driving experiences of up to 10 years (41.6%), whereas below five years was 14.9%.

5.3 Data analysis

After all focus group discussions were completed, the files were organised separately for transcription and analysis of the data collected from drivers and pedestrians. An online transcription service was used to transcribe the audio recordings accurately, which provided a transcription accuracy rate of 90% (https://transkriptor.com/support/). To minimise errors in the transcriptions, a four-step procedure was implemented.

Initially, the researcher and his assistants watched the recorded videos without referring to the transcriptions to refresh their memory of the discussion topics. Then, the research team compared the transcriptions with the video recordings to identify and correct any inaccuracies that occurred during the online transcription process. Later, all verified Bengali transcripts were translated into English using the Google Docs translation service. Finally, each focus group transcript was rechecked to create the final corrected transcription. The conceptual thematic framework was then applied for coding, and the analysis was conducted using NVivo 12. The credibility of coding could be enhanced by using an audit procedure (Johnson et al., 2020). An independent expert who had the necessary knowledge and experience to evaluate the translation and coding procedure was assigned for the qualitative thematic coding. Some key steps were followed in the coding audit procedure. Firstly, the researcher provided the expert with the necessary context, including the research objectives, the data collection process, and the coding procedure, including sharing transcripts, translations, and a coding book. Then, the researcher clarified the coding scheme to the expert, including the definitions of the codes and the rules for assigning them in the deductive qualitative data analysis. Later, sufficient time was given to the expert to review the data and the coding scheme thoroughly. Finally, the researcher arranged a meeting with the expert to discuss the quality and validity of the coding, including possible areas of concern or improvement. The coding was revised accordingly to enhance its credibility and validity.

On the other side, the survey data collected were entered directly into the SPSS 26 software tool. Before using SmartPLS 4 software, data were cleaned to identify outliers, followed by normality checks. Model variables were tested with statistical tests using SPSS, including correlations of the target variable with different variables (predictors and a test variable).

The pedestrians' perceptions data collection procedure and samples were stated in Chapter 4 (section 4.2.2). The perception difference between drivers and pedestrians on pedestrian behaviour were analysed with two sample independent test using SPSS. Smart PLS-SEM uses the partial least squares (PLS) algorithm for model estimation, which is robust to violations of normality assumptions and can handle small sample sizes. Hence, this modelling technique is applied in this study.

Multicollinearity within the inner and outer model was checked with the variance inflation factor (VIF) of the threshold of 3.3. The proposed model was established through initial model trimming by removing statistically non-significant (outer model item $p > 0.05$ and outer loading < 0.5) items and insignificant inner model paths ($p > 0.1$) stepwise. When the sample size is small, using a higher significance level, such as 0.1, is often recommended instead of the conventional 0.05. Therefore, the p-value was set as 0.1 as the significance level in interpreting the model results. The standardised root mean square residual (SRMR) was used to assess overall model fits, with 0.08 as the acceptable threshold. The R^2 value was used to describe the explanatory power of the models.

The multigroup analysis was conducted on the trimmed original COM-B model framework. Before multigroup analysis, three steps of the measurement invariance of composite models were followed. These were configural invariance in step-1, compositional invariance in step-2, and equal mean values and variances in step-3. However, Step-1 was automatically confirmed while performing MICOM in SmartPLS.

Finally, the analysis of the data in this study was done using a mixed-methods approach, combining quantitative and qualitative methods. The qualitative data of focus group participants were analysed using the thematic coding structure of the conceptual framework. Such discussions were supported by the findings from regression analysis and the survey key descriptives concerning the relevant factors. This approach allowed for a comprehensive examination of the research questions and provided a deeper and complete understanding of the complex dynamics involved behind the drivers' yielding behaviour and pedestrians' safe crossing use.

5.4 Results and discussion

5.4.1 Perception problems and pedestrian-driver interactions

Divers reported their perceptions on four types of behaviour that pedestrians reported. Those four items of the pedestrians' behaviours were related to the uses of nearby crossing (TB1), violation behaviours (TB2), aggression (TB3), and lapses (TB4). Table 5.1 shows the drivers' responses to the pedestrians' behaviour they have noticed while driving on the research roads. The highest response to pedestrians' lapses was "sometimes" and "frequently", with 40.6% each. Similarly, the highest response on pedestrians' uses of nearby crossings was sometimes (42.6%), other violation behaviour was frequent (46.5%), and aggression toward the driver was infrequent (52.5%).

Table 5.1 Descriptives of drivers' perception of pedestrians' behaviour

Variable	Response	Frequency (N = 202)	Percentage
Uses of nearby crossing (TB1)	Never	3	1.5
	Infrequent	80	39.6
	Sometimes	86	42.6
	Frequent	32	15.8
	Always	1	0.5
Violation behaviours (TB2)	Never	2	1
	Infrequent	13	6.4
	Sometimes	77	38.1
	Frequent	94	46.5
	Always	16	7.9
Aggression (TB3)	Never	52	25.7
	Infrequent	106	52.5
	Sometimes	42	20.8
	Frequent	2	1.0
	Always	0	0
Lapses (TB4)	Never	1	5
	Infrequent	22	10.9
	Sometimes	82	40.6
	Frequent	82	40.6
	Always	15	7.4

Table 5.2 shows the descriptive statistics of four variables (TB1–4) to understand the difference in perceptions between pedestrians and drivers.

Table 5.2 Differences in pedestrian and driver perceptions of behaviours

Variable	Group	N	Range	Mean	Std. Deviation (SD)
TB1	Pedestrian	302	4	3.78	0.795
	Driver	202	4	2.74	0.755
TB2	Pedestrian	302	3	2.16	0.782
	Driver	202	4	3.54	0.773
TB3	Pedestrian	302	4	1.94	0.895
	Driver	202	3	1.97	0.712
TB4	Pedestrian	302	3	2.13	0.741
	Driver	202	4	3.44	0.803

The Mann-Whitney U test showed a statistically significant difference between pedestrian and driver groups on TB1 ($U = 11639$, $p < 0.001$, $r = -0.551$), TB2

(U = 7478, p < 0.001, r = - 0.667), and TB4 (U = 8168, p < 0.001, r = - 0.653), except TB3 (U = 28834, p = 0.264, r = - 0.049).

Drivers reported that they frequently (40.6%) yielded to pedestrians, followed by sometimes (38.1%), always (9.4%), infrequently (8.4%), and never (3.5%). While comparing with pedestrians' responses on drivers' yield, the pedestrian reported drivers sometimes let them go 33.1%, followed, always (30.8%), frequently (26.2%), infrequently (8.3%), and never (1.3%). The Mann-Whitney U test showed a statistically significant difference with a small effect size between pedestrians and drivers on the yielding behaviour of drivers (U = 25131, p < 0.001, r = - 0.156), indicating that there was a meaningful distinction between the yielding behaviour of drivers as reported by drivers themselves and as perceived by pedestrians.

In pedestrian-driver interaction, drivers reported that pedestrians primarily used hand gestures with the L-straight-erect type (63.4%) for yielding. Pedestrians also reported using hand gestures with the L-straight-erect type (68.9%). Drivers (50%) reported their accident involving or seen, while 30.8% of pedestrians reported having an accident history.

However, when pedestrians start to cross a road, but the situation does not permit drivers to yield to pedestrians to cross, 47% of drivers reported that the pedestrians primarily run fast. In contrast, 47% of pedestrians reported they mostly stopped. The highest response on those actions of drivers and pedestrians was “sometimes”, with 46.5% and 39.4%, respectively.

During the drivers' focus group discussion, 42 statements and quotes were noted as per the drivers' responses to the specific questions, including pedestrians' behaviour around the designated crossings and drivers' yielding decisions at designated crossings. These statements represent common themes, critical insights, or specific issues raised by the drivers. The purpose of these statements and quotes were to disseminate them to the pedestrians focus group discussion to get feedback from the pedestrians' focus group participants to understand the difference in perceptions between the drivers and pedestrians regarding pedestrian behaviour and drivers yielding to pedestrians. The pedestrians' responses to questions Q1 regarding pedestrian behaviour and Q2 concerning drivers, as noted in the summary note (Appendix H), were categorised based on their agreements or disagreements. Table 5.3 shows the distribution of major agreements (n = 14 on pedestrians' behaviour and n = 6 on drivers' yield) and disagreements (n = 5 on pedestrians' behaviour and n = 5 on drivers' yield) that cover around 71% of the total statements or quotes. However, participants remained undecided on the remaining 29% of statements or quotes.

Table 5.3 Pedestrians' level of agreement on drivers' comments

	Major agreement		**Disagreement**	
Participants	Pedestrian behaviour	Drivers' yield	Pedestrian behaviour	Drivers' yield
Students and Workers	7	-	2	2
Students only	1	1	2	3
Workers only	6	5	1	-
Total statements & quotes	14	6	5	5

All student and worker participants strongly agreed with the drivers' observations regarding pedestrians' behaviour around crossings. The pedestrian focus group participants acknowledged that pedestrians often violate crossing rules, making it challenging for drivers to yield. They agreed that pedestrians frequently exhibit lapses, such as engaging in phone conversations during crossings, not paying attention to vehicles even when honked at, and failing to notice vehicles close to them.

Pedestrians also acknowledged that when they are in a group, one person typically raises a hand to signal drivers to stop or slow down, and others follow suit. Students agreed that they often engage in conversations and occasionally look back while crossing roads. Workers agreed with some of the drivers' comments as well. They confirmed that many pedestrians lack knowledge of using footbridges properly and often cross roads diagonally. Workers also agreed with the drivers' remarks that some marketplace workers, who may have limited education, resort to forceful tactics to stop vehicles (displaying aggressive behaviour).

Areas of disagreement among pedestrians regarding drivers' yielding behaviour are evident from focus group discussions. Students expressed disagreement with drivers' beliefs about not encountering problems if they let pedestrians go and also disagree with the idea that drivers yield when pedestrians wait for a long time with bags or drive during school class hours. However, workers showed agreement that drivers yield when they observe hand gestures from pedestrians seeking attention or when they encounter vulnerable individuals such as the elderly, women, blind, disabled, or those with children. Students also agreed that drivers yield when pedestrians reach the middle portion of a road while crossing.

Regarding factors where there is major agreement among workers, it was noted that their mood changes in the afternoon can impact yielding behaviour. They also agreed that they do not intentionally run their vehicles over pedestrians, especially considering the presence of children going to school. Additionally, workers concurred that there could be danger for passengers or drivers if they yield to pedestrians in situations where it is not safe to do so, such as when someone is running to cross a road. Furthermore, workers showed agreement that they are willing to yield to pedestrians at locations without designated crossings nearby but are not inclined to yield to those attempting to cross roads despite the availability of footbridges nearby.

However, there were areas of general disagreement among all participants, where the impact of overtime duties and being in a hurry on drivers' yielding behaviour is not uniformly agreed upon. Furthermore, the statement about pedestrians not reading the minds of drivers, especially during nighttime, and the need for pedestrians to judge the origin of the vehicle to avoid accidents, also elicited major disagreement among all participants:

> *As a driver, I try to understand the crossing motives of pedestrians and decide whether I should go or not. – (major disagreement by all)*
>
> *Pedestrians don't read the mind of a driver. When a vehicle is riding over the night……. pedestrians need to judge the origin of the vehicle from where it came…if they fail to do so, an accident occurs. – (major disagreement by all)*

5.4.2 Model variables with statistical tests

The target behaviour of this COM-B model was drivers' yield to pedestrians, which is tested with the test variable of frequency of near-accident situations. According to the drivers' experiences, near-crash situations were primarily infrequent (62.4%) while interacting with pedestrians trying to cross a road.

There should have a strong negative correlation between drivers' yield to pedestrians and the test variable of frequency of near-accident situations. This assumption implies that those who report yielding to pedestrians more frequently may have a lower likelihood of experiencing near-accidental situations if other factors remain the same. The Spearman correlation between the test variable (Mean 3.77, SD = 1.021) and the target variable (Mean 2.28, SD = 0.665) was statistically significant: ($r = -0.189$, $p < 0.01$).

Referring to the drivers' COM items (Appendix I), physical opportunity (O1) is measured with eight physical opportunity items (PO1–8), social opportunity (O2) with three social opportunity items (SO1–3), physical capability (C1) with three physical capability items (PC1–3), psychological capability (C2) with three psychological capability items (PsC1–3), and motivation with four reflective motivation items (RM1–4) and four automatic motivation items (AM1–4).

The descriptives of predictor variables are also shown in Appendix I. The Spearman correlation between the predictors and the target variables of drivers' yielding behaviour shows that PO items PO1–5 have significant correlations at the 0.01 level. Similarly, SO items SO1 ($p < 0.05$) and SO3 ($p < 0.01$), RM items RM1–3 ($p < 0.01$), all AM items ($p < 0.01$), and PC2 ($p < 0.05$) have significant correlations with the target behaviour.

Breusch-Pagan Test is used for heteroskedasticity, where the p-value (0.199) was more than 0.05, suggesting no heteroskedasticity issue. The value of VIF < 3.3, suggested no multicollinearity issue. The value of the Durbin-Watson test result (2.071) also suggested no auto-correlations in the residuals.

PLS regression found eight significant predictors in predicting drivers' yield (Figure 5.2). The regression model explained 45.1% of the variance in drivers' yield with those predictors. In the Analysis of Variance (ANOVA), the F-ratio measures how well the total regression model fits the data. The statistical value of $F(8, 193) = 19.786$, and a p-value of less than 0.001 suggests that the independent factors statistically substantially predicted the dependent variable (i.e., the regression model is a good fit for the data). The adjusted R-square value of this model is 0.428.

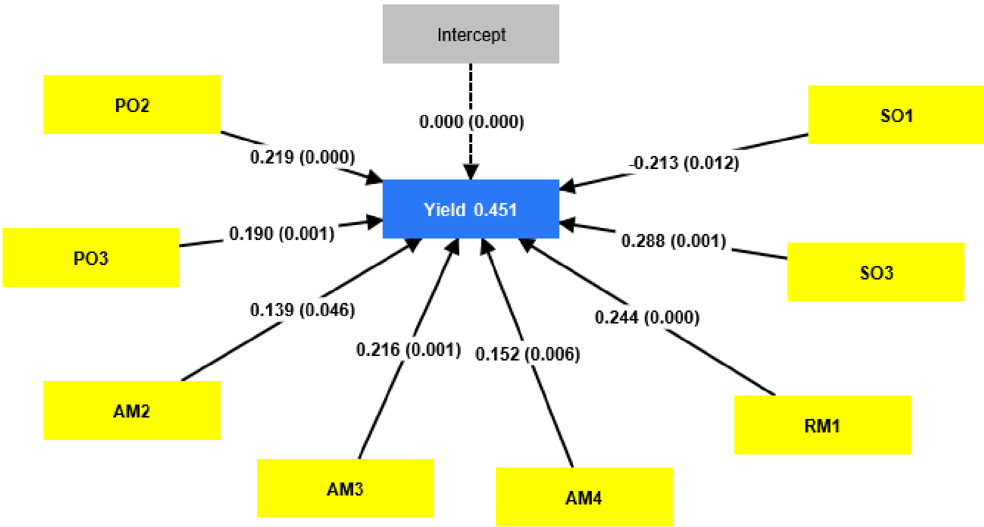


Figure 5.2 Regression model

The regression model confirmed that the pedestrians' avoiding random crossing (RM1; β = 0.244 & p < 0.001), pedestrians' assertiveness (AM3; β = 0.216 & p < 0.01), vulnerable groups such as children or women (AM2; β = 0.139 & p < 0.05), and pedestrians' fear expressions of traffic injury/death (AM4; β = 0.152 & p < 0.01) were significant drivers' motivational factors in Yield. Similarly, traffic sign or advance road marking (PO2; β = 0.244 & p < 0.001), enforcement (PO3; β = 0.190 & p < 0.01), pedestrians group crossing (SO3; β = 0.288 & p < 0.01), and many crossing users (SO1; β = - 0.213 & p < 0.05) were significant drivers' opportunity factors in Yield.

5.4.3 Drivers' yield prediction model and hypothesis testing

After trimming five insignificant inner model paths (O2 -> yield, C1 and C2 -> Motivation and Yield) and statistically non-significant outer model indicators (PO1, PO6–8, SO2, AM1, AM4, and RM4) of the remaining constructs from the initial model (Figure 5.3), the trimmed prediction model was established with a good model fit (SRMR = 0.041). Figure 5.4 shows the trimmed yield model with the λ and p-value for the outer model and the beta (β) and p-value for each path of the inner model.

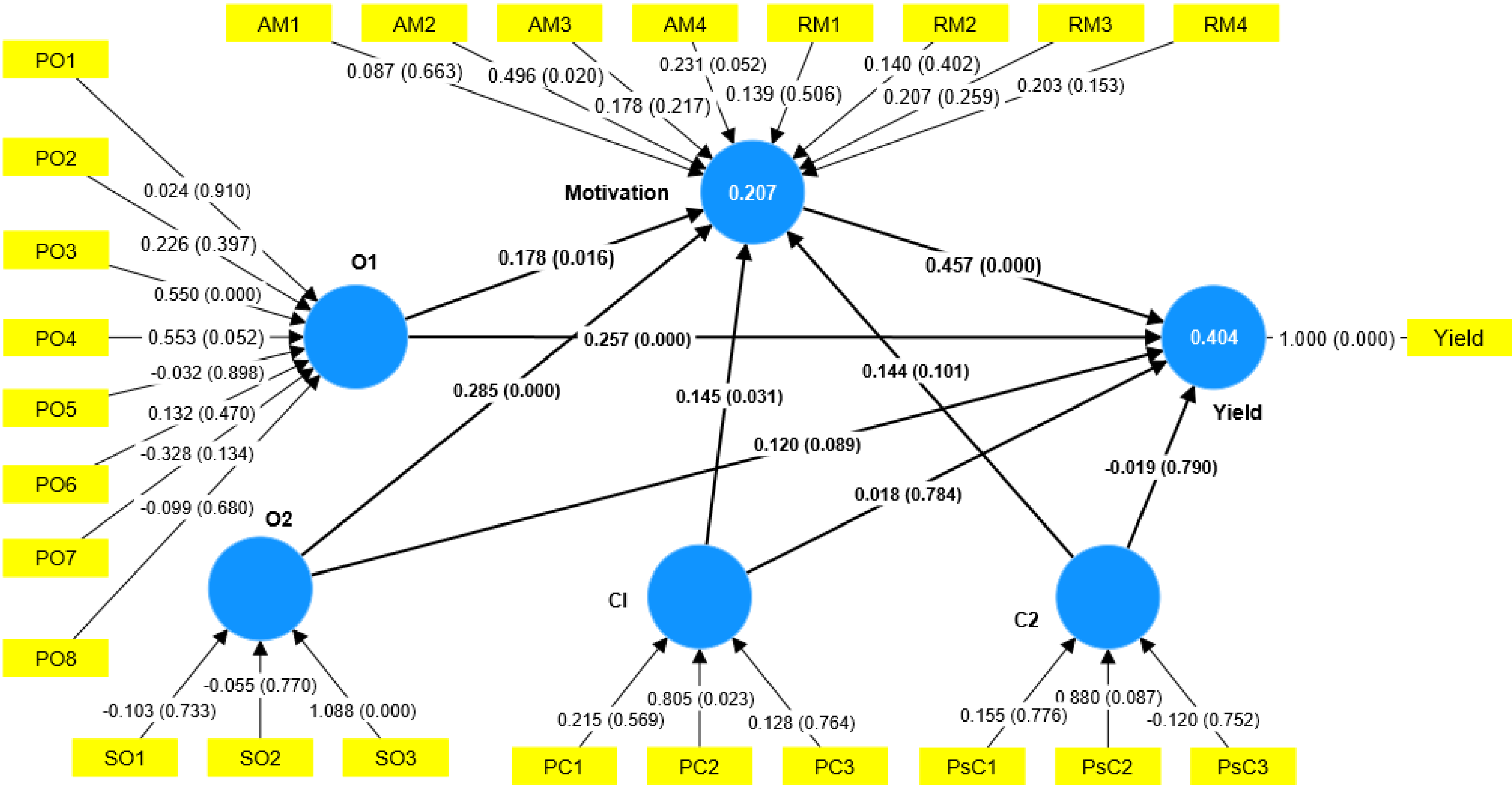


Figure 5.3 The initial yield model

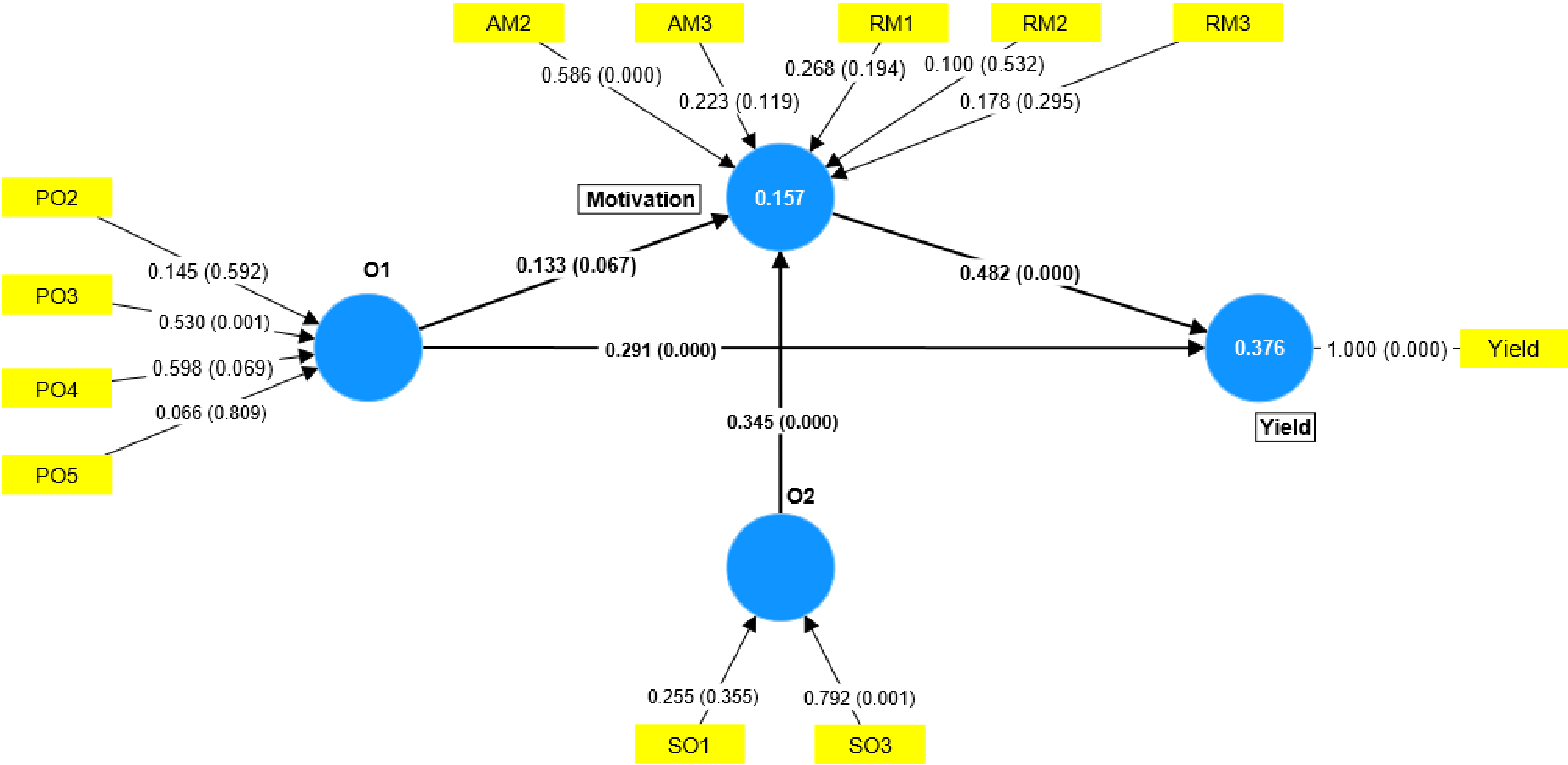


Figure 5.4 The trimmed yield model

The 11-factored trimmed model explained motivation with the maximum number (n = 5) of factors, followed by physical (n = 4) and social opportunity (n = 2). The model explained 37.6% of the variance in yield, followed by 15.7% variance in motivation. In model explanatory power, R^2 should be greater than 0.10 to be deemed adequate (Falk and Miller, 1992). In contrast, others suggest 0.26 as substantial (Cohen et al., 2014).

The model confirmed that the most contributory elements in the respective constructs include the enforcement (PO3) with $\lambda = 0.530$ ($p < 0.01$) and pedestrian fences over footpaths/median (PO4) with $\lambda = 0.598$ ($p < 0.1$) in physical opportunities; pedestrians group crossing (SO3) with $\lambda = 0.792$ ($p < 0.01$) in social opportunity; and vulnerable groups such as children or women (AM2) with $\lambda = 0.586$ ($p < 0.001$) in motivation. Social opportunity ($\beta = 0.345$, $p < 0.001$) and physical opportunity ($\beta = 0.133$, $p < 0.1$) significantly predicted motivation. Motivation ($\beta = 0.482$, $p < 0.001$) and physical opportunity ($\beta = 0.291$, $p < 0.001$) significantly predicted yield.

The multigroup analysis outcome between buses (n = 96) and light vehicles (n = 71) is shown in Appendix J. In predicting yield, the multigroup analysis found that the bus drivers ($\beta = 0.412$) had less motivation than the light vehicle drivers ($\beta = 0.668$), and that difference was significant at the 0.1 level.

The following hypothesis (H-1 to 4) were concluded:

(1) Physical and psychological capability had no significant impact on motivation and yield; therefore, those two constructs were eliminated in the prediction model. Hence hypothesis H-1 is rejected.

(2) Physical opportunities significantly predicted motivation ($p < 0.1$) and yield ($p < 0.001$), whereas social opportunities had a significant contribution to motivation ($p < 0.001$) but an insignificant direct contribution to yield. Hence hypothesis H-2 is confirmed except for the social opportunities in the direct prediction of the yield.

(3) Motivation significantly predicted yield ($p < 0.001$). Hence hypothesis H-3 is confirmed.

(4) The multigroup analysis found that the motivation affected the bus drivers' yield less than the light vehicle drivers at 0.1 significant level. Hence hypothesis H-4 is confirmed.

The endogenous latent variable ‘motivation’ was represented by the five factors: feeling comfortable when pedestrians avoid random crossing, positive attitude in yielding when pedestrians display good crossing behaviour, earlier consideration of potential risks due to pedestrians’ risky behaviour, natural empathy for the vulnerable group (children/women), and convincing pedestrians’ assertiveness; that were well covered the suggestive TDF domains of motivation. No physical or psychological capability components were exogenous latent variables that predicted motivation or yield. Only two exogenous latent variables, physical and social opportunity, were included in the model. Traffic signs/road marking, enforcement, pedestrian fences, and visibility are the three factors that represent environmental restructuring and resources domain under the opportunity. Many crossing users and group crossing are the two factors that represent the social influences domain under the opportunity in TDF.

Model path analysis showed that physical opportunity had more influence on the yield. In contrast, social opportunity had more influence on motivation. The multigroup analysis finds that the influence of motivation had significantly less effect on the bus drivers’ yield than on the light vehicle drivers. Data shows that drivers plying buses, particularly long-distance buses, are involved the most in Bangladesh’s accidents (49%). In a South Korean study, larger vehicles such as trucks and vans show more severity of pedestrian injuries than other types (Park and Ko, 2020).

In the drivers’ yield model, ‘motivation’ was represented by the five factors in which the vulnerable pedestrian groups, such as children or women, were the most contributory factor. The previous study in educational and commercial areas adjacent to two-lane roads reveals that female pedestrians positively impact drivers’ yielding behaviour (Schroeder et al., 2014). Overall, vulnerable groups (children/disabled/elderly) positively impact drivers’ yield, as mentioned earlier. Here, the drivers could have deep emotions toward that group, motivating them to yield. Besides those demographic factors, none of the pedestrians’ factors significantly contributed to the model prediction.

On the other hand, three environmental or contextual factors (enforcement, pedestrian fences over footpaths/median, and pedestrians group crossing) contributed significantly to the model prediction. Speed enforcement through manual policing or speed cameras was found effective. In the Australian state of New South Wales, 28-speed cameras were installed, resulting in a 71% drop in speeding and an 89% reduction in fatalities at the treated sites (Job and Sakashita, 2016). The benefit of pedestrian fences is an environmental modification, as they can separate pedestrians from traffic and benefit road users' behaviour (Thompson et al., 2013). Such facilities are self-enforcing and proven helpful in semi-urban or urban areas, as mentioned in Chapter 2. A study in an educative area adjacent similar to the research route (two-lane, one-way road) finds that drivers are more likely to yield to groups of pedestrians than individuals (Sun et al., 2003).

5.4.4 Factors in drivers' yielding behaviour

Pedestrians' avoiding random crossing significantly affected drivers' yielding to pedestrians, as the regression analysis revealed. The yield model shows that drivers motivate yield to pedestrians when pedestrians avoid random crossing and show good crossing behaviour (e.g., avoid violations). This outcome also supports the qualitative findings of this study.

According to the thematic coding structure of the conceptual framework for the drivers yielding behaviour, the NVivo analysis revealed that the most discussed topic among focus group participants was *barrier* (Appendix K). Pedestrians' crossing behaviour emerged as the key *barrier* to yield. Drivers reported instances where pedestrians violated crossing rules, avoided designated crossings, engaged in distracted behaviour such as using mobile phones, and occasionally showed aggression towards drivers. Drivers' positive *attitude* builds when the pedestrians' actions meet their expectations of good crossing behaviour. Some drivers acknowledged the pedestrians' priority in using the zebra crossing. However, the knowledge of pedestrian crossing use and rules compliances marked a major *barrier* in their discussion:

> *We are willing to yield to pedestrians even those who cross the road at a location where no designated crossing is nearby but do not for those*

who try to cross a road despite having a footbridge nearby. – Car driver (participant 5, focus group 2)

Many pedestrians come from rural areas. They do not know the rules of the road crossing. – Pickup driver (participant 3, focus group 3)

The focus group participants expressed their concerns about the pedestrians' risky behaviours, like sudden running or unpredictable decision changes in the middle of the road, which pose even greater challenges for drivers. Drivers' survey data also shows pedestrians show risky running behaviour while crossing a road:

Sometimes we intend to yield to someone, but due to his crossing action or move, we fall into danger or unexpected event. Especially if they try to cross and back from some point of the crossing path. – Bus driver (participant 4, focus group 3)

Sometimes pedestrians run and do not have enough time to control the vehicle, which is challenging to let them go. – Bus driver (participant 6, focus group 2)

Focus group participants reported that drivers become angry if they see pedestrians not using footbridges and cross the road randomly underneath it. No protection measures (e.g., fencing or enforcement) were available at the crossing sites to protect such underneath the crossing. Fences and enforcement are two alternative protection options, as found in the yield model and regression outcomes. The lack of such crossing facilities or measures emerged as a *barrier* in the focus group discussion. The participants were concerned about the psychological aspect of the drivers in the absence of such facilities. Studies have shown that drivers' most common form of emotion is anger, which can increase driving speed (Kadoya et al., 2021):

Having a footbridge, but someone is crossing underneath. In that case, feeling angry to get no logic behind such a crossing move despite having a footbridge nearby. – Covered van driver (participant 1, focus group 1)

In regression analysis, pedestrians' fear expressions of traffic injury/death emerged as a significant factor in drivers' yielding to pedestrians. Focus group participants emphasised the consequences of the pedestrians' actions from their *belief about consequences* in building drivers' intention or willingness to yield to pedestrians. They considered various safety-related factors, including concerns about pedestrian aggression and the risk of pedestrian injuries. Sometimes, they had to compromise the safety of pedestrians when they perceived more danger for their vehicle passengers in yielding. Therefore, they stick to a trade-off between the safety of vehicle passengers and pedestrians. The yield model suggests that drivers' earlier consideration of potential risks due to pedestrians' risky behaviour motivates drivers to yield to pedestrians. Possible risks could be reminded with fear-based communication, often used in road safety domains (Lewis et al., 2007), as fear is one of the strongest emotions anyone can feel, as stated earlier:

> *If someone does run to cross a road, but the situation does not permit us to yield, there could be a danger for the vehicle passenger if the driver yields. – Bus driver (participant 6, focus group 2)*

> *It is not the fact that we do not give yield. There is always a risk of an accident in such a case. – Truck driver (participant 1, focus group 3)*

The drivers' *emotions* are activated when they see old or disabled people on the road waiting to cross, and they also prioritise children and women while they try to cross a road, as revealed in the focus group discussion. The yield model and regression output also show that vulnerable groups such as children or women significantly impacted the drivers' motivation in yielding behaviour of drivers. Drivers' family members sometimes are in the same social-economic category, such as school-going boys, girls, or women workers. In such cases, the focus group participants emphasised on a *social/professional role* to play in Prioritising their crossing needs:

> *When we see children, women, or older people standing on the street for a long time crossing a road, we let them go voluntarily. – Truck driver (participant 5, focus group 3)*

> *We want to yield children during their school time and women. Because they could be our son or daughter. – Car driver (participant 9, focus group 2)*

As per the focus group discussion, the drivers often apply their *capability and control* in judging the situation and understanding the motives of pedestrians to adjust their behavioural responses in a particular situation. They emphasised the c*ommunication and decision-making* process in pedestrian-driver interactions. The adequate distance and visibility to notice any pedestrians' motives using their eye or gestural appeal are highlighted for the drivers' yielding decisions. In the survey, most drivers reported that pedestrians mostly use their gestures (right hand) while they try to cross a road. The yield model and regression output suggest that pedestrians' visibility and assertiveness through gestures and eye contact builds drivers' motivation in yielding behaviour. Such implicit type of communication could change behaviour (Fuest et al., 2017; Kellermann and Cole, 1994):

> *As a driver, I try to understand the crossing motives of pedestrians and decide whether I should go or not. - Bus driver (participant 4, focus group 3)*
>
> *We let them go when someone raises their hand before crossing roads, and we notice from a reasonable distance to halt the vehicle. – Bus driver (participant 6, focus group 2)*

In contrast to the action taken in response to the pedestrians' motives, drivers also often rely on earlier actions memorised for the driving experiences:

> *I have to think about what places pedestrians frequently cross. I should memorise those places in my mind. - Bus driver (participant 3, focus group 2)*

The yield model and regression analysis findings highlighted that road signage and advanced road markings significantly predict drivers' yielding behaviour. Drivers' focus group participants reported that inadequate visibility of road signs and markings made them challenging to identify crossing locations and adhere to traffic rules based on site conditions. The majority of focus group participants emphasised *environmental restructuring* or physical road facilities, such as road signage, markings, and road furniture, to facilitate the users:

> *When we see directional signboards and zebra road markings, it becomes easy to identify the crossing place so that we can yield. – Bus driver (participant 3, focus group 2)*

Participants in the focus groups also highlighted the positive impact of *social influences* on drivers' yielding behaviour, such as the presence of a group of pedestrians or a pedestrian group crossing at a specific time of the day. The yield model and regression results suggest that the pedestrian group crossing at specific times is an influential social opportunity factor in predicting drivers' yielding behaviour. When pedestrians know each other (Tezcan et al., 2019) or the same type of pedestrian (school student, garments worker) moves at a particular time for study or work purposes, forming a platoon. This platooning can attract drivers' attention, influencing drivers to reduce speed (Avinash et al., 2019; Sheykhfard and Haghighi, 2019). However, regression results support that many crossing users significantly negatively impact drivers' yielding behaviour. As per the focus group participant opinions, when pedestrians did not cross in groups and instead crossed individually in a random manner, drivers were less inclined to yield due to the prolonged waiting times:

> *At certain times, for example, during industry work or school time, when a large group of pedestrians crosses a road, we let them cross. – Car driver (participant 4, focus group 2)*

> *We usually yield in the morning when school students, workers, and office goers need to cross a road. – Car driver (participant 2, focus group 3)*

> *If we find a long queue or take more time to let them cross, then we do not yield. – Car driver (participant 5, focus group 2)*

5.4.5 Factors in pedestrians' safe uses of crossing

Pedestrians' safe use of crossings could be characterised by three essential compliance of crossing behaviour: avoiding violations, aggressive behaviour, and lapses. According to the thematic coding structure of the conceptual framework for the intention or willingness to the safe use of crossings, the NVivo analysis revealed that the most concerned topic among focus group participants was *barriers* (Appendix L). While discussing the *barriers* to safe crossing, the pedestrian focus group participants highlighted the demographic factors such as the pedestrian's age and gender, pedestrians' behaviour and knowledge, environmental and social barriers, and drivers' knowledge of traffic rules and their unyielding behaviour to pedestrians.

Participants acknowledged their limited knowledge of traffic rules and crossing skills. They mentioned that pedestrians aged 18-26 often do not obey traffic laws and engage in risky crossing behaviours, such as running or stopping in the middle of the road. Students reported being distracted by their school or college exams, leading to absent-mindedness and lapses in judgment while crossing. Pedestrians' confidence in their ability to cross the road positively influences their use of designated crossings. However, the focus group participants acknowledged that specific *barrier*s in pedestrians' capability and control adversely affect pedestrian-driver interactions. For example, pedestrians often rely on their visual estimation of vehicle speed, which can sometimes be inaccurate and lead to difficulties in interactions with drivers on the road:

> *Sometimes eye estimate doesn't really work. I mean that the eye estimate is a problem for both (pedestrians and drivers). – College student (participant 10, focus group 2)*

The participants emphasised the violation behaviour predominantly. They mentioned that when they are in a hurry or under peer pressure, they may cross the road at any location to save time. This behaviour indicates a disregard for designated crossings and a preference for convenience. According to the drivers' survey, 42.6% of pedestrians sometimes use nearby crossings, highlighting the prevalence of this unsafe violation behaviour in Bangladesh. A study has shown that such violations by jaywalkers can result in higher costs and risks (McIlroy et al., 2019):

> *When we are hurried or work under pressure, we do not see where the designated crossing is, and we cross at any location to save time. – Marketplace worker (participant 6, focus group 3)*
>
> *When a group of friends or acquaintances consisting of around ten people is crossing the street together, a scenario may arise where two or three individuals suggest using a footbridge. However, the remaining seven or eight individuals in the group oppose this suggestion, expressing concerns about the potential delay in crossing if they were to use the footbridge. – College student (participant 10, focus group 2)*

The pedestrians focus group participants expressed concern about drivers speeding and violating priority rules of the zebra crossing. They emphasised the importance of speed reduction management techniques before a zebra crossing and the functioning of appropriate actions of the police. Participants mentioned the limited presence of police officers and their focus on smaller vehicles suggesting a desire for stricter enforcement of traffic rules and regulations to ensure safer pedestrian conditions. Women often feel insecure about using footbridges or underpasses with insufficient light or security in the evening. Pedestrians expressed concerns about drivers' behaviour, particularly regarding speeding and violating priority rules at zebra crossings highlighting the vulnerability of certain groups, such as children and women, who may face increased risks when crossing the road. The presence of traffic police is recognised as a *facilitator* for the safe crossing of pedestrians, especially for vulnerable road users. Retting (2017) states that more law enforcement can boost yielding rates and promote pedestrian safety. The focus group participants commented that pedestrians feel secure when there is no or less traffic on the road and have time to cross a road. However, they are concerned about the safe use of designated crossing in situations where drivers show reluctant to yield to pedestrians:

In the case of crossing, it is much better to have a traffic policeman, which helps pedestrians to cross a road. Often, older people or children are also motivated. – College student (participant 2, focus group 2)

The number of police is limited. The police mainly focus on small vehicles. – College student (participant 9, focus group 2)

If the speed of the vehicles had been reduced a little, we would have had fair use of crossings. However, when we want to cross, they do not slow down. – College student (participant 9, focus group 2)

We do not feel confident using zebra crossing as we do not sure whether the driver will slow their vehicles before crossing or not. There is uncertainty built from past experiences that usually drivers do not want to stop. – Marketplace worker (participant 9, focus group 3)

When the road becomes free or less traffic, we want to cross. – School student (participant 10, focus group 1)

When vehicles are fewer, especially during the strike, drivers do not slow down their vehicles. In such a case, we do not want to use the designated crossing due to fear of an accident. – Marketplace worker (participant 3, focus group 3)

The participants also noted that zebra crossings are often not visible, leading to confusion and uncertainty when deciding where to cross. Pedestrians focus group participants also emphasised the *environmental restructuring* to facilitate safe crossing. Concerning traffic signs or advanced road marking, a study shows that when there is no zebra crossing or traffic signal, the crossing probability is less than 50% (Rasouli et al., 2017a). They emphasised installing high-visibility zebra crossings, light signal systems, suitable locations of crossings, and other facilities for drivers' compliance with the crossing sites. A previous study also shows that high visibility marking increases pedestrians' safety (Sarwar et al., 2017). The participants preferred the presence of a traffic light signal system to facilitate pedestrian safety. In the absence of such a system, they suggested the installation of speed reducers before the crossing area to ensure that drivers would yield to pedestrians and enhance pedestrian safety in safe crossing. Pedestrians, especially workers, perceive the *benefits* of crossings conveniently located near their workplace. Additionally, they see it as their *social or professional role* to utilise designated crossings:

> *Zebra crossings are also not visible in most cases. – Marketplace worker (participant 3, focus group 3)*
>
> *If there was a light with the zebra crossing or a policeman was standing all the time, we would have understood that we could cross through here. Then we would not have crossed into another place. - College student (participant 10, focus group 2)*
>
> *We intend to cross when the drivers slow or have a speed reducer on the road to force drivers to slow their vehicles. – School student (participant 6, focus group 1)*

Belief about consequences for pedestrians' actions played an essential role in pedestrians' intention or willingness to use crossings safely. Participants mentioned their fear of accidents and their impact on their crossing behaviour. They said using designated crossings slightly farther away due to the anxiety associated with crossing at a location with uncertain driver behaviour. Fear-arousing messages can be persuasive in changing behaviour, depending on cultural differences. In countries such as Australia, New Zealand, the United States, and Great Britain, it is a common practice to display explicit pictures of crashes, causalities, injuries and blood, and the grief of traffic victims (Goldenbeld, 2007):

> *Due to the fear of an accident, we use the crossing though it is a little far away. – Garments worker (participant 2, focus group 4)*

Focus group participants highlighted the *social influences*, as the group dynamic and social influence play a significant role in determining pedestrians' behaviour. If others in the group choose not to use the footbridge, it reinforces the perception that doing so is unnecessary or inconvenient. Literature supports that group members are less likely to follow someone breaching the law, such as crossing at a red light (Lefkowitz et al., 1955). Another study shows groups have a more stable overall behaviour due to difficulty in changing the direction of movement and a tendency to maintain cohesion and communication among themselves (Bandini et al., 2014):

> *Many times, even after seeing the footbridge, it is seen that no one is using that crossing. So, why would anyone cross that footbridge alone? – College student (participant 9, focus group 2)*

Pedestrians try to communicate with drivers using their eyes and hands as a means of *communication and decision-making process*. Pedestrians focus group participants stated that while they cross a road, they try to communicate with drivers by raising their hands. When drivers respond to their gestural appeal and yield, they feel safe using crossings. They reported that drivers usually do not want to yield unless pedestrians seek their attention before crossing a road. That informal approach of drawing the drivers' attention is quite common in developing countries due to the lack of a light signal system in a designated zebra crossing:

> *I raise my hand to slow the vehicle's speed. Then, I decide to cross if the driver responds to my gesture; otherwise, I do not cross. – Marketplace worker (participant 4, focus group 3)*

5.5 Implications for practice and policy

This study found a significant difference between pedestrian and driver groups regarding pedestrian violations and lapses, as well as drivers' yielding behaviour, suggesting several implications for practice and policy. Therefore, these research findings would help the designers and policy makers to explore the underlying reasons for differences in perceptions and behaviours in pedestrian-driver interactions.

The findings of the yield model suggest that physical and psychological capability do not significantly impact motivation and yield, indicating that interventions and strategies aimed at improving pedestrian and driver behaviour should focus on other factors rather than solely targeting individuals' capabilities. Secondly, it is crucial to prioritise physical opportunities, such as improving infrastructure and creating safe and accessible crossing points, as these factors significantly influence motivation and yield. Social opportunities also motivate individuals, highlighting the importance of promoting a supportive social environment for safe road behaviours. Furthermore, the strong relationship between motivation and yield underscores the need for interventions that enhance individuals' motivation to prioritise pedestrian safety and yield to pedestrians.

The study also highlights the importance of considering different driver groups in road safety initiatives, as the analysis revealed that motivation had a significantly different effect on yield between bus drivers and light vehicle drivers. This implies that tailored approaches should be developed to address specific challenges and factors influencing different driver groups.

The regression model identifies eight significant factors in drivers' yield behaviour. The model found seven significant positive factors: pedestrians' presence in the designated area by avoiding random crossing, pedestrians' assertiveness, vulnerable groups such as children or women, traffic signs or advance road marking, pedestrians' group crossing during peak hours, enforcement, and pedestrians' fear of traffic injury or death. The only variable negatively correlated with drivers' yielding was the number of people crossing often.

The deductive thematic framework analysis explores the factors that affected drivers' yielding and pedestrians' safe crossings use. Therefore, a consensus among drivers and pedestrians was established around those factors. The following broad areas were highlighted in the pedestrian focus group discussion that could be the key to promoting safe crossing use:

1. *Pedestrians' knowledge and behaviour:* The focus group participants acknowledged the importance of pedestrians' knowledge of traffic rules and safe crossing skills. By obeying traffic laws and avoiding risky crossing behaviours, pedestrians contribute to a safer crossing environment. This factor is related to the drivers' perception of pedestrians' behaviour mentioned in the drivers' focus group and the yield model. If drivers observe pedestrians displaying good crossing behaviour, they are more likely to yield and prioritise their safety.

2. *Environmental and social barriers:* Pedestrians mentioned that environmental and social factors could influence their decision to use designated crossings. Factors such as insufficient lighting, inadequate security in underpasses or footbridges, and peer pressure can deter pedestrians from utilising safe crossing facilities. These barriers are related to drivers' perceptions and behaviour, as mentioned in the drivers' focus group and the yield model. If drivers know these barriers, they can adjust their behaviour and be more cautious in yielding to pedestrians.
3. *Drivers' knowledge and behaviour:* Pedestrians emphasised the importance of drivers' knowledge of traffic rules and willingness to yield to pedestrians. They expressed concerns about drivers speeding and violating priority rules at zebra crossings. This factor aligns with the drivers' focus group discussion and the yield model, where drivers' knowledge of traffic rules and their yielding behaviour are crucial for safe pedestrian crossings.

Designers should consider the consensus among the drivers and pedestrians in designing interventions that could benefit pedestrians and drivers in meeting their expectations and achieving safe use of crossings. Transportation agencies in developing countries should focus more on improving drivers' motivational and opportunity factors to meet the expectation of road users (drivers and pedestrians). Considering these implications, practice and policy can be tailored to promote pedestrian safety and foster responsible behaviour among all road users.

The study also recommends that designers could boost the use of crossing facilities by adding other promising treatments, such as light, signal, or raised crossing, proven effective in similar contexts or established in the literature. Training could be the key for drivers and pedestrians to enhance implicit communication, including training on pedestrians' assertiveness with eye contact, expressing their intention to cross using gestures, and the right-of-way rules in a designated crossing.

Chapter 6
Study 3: Shared Responsibility for the vulnerable road users: Intervention with a co-design and behaviour change model

6.1 Introduction

6.1.1 Background

The low uses of designated crossing facilities indicate a gap between the road user expectations of crossing facilities and the designers' choice of infrastructure. While intervention design is a key strategy for improving pedestrian safety, Bangladesh's current institutional design practices and their impact on pedestrian safety are poorly understood.

In Bangladesh and other developing countries, it is debatable whether poor design of facilities or violation of traffic rules by road users is the leading cause of pedestrian injuries and deaths. Professionals, pedestrians and drivers tend to blame each other. Shared responsibility for road safety is crucial for protecting vulnerable road users such as commuting students and workers who face higher injury risks while crossing highways. Safe System highlights the responsibilities of authorities to provide safe facilities. However, little attention has been given to how authorities can better understand user needs and willingness to change behaviour.

The key objectives of this study are to improve the intervention design for the safety of vulnerable road users and to address the blaming culture among pedestrians-drivers-authority by suggesting a way-out technique to the authorities. Therefore, this study investigates the current design practice in Bangladesh, and compares it with the effect of co-design on quality of outcome (intervention 1) and then investigates what level of additional improvement can be achieved by applying a behaviour change model in the co-design process (intervention 2). Finally, the study evaluates the stakeholders' views on those interventions in improving the blaming culture that ultimately threatens the safety of vulnerable road users.

6.1.2 Research sites and experimental research design

This experimental study examines four research sites that serve as representative crossings within the road network of Bangladesh. These sites include a zebra crossing in front of ‘Dendabor School and College’ (location-1) and a footbridge with an underpass nearby at ‘Bipyl’ (location-2) along the N540 highway. Furthermore, zebra crossings are in front of ‘Narshingdi Abdul Kader Mollah College’ (location-3) and the ‘Morjal’ marketplace area (location-4) on road N2. Those research site details are stated with site pictures in Chapter 3 (section 3.2).

These experimental research activities are divided into three stages (Figure 6.1). In stage I, Before the design workshops, Initially, key informants (n = 3) from the Roads and Highways Department (RHD) were interviewed, and available design guidelines were searched. Finally, as part of the experiments, the researcher gathered improvised prototype designs of the research crossing sites from road agency professionals to improve safe crossing practices and increase the utilisation of crossings. In stage II, four focus group discussions (involving students and workers) were conducted and the research team just before the design workshops commenced. In the design workshops, the participants’ design team prepared low-fidelity sketch drawings for the research crossing sites in the presence of the institutional designer and research team (as facilitator). After completing all workshops, in stage III, intervention prototypes were reproduced following design sketches and incorporating participants’ recommendations for each site. This included creating before-after condition prototype drawings based on the pre-workshop and workshop-suggested prototype sketch drawings provided by institutional designers and workshop participants, respectively. Those prototypes were evaluated through stakeholders’ feedback and experts’ evaluations. The researcher and his team conducted the research activities from December 2021 to March 2022.

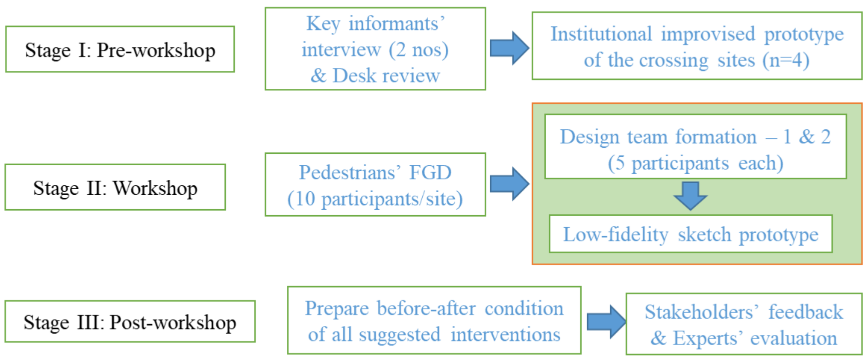


Figure 6.1 Stages of the experimental research

6.2 Experiments

6.2.1 Stage I: Pre-workshop

6.2.1.1 Desk review and key informant's interview

The RHD headquarter of Bangladesh was visited to understand the current design practice in intervention designing on the major arterial road of the country. Three key informants are identified based on their roles and organisational position in RHD who are involved in the design or making implementation decisions. As per the RHD organogram, the road safety division, headed by an executive engineer, is the key person identified for the interview with the researcher. Interviews regarding organisational design practice and the guidelines followed in designing interventions were conducted. The interview was audio recorded, and the researcher noted the key points afterwards; hearing the recording multiple times after interviewing, The necessary information about road safety regulatory bodies, strategies, and institutional road safety or design guidelines was collected. The executive and sub-divisional engineers of local road divisions also often design interventions and play a vital role in implementing them within their jurisdiction. Therefore, the Executive Engineer and Sub-Divisional Engineer of the Manikganj Road Division were also chosen as key informants for the interview. Interviews were conducted, and they were audio recorded accordingly. The key informants in this study were provided with specific instructions regarding the focus of the interview. They were asked a series of questions and engaged in discussions on various topics related to designing and developing interventions at the research sites. These topics included the process of designing interventions, prioritisation of the number of crossings and the types of crossings to be implemented, their involvement and contributions to the design of crossings at the research sites, issues related to blaming culture among road authorities and road users, data management and analysis processes, and reasons for the underutilisation of existing crossings. During these interviews, no financial constraints or limitations were imposed on the key informants. They were encouraged to provide insights and feedback freely within the scope of the discussion. This approach allowed for open and candid discussions with the key informants, facilitating a comprehensive understanding of the factors and challenges involved in developing interventions to promote road safety and improve crossing facilities.

6.2.1.2 Institutional improvised prototype

The four research sites were visited by the research team, and photographs of each crossing site were taken. Local road agency professionals were requested to redesign the available crossing facilities for enabling pedestrians to use the designated crossing facilities more effectively. The improvised prototype for the three sites (zebra crossing, underpass, and footbridge) under their road jurisdictions was designed by the office of the executive engineer of Manikganj and Narshingdi road division. Those prototype drawings, along with traffic data and available maps, were collected by the research team before the design workshop for participants (students and workers), except for site 3.

6.2.2 Stage II: Workshop

Before arranging workshops for focus group discussions and designing interventions for the research sites, the researcher visited the schools, colleges, marketplaces and garments factories near the N2 and N-540 routes to meet with the institutional representatives. With the help of those representatives, the most suitable participants were selected who cross the research route(s) regularly and could provide more information/insights for the research sites. The total number of participants was 40 (each focus group participants number was 10; from college, school, marketplace, and garments industry). Four workshops were held on different days. Three workshops were held at suitable venues fixed earlier in consultation with respective institutional representatives, and one workshop was held using an online platform.

On each workshop day, the focus group discussion was held among the participants (n=10) in the workshop's first session. A moderator role and a note-taker role were performed by the member of research team. The discussion was held on some issues with two objectives. The discussion on pedestrians' crossing behaviour around designated crossing facilities, situations to decide their willingness or intentions to use the designated crossing safely, and probable solutions. This part of the discussion aimed to prepare the participants for designing intervention at the design-workshop. Some key drivers' comments on their yielding intentions and views on pedestrians' behaviour, which had been noted earlier when a group of drivers was interviewed before the workshop day, were also shared by the research team. In the later part of the discussion, the participants' perceptions of blaming culture among pedestrians-drivers-authorities were discussed based on the summary notes on the same issue discussed earlier within three drivers' focus groups (n = 19). Drivers' feedback on blaming culture was categorised based on verbal and gestural expressions. Strong consensus or disagreement was labelled as major agreement or disagreement, respectively. Silence or uncertainty indicated general agreement or neutrality. This approach helped identify predominant attitudes and levels of consensus within the focus groups. Discussions with drivers and pedestrian focus groups aim to understand the blaming issue and supplement the stakeholders' view to conclude this study. Each focus group discussion took around 45 minutes, audio and video recorded.

In the second session of workshops, the participants were randomly divided into two design groups (Groups 1 & 2) for designing crossing sites 1, 2, and 4 based on an odd-even registration serial at the workshop venue. The design workshop's mission was briefed before starting the design procedure of interventions. In the venue, the researcher also supplied logistics such as pencil, paper, sharpener, eraser, scale, site picture, hand-sketched site condition drawing, and Google map of the crossing site. At the venue, one design team (Group 1) used a behavioural change framework-based needs identification form (Appendix M); the other (Group 2) did not. However, one workshop was held using online platforms due to governmental COVID restrictions on physical gatherings at the venue. Therefore, all participants participated in two design teams through the online platform for designing crossing site 3. The online web-based platform 'BehaveForDesign' (Appendix N) facilitates the participants in designing interventions where the researcher uploaded the behavioural change framework-based needs identification form and other site information before starting the design workshop.

Dendabor (location 1) zebra crossing site was near the school; therefore, both design team participants were students. Within the school premises, one group sat in a classroom to design the crossing site without using any behavioural model. The other group sat in a classroom with desktop computers, where the behavioural model was applied to design participants in designing crossing sites. At ‘Bipyl’ (location 2), the footbridge and underpass site were nearby the garments industries. Therefore, both design team participants were garment workers. The two-lane zebra crossing (location 3) was in front of Abdul Kader Mollah City College. Therefore, the design participants for crossing site 3 were college students. The marketplace workers participated in designing the intervention for the zebra crossing located at the Morjal marketplace area (location 4).

In the workshops, two types of experiments were done. Experiment-1 focuses on the difference between the conventional intervention design (type design/self-judgement) and participatory intervention design (users centred). Experiment-2 focuses on the difference between the participatory intervention design applying the behaviour change model form (Group-1) and the participatory intervention design without applying such behavioural model (Group-2). During all design sessions, the local road agency professional facilitated the design team by noting the participants’ design thoughts and reflecting those into the sketch drawings with their consent. The design team was facilitated in understanding the forms, and the comments and suggestions made by the design participants were noted for quick retrieval of information afterwards. At the end of each workshop, the participants took part in a workshop feedback questionnaire form on the participatory process. All design team activities were video-recorded.

6.2.3 Stage III: Post-workshop

6.2.3.1 Stakeholder identification, expert panel, and document preparation

After completing all workshops, key stakeholders and experts were identified with one key official from each of the institutions, such as RHD, Bangladesh Road Transport Authority (BRTA), Highway Police, Road Transport and Highway Division (RTHD), including drivers’ association leader, school-teacher, garments industry manager, student activist, and the leader of pedestrians welfare association. An expert panel was formed for intervention evaluation, following a few criteria (Molund and Schill, 2004), such as having evaluation expertise, subject matter expertise and local knowledge, independence and detachment, and availability or willingness to give voluntary service to this research. The panel had four members (one certified road safety auditor, one anthropologist, one Accident Research Institute (ARI) academic, and one international transportation specialist). After consultation with the research supervisors, the researcher communicated with the expert panel members to evaluate interventions.

Later, two PowerPoint presentation slides were prepared for presenting all interventions for getting stakeholders' feedback and experts' evaluations. Those presentation slides included vital research information and outlined the scope of giving feedback or evaluation. To understand the proposed interventions of the designers and workshop participants, a before–after scenario was prepared on Google Maps for each research site based on the workshop participants' chosen intervention options and designers' sketch drawings.

6.2.3.2 Interview with stakeholders and experts

All stakeholders and experts were communicated and sought an appointment for the interview. After getting an appointment, documents were supplied before the meeting to understand the interview content and questions they would be asked.

Stakeholder interviews were taken on one-to-one interview session, where the interviewee was asked to give opinions on the experiments using perception rating on each intervention. The perception rating was based on safety and practicability. In safety rating, the researcher explained the 5-point Likert scale, where 1 is the lowest, and 5 is the highest probability regarding pedestrians' safety and conflict resolution with vehicles if the suggested intervention applies to the research site. Similarly, practicability rating means value for cost and feasible to implement, where 1 is the lowest and 5 is the highest probability. At the end of the presentation, the four questions (Q1–Q4) were asked. All interview sessions were in Bengali language and audio recorded.

Q1. Do you find the participatory design involving road users effective in achieving safe infrastructure? Will you advocate participatory design within your Organisation or support the stakeholders who provide infrastructure?

Q2. Does a COM-B model help structure participants' discussion about behaviour problems and help identify appropriate behavioural change solutions?

Q3. Will this work affect you or your government's future policies?

Q4. What are your suggestions on resolving the so-called 'blaming game' among pedestrians-drivers- authorities?

In the experts' interview, the researcher interviewed four experts individually. During the one-to-one interview session, the researcher presented the presentation slide that was supplied earlier to them. The interviewee was asked to give an expert opinion on each intervention of the experiments using Nielsen's severity rating (Nielsen, 1992). Regarding the scale rating, the researcher explained the 5-point Likert scale, where 0 = No usability problem at all; 1 = cosmetic problem only; 2 = minor usability problem; 3 = major usability problem; and 4 = usability catastrophe if the suggested intervention applies to the research site. However, the researcher gave options to evaluate the interventions with any other preferred scale they prefer.

6.3 Analysis

After completing stakeholder interviews, all audio recordings were electronically transcribed in the Bengali language using an online transcription service 'Transkriptor' with a 90% accuracy rate (https://transkriptor.com/support/). Later, the recording was listened to, and the transcribed document was corrected. Finally, all verified Bengali documents were translated into English using the google doc translation service. The translated interview transcript was also rechecked for the final corrected transcription. The same procedure was followed for transcribing the focus group discussion on the role of stakeholders in addressing the blaming culture among pedestrians, drivers, and authorities.

In this study, content analysis was utilised to analyse transcripts of interviews that addressed four key questions relating to participatory design, the COM-B model, future policies, and the blaming game among road users. Similarly, the perceptions of focus group participants as pedestrians and drivers were investigated by analysing the focus group discussion summary notes on blaming culture. The aim was to ascertain the participants' perceptions and attitudes towards road safety infrastructure and shared responsibility by analysing their responses about these pre-existing concepts. Consequently, a deductive approach was used, and then the stakeholders' reactions to them were evaluated, providing valuable insights into their perspectives.

6.4 Results and discussions

6.4.1 Organisational design practice

The National Road Safety Council (NRSC) was established in 1995 and acts as an apex body for approving and driving forward the national policy and plans in Bangladesh. NRSC holds periodic meetings to provide policy-level guiding decisions and directives to road safety-related stakeholder organisations. The various stakeholder organisations implement their plan and program following the National Road Safety Action Plan with eight priority sector activities to improve road safety. Each of the stakeholders follows some guidelines and standards.

In RHD, the central road safety division is responsible for the geometric standard of the highways and designing road safety interventions. This division often gives technical advice and opinion on any complex issues related to road safety. It operates under Road Design and Safety Circle within the Technical Services Wing of RHD. The road safety division has a sub-division to communicate and verify field divisions' different road safety-related development work where the interventions are implemented on the road sites.

According to the final report of CONSIA (2013), vulnerable road users, a poor segment of the population, and children are at the most risk, including low-income workers in Bangladesh. The report acknowledged that RHD has road safety guidelines, manuals and procedure notes. However, the report found that the RHD road safety policy is unclear on how road safety issues are supported and prioritised. The interaction between stakeholders and the role of stakeholders in applying policy and guidelines in any road safety improvement scheme is often unclear. The report recommended that the government of Bangladesh and its line ministry 'RTHD' show a stronger commitment to road safety by adopting the following policy statement: *road accident fatalities and* *serious injuries are unacceptable and avoidable*, emphasising the Safe System approach.

The researcher finds information on intervention design practices from the three key informants' interviews. The executive engineer of RHD informed that footbridges, zebra crossings, and underpasses are common types of pedestrian crossings in some places. There is no signal-based crossing on the highways of Bangladesh. The road safety unit ensures that the design follows RHD design guidelines. RHD follow Road Safety Manual, Geometric Design Standard Manual, Road Safety Audit Manual, and Traffic Signs and Road Marking Manual. In RHD, consultants usually design large-scale projects, mainly recommending zebra crossing and underpass. They sometimes take road users' or the local community's opinion, but minimal information is available to the road safety unit. The field road divisions are the key unit for implementing different interventions to ease safe crossings of pedestrians. Therefore, the researcher interviewed one of the research route's field division officials (executive and sub-divisional engineers). The key information or feedback on the questions (1–6) is incorporated in Appendix O.

6.4.2 Experimental interventions

6.4.2.1 Introduction

Experimental intervention 1 showed the difference between the conventional intervention design by engineers and co-design (users-centred). Experimental intervention-2 showed how much additional improvement of interventions by behavioural model application in the co-design process.

6.4.2.2 Designing interventions of research sites 1 and 2 on N540

For research site 1, the local road agency engineers and participants identified three common interventions: widening the zebra crossing to accommodate high pedestrian flow, installing a median barrier to prevent random crossing, and placing informative traffic signs. The participants also suggested additional interventions, such as removing the height of the median to facilitate easier crossing, implementing plantations to protect shops and prevent encroachment, installing speed reducers to manage vehicle speed, incorporating flashing light signals to alert drivers, and installing CCTV cameras for monitoring purposes.

In the case of research site 2, the local engineers identified three interventions: closing the median gap to enhance pedestrian safety, relocating the median gap to a safer location, and installing traffic signs to provide information to users. The co-design participants from Group 1 and Group 2 also agreed on these interventions. Additionally, Group 1 suggested displaying billboard messages to educate about rules and fines, installing CCTV cameras for safety and monitoring, incorporating motivational messages to encourage safe behaviour, and integrating safety messages into institutional routines. Group 2 proposed interventions such as providing dustbins, improving drainage facilities to maintain cleanliness in the underpass, and improving lighting to address issues of darkness.

Figure 6.2 showcases the workshop participants' settings and designs, illustrating specific physical infrastructure components of the interventions for each site of N540. Design sketches are shown in Appendix P.

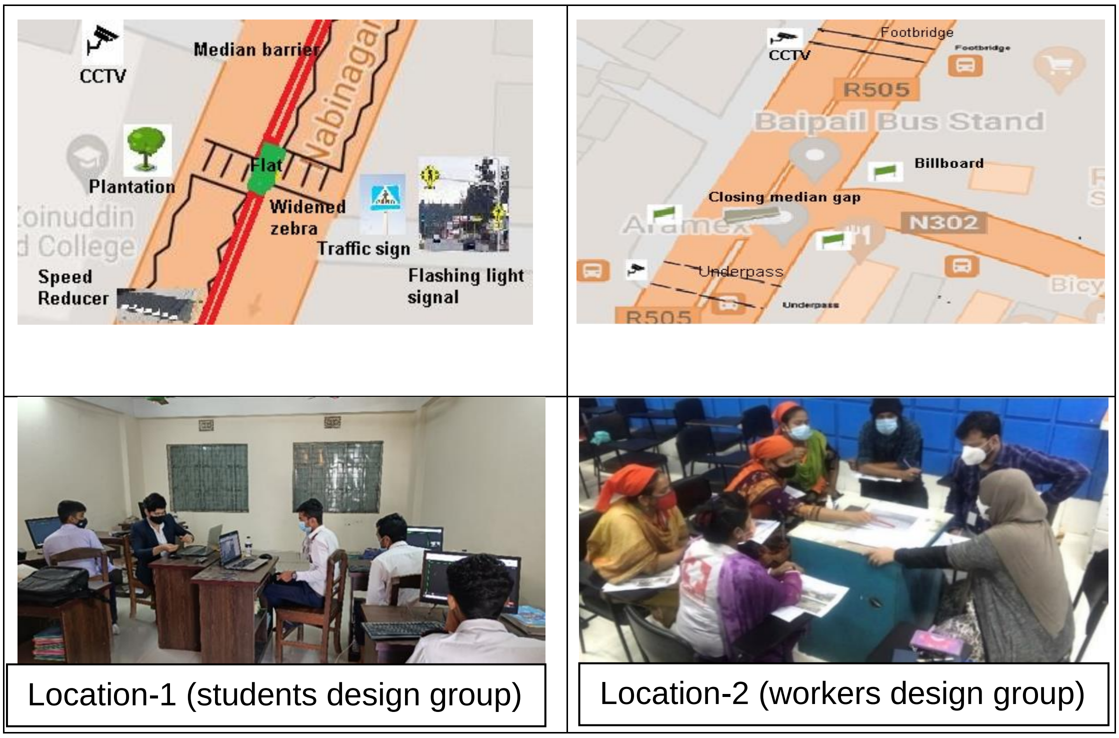


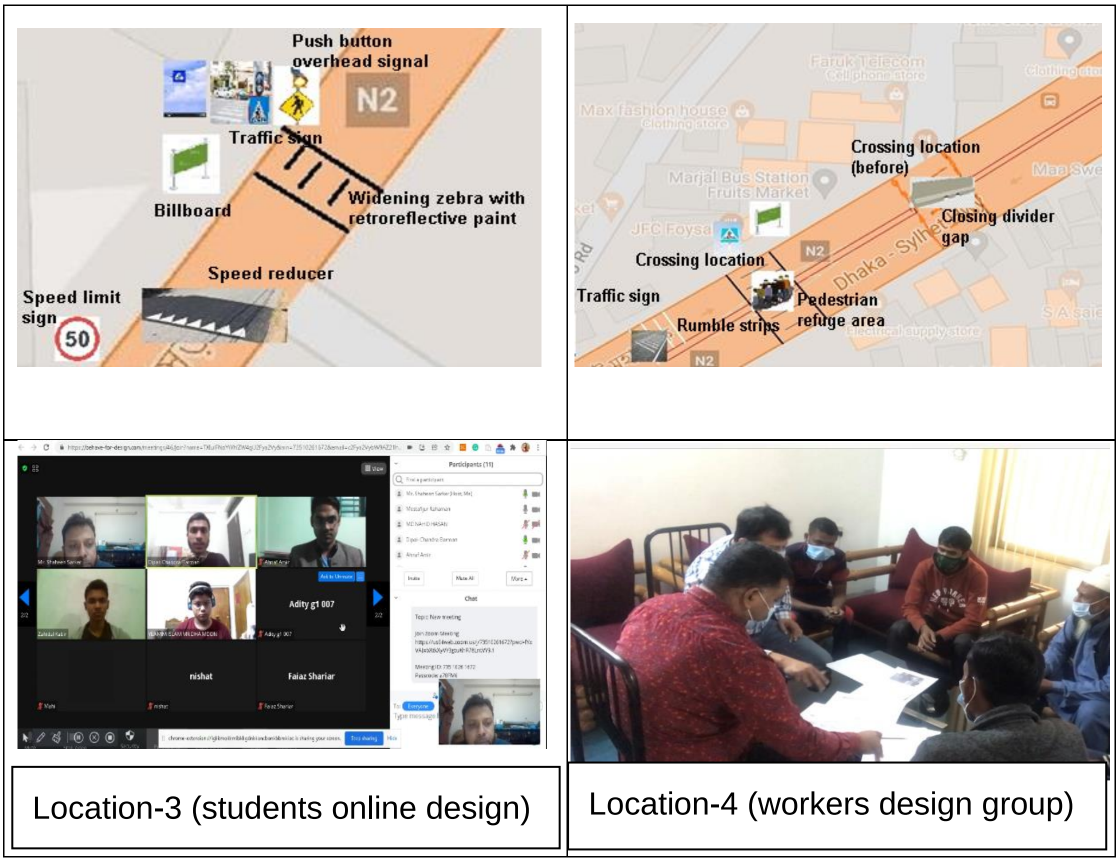
Figure 6.2 Workshop and design for site 1 (left-top) and site 2 (right-top)

6.4.2.3 Designing interventions of research sites 3 and 4 on N2

For research site 3, both Group 1 and Group 2 participants identified common interventions, which included the implementation of speed reducers to ensure safe vehicle speeds and the installation of push buttons or sensor-operated signals with overhead signs. Additionally, Group 1 participants suggested widening zebras to accommodate peak pedestrian flow, displaying billboard messages to inform about rules, fines, and attention, incorporating motivational messages, and arranging off-site education or hiring a resource person for pedestrian safety. Group 2 participants suggested the use of retro-reflective paint to enhance crossing visibility, installing overhead speed limit signs for drivers, and increasing police enforcement.

As for research site 4, the local engineers identified four interventions: closing divider gaps to protect pedestrians, relocating crossing gaps to safer locations, installing traffic signs for road users, and implementing rumble strips to enhance driver speed awareness. These interventions were also identified by Group 1 participants, who additionally suggested displaying billboard messages on rules, fines, attention, and motivation, increasing the number of pedestrian refuge areas with additional safety measures, and enhancing police enforcement. Group 2 participants concurred with the idea of increasing pedestrian refuge areas with safety measures and also included some of the interventions identified by the engineers.

Figure 6.3 showcases the workshop participants’ settings and designs, illustrating specific physical infrastructure components of the interventions for each site of N2. Design sketches are shown in Appendix P.



Location-3 (students online design)

Location-4 (workers design group)

Figure 6.3 Workshop and design for site 3 (left-top) and site 4 (right-top)

In summary, users' and engineers' interventions primarily focus on physical and environmental aspects, aiming to modify the infrastructure and traffic management as physical opportunities to enhance road safety. However, road users also suggested a few interventions targeting the change in road users' behaviour. They emphasised social and psychological aspects to persuade and educate road users for safer practices.

6.4.3 Intervention evaluation

6.4.3.1 Experts safety audit & usability testing of interventions

While interviewing experts individually, each expert evaluated the interventions of local engineers (professionals) and workshop participants, seeing the PowerPoint presentation slides on each research site (Appendix Q). A total of four experts evaluated all interventions. However, three experts assessed interventions on Nielsen's severity rating (Table 6.1), and one expert evaluated them qualitatively.

For research site 1, three experts evaluated the severity rating of interventions. The engineers' intervention received an average score of 3.0 (range 2–4), while the combined intervention received an average score of 0.66 (range 0–1). For research site 2, three experts evaluated the severity rating of interventions. The engineers' intervention received an average score of 2.66 (range 2–3), the intervention of Group 1 received an average score of 1.33 (range 1–2), and the intervention of Group 2 received an average score of 1.66 (range 0–3). Expert 4 positively commented on the co-design and behaviour change model, explicitly mentioning the effectiveness of embedding safety messages into institutional routines. For research site 3, two experts evaluated the severity rating of interventions. The intervention of Group 1 received the same rating of 1, indicating a relatively lower severity of usability problems. The intervention of Group 2 received an average score of 0.5 (range 0–1), indicating a slightly higher severity of usability problems but still relatively low. Expert 4 favoured various interventions suggested by both groups, particularly emphasising the benefits of speed-reducing measures and signals. The expert also highlighted flaws in the existing educational curriculum and praised the people-centred approach implemented by the World Bank in countries like Tanzania. For research site 4, two experts evaluated the severity rating of interventions. Both experts rated the prototypes with the same ratings. The engineers' intervention received a severity rating of 3, the intervention of Group 1 received a severity rating of 0, and the intervention of Group 2 received a severity rating of 2.

In the following Table 6.1, "E" refers to engineers' interventions, "U" refers to users' interventions combined of Group 1 and Group 2, "u1" refers to interventions of user Group 1, and "u2" refers to interventions of user Group 2. N/A denotes not applicable.

Table 6.1 Experts' evaluation of interventions

Experts	Site-1 rating		Site-2 rating			Site-3 rating		Site-4 rating		
	E	U	E	u1	u2	u1	u2	E	u1	u2
Road safety auditor	2	1	3	2	2	1	0	3	0	2
Academic	3	0	2	1	0	1	1	3	0	2
Anthropologist	4	1	3	1	3	N/A				

The interventions proposed by Group 1 exhibited fewer usability issues than those proposed by Group 2, indicating that the inclusion of the behaviour change model in the co-design process contributed to the development of more effective and user-friendly interventions. It is worth noting that both Group 1 and Group 2 interventions surpassed the interventions proposed by the engineers across all four research sites. This success of the co-design interventions highlights the significance of collaborative and participatory approaches in addressing road safety concerns.

6.4.3.2 Perception rating on interventions

In the interviews, nine stakeholders gave feedback on the interventions, seeing the PowerPoint presentation slides similar to those prepared for the experts. However, the stakeholders responded with a perception rating based on the safety and practicability of all interventions (Table 6.2). Table 6.2 displays the stakeholders' assessments, indicating each design prototype's safety rating (S) and practicability rating (P) in parentheses. The other symbols in Table 6.2 have the same meaning as in Table 6.1.

Table 6.2 Perception rating on interventions

Stake-holders	Site-1 Ratings (S, P)		Site-2 Ratings (S, P)			Site-3 Ratings (S, P)		Site-4 Ratings (S, P)		
	E	U	E	u1	u2	u1	u2	E	u1	u2
RHD	(3,3)	(4,4)	(3,3)	(4,4)	(4,4)	(3,3)	(2,2)	(3,3)	(4,4)	(2,3)
RTHD	(3,4)	(4,4)	(3,4)	(5,3)	(4,4)	(3,4)	(4,3)	(3,4)	(4,3)	(3,4)
BRTA	(2,2)	(4,4)	(1,1)	(3,3)	(2,2)	(3,3)	(3,3)	(1,1)	(3,3)	(2,2)
Police	(3,3)	(4,4)	(3,3)	(4,4)	(4,4)	(3,3)	(4,4)	(3,3)	(4,4)	(3,3)
Activist	(3,4)	(4,4)	(3,3)	(4,4)	(4,4)	(4,4)	(3,3)	(3,3)	(5,5)	(3,3)
School teacher	(3,3)	(5,3)	(2,3)	(4,3)	(3,4)	N/A				
Student leader	(2,2)	(3,3)	(2,2)	(3,3)	(3,3)	(3,3)	(2,3)	N/A		
Garments manager	(4,3)	(5,4)	(4,3)	(5,4)	(5,4)	N/A				
Drivers' leader	3, N/A	4, N/A	N/A							

(a) On safety rating-

1. For site 1, all stakeholders gave responses, where the engineers' intervention received an average score of 2.88 (range 2–4), and the combined intervention (of the behavioural model-applied and non-applied groups) received an average score of 4.11 (range 3–5).
2. For site 2, eight stakeholders gave responses, where the engineers' intervention received an average score of 2.62 (range 1–4), the intervention of behavioural model-applied groups received an average score of 4.0 (range 3–5), and the model non-applied groups received an average score of 3.63 (range 2–4).
3. For site 3, six stakeholders gave responses, where the intervention of behavioural model-applied groups received an average score of 3.17 (range 3–4), and the model non-applied groups received an average score of 3.0 (range 2–4).
4. For site 4, five stakeholders gave responses, where the engineer's intervention received an average score of 2.6 (range 1–3), the intervention of behavioural model model-applied groups received an

average score of 4.0 (range 3–5), and the model non-applied groups received an average score of 2.6 (range 2–4).

(b) On practicality rating-

1. For site 1, eight stakeholders gave responses, where the engineers' intervention received an average score of 3.0 (range 2–4), and the combined intervention received an average score of 3.75 (range 3–4).
2. For site 2, eight stakeholders gave responses, where the engineers' intervention received an average score of 2.75 (range 1–4), the intervention of behavioural model-applied groups received an average score of 4.0 (range 3–5), and the model non-applied groups received an average score of 3.63 (range 2–4).
3. For site 3, six stakeholders gave responses, where the intervention of behavioural model-applied groups received an average score of 3.33 (range 3–4), and the model non-applied groups received an average score of 3.0 (range 2–4).
4. For site 4, five stakeholders gave responses, where the engineers' intervention received an average score of 2.8 (range 1–4), the intervention of behavioural model-applied groups received an average score of 3.8 (range 3–5), and the model non-applied groups received an average score of 3.0 (range 2–4).

In summary, the interventions proposed by Group 1 received higher safety ratings than those offered by the engineers indicating that users' interventions with the behavioural model were perceived to be safer. For example, at Site 1, the combined intervention of both groups had an average safety rating of 4.11, while the engineers' intervention had an average safety rating of 2.88. Similarly, at Site 2, the behavioural model-applied intervention had an average safety rating of 4.0, while the engineers' intervention had an average safety rating of 2.62.

Conversely, the practicality ratings indicate that the combined intervention and the behavioural model-applied groups generally received higher average scores than the engineers' and model non-applied groups. However, the practicality ratings varied at different sites, highlighting the need to consider site-specific factors when evaluating the effectiveness and feasibility of interventions.

Overall, the behavioural model users positively impacted the safety ratings, but their impact on the practicality ratings was more varied.

6.4.4 Shared responsibility

6.4.4.1 Perceptions of pedestrians and drivers on blaming culture

Drivers and pedestrians provided valuable feedback on blaming culture, revealing areas of agreement and disagreement. Pedestrians showed major agreement on several issues, including the need for administrative organs to function effectively. They also observed that traffic discipline improves during traffic weeks, saying, "*When traffic week observes, then discipline increases on the road*." They also agreed that more driving training centres should be for safer roads. Pedestrians expressed major agreement regarding the absence of traffic signs, signals, and lighting in certain areas, leading to accidents, and appreciated the benefits of installing these facilities, as one participant of the student focus group stated:

> "*There was no traffic sign/signal, board, or lighting in the black spots. Nothing was given at all! Many accidents happened. You wouldn't have missed the day that the truck or bus toppled over the island …………*
>
> *At last, all things are installed, including traffic signs/signals, board, lighting, and even road marking in those spots. This has greatly benefited the people. However, what the accident happened in between- no one took responsibility for it." (Drivers focus group)*

However, drivers and students had a major disagreement regarding pedestrians' role in accidents. While pedestrians argued with the drivers' statement, "*In most cases. . . . Pedestrians don't find their fault*," students and workers pointed out that drivers are often responsible for accidents and stressed the need for increased awareness and understanding among all road users:

> *"In some cases true, but drivers are also responsible in other cases. All need to be more aware and understand the vehicle speed, attitude, need to read the mind of each other." (Pedestrians focus group)*

Additionally, pedestrians firmly agreed with the drivers' views that the crash investigation system of foreign countries greatly differs from Bangladesh, suggesting consideration should be given to everyone involved, not just the vehicles, emphasising the need for a comprehensive approach to accidents:

> *"Foreign (traffic) system is different! In any accident. . . . In our country,…. the public doesn't see it." (Drivers focus group)*

Pedestrians and drivers stressed the importance of enforcing existing laws equally for all citizens. Students and workers pointed out issues of partial implementation for the poor and rich, stating, *"Rules for poor but not for rich, that is a problem.*" One notable quote from pedestrians stressed the responsibility of drivers, which sparked a disagreement between students and workers. While pedestrians argued that drivers are often at fault, students and workers acknowledged that both parties must be more aware, understand each other's actions, and consider vehicle speed and attitude to avoid accidents. In another quote, "*I should rectify it first. If I'm not right, none can fix it. I have to be right.*" a driver expressed the need for self-correction, emphasising the importance of being a responsible driver:

> *In most cases, drivers are responsible… ….... All need to be more aware and understand the vehicle speed, and need to read the mind of each other. (Students focus group)*

In summary, the feedback from drivers and pedestrians, sheds light on a blaming culture in traffic injury and casualties. While there are areas of agreement, such as the need for effective administrative organs, improved traffic discipline during traffic weeks, and installing traffic signs and facilities in accident-prone areas, there are also significant disagreements. Pedestrians and drivers differ in their views on pedestrian fault in accidents, with students and workers emphasising the need for increased awareness and understanding among all road users. Moreover, the foreign traffic system and the need for a comprehensive approach to accidents are subjects of agreement between drivers and pedestrians. However, issues regarding enforcing existing laws equally for all citizens and the responsibility of drivers sparked further disagreements between participants. Despite these disagreements, the feedback highlights the importance of promoting a culture of accountability and awareness among all road users to enhance road safety and reduce traffic injuries and casualties.

6.4.4.2 Collaborative approaches for promoting road safety

The stakeholders agreed that participatory design is a practical approach to achieving safe infrastructure. Specifically, the RHD representative appreciated the participatory process for taking users' opinions in the infrastructure design and implementation:

> *In order to take into account users' comfort and viewpoint, I would appreciate the participatory approach. (RHD)*

During the interviews with RHD designers, it was discovered that they adhere to the Road Sign and Geometric Design Manual of RHD, typically utilising a standard type-design crossing, as illustrated in Figure 6.4.

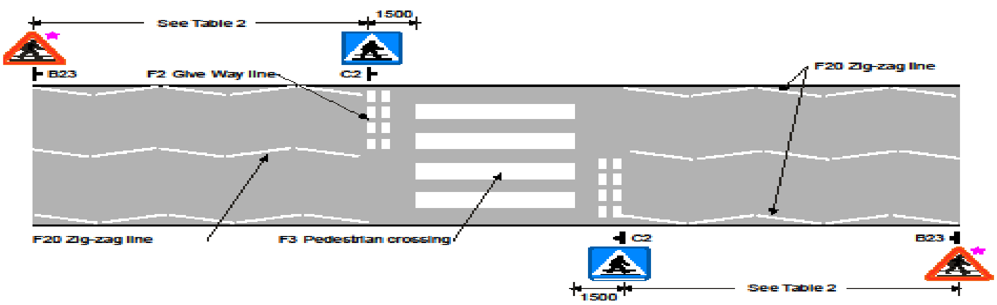


Figure 6.4 General roadside sign, marking and zebra crossing

Participatory design holds great value in empowering victims to enhance their security, as stated by the Police representative. By actively involving victims in the design process, they can gain a deeper understanding of how to improve their safety:

Participatory design is useful in enabling victims to comprehend how to enhance their security. (Police)

The activist emphasised the significance of including users' perspectives in project development, highlighting the consequences of neglecting user views. By incorporating user feedback and involving them in the design process, projects can be tailored to meet users' needs, ensuring that the resulting amenities are functional and cater to users' preferences and requirements. Such an approach could have a positive impact on the users using designated crossings:

Frequently, our projects are developed and executed without considering the views of users, resulting in inadequate amenities that are unacceptable to them. As a consequence, users are unable to utilise the facilities following project implementation, leading to the emergence of various issues. (Activist)

Getting feedback from the users is always good. (Student leader)

If this (crossing design) is done through participation, more users will use it. (Garments manager)

The stakeholders recognised the potential usefulness of the behavioural model in facilitating their discussions about behaviour problems and finding appropriate solutions for behavioural change. They acknowledged that the model could serve as an eye-opener, allowing them to estimate the potential consequences of their actions and understand the limitations of their capabilities. This understanding would enable them to customize their intentions or behaviour where needed.

The COM-B model can serve as an eye-opener, allowing stakeholders to estimate the potential consequences of their actions and understand the limitations of their capabilities. When engaged in the participatory process, stakeholders also become aware of the engineers' limitations, enabling them to customize their intentions or behaviour without sacrificing their objectives. Therefore, incorporating the COM-B model can help. (RHD)

The RTHD representative believed the COM-B model could help participants perceive their flaws and understand where to change. The Police representative suggested utilising checklists based on the model's three components - Capability, Opportunity, and Motivation - would be helpful. These checklists would allow participants to identify missed points during the participatory process and ensure synchronization. The stakeholders, not experts, could provide valuable feedback when identifying missed issues, enhancing the model's effectiveness. The school teacher believed that a behavioural model would make identifying problems among the participants easier. By using the model as a framework, the teacher could pinpoint specific areas of concern and address them effectively during the participatory discussions:

> *Following the model, participants can identify their flaws and understand their behavioural issues. This understanding enables them to determine what changes they need to make, making the model valuable in achieving positive outcomes. (RTHD)*
>
> *I think it will help if we use checklists based on the model's three components: Capability, Opportunity, and Motivation. By checking if they have missed any points during the participatory process, participants can benefit from the synchronization and identify any missed points. Since they are not experts, they can provide positive or negative feedback when identifying missed points. (Police)*
>
> *If we use this model, it will be easier to identify problems among the participants. (School teacher)*

During the discussions, stakeholders recognised the potential impact of the participatory design process and the use of the COM-B model on future policies. They agreed that involving road users in the design process would bring forth hidden issues that might not be apparent otherwise. This inclusive approach ensures that users' needs and perspectives are considered, benefiting both the users and policymakers. The RTHD representative emphasised the importance of incorporating user input into policy formulation to create effective policies that address the actual needs and concerns of road users:

> *When policies are formulated, many issues often remain hidden and do not surface. By involving users in the process, we can ensure that their needs and perspectives are considered, which can benefit both the users and policymakers. (RTHD)*

The stakeholders recognised the importance of effectively disseminating the utilities of co-design to maximize its impact. They emphasised the need for the findings and insights to be shared in a forum that is accessible to policy designers and decision-makers. The BRTA representative expressed confidence that if the information is presented and discussed on such a platform, it will have a meaningful influence on future policies and initiatives. By reaching the right audience, the work can contribute to shaping the direction and implementation of policies that address the needs and concerns of road users effectively:

> *Definitely, it will have an impact if it is disseminated in an appropriate forum for those who design or are policymakers. (BRTA)*

Stakeholders recognised the need to address the blaming culture among pedestrians, drivers, and authorities. They believed involving all stakeholders in the design process would reduce the blaming game. By including all relevant parties, everyone would gain a better understanding of each other's limitations and perspectives, leading to a decrease in blame:

> *If we involve the users in the design process, they will have no reason to blame anyone. They will not be able to say that they do not understand the policy or why certain decisions were made. They will be more likely to accept and follow the design willingly. (RTHD)*
>
> *If we design involving all stakeholders, the blaming game will also decrease----------Because everyone will understand the limitations of everyone. (Police)*

The stakeholders also suggested various approaches to address the blaming game. They emphasised the importance of discussing government policy decisions involving the media to find ways to move beyond the culture of blame.

The RHD representative believed that following The Safe System approach could eliminate the blaming game naturally:

> *An opportunity to discuss the government policy decisions involving the media could find a way to get out of the culture of blaming each other. (Activist)*
>
> *If we could follow The Safe System approach, this blame game would be eliminated naturally. (RHD)*

Additionally, the student leader highlighted the significance of training drivers and reducing their working hours to mitigate blaming. The garments manager emphasised the importance of planning and following a participatory process to reduce blaming. Lastly, the drivers' leader stressed the need to refrain from blaming until the true culprit is determined, whether it be the authority, driver, pedestrian, or any other government agency:

> *There is the matter of giving training to the drivers. Our country does not do that. Drivers' labour hours also need to be reduced. There is no such initiative in our country. (Student leader)*
>
> *If anything is done by planning and following a participatory process, then it will reduce the blaming. (Garments manager)*
>
> *It is not right to blame someone until it is determined who is the real culprit. Whether it is the authority, be it the driver, the pedestrian, the BRTA or any other government agency. (Drivers leader)*

In summary, the participatory design emerges as a powerful tool for promoting road safety, as highlighted by stakeholders during interviews. The consensus among the stakeholders reveals that the adoption of a participatory approach fosters a shared responsibility in achieving safe infrastructure. By actively involving road users in the design and implementation process, their opinions, comfort, and viewpoints are considered, empowering them to play a vital role in enhancing their own security. Stakeholders recognise that neglecting user views in project development can lead to inadequate amenities that fail to cater to users' needs, resulting in road safety issues. In contrast, involving users in the design process ensures that road safety measures are functional and tailored to users' preferences, promoting the effective utilization of designated crossings. Through participatory design, stakeholders collectively embrace the shared responsibility of fostering a safer road environment by actively engaging all relevant parties in the decision-making process.

Secondly, utilising the COM-B model helps structure discussions around behaviour problems and facilitates the identification of appropriate behavioural change solutions. This model promotes self-awareness and personal responsibility as participants recognise their limitations and make customized behavioural adjustments. Through this process, shared responsibility for individual actions and changes emerges, contributing to collective responsibility for the overall outcomes.

Thirdly, involving all stakeholders in the design process reduces the culture of blaming. When each stakeholder is included, they better understand the challenges and limitations others face. This shared understanding fosters empathy and cooperation, leading to collective responsibility for the success of the infrastructure. Blaming is minimised as stakeholders work together towards common goals.

Lastly, involving all stakeholders in the design process informs future policies, instilling a sense of shared responsibility for creating compelling and impactful policies. When stakeholders are actively involved in policy-making, they feel accountable for the policies' outcomes and take ownership of their implementation. This shared responsibility ensures policies are more comprehensive and reflect all stakeholders' diverse perspectives and needs.

6.5 Implications for practice and policy

The results of this study hold significance for the implementation of road safety measures and policies. The interventions developed through co-design and the behavioural model were found to be more usable than those produced by engineers. The engineers and users both perceived the utility of physical restructuring of the research sites. The users' interventions address various components of the COM-B model by suggesting various reflective and automatic motivation-targeted interventions by enhancing physical capability, psychological capability, and social opportunity. Combining these intervention types can improve road safety through comprehensive measures targeting different aspects of road user behaviour and infrastructure. Policymakers and road safety practitioners should consider adopting a co-design approach that engages pedestrians, drivers, and other vulnerable road users. This inclusive process can lead to the creation of safer road infrastructure and the promotion of sustainable behaviours.

Pedestrians' and drivers' view on resolving blaming others in traffic injuries has few implications for practice and policy:

1. *Enforcement of existing laws equally for all citizens:* It is essential to ensure everyone is held accountable for their actions, regardless of their social status or economic background.
2. *Raising awareness of road rules and safety among all road users:* Raising awareness of road rules and safety among all road users can be improved by making the information more accessible and tailored to the audience.
3. *Ensuring that administrative organs function effectively:* This includes providing enough traffic police officers on the roads, appropriately trained, and the resources they need to do their job effectively.
4. *Installing traffic signs, signals, and lighting in dark areas:* Installing traffic signs, signals, and lighting in poorly lit areas can reduce accidents. It makes it easier for drivers and pedestrians to see each other and know what to do in certain situations.
5. *Providing more driving training centres:* This can help improve drivers' skills and make them more aware of the risks associated with driving.

Furthermore, the stakeholder interviews revealed the value of the COM-B model in structuring discussions and identifying appropriate behavioural change solutions. It is important for policymakers and authorities to acknowledge the advantages of including this model in their decision-making procedures. It can help address behaviour problems and promote responsible road behaviour among all stakeholders. By understanding the limitations and challenges each group faces, shared responsibility for road safety can be fostered, leading to better outcomes.

To address the implications of this research, several policy steps are recommended. First, sharing the study’s findings with policymakers, road safety committees, and relevant government agencies is crucial. This knowledge can inform policy discussions and initiatives to reduce the blaming culture and promote stakeholder collaboration. Second, investing in comprehensive driver training programs that prioritise safe driving practices and raise awareness of vulnerable road users is essential. This can be achieved through collaborations with educational institutions to improve the road safety curriculum. Lastly, active engagement with the media is vital to ensure responsible reporting on road safety issues. Press conferences, media campaigns, and interviews can facilitate open discussions and promote transparent information sharing.

It is essential to use the Safe System approach to minimise the risk of severe injury or death for all road users, especially vulnerable ones, to ensure their safety. The Safe System approach emphasises a holistic and multidisciplinary approach, considering various factors such as road design, speed management, vehicle technology, and user behaviour. By combining the Safe System approach principles with participatory design and behaviour change models, policymakers can enhance the safety of vulnerable road users and create an inclusive road environment that promotes shared responsibility. Through the collective efforts of all stakeholders, sharing knowledge and insights, and promoting responsible behaviour, it is possible to create a safer road environment while reducing the blaming culture and protecting the well-being of all road users, particularly the most vulnerable.

Chapter 7
Discussions

The Discussions chapter presents a concise summary of the key findings from three studies. Study 1 focused on predicting safe crossing behaviour, revealing influential factors for designing targeted interventions. Study 2 explored pedestrian-driver interactions, identifying areas for improving pedestrian safety. Study 3 demonstrated the effectiveness of participatory design in enhancing road safety and fostering shared responsibility among road users. The chapter interprets the results in the context of the study objectives, highlighting the insights gained from the associated study(ies). Additionally, it acknowledges the research's limitations and suggests future directions for further advancements in road safety studies. Overall, the chapter provides valuable insights that can contribute to creating safer road environments for all stakeholders.

7.1 Summary of study findings

7.1.1 Predicting safe crossing behaviour (Study 1)

Development of a conceptual model: The study developed a conceptual model to understand the interplay between capability, opportunity, and motivation in predicting safe crossing behaviour. The model explains 42% of the variance in safe crossing use and 34.5% in motivation. Opportunity was the most influential factor, followed by motivation and capability. Capability indirectly influenced safe crossing behaviour through motivation, while opportunity directly and indirectly affected behaviour. Demographic factors such as gender, profession, and age significantly impacted safe crossing behaviour. The prediction model results indicate: (i) Opportunity's contribution to safe crossing use is the highest compared with other (Capability and Motivation); (ii) Motivation is the key mediator for Capability and Opportunity in predicting safe crossing use; (iii) Physical opportunity influences the safe crossing use partially through automatic motivation; and (iv) Social opportunity significantly influences pedestrians' physical and psychological capabilities, where psychological capability influences the target behaviour fully through reflective motivation.

Importance of physical and social opportunities:

The study found that physical opportunity is crucial in promoting safe crossing behaviour. Factors such as visibility of drivers, short crossing time, easy access, usability in all weather conditions, presence of traffic signs and road markings, availability of waiting areas, pedestrian fences, and convenient location are important physical opportunities that influence safe crossing use. Other factors, such as speed reducers before crossings and measures against traffic law violators were also correlated with avoiding violations and lapses. Physical opportunity influences safe crossing use through automatic motivation factors such as habit, guilty or good feelings, and consideration of benefits of avoiding risky crossings; have vital contribution against violations and aggression.

Interestingly, the study observed that students are more motivated to use crossing facilities than workers and older individuals. This could be attributed to students having more flexible schedules and fewer time constraints, allowing them to prioritise safety over convenience. They may also have a higher awareness of the importance of following traffic rules and guidelines and greater exposure to safety awareness campaigns and educational programs related to road safety.

Social opportunity also plays a significant role in promoting safe crossing behaviour. Factors such as the presence and influence of influential people, education and support from family/institutions, parental safety alert reminders, many users in crossing or group crossings, and many known users using the crossing are key social opportunities contributing to safe crossing use. Social opportunity influences pedestrians' physical and psychological capabilities and also affects safe crossing use through physical capability. Thus, there is a significant contribution of social opportunity in avoiding aggressions and lapses.

Capability and motivational factors:

Physical capability directly affects target behaviours, with the ability to walk and strength being the most influential physical capability factors in safe crossing use. Psychological capability influences target behaviour through reflective motivation factors such as satisfaction with crossing use, safety priority over convenience, consideration of the benefit of avoiding risky crossings, and planning for improving behaviour. Psychological capability is crucial in avoiding lapses. Factors such as mood control in assertive crossing, attention or thinking before crossing, knowledge of traffic rules, and the provision of fines for violations are key psychological capability factors that influence safe crossing use. Among them, paying attention or thinking before crossing has the most significant role in avoiding violations and lapses.

Motivation factors, including safety priority, habit formation, guilt or good feelings, and consideration of benefits of avoiding risky crossings play significant roles in various components of safe crossing behaviour (i,e., avoiding violations in using crossings and lapses). Satisfaction with crossing use, thinking about the benefits of avoiding risky crossings, and habit formation were identified as the most significant factors in violations, aggressions, and lapses, respectively. Motivation factors are summarised in Table 7.1, which is supported by existing literature on pedestrian safety, as mentioned in Chapter 2.

Table 7.1 Motivation factors and their significance

Motivation factors	**Significant components** (*most significant component)
Planning	Violations and lapses
Safety priority over convenience	All
Feelings in crossing use	All
Satisfaction with crossing use	Violations* and lapses
Habit	All (lapses*)
Consideration of benefits of avoiding risks	All (aggression*)

Gender differences in motivation for safe crossing behaviour:

The study revealed that motivation significantly influenced males more than females. Research suggests that women have lower probabilities of choosing footbridges and underpasses compared to men (Anciaes and Jones, 2018). This could be attributed to men having a higher habit of crossing the street safely, potentially due to greater exposure to traffic and early instruction on safe crossing practices. Studies have found that boys demonstrate higher confidence in crossing situations and are more willing to travel actively to and from school (Larsen et al., 2009; Meir et al., 2023). However, it is essential to note that women may also have additional concerns, such as personal safety fears, especially in dark or poorly lit footbridges and underpasses, or if they carry additional baggage such as children or shopping. These concerns may demotivate them in using such crossing facilities.

Studies have found that men prioritise safety over convenience when crossing the street, while women may prioritise reaching their destination quickly (Yagil, 2000; Havard and Willis, 2012). Moreover, it has been observed that pedestrians motivated by instrumental considerations, such as reaching their destination quickly, are more likely to engage in unsafe crossing behaviour. Instrumental motives predict women's unsafe crossing behaviour, whereas men are more inclined to engage in proactive planning and consider safety measures before crossing (Yagil, 2000). Regarding persuasive appeals, positive emotional appeals may be more effective for men, while fear appeals may be more effective for women (Wundersitz et al., 2010).

7.1.2 Understanding pedestrian-driver interactions (Study 2)

Perception differences between drivers and pedestrians:

This study examined the contrasting perceptions of pedestrian behaviours between pedestrians and drivers. Key findings revealed significant differences in their perceptions regarding pedestrian violations and lapses. However, no significant difference was observed concerning pedestrian aggression towards drivers. The study also compared drivers' self-reported yielding behaviour with pedestrians' perceptions, highlighting differences in yielding practices. Additionally, the research explored the gestures and actions employed by pedestrians and drivers during interactions and uncovers perception discrepancies between the two groups.

The focus group discussions revealed several agreements and disagreements between pedestrians and drivers regarding pedestrian behaviour and drivers' yielding practices. While participants agreed on pedestrian behaviour, the consensus on drivers' yielding behaviour was minimal. These differences in perception were influenced by varying views and attitudes, particularly noticeable between workers and students.

Workers agreed with drivers' observations that yielding occurs when pedestrians raise a hand from a reasonable distance, when vulnerable groups are waiting to cross, or when pedestrians cross in areas without designated crossings. On the other hand, students acknowledged their lapses, such as engaging in conversations and occasionally looking back while crossing. Workers also emphasised the lack of knowledge among pedestrians in using footbridges properly, resulting in violations like diagonal road crossings. Additionally, workers agreed with drivers' perspectives on aggressive behaviour displayed by some marketplace workers.

Yield model and importance of opportunity factors: The yield model developed in the study explains 37.6% of the variance in drivers' yield and 15.7% of the variance in their motivation. A negative correlation was established between the frequency of drivers' yielding and the frequency of near-accident situations reported by drivers. Physical opportunities significantly predicted drivers' motivation and yielding, while social opportunities significantly contributed to drivers' motivation. The study also found that motivation significantly influenced drivers' yielding to pedestrians, with a lesser effect observed among bus drivers than light vehicle drivers. However, drivers' physical and psychological capabilities did not significantly impact their motivation and yielding.

Factors influencing drivers' yielding behaviour: The study identified several pedestrians' attributes and behavioural characteristics significantly influencing drivers' yielding behaviour. Pedestrian factors that motivated drivers to yield to pedestrians included avoiding random crossings, displaying vulnerability, showing fearful expressions to drivers, and exhibiting convincing assertive crossing. Environmental factors, including traffic signs, road markings, enforcement, pedestrian fences, and visibility, also played significant roles in drivers' yielding behaviour. Social factors, such as group crossings, had a significant impact on drivers' yielding behaviour. Social factors, such as group crossings, had a significant impact on drivers' yielding behaviour. This was especially true at times when these groups naturally formed, such as during school or work hours. However, the more pedestrians who crossed the road individually, without forming a group, the less likely drivers were to yield to them.

Barriers and facilitators in drivers' yielding to pedestrians:

The thematic coding structure of the conceptual framework identified key barriers to drivers' yielding to pedestrians, including pedestrians' crossing behaviour, risk of vehicle damage or pedestrian injuries, lack of crossing facilities, inadequate visibility of road signs and markings, and absence of protection measures. If pedestrians are seen breaking crossing rules, avoiding designated crossings, or being distracted, drivers may be less likely to yield to them. Moreover, the risk of vehicle damage or pedestrian injuries, especially when pedestrians suddenly run into traffic without allowing enough time for drivers to brake or when drivers feel that stopping a vehicle in such a situation can injure a passenger influence drivers' decision. Drivers' hurries and the unpredictable crossing actions or moves of pedestrians can further deteriorate the situation. Finally, drivers are less likely to yield if they are unaware of crossing points, if there are poor crossing facilities or maintenance, if no protection measures (e.g., fencing or enforcement) are available to prevent random crossings, and if road signs and markings are not clear or visible.

Conversely, facilitators such as pedestrians' fear expression of injury and communication with drivers, drivers' emotions and decision-making, social influences, and environmental restructuring motivate drivers for their yielding to pedestrians. Drivers tend to yield more often when they perceive that pedestrians are afraid of being hit by their vehicles. Moreover, if drivers feel empathy towards pedestrians or have a sense of responsibility to safeguard vulnerable groups, they are also more inclined to yield. Their judgment and understanding of the situation can also influence their behaviour. Having enough time to make a decision and being in an environment that makes it easy to yield are also factors that can increase the likelihood of drivers yielding. Finally, if drivers are aware of specific times when pedestrian groups cross, this can also impact their decision to yield.

Barriers and facilitators in pedestrians' safe crossing use:

Thematic analysis revealed that key barriers to safe crossing include demographic factors, pedestrians' behaviour and knowledge, environmental and social barriers, and drivers' behaviour. Demographic characteristics, such as the age and gender of pedestrians, can influence their safe use of crossings.

Pedestrians unaware of traffic rules and crossing skills, avoiding footbridges in hurries or preferring convenience over safety, and their distracted mind may be more likely to cross at unsafe locations. Crossing the road can pose significant risks to pedestrians, especially when environmental or infrastructural barriers such as low visibility, less security for women in the evening, occupying grade-separated crossing by drug-addicted people, or the lack of designated crossings are present. Peer pressure or the fear of being judged by others, a social barrier, can discourage pedestrians from using designated crossings. Drivers who do not follow crossing regulations or refuse to yield to pedestrians put pedestrian safety at risk.

Conversely, facilitators such as feeling safe and confident while crossing, communication and decision-making through gestures and eye contact, environmental restructuring, social influences, enforcement for the safety of vulnerable road users, and perceptions of their ability and control are important factors in promoting safe crossing behaviour. Pedestrians have a higher chance of crossing safely if they feel secure and self-assured, communicate efficiently with drivers, use designated crosswalks that have good visibility, see police officers in the vicinity, and have acquaintances, relatives, or colleagues who utilise crosswalks.

7.1.3 Enhancing road safety through participatory design (Study 3)

Users' interventions in co-design: The interventions proposed by the users across the four research sites encompass various strategies, encompassing physical, social, psychological, automatic, and reflective motivation interventions to enhance road safety. Physical opportunities interventions focus on altering the physical environment to facilitate safer pedestrian crossing, including widening zebra crossings, installing median barriers, and implementing speed reducers. Social opportunities interventions seek to create a supportive social environment for safe pedestrian crossing, involving the display of billboard messages, installation of CCTV cameras, and integration of safety messages into institutional routines. Physical capability interventions aim to enhance pedestrians' physical abilities for safer road crossing, such as providing dustbins, improving drainage facilities, and enhancing lighting. Psychological capability interventions address pedestrians' psychological readiness for safe crossing by displaying motivational messages, arranging off-site education, and engaging a resource person for pedestrian safety.

Evaluation and feedback on interventions: Experts evaluated interventions by local engineers and workshop participants at four sites. The evaluation results indicated that co-design interventions generally had fewer usability problems than those designed solely by engineers. Stakeholders also provided feedback on the safety and practicability of interventions at each site, where the interventions of behavioural model users were perceived as safer compared to the engineers' interventions. The practicality ratings showed mixed results, with some interventions by behavioural model users receiving slightly higher scores than the engineers' interventions. The stakeholders emphasised shared responsibility for improving the road safety situation and institutional design practices.

Perspectives of road users on traffic accidents and blaming culture: The road users' statements and quotes of drivers and pedestrians reveal a blaming culture integrated with traffic accidents in Bangladesh. Both drivers and pedestrians believe that the other party is often to blame for accidents. The culture of blaming others can hinder efforts to enhance road safety. This behaviour can discourage individuals from owning up to their actions and taking responsibility. Both groups agree on the importance of effective administrative organs, improved traffic discipline during traffic weeks, and installing traffic signs and facilities in accident-prone areas. However, a major disagreement arises between drivers and students regarding pedestrian fault in accidents, with students and workers emphasising the need for increased awareness and understanding among all road users. They all emphases on developing the system for the proper accident investigation following the developed countries.

Promoting safer Infrastructure through participatory design: Stakeholders evaluating interventions at different sites unanimously recognised the practicality and effectiveness of participatory design in achieving safer infrastructure. The active engagement of road users, including pedestrians and drivers, in the design process fostered a sense of shared responsibility and ensured that diverse perspectives were considered. Participatory design is highly regarded for its capacity to offer stakeholders meaningful insights into the requirements and perspectives of users, which ultimately help to develop solutions that are both safer and more user-friendly. Moreover, incorporating the COM-B model during discussions offered a structured framework to identify behaviour-related issues and tailor appropriate behavioural change solutions. Stakeholders found the model instrumental in helping participants understand the consequences of their actions and recognise their limitations, thus contributing significantly to positive outcomes.

Influencing future policies and decision-making: Influencing future policies, stakeholders recognised the profound impact of participatory design and the COM-B model on informing and shaping future policies. Including road users in the design process brought hidden issues to light, ensuring that users' actual needs and concerns were considered in policymaking. To maximise the impact of participatory design, stakeholders emphasised disseminating findings and insights in forums accessible to policy designers and decision-makers. By reaching the right audience, the participatory approach in intervention designing could significantly influence the development and implementation of policies that prioritise road safety and meet the needs of all stakeholders. Incorporating user perspectives in policymaking can lead to better-informed decisions, greater user satisfaction, and improved road safety. The involvement of road users in shaping policies fosters a sense of ownership and shared responsibility, creating a culture of collaboration and cooperation between all stakeholders.

Resolving the blaming culture through collaboration: One of the critical aspects discussed by stakeholders was the need to address the culture of blaming among pedestrians, drivers, and authorities. They highlighted the transformative power of involving all stakeholders in the design process, leading to a reduction in the blaming game. This approach encouraged mutual understanding of different parties' limitations, perspectives, and challenges. Additionally, stakeholders suggested various strategies to mitigate blaming, such as discussing government policy decisions involving the media to find ways to move beyond the blame culture. The Safe System approach was also seen as a natural solution to eliminate blaming, fostering a collaborative environment focused on improving road safety. Training drivers, reducing working hours, and adhering to participatory processes were emphasised as additional measures to promote a collaborative and responsible road safety ecosystem.

7.2 Study objectives and interpretation of results

7.2.1 Objective 1 (achieved by Studies 1, 2, and 3)

Objective 1: *To identify factors that motivate pedestrians to use a designated crossing.*

Correlation between near-accident situations and the behavioural items: Study 1 found a significant correlation between near-accident situations and behavioural items: violations, aggressions, and lapses. Based on the results, it is recommended that efforts to enhance pedestrian safety should target all three of these elements. The conceptual model for predicting the target behaviour (safe crossing use) indicated that motivation, as a significant predictor and the key mediator, is vital in avoiding violations, aggressions, and lapses, suggesting that the motivation factors have a specific role in addressing pedestrians' behaviour.

Motivation factors Influencing safe crossing behaviour:

Study 1 found that six motivation factors significantly impact addressing risky pedestrian behaviour. The study also found that men are more motivated to use crossing facilities than women.

a) *Planning for improving behaviour:* Pedestrians who intend to enhance their crossing behaviour are more likely to avoid violations and lapses, emphasising the role of proactive planning in promoting safe crossing practices.
b) *Safety priority over convenience:* Prioritising safety over convenience is essential in avoiding risky behaviour, regardless of the specific behavioural component, underlining the significance of safety-oriented decision-making.
c) *Feelings in crossing use:* Pedestrians who feel good about avoiding risky behaviour are more likely to continue doing so in the future, suggesting the importance of emotional aspects in influencing safe crossing practices.

d) *Satisfaction with crossing use:* High satisfaction with the crossing experience significantly contributes to avoiding risky behaviour, particularly in violations and lapses, indicating the relevance of positive experiences in promoting safe crossings.
e) *Habit:* The habitual nature of crossing safely significantly influences all behavioural components, particularly lapses, underscoring the need to develop safe crossing habits to reduce risky behaviours.
f) *Consideration of benefits of avoiding risky crossings:* Pedestrians who think about the benefits of avoiding risky behaviour are more likely to engage in safe crossings, especially in preventing aggressive behaviours, suggesting the role of cognitive processes in influencing safe behaviour.

Opportunity and capability factors mediating motivation:

Study 1 highlights the interdependence of motivation factors with opportunity and capability factors, emphasising the importance of physical and social opportunities in promoting safe crossing behaviour.

a) *Opportunity factors:* Key physical opportunities, such as visibility of drivers, short crossing time, easy access and usability in all weather conditions, traffic signs and road markings, pedestrian refuge or waiting areas, pedestrian fences, convenient location, speed reducers before crossings, and measures against traffic law violators are also found to have major contribution in avoiding violations in using crossings. Influential social factors, including the presence and influence of others, support from family/institutions, parental safety reminders, group crossings, and known users, play a crucial role in avoiding aggressions and lapses. The role of physical opportunities in building the motivation of students is remarkable. The role of social opportunity is vital in influencing pedestrians' physical and psychological capabilities.
b) *Capability factors:* The psychological capability influences the target behaviour through motivation predominantly compared to the physical capability. Psychological capability is crucial in preventing lapses and promoting safe crossing behaviour. The study identified specific psychological capability factors, including mood control in assertive

crossing, paying attention before crossing, knowledge of traffic rules, and awareness of fines for violations.

Acknowledging the impact of demographic factors: Study 2 acknowledges the influence of demographic factors such as age and profession on pedestrians' crossing behaviour, complementing the findings of Study 1 and providing insights into how specific groups may differ in their motivations for using designated crossings.

Theoretical Domains of TDF and intervention functions in motivation:

Study 2 used Theoretical Domains Framework (TDF) in a conceptual thematic coding framework for analysing qualitative findings from the focus group discussions, thereby providing valuable supplementary information that enhances and expands upon the findings of Study 1 regarding factors influencing safe pedestrian crossing behaviour. The two studies (1 & 2) together contribute to a more comprehensive understanding of motivation factors.

According to Michie et al. (2014), several intervention functions are aligned in motivation corresponding to different components of the Theoretical Domains Framework (TDF). These intervention functions aim to target specific aspects of motivation and facilitate behaviour change by aligning with different domains of the TDF.

In the context of automatic motivation, intervention functions such as training and environmental restructuring align with the reinforcement component of the TDF. Additionally, persuasion, modelling or role model, and enablement interventions are associated with the TDF component of emotion. It is worth noting that incentivisation and coercion can be applied as intervention functions for the reinforcement and emotion categories.

Regarding reflective motivation, intervention functions such as education, persuasion, and modelling are relevant across various TDF domains of professional/social role and identity, beliefs about capabilities, optimism, consequences, intentions, and goals. Moreover, enablement interventions apply to beliefs about capabilities, optimism, and goals, while incentivization and coercion interventions can be utilised for intentions and goals.

Automatic motivation factors and intervention functions:

In study 1, habit and feelings in crossing use emerged as the most influential automatic motivational factors. The qualitative analysis of Study 2 identified TDF domains such as reinforcement and emotion that support the automatic motivation factors for the safe use of crossings. Study 3 involves the users to identify a set of intervention functions for the research sites that enhance automatic motivation of vulnerable road users include training, environmental restructuring, and persuasion.

The suggested automatic motivation interventions, such as training, environmental restructuring, persuasion, coercion, and modelling, can address the barriers in safe crossing practice and promote safe crossing behaviour:

a) *Addressing habitual risky behaviours:* Pedestrians, particularly those aged 18-26, tend to engage in risky crossing behaviour due to habitual tendencies. In addressing such, training can be arranged to improve pedestrians' skills through safe crossing practices, including proper communication strategies with drivers and breaking their habitual patterns of risky behaviour. Training can influence pedestrians' automatic responses by giving them the knowledge and skills to make safe crossing decisions without conscious effort. Environmental restructuring also positively impacts the students' motivation, which could help them feel safe and confident to alter their habitual violations and lapses in crossings. The design workshop participants suggest integrating safety messages into institutional routines as reminder for safe crossing use. In addition to the benefits of habitual breaking risky crossing behaviours, integrating safety messages into institutional routines can also help to raise awareness of safety issues and promote positive safety behaviours.
b) *Addressing safety concerns and fear of accidents:* Displaying motivational messages in the environment can remind pedestrians to follow safe road practices, as users recommends in design experiments. Positive persuasive motivational messages can subtly influence pedestrians' behaviour, encouraging them to consider road safety while crossing automatically. On the other side, pedestrians are concerned about their safety for their risky crossings and about drivers' speeding and reluctance in yielding behaviour

that leads to fear of accidents. Negative persuasion interventions, such as fear-arousing messages or campaigns emphasising the consequences of risky behaviour, can address these concerns and promote safer crossings. Coercion interventions can discourage pedestrians from engaging in risky crossing behaviour and help pedestrians, by controlling drivers' speeding through fines, penalties, or other punishments.

c) *Environmental restructuring for trust and confidence:* Participants emphasise the importance of environmental restructurings, such as installing high visibility zebra crossings, light signal systems, and speed reducers. In experimental settings, the vulnerable road users also suggest design recommendation for the research site such as widening zebra crossings, installing median barriers, and implementing speed reducers. Implementing these changes can enhance pedestrians' trust in the infrastructure and positively influence their willingness to use designated crossings. Such measures make it easier and safer for pedestrians to navigate road crossings without requiring extensive thought or deliberation. The redesigned infrastructure encourages pedestrians to choose safer crossing behaviours naturally.

d) *Feeling safe in group crossing:* Pedestrians highlight the influence of social factors on crossing behaviour. When crossing the street with a group, individuals tend to feel safer when they observe others adhering to safety measures. Modelling interventions can be implemented to promote safe crossing practices within groups, encouraging adherence to crossing rules and discouraging law-breaking behaviours. Community leaders, peers, or other influential individuals are also crucial in safe crossing practice in daily life.

Reflective motivation factors and intervention functions:

Planning, safety priority over convenience, satisfaction in crossing use, and consideration of benefits in avoiding risks are considered influential reflective motivational factors in Study 1. The qualitative analysis of Study 2 identified TDF domains such as professional/social role and identity, beliefs about capabilities, consequences, and intentions or goals as the reflective motivation factors for the safe use of crossings. Study 3 involves the users identifying a set of intervention functions for the research sites that enhance the reflective motivation of vulnerable road users, including education, modelling, enablement, incentivisation, and coercion.

Intervention functions, such as education, persuasion, modelling, enablement, incentivisation, and coercion, can target different components of reflective motivation in addressing the barriers in safe crossing practice and promoting safe crossing behaviour:

a) *Educating about safe crossing planning:* To address pedestrians' hurries or pressured crossing behaviour, interventions can focus on educating pedestrians about the importance of planning their crossings, considering designated crossings, and allowing sufficient time for safe crossing. It could enhance the belief in their ability and control to use crossings safely. In design workshops, the users emphasise in arranging off-site education and engaging resource persons for pedestrian safety. By providing in-depth knowledge about road safety risks, consequences, and benefits of safe crossing behaviours, education can influence pedestrians to make thoughtful and informed decisions while crossing the road.
b) *Reinforcing safety priority over convenience and users' enablement:* Participants express concerns about drivers' behaviour, such as speeding and violating priority rules of the zebra crossing. Interventions can employ persuasive strategies to emphasise the potential consequences of unsafe driver behaviour, such as accidents and injuries. By highlighting the consequences of not prioritising safety, pedestrians can be reminded of the importance of putting safety first. At the same time, improving the physical capabilities of pedestrians through interventions could be the key to enable individuals to remove the barriers in using grade-separated crossing facilities, where available. Design participants address such obstacles by providing dustbins, improving drainage facilities, and enhancing lighting in grade-separated crossing areas. This intervention empowers pedestrians to make reflective decisions, knowing that the environment supports their safety.
c) *Enhancing satisfaction and optimism about safe crossing:* Pedestrians feel safer and more confident when vehicles are at a reasonable distance while they cross. Interventions can focus on creating safer traffic conditions, such

as driver education programs, speed reduction measures and increased visibility of crossings, to enhance pedestrians' satisfaction and optimism about safe crossing practices. At the same time, punishing drivers for violating the crossing priority rules and fines for speeding can enhance the trust in safe crossing. The participants of design workshops also recommend enforcement through the police.

d) *Leveraging beliefs about consequences:* Pedestrians' experiences witnessing or being involved in road accidents encourage them to use designated crossings instead of engaging in risky behaviour. Incorporating fear-arousing messages, such as sharing stories or images of real accidents, can leverage pedestrians' beliefs about the benefits of avoiding risky crossings and encouraging safer behaviours. The qualitative finding reveals the influence of peer pressure in crossing behaviours. As design participants recommend billboard messages, incorporating quotes by peers who have experience with injuries or incorporating past tragic pictures of casualties could strengthen the beliefs about consequences.

e) Effective Communication Strategies: Pedestrians communicate with drivers using hand gestures to indicate their intention to cross. Education and guidance on effective communication strategies at crossings can be provided to pedestrians and drivers, promoting better understanding and safer crossing practices. Hiring resource persons, as design workshop participants recommend, a person such as traffic police, can train both drivers and pedestrians for effective communication, including the meaning of road signals and the priority of users in interpreting the manual (e.g., hand raising), semi-automated (pedestrian activated push-button), and automated traffic signal system (e.g., flashing light beacon). The design participants emphasise the semi-automated or automated signal system, which is not available in the highway crossings in Bangladesh.

f) *Using professional identity and role model in safe crossing use:* Pedestrians with professional identity, such as workers, perceive the benefits of crossings conveniently located near their workplace. Additionally, they see it as their social or professional role to utilise designated crossings. Workers and students can use their professional roles to promote designated crossings in many ways. The design workshop participants recommend monitoring the road crossing behaviour using CCTV. This intervention can motivate the institutions by showcasing positive role models who consistently practice safe crossing behaviours. Pedestrians observing responsible behaviour in others may be inspired to adopt similar safe practices. They can educate, persuade, model, enable, incentivise, and organize events to raise safety awareness about the importance of using designated crossings. They can also discuss the importance of using designated crossings in the media, community meetings, or other public forums. Additionally, they can advocate for changes to make designated crossings more accessible and visible.

Focus on environmental restructuring and social opportunities:

Study 1 emphasised the crucial role of physical and social opportunities in promoting safe crossing behaviour. Study 2 provides further insights by focusing on environmental restructuring as an opportunity-enhancing factor. It highlights the need for changes in the physical environment, such as installing high-visibility zebra crossings, light signal systems, and other facilities that enhance drivers' visibility and compliance. This aligns with Study 1's findings that physical opportunities, such as the visibility of drivers and the presence of traffic signs and road markings, significantly influence safe crossing behaviour. Study 3 also revealed that the engineers and users agree on the usefulness of physical restructuring of the research pedestrian crossing sites. Physical opportunities not only motivate pedestrians in safe crossing use but also motivate drivers in yielding to pedestrians, as the yield model reveals that physical opportunities could predict drivers' motivation and yield significantly. The thematic analysis also finds some environmental barriers to the yielding decision of the driver, such as poor visibility or lack of designated crossings and other facilities such as fencing, speed reducer or enforcement.

Study 1 also highlighted the role of social opportunities in the influence of psychological capability. Study 2 supplements this by emphasising the role of friends, family, and co-workers as social factors in crossing. It highlights peer pressure as a barrier and the importance of communication with drivers through gestures and eye contact to seek their attention and ensure safe crossings.

These findings align with the results of Study 1. Study 3 supplements the importance of changing environments through messages and role play. Social opportunities also significantly contribute to pedestrian safety as the yield model reveals that it can predict drivers' motivation, as per Study 2 findings.

7.2.2 Objective 2 (achieved by Study 2)

Objective: *To establish the factors that could promote driver yielding with a consensus among drivers and pedestrians for enhancing pedestrian safety.*

The common factors drivers and pedestrians emphasise for their yielding and safe crossing are pedestrian Knowledge and behaviour, drivers' Knowledge and behaviour, empathy and sense of social responsibility, assertiveness in pedestrian-driver interaction, environmental restructuring, enforcement, and group crossing. These factors demonstrate the shared perspectives of drivers and pedestrians regarding the factors that influence yielding behaviour and safe crossing use.

The qualitative findings provide additional insights and support for the quantitative results by offering a deeper understanding of the factors influencing drivers' yielding behaviour. The qualitative finding of factors emphasised by pedestrians for safe crossing use complements the drivers' yield factors derived from quantitative and qualitative results.

Pedestrian knowledge and behaviour: The qualitative findings reveal that drivers find major barriers in their yielding decision when pedestrians display violations and lapses in using designated crossings. This aligns with the quantitative finding that avoiding random crossing or using designated crossings is a significant factor in drivers' yielding behaviour. Similarly, the qualitative findings highlight that drivers consider the potential risks associated with pedestrians' behaviour. This supports the quantitative finding that drivers benefit from considering the potential risks related to pedestrians' behaviour early. These factors also reach a consensus with pedestrians' interest in safe crossing use by acknowledging that pedestrian behaviour and knowledge, especially violations in crossing use and risky crossing behaviour of the younger population, are the key barriers to safe crossing use.

Drivers' empathy and sense of social responsibility towards VRUs: The qualitative findings provide insights into the emotional aspects influencing drivers' yielding behaviour. Drivers are more likely to yield to pedestrians who they feel are in vulnerable groups because they do not want to be responsible for an accident. They feel empathy towards vulnerable groups such as children, women, or older people, or seeing pedestrians that bear similar professions with drivers' family members. This aligns with the quantitative finding that drivers' emotions are active when pedestrians exhibit fear expression of traffic injury or casualties. The qualitative findings highlight drivers' social responsibility towards vulnerable groups such as children, women, and older people. This aligns with another quantitative finding that drivers' professional roles significantly impact their yielding behaviour. These factors also agree with pedestrians' interest in safe crossing use. Overall, as pedestrians, the students and workers do not disagree that drivers yield to vulnerable groups, such as school students, while they cross a road to reach their institutions.

Environmental restructuring and enforcement: Qualitative and quantitative findings emphasise the visibility of crossing sites and pedestrians for the drivers' yielding decision to pedestrians. Results also suggest that drivers are more likely to yield to pedestrians who are assertive in crossing because they perceive them as being more confident and understand their crossing motives. Road signs and markings can influence drivers' yielding behaviour. These factors also agree with pedestrians' interest in safe crossing use, as pedestrians highlight some key barriers in their willingness to use crossings, including visibility obstructions and poor crossing facilities. The findings also highlighted other elements to improve environmental conditions, including enforcement. Drivers are more likely to yield to pedestrians when they find pedestrian fences or other measures such as installing speed reducers before a crossing or enforcement that help to keep pedestrians safe. The qualitative findings provide specific examples of violations and lapses in drivers' compliance with traffic rules and following speed limits. Pedestrians highlighted that feeling safe and confident is the key facilitator for safe crossing use, which can be ensured by enforcing the drivers' speed limit violations.

Pedestrians' assertiveness in pedestrian-driver interaction: The qualitative findings provide further insight into how drivers use their experience and knowledge to assess the situation and make decisions regarding yielding to pedestrians. By relying on their memorised driving experiences and familiarity with frequently used crossing locations, drivers can gauge the behaviour of pedestrians and adjust their yielding behaviour accordingly. This aligns with the quantitative finding that drivers' physical and psychological capabilities do not significantly impact their motivation and yield, as it suggests that drivers' decision-making is more influenced by their subjective assessments and familiarity with the situation rather than their innate abilities. The qualitative findings emphasise the importance of communication and decision-making between pedestrians and drivers. Drivers mentioned that pedestrians' assertiveness through gestures and eye contact influences their motivation to yield. This aligns with the quantitative finding that pedestrians' assertiveness is a motivational factor for drivers' yield. These factors also agree with pedestrians' interest in safe crossing use.

Group crossing: The qualitative findings suggest that drivers are more likely to yield to pedestrians crossing in a group, which aligns with the positive correlation observed in the quantitative results. Additionally, the qualitative findings mention that drivers are often willing to yield during specific times, such as school start or workers' lunchtime, indicating a connection between particular times and drivers' yielding behaviour. While the qualitative findings do not explicitly mention the negative correlation between many crossing users and drivers' yield, they support the notion that drivers are more likely to yield to pedestrians in certain social contexts, such as group crossing or during specific periods. These factors also reach on consensus with pedestrians. Pedestrians often feel safe remaining in a group while crossing a road, especially students and workers, when travelling at a particular time to reach their institutions.

7.2.3 Objective 3 (achieved by Studies 1 and 2)

Objective: *To recommend an intervention design strategy for the pedestrian and driver to meet the respective target behaviours of drivers' yielding and pedestrians' safe crossing use.*

Designing effective interventions for pedestrian safety: Designing effective interventions to improve pedestrian safety and promote desired behaviours from drivers and pedestrians requires a careful balance between actual demand

and available resources. A cost-effective solution that fosters motivation and addresses the interests of road users can be achieved by optimising intervention design strategies. The insights gained from Study 1 have practical implications for the development of such strategies:

a) *Targeting reflective and automatic motivation factors*: Motivational factors significantly influence pedestrians' safe use of crossings. Designers should target reflective and automatic motivation factors to encourage safe crossing use. Reflective motivation strategies may involve safety priority campaigns, educational programs, and awareness about fines for violations. Automatic motivation strategies can include creating positive emotions related to crossing use, emphasising the benefits of avoiding risky crossings, and facilitating convenient and efficient crossing experiences. Prioritising factors such as pedestrian satisfaction, the consideration of benefits of avoiding risky crossings, and habit formation can effectively promote safe crossing use. Designers can enhance pedestrian satisfaction by creating environments that meet their needs and expectations, leading to increased compliance with crossing rules. By emphasising the benefits of avoiding risky crossings, pedestrians can make informed decisions and reduce impulsive and risky behaviour. Fostering habit formation helps establish positive and automatic crossing behaviours, ensuring consistent and safe practices. Designers can contribute to creating safer crossing environments by emphasising these factors.

b) *Improving physical opportunities for safe crossing use:* When designers aim to enhance pedestrians' physical opportunities, they can maximise the benefits by prioritising physical opportunity factors that foster automatic motivation. This can be achieved in various ways: (i) Designing visually appealing and inviting pedestrian environments, incorporating attractive landscaping, public art, and well-maintained infrastructure. Improving accessibility for all pedestrians, including those with disabilities or limited mobility, by providing ramps, curb cuts, and tactile paving at crossings can also provoke positive emotions; (ii) Emphasising the benefits of avoiding risky crossings through strategically placing traffic signs and fencing to guide pedestrians towards designated crossing points and discourage risky behaviour like jaywalking. Clear signage and physical barriers remind pedestrians of the importance of safe crossing practices; and (iii) Facilitating convenient and efficient crossing experiences by implementing pedestrian-friendly infrastructure, including clear and visible pedestrian crossings, traffic signs, and road markings. Designers can also consider including refuge areas or pedestrian islands in longer or wider crossings to provide pedestrians a safe place to stop midway through the crossing, reducing perceived risk and increasing comfort.

c) *Utilising existing footbridges to improve pedestrian safety:* In LMICs, footbridges are commonly used infrastructure despite their drawbacks concerning broader sustainable development goals. To improve pedestrian safety in those countries, it is crucial to implement strategies that promote using existing infrastructure, including footbridges (Hasan and Napiah, 2018). These strategies may include: (i) Installing escalators or elevators to enhance accessibility and convenience and encouraging non-users to utilise footbridges; (ii) Implementing fences or barriers to provide safety and security, promoting footbridge usage; and (iii) Effectively conveying safety messages through posters to communicate the benefits of using footbridges and promote safe mobility among non-users.

d) *Leveraging social opportunities for safe crossing practices:* Designers can positively impact motivation factors that encourage safe crossing practices by creating social opportunities. This can be achieved through various approaches, such as involving influential individuals, collaborating with families and institutions, facilitating group crossings, and implementing safety alert reminders. For instance, a local celebrity endorsing the importance of using designated pedestrian crossings can create a positive social norm and motivate others to follow suit. Collaborating with families and institutions, such as schools or workplaces, can create a supportive environment that promotes safe crossing behaviours through safety education programs and incorporating safe crossing practices into the curriculum or workplace policies. Facilitating group crossings fosters a sense of community and encourages pedestrians to cross together, promoting safety in numbers. Additionally, involving influential individuals and leveraging social networks can raise awareness and education on the importance of using designated crossings, enhancing pedestrians' physical capability to make safer choices. Incorporating safety alert reminders in the built environment, such as signs or pavement markings near pedestrian crossings, reminds individuals to use designated crossings and follow traffic rules, contributing to individuals' physical capability to make safer crossing choices by stop and look both ways for traffic, use designated crossings where available, and cross efficiently while staying alert to your surroundings to ensure your safety. Pedestrians can enhance their safer crossing practice by stopping and looking both ways for traffic, using designated crossings where available, and crossing efficiently while staying alert.

e) *Enhancing Psychological Capabilities through Social Opportunities:* Leveraging social opportunity to maximise its impact on safe crossing use involves considering its influence on pedestrians' psychological capabilities. Safety education programs and campaigns can raise awareness about safe crossing practices, enhancing psychological capabilities by instilling a sense of responsibility and awareness. Visual cues and reminders in the built environment can prompt pedestrians to be more attentive and cautious before crossing. Creating environments that regulate pedestrians' moods and emotions, incorporating greenery, pleasant lighting, or calming design features near crossings, can promote receptive mindsets to safe crossing practices. Furthermore, incorporating normative or social influence messaging in interventions by highlighting high compliance rates of using designated crossings fosters a sense of social responsibility and conformity, enhancing psychological capabilities.

The insights gained from Study 2 also have practical implications for the development of such strategies:

a) *Bridging perception gaps in pedestrian-driver interactions:* There is a perception difference between drivers and pedestrians regarding their behaviours and yielding frequency. However, a significant correlation exists between drivers' yielding frequency and reported near-accident situations, emphasising the importance of drivers' yielding behaviour in promoting safer pedestrian-driver interactions and reducing near-accident risk. Initiatives and interventions are needed to encourage and promote drivers' yielding behaviour to enhance road pedestrian safety. To bridge the perception gaps in pedestrian-driver interactions, intervention design strategies should consider common factors aligning with the mutual interests of pedestrians and drivers. These factors include pedestrian behaviour, communication and decision-making, environmental restructuring and visibility, social factors, enforcement, and attitudes and beliefs about consequences. By addressing these factors and adopting a consensus-building approach, interventions and strategies can be developed to promote safer interactions and enhance pedestrian safety.

b) *Consensus-building approach for identifying influential factors:* The consensus-building approach used in the studies, involving thematic coding based on behaviour change theories and perspectives from drivers and pedestrians, is crucial in identifying influential factors. By considering the consensus of drivers and pedestrians, interventions can be designed to meet the expectations and needs of both groups, even with limited resources in developing countries.

c) *Intervention strategies targeting drivers' yielding behaviour:* The findings also suggest that interventions targeting drivers' yielding behaviour should focus on motivation, physical opportunities, and social opportunities. Enhancing drivers' motivation can be achieved by addressing comfort, attitudes, risk perception, empathy, and assertiveness. Providing physical opportunities, such as designated waiting areas, and improving communication through hand gestures and eye contact, can also promote yielding behaviour. Additionally, social opportunities play a significant role in motivating drivers to yield by fostering a sense of community among pedestrians and increasing awareness of group crossings.

d) *Improve communication skills and understanding:* Training programs are essential in improving communication and mutual understanding between drivers and pedestrians. Training drivers and pedestrians on assertiveness, effective use of gestures, and knowledge of right-of-way rules can enhance their implicit communication and contribute to improved road safety.

e) Developing context-Specific interventions for developing countries: By adopting a consensus-based approach, considering context-specific interventions, and implementing training programs, it is possible to overcome resource limitations and create safer environments for drivers and pedestrians in developing countries. Incorporating these recommendations into road safety initiatives allows for developing interventions and strategies that address drivers' and pedestrians' specific needs and behaviours, ultimately promoting safer pedestrian-driver interactions and overall road safety.

7.2.4 Objective 4 (achieved by Study 3)

Objective: *To improve the intervention design for the safety of vulnerable road users.*

Evaluation of Interventions: The study evaluates interventions, which are designed by local engineers and behavioural model users at different sites. Interventions that apply the behavioural model result in higher safety ratings and have fewer usability problems than those designed solely by engineers. Expert evaluations emphasise the incorporation of speed-reducing measures and signals in intervention design for pedestrian safety, including the motivational elements to change road users' behaviour. These measures are deemed crucial for enhancing the safety of vulnerable road users.

Importance of co-design: The study highlights the effectiveness of co-design interventions, in which vulnerable road users actively participate in the design process. Co-designed interventions are perceived as safer and covers multidimensional aspects of pedestrian safety than those designed solely by engineers. This suggests that involving different stakeholders, including vulnerable road users, in the intervention design can lead to more effective and user-centred solutions.

The usefulness of the behavioural model: The design participant team identifies the road safety problem using the behavioural model and suggests a few innovative solutions. Stakeholders also highlight the usefulness of the behavioural model in structuring discussions about behaviours problems and identifying suitable behavioural change solutions. The model can help road users estimate the consequences of their actions, understand their limitations, and customise their behaviours accordingly.

7.2.5 Objective 5 (achieved by Study 3)

Objective: *To address the blaming culture among pedestrians-drivers-authorities by suggesting a solution to the authorities.*

Participatory design and shared responsibility: The study emphasises that involving all stakeholders, including pedestrians, drivers, and authorities, in the design process can help reduce the blaming culture. By fostering shared responsibility and ensuring that the needs and perspectives of all stakeholders are considered, authorities can create a collaborative environment for addressing road safety issues. Authorities should adopt a participatory design approach involving pedestrians, drivers, and relevant authorities in decision-making. Using a behavioural model in the co-design process could help authorities understand road users' behaviour and propose appropriate interventions accordingly. Moreover, stakeholders can contribute their insights and suggestions. By promoting shared responsibility, authorities can encourage a collective effort to improve road safety.

Dissemination of Findings: The key message that can be drawn for the authorities from the study is the urgent need to address the blaming culture surrounding traffic accidents. Drivers and pedestrians are seriously concerned about the role of authorities and the accident investigation system, which hinders progress in improving road safety. The authorities can consider the following steps:

a) *Public awareness campaigns:* Launching targeted awareness campaigns that emphasise the importance of taking responsibility for one's actions on the road. These campaigns should shift the focus from blame to understanding and empathy, encouraging drivers and pedestrians to be more mindful of each other's actions and consider their contributions to road safety.
b) *Traffic discipline reinforcement:* Strengthening traffic discipline enforcement, not just during designated traffic weeks, but on an ongoing basis. This includes strict monitoring of traffic violations and implementing appropriate penalties for offenders, regardless of their status.
c) Infrastructure improvements: Investing in the installation and maintenance of traffic signs, signals, lighting, and road markings in accident-prone areas.

Corrective measures of infrastructure in place can greatly decrease the chances of crashes and make it easier for road users to navigate safely.

d) *Driving training centres:* Establishing more driving training centres to ensure that drivers receive proper education and training before getting on the road. This will contribute to a more responsible and competent driving culture.

e) *Comprehensive approach to accident investigation:* Adopting a comprehensive approach in investigating the root cause of accidents, considering all factors involved, including road conditions, infrastructure, vehicle maintenance, and the behaviour of all parties involved, rather than solely attributing blame.

f) *Equal implementation of laws:* Ensuring existing traffic laws are enforced equally for all citizens, regardless of socio-economic status. Avoiding partial implementation based on wealth or influence will enhance trust in the legal system and promote a sense of fairness.

The study highlights the importance of disseminating the findings in appropriate forums for designers and policymakers. Sharing the results with relevant authorities can raise awareness about the blaming culture and its impact on road safety. By informing policymakers about the study’s recommendations, authorities can initiate actions to address the issue. Authorities should actively share the study’s findings with policymakers, road safety committees, and relevant government agencies. They can organise workshops or conferences where the study’s results are presented, inviting discussions on strategies to tackle the blaming culture. By raising awareness and encouraging dialogue, authorities can facilitate a shift in the mindset and actions of all stakeholders.

Training and Education: The study highlights the need for driver training and addresses flaws in the existing educational curriculum. By providing appropriate training to drivers and enhancing road safety education, authorities can contribute to a safer road environment and reduce the blaming culture. Governments must make a significant investment in comprehensive driver training programs that include all facets of safe driving, including increased awareness of vulnerable road users and responsible road behaviour. Additionally, authorities should collaborate with educational institutions to revise and improve the existing road safety curriculum, ensuring it addresses the specific needs and challenges pedestrians, drivers, and authorities face.

Media Engagement: The study suggests that involving the media in discussions about government policy decisions can help shift away from blaming. By shaping public opinion and promoting more constructive dialogue, authorities can create a positive atmosphere for addressing road safety issues. Authorities should actively engage with the media and encourage responsible reporting on road safety issues. They can organise press conferences, media campaigns, or interviews to discuss government policy decisions related to road safety. By providing transparent information and engaging in open discussions. Authorities can foster a more balanced and informed public discourse.

7.3 Study limitations and future research directions

The research limitation is the small sample size, with only 302 respondents from pedestrians and 202 from drivers. In the pedestrian survey, the survey population excludes older people and children below ten years. The study also had a relatively small sample size for the drivers' focus group (19 participants) and the pedestrians' focus group (40 participants). The limited number of participants and survey population may not fully represent the population of drivers and pedestrians in Bangladesh. However, the prediction model for pedestrians' behaviour suggests the out-of-sample predictive power, in other words, it proves the generalisability of prediction results. The study involved a relatively small number of participants who are the vulnerable target group of pedestrians, students and workers in the design workshops, which may limit the generalisability of the results. The small sample size might not represent the drivers' perspectives and behaviours of all potential road users in the area. Including a more extensive sample size and including drivers in design-workshops could provide a more comprehensive understanding of the design requirements and behaviours related to road crossing practices.

The study focused on specific routes and areas in Bangladesh, such as the N-540 and N-2 highways. The study included four research sites on two highways in Bangladesh, having typical types of crossings. These sites were selected to represent a range of road conditions and pedestrian behaviours, including different crossing types (zebra crossing, underpass, and footbridge), different traffic volumes (semi-urban and rural), and different land uses (school, industries, and marketplace). These sites were selected as representative crossings but may not fully capture the diversity of road conditions and crossing behaviours across the country. Including a broader range of research sites could provide a more comprehensive understanding of the challenges and potential solutions related to road-crossing practices in Bangladesh. The findings may not apply to regions or countries with different road conditions, traffic patterns, and cultural contexts. The results should not be extrapolated to a larger group without caution.

The research activities were conducted within a specific time frame from December 2021 to March 2022. This limited period may have constrained the depth and breadth of the study. Longer-term studies could provide more opportunities for in-depth exploration, monitoring, and evaluation of the interventions and potential changes in crossing behaviours over time.

Other factors that could affect the results include COVID situation-related stress, forgetting the pre-COVID behaviour and attitude, and the influences of teachers or institutional managers. The study used self-reported information from drivers and pedestrians, which could be biased due to social desirability or memory. Participants might provide responses they perceive as socially acceptable rather than reflecting their proper behaviours or attitudes. Additionally, participants may not accurately remember or report their experiences, leading to potential inaccuracies in the data. Respondents are expected to remember their pre-COVID behaviour as pedestrians know the research sites near their institutions, and drivers drive on their regular routes. In the pedestrian survey, the research team briefed the research objectives and ethical issues to the representative teachers or the industry managers before distributing questionnaires to the respondents, which minimises their influence on the respondents. There are some study-specific limitations.

Study 1 reveals significant differences in aggression and road safety lapses between at-grade and grade-separated crossings due to inherent design variations. More research needed to find the cause and solutions for this problem. At-grade crossings pose a higher risk of conflicts and aggression, while grade-separated crossings offer physical separation, reducing aggressive behaviours. However, no significant difference was found in violations between the two groups. Age (older age than younger) and profession (worker than student) negatively influenced crossing behaviour, emphasising the need for tailored approaches. Prioritising safety, designers can implement traffic calming strategies and advocate for stricter enforcement. The absence of certain facilities could affect study results, but a co-design approach can uncover innovative solutions. Collaborative design processes address pedestrian needs and lead to effective safety interventions.

In Study 2, the sample size was rather small for detecting significant effects, which could lead to a lack of statistical power to detect meaningful relationships between physical/psychological capability factors and drivers' motivation to yield. In such cases, larger sample sizes may be necessary to uncover significant effects. While the factors mentioned in the study are crucial for pedestrian safety, other factors could substantially impact drivers' decision-making at pedestrian crossings. Future research could explore a broader range of factors to identify the key determinants of drivers' motivation and yielding behaviour.

Study 3 finds that the practitioners have limited knowledge of behavioural models and their application in intervention design. This limitation could have influenced the quality and effectiveness of the interventions developed in the workshops. Future research should focus on improving the understanding and knowledge of behavioural models among road agency professionals to enhance the design process and the effectiveness of interventions. While the study incorporated participatory design approaches, the study did not apply Behaviour Change Techniques (BCTs) due to time constraints in design workshops. Future studies should explore the effectiveness of incorporating BCTs in intervention designs.

Overall, it is acknowledged that the exposure of both drivers and pedestrians can significantly impact their behaviours. Exposure can vary based on factors like time of day, day of the week, and specific locations. However, as the target group of road users are local students and workers, they need to travel regularly on the weekdays. Therefore, they need to be exposed to the medium to high-speed road environment, where drivers who drive on specific routes are familiar with interacting with pedestrians during their crossing. Pedestrians mostly cross a particular road in the morning when their institution or workplace opens and in the afternoon when they return home. Pedestrians reported their attitude and behaviour of past events (before COVID). The target group of pedestrians is likely to be exposed to the same road environment on a regular basis, so the impact of exposure on their behaviour is likely to be limited. However, other types of pedestrians and drivers who are not frequent users of the specific route may be more affected by exposure, as they may be less familiar with the road environment and the interactions between drivers and pedestrians.

The study also acknowledged the difficulties in standardising locations, given the diversity of road conditions, traffic patterns, and cultural contexts in Bangladesh. Few steps were taken to manage these variations, such as focusing on two highways with similar characteristics (four-lane divided highways with a high traffic volume), sites selected to represent a range of road conditions and pedestrian behaviours and data collection methods were standardised across all research sites. However, the study could not fully account for the variation between locations due to the small sample size. The study discussed the potential role of location-specific factors, such as crossing type, in influencing driver and pedestrian behaviour. However, the small sample size limited the ability to conduct a detailed analysis of this issue.

This research applied the core part (COM-B model) of the Behavioural Change Wheel (BCW) for behavioural investigation, operationalised with the TDF domains. The COM-B model was also applied in the co-design settings for the design of interventions. The interactions between the COM-B components revealed the complex relationship that helped in maximising the benefit of interventions. This research also investigated the possible intervention functions, as in the outer part of the BCW. However, the study did not examine how the interventions could be implemented through policy functions of BCW or how behaviour change techniques could be applied in the co-design process.

Chapter 8
Conclusions and recommendations

This chapter presents a summary of the entire research, highlighting the key findings and insights from the three investigations conducted. The chapter then emphasises the contributions made to the field of road safety. The implications for practice are discussed, underscoring the significance of incorporating user perspectives and shared responsibility in road safety initiatives. The recommendations section offers specific guidelines for practitioners and designers to implement safer infrastructure and behaviour change interventions. Additionally, recommendations for future research are proposed to address potential gaps and further advance road safety studies. Lastly, the chapter concludes by reaffirming the significance of the study's outcomes and their potential impact on creating safer road environments for all users.

8.1 Summary of the study

The three studies conducted on enhancing pedestrian safety and promoting drivers' yielding behaviour at designated crossings in Bangladesh offer valuable insights utilising the COM-B (Capability, Opportunity, and Motivation-Behaviour) model. The first study identifies the influence of COM-B factors on different components of safe crossing use. The study examines the role of opportunity, motivation, and capability in predicting safe crossing behaviour. The study highlights the need for comprehensive interventions, including pedestrian-friendly infrastructure design and social elements to improve pedestrian safety. Factors such as planning for behaviour improvement, safety prioritisation, feelings, satisfaction, and habit formation play essential roles in encouraging safe crossing practices. The second study focuses on promoting pedestrian safety by identifying factors influencing drivers' yielding behaviour at designated crossings in Bangladesh. Study 2 builds upon the findings of Study 1 by exploring factors that could promote drivers' yielding to pedestrians in pedestrian-driver interactions. The qualitative insights provide a deeper understanding of drivers' perspectives and highlight the importance of pedestrian knowledge, assertiveness, environmental conditions, communication, and driver compliance with traffic rules. The study finds several contributory factors that can promote pedestrian safety, including motivation factors such as avoiding random crossing by pedestrians and opportunity factors such as traffic signs and enforcement. The third study investigates the design practice in Bangladesh and evaluates the effect of co-design and behaviour change models on intervention outcomes for vulnerable road users. It compares conventional designs with co-designed interventions and explores the additional improvement achieved by applying behaviour change models. The study finds that traditional designs had usability problems, while co-design interventions addressed these issues effectively. Furthermore, the application of the behaviour change model enhanced the interventions. From the three studies, interventions focusing training, environmental restructuring, education, persuasion, modelling, enablement, incentivisation, and coercion can motivate pedestrians in safe crossing use. Concerning blaming culture among pedestrians-drivers-authorities, pedestrians and drivers reflect the importance of shared responsibility. Stakeholder interviews indicate that the co-design approach and behaviour change model promotes shared responsibility and address the blame culture associated with road safety.

8.2 Contributions to the field

The studies collectively contribute to road safety by providing practical recommendations for practitioners and designers. They highlight the importance of considering motivational, opportunity, and capability factors in intervention design and the significance of stakeholder engagement, infrastructure improvements, behaviour change strategies, and collaborative approaches. These findings can inform policy decisions, guide infrastructure design, and help develop effective interventions to enhance pedestrian safety and drivers' yielding behaviour.

The first study contributes to the research community by applying the COM-B model to understand pedestrian motivations for safe crossing use. It highlights the importance of opportunity and motivation in predicting safe behaviour. The findings emphasise the need for comprehensive interventions and pedestrian-friendly infrastructure design in low- and middle-income countries like Bangladesh. The second study utilises behaviour change theories and the Theoretical domains framework (TDF) to analyse qualitatively with a thematic coding framework to understand how the factors revealed from quantitative findings affect the drivers' yielding behaviour at designated crossings. Additionally, a consensus was established between the pedestrians and drivers concerning their different competing interests at crossings. Studies 1 and 2 provide insights into the motivations and opportunities of the competing road users that can promote pedestrian safety. The findings can inform policymakers, highway designers, and stakeholders in developing strategies to enhance driver behaviour and prioritise pedestrian safety.

The third study explores the effectiveness of co-design and behaviour change models in addressing design flaws and promoting proper facility use. It highlights the safety of vulnerable road users who are the victim of blaming culture. The perceptions of road users amidst blaming the nexus of pedestrians-drivers-authorities reveal the importance of shared responsibility among stakeholders involved. Authorities who provide interventions also undergo an intervention development process with the vulnerable pedestrian groups and apply behaviour change principles to enhance intervention outcomes. The study emphasises the importance of shared responsibility and can guide authorities in improving road infrastructure and promoting sustainable safety solutions for VRUs.

These studies collectively enhance our understanding of pedestrian safety in Bangladesh and provide valuable insights into the factors influencing safe crossing behaviour, drivers' yielding behaviour, and effective intervention design. The findings can inform policymakers, highway designers, and stakeholders to improve road safety and protect vulnerable road users.

8.3 Implications for practice

Infrastructure design: Practitioners and designers should prioritise pedestrian-friendly infrastructure that addresses the specific factors identified in the studies. This includes improving visibility, reducing crossing times, ensuring accessibility in all weather conditions, and implementing traffic signs and road markings. Additionally, pedestrian fences, speed reducers, and enforcement against traffic law violators can enhance pedestrian safety. Footbridges should be designed with features like escalators or elevators and safety barriers to encourage their use.

Optimising the resources in utilisation: This study highlights the importance of optimising intervention design strategies in LMICs to improve pedestrian safety and promote desired behaviours from drivers and pedestrians. Targeting reflective and automatic motivation factors, enhancing physical opportunities for safe crossing, utilising existing footbridges, leveraging social opportunities, and bridging perception gaps in pedestrian-driver interactions are key strategies to foster safer road environments. Training programs to improve communication skills and context-specific interventions are crucial for overcoming resource limitations and creating safer road environments for all road users. By prioritising effective intervention design strategies, LMICs can maximise the impact of their limited resources and make significant strides in enhancing pedestrian safety and overall road safety.

Comprehensive interventions: The studies emphasise the need for comprehensive interventions that address multiple factors influencing pedestrian safety. Practitioners should consider a holistic approach that includes infrastructure improvements, behaviour change strategies, and stakeholder involvement. By implementing comprehensive interventions, practitioners can maximise the effectiveness of road safety initiatives and reduce pedestrian fatalities.

Behaviour change strategies: Practitioners, who develop and implement interventions, can utilise behaviour change theories and the COM-B model to develop strategies targeting pedestrians' and drivers' motivations, capabilities, and opportunities. Interventions should target both reflective and automatic motivation factors identified in the studies. Reflective motivation-enhancing strategies, such as safety campaigns and education programs, can raise awareness about the risks and fines associated with risky pedestrian behaviours. An automatic motivation-enhancing strategy should focus on creating positive emotions, emphasising the benefits of safe crossings, and providing convenient crossing experiences. Practitioners should consider factors like pedestrian satisfaction, habit formation, and consideration of benefits in crossing practices when designing behaviour change interventions.

Practitioners can promote positive behaviour change and enhance pedestrian safety by understanding and addressing these factors.

Stakeholder engagement: Practitioners should foster collaboration and shared responsibility among stakeholders to create a safer road environment. Stakeholder engagement can help identify specific needs, address concerns, and develop a sense of ownership, leading to more effective road safety initiatives. Practitioners should address the blaming culture among pedestrians, drivers, and authorities. A more collaborative and safer road environment can be created by promoting shared responsibility, fostering communication, and improving understanding among stakeholders. Strategies such as improving driver training, engaging with the media to spread road safety awareness, and involving influential individuals can reduce blame and create a safety culture.

Collaborative design approach: Practitioners should adopt a co-design approach that involves vulnerable road users in the design process. Engaging pedestrians and drivers in consensus-building activities can lead to more effective and practical interventions. The studies emphasise the usefulness of behavioural models in identifying road safety problems and suggesting appropriate solutions. Tailored interventions can be made by working together with the target audience to meet their unique needs and preferences. By incorporating user perspectives, practitioners can enhance road safety interventions' usability, acceptability, and effectiveness.

Policy and decision-making: The findings from these studies have practical implications for policymakers and highway designers. Policymakers must acknowledge their stake in road safety and make informed decisions prioritising pedestrian safety. Practitioners can use the thematic coding framework and empirical evidence from the studies to inform policy development, infrastructure planning, and decision-making processes.

8.4 Recommendations

8.4.1 Recommendations for practitioners and designers

Implement multifaceted and context-specific interventions: Road safety interventions should be comprehensive, combining infrastructure improvements with behaviour change strategies. Practitioners should consider the unique characteristics of the road environment, cultural norms, and socioeconomic factors when designing interventions. Practitioners can maximise their impact on road safety outcomes by addressing multiple factors simultaneously and customising interventions.

Prioritise pedestrian-friendly infrastructure: Designers should Prioritise the development of pedestrian-friendly infrastructure to create safer road environments. This includes ensuring clear visibility of pedestrians, providing adequate crossing times, improving accessibility of footbridges and underpasses, and strategically placing traffic signs and road markings. Designers should also incorporate features such as refuge areas and appropriate fencing to enhance pedestrian safety and encourage proper use of designated crossings.

*Advocate for using behaviour change theories: Practitioners and designers can u*se behaviour change theories, such as the COM-B model, to inform their interventions. By understanding pedestrians' and drivers' motivations, capabilities, and opportunities, practitioners can design targeted interventions that address specific behavioural factors influencing road safety. This may involve developing persuasive communication strategies, providing incentives for desired behaviours, and creating supportive environments that facilitate safe road use.

Evaluate and monitor interventions: Practitioners should establish a framework for regular evaluation and monitoring of road safety interventions. By collecting data on behaviour change, safety outcomes, and user feedback, practitioners can assess the effectiveness of their interventions and make necessary adjustments. Continual assessment assists in pinpointing areas that require enhancement, supports decision-making based on evidence, and guarantees that interventions remain pertinent and effective over a period.

8.4.2 Recommendations for future research

Sample size and representation: Future research should aim to overcome the limitations of small sample sizes and limited representation by conducting studies with larger and more diverse samples. Including a broader range of participants, including older individuals and children, can provide a more comprehensive understanding of road-crossing practices. A larger sample size of drivers will increase the findings' generalisability and enhance the results' reliability.

Contextual variations: To enhance the generalisability of the findings, future research should consider contextual variations in road safety practices. A study focusing on seat-belt behaviour indicated that the differences between self-reported and observed usage rates were smaller in countries with high seat-belt use compared to low-use countries, suggesting that observation studies offer more realistic and valid usage rates than self-reported data (Özkan et al., 2012). This finding can apply to the present study, supporting behavioural observation to understand the intention-behaviour gap in safe crossing practices. Furthermore, understanding road crossing challenges and solutions comprehensively requires exploring variations in road conditions, traffic patterns, and cultural contexts. Future research should include diverse research sites across regions and countries to gain valuable insights into pedestrian behaviour and driver yielding. Comparing findings across contexts can identify commonalities and differences, leading to practical strategies for improving road safety outcomes.

Long-term studies: Conducting longer-term studies will enable researchers to delve deeper into the effectiveness of interventions and observe potential changes in crossing behaviours over time. This will provide valuable insights into the sustainability and long-lasting impact of interventions and any potential behavioural adaptations that may occur. Long-term studies require consideration of external factors.

Mixed-methods approach: Supplementing the applied quantitative and qualitative data, other qualitative research methods, such as in-depth interviews or ethnographic observations, can provide deeper insights into the experiences, perceptions, and motivations of both drivers and pedestrians. Combining quantitative and qualitative data will offer a more comprehensive understanding of the complex factors influencing road-crossing practices.

Comparative studies: Conducting comparative studies between different intervention designs and approaches can contribute to evidence-based design practices. Comparing outcomes and impacts of interventions with varying levels of user involvement, behavioural change techniques, or infrastructure improvements will provide insights into the effectiveness of different strategies. Comparative studies can help identify the most effective interventions and guide decision-making for practitioners and designers.

Knowledge transfer and capacity building: Future research should focus on knowledge transfer and capacity building among road agency professionals. Providing training and resources to enhance their understanding and application of behavioural models, design guidelines, and intervention strategies will support the development of safer road infrastructure. Capacity-building initiatives can ensure the effective implementation of evidence-based practices and promote a culture of continuous improvement in road safety.

Evaluation of interventions: Future research should prioritise implementing and evaluating interventions developed in previous studies on a larger scale. Gaining a more thorough understanding of how interventions perform in real-world scenarios will aid in making decisions based on evidence. Evaluating the long-term impact of interventions on road safety outcomes and pedestrian behaviours will contribute to developing effective and sustainable road safety interventions.

8.5 Final conclusion

The three studies in this research provide valuable insights into enhancing pedestrian safety and promoting drivers' yielding behaviour at designated crossings in Bangladesh. The studies collectively contribute to road safety by providing practical recommendations for practitioners and designers. They highlight the importance of effective intervention design by suggesting an optimisation strategy for the designers to maximise benefits of interventions. The suggested *UPLIFT* strategy consists of:

- Upgrading the safety and accessibility features of available crossings;
- Providing adequate physical opportunities for safe crossing use;
- Leveraging social opportunities for safe crossing practices;
- Improving psychological capabilities through social opportunities;
- Focusing on shared interests for pedestrian-driver consensus; and
- Targeting reflective and automatic motivation factors.

The first study emphasises the need for comprehensive interventions and pedestrian-friendly infrastructure to enhance pedestrian safety. The influence of social and physical opportunities is significant in addressing pedestrian violations, lapses, and aggressions. Factors such as planning for behaviour improvement, safety prioritization, positive feelings, satisfaction, and habit formation play crucial roles in encouraging safe crossing practices.

The second study highlights the factors that can promote drivers' yielding to pedestrians, including pedestrian knowledge, assertiveness, environmental conditions, communication, and driver compliance with traffic rules. It underscores the importance of motivation factors like avoiding random crossing and opportunity factors like traffic signs and enforcement in promoting pedestrian safety.

The third study demonstrates the effectiveness of co-design and behaviour change models in addressing design flaws and promoting proper facility use. It also highlights the significance of shared responsibility among stakeholders to tackle the blaming culture associated with road safety. The Safe System approach does consider the behaviour of road users, but it does not solely focus on it. The Safe System approach argues that the environment should be designed to minimise the risk of injury or death even when road users make mistakes. So, ultimately the fate of the consequence of behaviour lies in the designers' decision who design the environment for the users. However, In LMICs, institutional weakness in designing appropriate interventions and lack of user ownership are significant challenges. Even though the end user withstands the worst road traffic injury and death load, they rarely initiate safety intervention decisions. Therefore, the Safety System principles may not succeed when designers fail to understand and change the users' behaviour with the designers' choice of infrastructure selection. In developing countries, the design may not be robust due to a lack of expertise or resources, so the user has to adapt to poor design. Here, users' involvement in the design process (co-design) should change their behaviour to be safer because they are partly responsible for the design they produce. Co-design does not contradict but adds to the Safe System principle to overcome inherent weakness in applying principles in developing countries.

The key message for authorities is to adopt a holistic approach that considers infrastructure improvements, behaviour change strategies, stakeholder engagement, and collaborative design. Policymakers should prioritise pedestrian-friendly infrastructure, implement comprehensive interventions, and utilise behaviour change theories to address road safety challenges. Stakeholder engagement and shared responsibility are essential in creating a safer road environment for vulnerable road users.

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Appendices

Appendix A COM-B Pedestrian Questionnaire with Bengali version

Target Behaviour- Use pedestrian crossings safely

Instructions- This questionnaire will ask about your personal experiences with, or reactions to, the uses of pedestrian crossing facilities (such as zebra crossing, footbridge, underpass, or any other type) when crossing a road. This survey will be used to understand the overall population's behaviour rather than individuals as it does not trace responses back to the participants. You can use this paper questionnaire or access the website (https://behave-for-design.com/) to fill the questionnaire.

(A) Demographic information- Please use tick (✓)

1. Please indicate your gender o Male o Female o Other/Prefer not to say **2. What is your current marital status?** o Married o Single o Divorced or widowed	**3. Do you have children?** o Yes o No **4. Please mark your age in the following age ranges** o Below 12 years o 12-18 years o 19-25 years o 26-32 years o 33-39 years o 40 years and above	**5. Please indicate your profession** o Secondary school student o College/University student o Industry/Garment worker o Marketplace worker o Other, specify.................... **6. Have you ever been involved in an accident while crossing the road?** o Yes o No

(B) Behaviour

7. Which type of crossing was nearest to you before March/2020 (pre-COVID time)? Please tick (✓) one box only-


Zebra crossing ☐


Footbridge ☐


Underpass ☐


Non-priority type ☐

8. Recalling your pre-COVID behaviour (before March/2020), how often were you involved in any of the following behaviours? Please rate the following statements with a tick (✓), using the scale shown on the right.	**Scale** **1** Never **2** Infrequently **3** Sometimes **4** Frequently **5** Always				
	1	**2**	**3**	**4**	**5**
(a) when I had a chance to use my nearby crossing, I used that					
(b) to save time or for my own convenience, intentionally, I was involved in violation behaviours such as crossing diagonally from where I was to the destination point, using prohibited crossing paths, etc.					
(c) I expressed my anger through behaviours such as walking slowly, yelling at drivers or gesturing rudely, hitting a vehicle etc.					
(d) I realised after crossing that I failed to pay attention or look at the traffic properly because of talking to someone, using a mobile phone, joining someone on the opposite side etc.					

9. When you were in a situation where you had to use your hand to cross the road, which of the following gesture have you made most, and how often have the drivers let you go?

Please tick (✓) only one box above the picture that represents your gesture.

☐	☐	☐	☐	How often let go? Tick (✓) -
				Never let go ☐ Infrequently let go ☐ Sometimes let go ☐ Frequently let go ☐ Always let go ☐

10. After starting crossing, when you have seen that drivers don't want you to cross the road, which of the following actions did you do the most and how often?

Tick (✓) *one box only*	How often you have done? Tick (✓) *one box only*
Stopped ☐ Returned ☐ Ran fast across the road ☐	Never ☐ Infrequently ☐ Sometimes ☐ Frequently ☐ Always ☐

11. How often have you ended up in a near-accident situation when the drivers were not responding to you while crossing the road? Please tick (✓) one box.

Never ☐ Infrequently ☐ Sometimes ☐ Frequently ☐ Always ☐

(C) Capability, Opportunity and Motivation

12. Recalling again the pre-COVID situation, how much do you agree with the following statements? Please rate each item with a tick (✓) using the scale shown on the right.	**-2** Strongly disagree **-1** Disagree **0** Neither **+1** Agree **+2** Strongly agree **Scale**				
	-2	**-1**	**0**	**+1**	**+2**
Statement: **When I had the following physical opportunities, I used the crossing safely-**					
short crossing time					
convenient location of crossing					
easy access to crossing & usable in all weather					
having traffic sign and road marking					
enforcement measures against traffic law violators					
pedestrian fence on footpath/median to ensure crossing in a designated area					
adequate space/right of way for pedestrians to meet peak hour flow					
visibility of drivers and pedestrians to each other					
enough waiting area in the middle/at side of a road					
having vehicle speed reducer before the crossing					

Scale	-2	-1	0	+1	+2
Statement: **I had the following social opportunities to use the crossing safely**					
getting education and support from family/institution					
many people known to me use the crossing					
parental safety alert reminders from time to time					
many pedestrians /crossings in group at specific times					
influential people (teachers/managers/leaders) use the crossing					
Statement: **I was motivated to use the crossing safely because I -**					
planned to improve my crossing behaviour					
was satisfied to use the crossing					
benefitted from avoiding risky crossings, such as sudden running, indecision on the road, crossing inter-vehicle gaps, assuming drivers would let go					
felt confident that I could use the crossing safely					
prioritised safety over convenience					
was persuaded from awareness campaign					
received reward/praise for using the crossing					
used crossing seeing other pedestrians who used it					
Statement: **I was motivated to use the crossing safely because of my -**					
faith in God, which strengthens my willingness to use					
habit formed from previous good experiences					
good feeling for use/guilty feelings for not use					
feeling the need for self-protection for the sake of beloved ones					
fear of traffic injury/death					
Statement: **I was physically able to use the crossing safely because I -**					
was able to walk					
was able to use stairs if needed					
had strength to overcome tiredness					
was able to make hand gesture or eye contact with the drivers					
Statement: **I was psychologically able of using the crossing safely because I -**					
estimated vehicle speed/distance rightly					
controlled my mood in assertive crossing actions					
paid attention or thought before crossing					
knew the meaning of traffic signs/road marking & user priority					
knew the provision of fines for violations					

End of Survey and Thank you for completing it

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COM-B প্রশ্নপত্র

আচরণজনিত লক্ষ্য - নিরাপদে পথচারী ক্রসিং ব্যবহার

নির্দেশনা - এই প্রশ্নপত্রটি রাস্তা পার হওয়ার সময় পথচারীদের পারাপারের সুবিধাগুলির (যেমন জেব্রা ক্রসিং, ফুট ওভার ব্রিজ, আন্ডারপাস) ব্যবহারের বিষয়ে আপনার ব্যক্তিগত অভিজ্ঞতা বা প্রতিক্রিয়া সম্পর্কে জিজ্ঞাসা করবে। এই জরিপটি ব্যক্তির পরিবর্তে জনসংখ্যার সামগ্রিক আচরণ বোঝার জন্য ব্যবহার করা হবে, যেহেতু প্রতিক্রিয়াগুলি অনুসন্ধানে এটি অংশগ্রহণকারীদের কাছে ফিরে আসবে না। প্রশ্নপত্রটি পূরণ করতে আপনি এই কাগজের প্রশ্নপত্রটি ব্যবহার করতে পারেন অথবা ওয়েবসাইট (https://behave-for-design) প্রবেশ করতে পারেন।

(ক) জনসংখ্যা সংক্রান্ত তথ্য - অনুগ্রহ করে টিক চিহ্ন (✓) ব্যবহার করুন

১. আপনার লিঙ্গ কি?
o পুরুষ
o মহিলা
o অন্যান্য/বলতে ইচ্ছুক নহে

২. আপনার বর্তমান বৈবাহিক অবস্থা কি?
o বিবাহিত
o অবিবাহিত
o তালাকপ্রাপ্ত বা বিধবা

৩. আপনার কি সন্তান আছে?
o হ্যাঁ o না

৪. আপনার বয়সের ক্যাটাগরি চিহ্নিত করুন
o ১২ বছরের নিচে
o ১২ - ১৮ বছর
o ১৯ - ২৫ বছর
o ২৬ - ৩২ বছর
o ৩৩ - ৩৯ বছর
o ৪০ বছর এবং উপরে

৫. আপনার পেশা কি?
o মাধ্যমিক বিদ্যালয়ের শিক্ষার্থী
o কলেজ / বিশ্ববিদ্যালয়ের শিক্ষার্থী
o শিল্প / গার্মেন্টস কর্মী
o বাজার কর্মী
o অন্য,উল্লেখ করুন ....

৬. আপনি কি কখনো রাস্তা পার হওয়ার সময় দুর্ঘটনার শিকার হয়েছেন?
o হ্যাঁ o না

(খ) আচরণ

৭. মার্চ/2020 এর আগে (কোভিড পূর্ববর্তী সময়) কোন ধরনের ক্রসিং আপনার সবচেয়ে নিকটবর্তী ছিল? অনুগ্রহ করে শুধুমাত্র একটি বক্সে টিক (✓) দিন -

জেব্রা ক্রসিং ☐

ফুট ওভার ব্রিজ ☐

আন্ডারপাস ☐

অগ্রাধিকারহীন ধরণ ☐

৮. আপনার কোভিড পূর্ববর্তী (মার্চ/ ২০২০ এর আগে) আচরণ স্মরণ করে, আপনি কত ঘন ঘন নিম্নলিখিত আচরণগুলিতে জড়িত ছিলেন? ডানদিকে দেখানো স্কেল ব্যবহার করে অনুগ্রহ করে নিচের বিবৃতিগুলোকে টিক (✓) দিন।

স্কেল
১ কখনোই না
২ কদাচিৎ
৩ মাঝে মাঝে
৪ ঘন ঘন
৫ সবসময়

	১	২	৩	৪	৫
(ক) যখন আমার কাছাকাছি ক্রসিং ব্যবহার করার সুযোগ পেয়েছিলাম, আমি সেটি ব্যবহার করেছিলাম					
(খ) সময় বাঁচাতে বা নিজের সুবিধার জন্য, আমি ইচ্ছাকৃতভাবে নিয়মলঙঘন আচরণে জড়িত ছিলাম যেমন কোনাকুনিভাবে গন্তব্যস্থলে গমন, নিষিদ্ধ ক্রসিং পথ ব্যবহার ইত্যাদি					
(গ) আমি ধীরে ধীরে হেটে, চালকের দিকে চিৎকার বা অভদ্রভাবে অঙ্গভঙ্গি করে , গাড়িতে আঘাত ইত্যাদি আচরণের মাধ্যমে আমার রাগ প্রকাশ করেছিলাম					
(ঘ) পার হওয়ার পর বুঝতে পেরেছিলাম যে কারো সাথে কথা বলা, মোবাইল ফোন ব্যবহার করা, উল্টো দিকের কারো কাছে যাওয়া ইত্যাদি কারণে আমি পারাপারে মনোযোগ দিতে বা যানবাহনের গতিবিধি লক্ষ্য করতে ব্যর্থ হয়েছি					

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৯. যখন আপনি এমন অবস্থায় ছিলেন যেখানে আপনাকে রাস্তা পার হওয়ার জন্য আপনার হাত ব্যবহার করতে হয়েছিল, নিচের কোন অঙ্গভঙ্গিটি আপনি সবচেয়ে বেশি করেছেন এবং কতবার চালকরা আপনাকে যেতে দিয়েছেন? অনুগ্রহ করে ছবির উপরে একটি বাক্সে টিক (✓) দিন যা আপনার অঙ্গভঙ্গি উপস্থাপন করে।

☐	☐	☐	☐	কতবার যেতে দিয়েছে?, টিক (✓) দিন-
				যেতে দেয়নি ☐ কদাচিৎ যেতে দিয়েছে ☐ মাঝে মাঝে যেতে দিয়েছে ☐ ঘন ঘন যেতে দিয়েছে ☐ সবসময় যেতে দিয়েছে ☐

১০. ক্রসিং বা রাস্তা পারাপার শুরু করার পর, যখন আপনি দেখেছিলেন যে চালকরা আপনাকে রাস্তা পার হতে দিতে চায় না, তখন নিচের কোনটি আপনি সবচেয়ে বেশি করেছিলেন ?

শুধুমাত্র একটি বাক্সে টিক (✓) দিন	আপনি কতবার করেছেন?, *শুধুমাত্র একটি বাক্সে টিক (✓) দিন*
থেমেছি ☐ ফিরে এসেছি ☐ দ্রুত দৌড়ে রাস্তা পার হয়েছি ☐	কখনোই না☐ কদাচিৎ☐ মাঝে মাঝে☐ ঘন ঘন☐ সবসময়☐

১১. রাস্তা পার হওয়ার সময় যখন চালকরা সাড়া দিচ্ছিল না, এমন অবস্থায় প্রায় দুর্ঘটনার পরিস্থিতিতে আপনি কত ঘন ঘন পড়েছিলেন? দয়া করে একটি বাক্সে টিক (✓) দিন -

কখনোই না ☐ কদাচিৎ ☐ মাঝে মাঝে ☐ ঘন ঘন ☐ সবসময় ☐

(গ) সক্ষমতা, সুযোগ ও অনুপ্রেরণা

১২. কোভিড শুরু হওয়ার আগে, নিম্নের কারণ/বিবৃতিগুলির সাথে আপনি কেমন মতামত পোষণ করেন? ডানদিকে দেখানো স্কেল ব্যবহার করে প্রতিটি আইটেমকে টিক (✓) দিয়ে রেট দিন।	**স্কেল** **-২ মোটেই একমত না** **-১ একমত না** **০ কোনোটিই না** **+১ একমত** **+২ পুরোপুরি একমত**				
	-২	-১	০	+১	+২
বিবৃতি: **নিরাপদে ক্রসিং ব্যবহার করার জন্য আমার নিম্নলিখিত বাস্তব সুবিধা/সুযোগ ছিল-**					
সংক্ষিপ্ত ক্রসিং সময়					
ক্রসিংয়ের অবস্থান সুবিধাজনক					
সহজে এবং সব ঋতুতে ব্যবহার উপযোগী ক্রসিং					
ট্রাফিক সাইন এবং রোড মার্কিং থাকা					
ট্রাফিক আইন অমান্যকারীর বিরুদ্ধে ব্যবস্থা					
একটি নির্দিষ্ট এলাকায় পারাপার নিশ্চিত করতে ফুটপাথ/মাঝে পথচারী বেড়া					
পিক আওয়ারে পথচারীদের জন্য পর্যাপ্ত জায়গা/রাইট অফ ওয়ে					
চালক এবং পথচারীর পারস্পরিক দৃশ্যমানতা					
রাস্তার মাঝখানে/পাশে যথেষ্ট অপেক্ষার জায়গা					
ক্রসিং এর আগে গাড়ির গতি হ্রাসকরণ ব্যবস্থা					

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স্কেল	-২	-১	০	+১	+২
বিবৃতি: **নিরাপদে ক্রসিং ব্যবহার করার জন্য আমার নিম্নলিখিত সামাজিক সুযোগগুলো ছিল-**					
পরিবার/প্রতিষ্ঠান থেকে শিক্ষা/সহযোগিতা পাওয়া					
আমার পরিচিত অনেকেই ক্রসিং ব্যবহার করেন					
সময়ে সময়ে পিতামাতা কর্তৃক নিরাপত্তা বিষয়ক সতর্কতা					
নির্দিষ্ট সময়ে অনেক পথচারী দল বেঁধে পার হওয়া					
প্রভাবশালী ব্যক্তিদের (শিক্ষক/ম্যানেজার/নেতা) ক্রসিং ব্যবহার					
বিবৃতি: **আমি নিরাপদে ক্রসিং ব্যবহার করতে অনুপ্রাণিত হয়েছিলাম কারণ আমি -**					
আমার পারপারের আচরণ উন্নত করার পরিকল্পনা করেছিলাম					
ক্রসিং ব্যবহার করে সন্তুষ্ট ছিলাম					
ঝুঁকিপূর্ণ পারাপার এড়িয়ে উপকৃত হয়েছি, যেমন হঠাৎ দৌড়ানো, রাস্তায় সিদ্ধান্তহীনতা, যানবাহনের ফাঁক দিয়ে পার হওয়া, চালক যেতে দেবে ধরে নেয়া					
আত্মবিশ্বাসী ছিলাম যে আমি নিরাপদে ক্রসিং ব্যবহার করতে পারব					
সুবিধার চেয়ে নিরাপত্তাকে প্রাধান্য দিয়েছিলাম					
সচেতনতা অভিযান থেকে উৎসাহিত হয়েছিলাম					
ক্রসিং ব্যবহার করার জন্য পুরস্কার/প্রশংসা পেয়েছিলাম					
অন্য পথচারীদের দেখে ক্রসিং ব্যবহার করেছি					
বিবৃতি: **আমি নিরাপদে ক্রসিং ব্যবহার করতে অনুপ্রাণিত হয়েছিলাম কারণ আমার -**					
সৃষ্টিকর্তার প্রতি বিশ্বাস, যা আমার ব্যবহার করার ইচ্ছাকে শক্তিশালী করে					
আগের ভালো অভিজ্ঞতা থেকে তৈরি অভ্যাস					
ক্রসিং ব্যবহারে ভাল অনুভূতি/ব্যবহার না করার জন্য অপরাধী অনুভূতি					
প্রিয়জনদের জন্য আত্মরক্ষার প্রয়োজন অনুভব করি					
সড়ক দুর্ঘটনাজনিত আঘাত/মৃত্যুর ভয় আছে					
বিবৃতি: **আমি নিরাপদে ক্রসিং ব্যবহার করতে শারীরিকভাবে সক্ষম ছিলাম কারণ আমি -**					
হাঁটতে পেরেছিলাম					
সিঁড়ি ব্যবহার করতে পেরেছিলাম					
ক্লান্তি কাটিয়ে ওঠার শক্তি ছিল					
চালকদের সাথে হাতের ইশারা বা চোখের যোগাযোগ করতে সক্ষম হয়েছিলাম					
বিবৃতি: **আমি নিরাপদে ক্রসিং ব্যবহার করতে মানসিকভাবে সক্ষম ছিলাম কারণ আমি -**					
যথাযথভাবে গাড়ির গতি/দূরত্ব অনুমান করতে পেরেছিলাম					
জোরপূর্বক পারাপারের সময় মেজাজ নিয়ন্ত্রণ করতে পেরেছিলাম					
মনোযোগ দিয়ে বা চিন্তা করে পার হয়েছিলাম					
ট্রাফিক চিহ্ন/ রোড মার্কিং এর অর্থ এবং ব্যবহারকারীর অগ্রাধিকার সম্পর্কে জানতাম					
নিয়মলঙ্ঘনের জন্য জরিমানার বিধান সম্পর্কে জানতাম					

সমীক্ষার সমাপ্তি এবং এটি সম্পন্ন করার জন্য আপনাকে ধন্যবাদ

Appendix B COM-B Driver Questionnaire with Bengali version

ID-

Target Behaviour- yielding to pedestrian

Instructions- This questionnaire will ask about your personal experiences with, or reactions to, the yielding attitude towards pedestrians (especially students and workers) around available crossing facilities (such as zebra crossing, footbridge, underpass, or any other type). Please submit the filled questionnaire to the surveyor in person.

Please use tick (✓)

1. What is your educational status? o Primary school o High school o College/University **2. What type of vehicle do you drive?** o Bus/Minibus o Truck/pick-up o Private Car o Three-wheeler or other slow-moving types	**3. Where there is moderate pedestrian traffic, what is the speed limit for vehicles?** o 40 Km/hour o 60 Km/hour o 80 Km/hour **4. How many years of driving experience do you have?** o Below 5 years o 5-10 years o 11-20 years o 21-30 years o above 30 years	**5. In which route(s) you drive frequently?** o Nabinagar to chandra highway o Dhaka-Sylhet highway o Highway route other than the above two **6. When pedestrians cross the road, have you ever been involved in or seen an accident?** o Yes o No

Behaviour

7. Which types of crossings have you seen on the roads while driving before March/2020 (pre-COVID time)? Please use tick mark (✓) on one or more boxes-

Zebra crossing ☐

Footbridge ☐

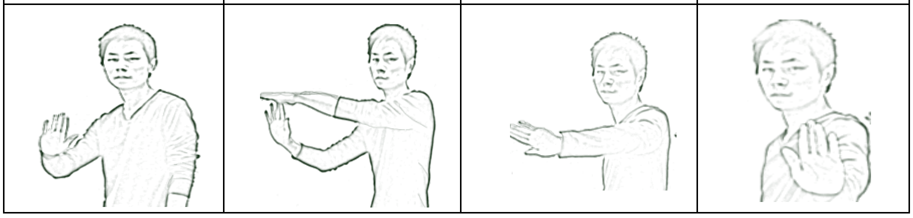
Underpass ☐

Non-priority type ☐

8. Recalling the pre-COVID situation (before March/2020), how often have you noticed the pedestrians (especially students/garment industry or marketplace workers) being involved in the following behaviours <u>around pedestrian crossings</u>? Please rate the following statements with a tick (✓), using the scale on the right.	**Scale** **1** Never **2** Infrequently **3** Sometimes **4** Frequently **5** Always				
	1	**2**	**3**	**4**	**5**
(a) when there was a nearby crossing to them, they used that					
(b) they were involved in violation behaviours such as crossing diagonally from where they were to their destination point, using prohibited crossing paths, etc.					
(c) they expressed their anger through behaviours such as yelling at drivers, making a rude hand gesture, walking slowly, hitting a driver's vehicle, etc.					
(d) they failed to pay attention or look at the traffic properly because of talking to someone, using a mobile phone, joining someone on the opposite side, etc.					

9. When you were in a situation where pedestrians used their hands, which of the following gestures they mostly made? Please tick (✓) only one box above the picture that represents the pedestrians' gesture.

☐	☐	☐	☐



10. What level did you yield to pedestrians generally, with or without their gestural appeal?

Never ☐ Infrequently ☐ Sometimes ☐ Frequently ☐ Always ☐

11. When pedestrians have started crossing, but there was a situation that did not allow them to complete the crossing, which of the following actions have they mostly made, and how often?

Tick (✓) one box only	How often they did? Tick (✓) one box only -
Stopped ☐ Returned ☐ Ran fast across the road ☐	Never ☐ Infrequently ☐ Sometimes ☐ Frequently ☐ Always ☐

12. How often have you ended up in a near-accident situation while interacting with pedestrians when they cross a road? Please tick (✓) one box.

Never ☐ Infrequently ☐ Sometimes ☐ Frequently ☐ Always ☐

Capability, Opportunity, and Motivation

13. Recalling again the pre-COVID situation, how much do you agree with the following statements about how you allow pedestrians to cross? Please rate each item with a tick (✓) using the scale on the right.	**-2** Strongly disagree **-1** Disagree **0** Neither **+1** Agree **+2** Strongly agree **Scale**				
	-2	**-1**	**0**	**+1**	**+2**
Statement: **I have yielded to pedestrians, while seeing following physical opportunities-**					
short crossing path & designated waiting area for pedestrians					
traffic sign or advance road marking available					
measures against traffic law violators					
pedestrian fences on footpath/median to ensure crossing in a designated area					
drivers & pedestrians are visible to each other					
enough waiting area in the middle/at side of a road					
having speed reducer before crossing					
crossing on speed reducer					

Scale	-2	-1	0	+1	+2
Statement: **I have yielded to pedestrians, while noticing following social opportunities-**					
many pedestrians use the crossing					
warning against random crossers through their verbal or gestures					
crossing in groups at specific times					
Statement: **I was motivated to let pedestrians cross-**					
when they were in the specified area by avoiding random crossing which was comfortable for me					
when they had good crossing behaviour, which triggered my positive attitude					
because I considered earlier because of the potential risks as they could show impulsive behaviour, or assume that I would yield to them					
when they knew the meaning of traffic signs/marking as I expected					
Statement: **I was motivated to let them cross because of their -**					
profession, as I have family members with a similar profession					
vulnerable group (children/women), to whom I care naturally					
assertiveness (waiting in the street, walking quickly or extending an arm toward the crossing) which made me stop then					
fear expression of traffic injury or casualties that made me anxious					
Statement: **I was physically able to let pedestrians cross, when they -**					
were at distances but they were visible for my good eyesight					
used hand gesture/eye contact I braked					
were dressed in unique colours I noticed easily					
Statement: **I was psychologically able to let pedestrians cross, when they -**					
well-judged my vehicle speed/distance that prompted me to make in-time decision					
displayed different types of crossing behaviour earlier that I remembered					
followed traffic signs/marking and crossing priority rules that were known to me					

Opinion-based Question-14. We know, some of the facilities are not in place on highways, such as overhead flashing beacons (overhead lights on a street that on and off) or signal/push button-based crossings. Taking these options into account with present available options (traffic signs/markings), which facilities would you like to see on highways to ensure drivers' yielding behaviour towards pedestrians are adequate? Please choose with tick (✓) on one or more boxes.

☐ overhead flashing lights over crossing
☐ signal/push button-based crossings
☐ present available options (traffic signs/ stop line before crossing)

End of Survey and Thank you for completing it

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পরিপূরক COM-B **প্রশ্নপত্র** (চালকদের জন্য)

আচরণগত লক্ষ্য - পথচারীদের যেতে দেয়া

নির্দেশনা - এই প্রশ্নপত্রটি পথচারীদের পারাপারের বিদ্যমান সুবিধাগুলির (যেমন জেব্রা ক্রসিং, ফুট ওভার ব্রিজ, আন্ডারপাস, বা অন্য কোন ধরনের) আশেপাশে পথচারীদের (বিশেষ করে ছাত্র ও শ্রমিক) প্রতি আপনার ব্যক্তিগত অভিজ্ঞতা, অথবা প্রতিক্রিয়া সম্পর্কে জিজ্ঞাসা করবে। দয়া করে জরিপকারীর কাছে ব্যক্তিগতভাবে পূরণকৃত প্রশ্নপত্র জমা দিন।

অনুগ্রহ করে টিক (✓) ব্যবহার করুন

১. আপনার শিক্ষাগত যোগ্যতা কি?
o প্রাথমিক বিদ্যালয়
o উচ্চ বিদ্যালয়
o কলেজ/বিশ্ববিদ্যালয়

২. আপনি কোন ধরনের গাড়ি চালান?
o বাস/মিনিবাস
o ট্রাক/পিক-আপ
o ব্যাক্তিগত গাড়ি
o থ্রি-হুইলার বা অন্যান্য ধীর গতির যান

৩. যেখানে মাঝারি পথচারী যাতায়াত আছে, সেখানে যানবাহনের গতি সীমা কত?
o ৪০ কিমি/ঘন্টা
o ৬০ কিমি/ঘন্টা
o ৮০ কিমি/ঘন্টা

৪. আপনার কত বছরের গাড়ি চালনার অভিজ্ঞতা আছে?
o ৫ বছরের নিচে
o ৫ - ১০ বছর
o ১১ - ২০ বছর
o ২১ - ৩০ বছর
o ৩০ বছরের উপরে

৫. আপনি কোন রুটে ঘন ঘন গাড়ি চালান?
o নবীনগর থেকে চন্দ্রা হাইওয়ে
o ঢাকা-সিলেট মহাসড়ক
o উপরের দুটি ছাড়া অন্য হাইওয়ে রুট

৬. পথচারীদের রাস্তা পার হওয়ার সময় ,আপনি কি কখনও দুর্ঘটনার সাথে জড়িত ছিলেন বা দেখেছেন?
o হ্যাঁ
o না

আচরণ

৭. মার্চ/২০২০ এর আগে (কোভিড পূর্ববর্তী সময়)গাড়ি চালানোর সময় আপনি রাস্তায় কোন ধরণের ক্রসিং দেখেছেন? দয়া করে এক বা একাধিক বাক্সে টিক (✓) ব্যবহার করুন-


জেব্রা ক্রসিং ☐


ফুট ওভার ব্রিজ ☐


আন্ডারপাস ☐


অগ্রাধিকারহীন ধরণ ☐

৮. কোভিড পূর্ববর্তী (মার্চ/ ২০২০ এর আগে) আচরণ স্মরণ করে, <u>ক্রসিং এর চারপাশে</u> আপনি কত ঘন ঘন পথচারীদের (বিশেষত শিক্ষার্থী/পোশাক শিল্প বা বাজার শ্রমিক) নিম্নলিখিত আচরণগুলির সাথে জড়িত থাকতে লক্ষ্য করেছিলেন? দয়া করে ডানদিকের স্কেল ব্যবহার করে নিচের বিবৃতিগুলোকে টিক (✓) দিয়ে রেট দিন।	**১ কখনোই না ২ কদাচিৎ ৩ মাঝে মাঝে ৪ ঘন ঘন ৫ সবসময়**				**স্কেল**
	১	২	৩	৪	৫
(ক) যখন তাদের কাছাকাছি ক্রসিং ছিল, তারা সেটি ব্যবহার করেছিল					
(খ) তারা নিয়মলঙ্ঘন আচরণে জড়িত ছিল যেমন কোনাকুনিভাবে গন্তব্যস্থলে গমন, নিষিদ্ধ ক্রসিং পথ ব্যবহার ইত্যাদি					
(গ) ধীরে ধীরে হেটে, চালকের দিকে চিৎকার বা অভদ্রভাবে অঙ্গভঙ্গি করে , গাড়িতে আঘাত ইত্যাদি আচরণের মাধ্যমে তারা তাদের ক্ষোভ প্রকাশ করেছিল					
(ঘ) কারো সাথে কথা বলা, মোবাইল ফোন ব্যবহার করা, উল্টো দিকের কারো কাছে যাওয়া ইত্যাদি কারণে তারা পারাপারে মনোযোগ দিতে বা যানবাহনের গতিবিধি লক্ষ্য করতে ব্যর্থ হয়েছিল					

৯. যখন আপনি এমন অবস্থায় ছিলেন যেখানে রাস্তা পার হওয়ার জন্য পথচারীরা তাদের হাত ব্যবহার করেছিল, তখন নিচের কোন অঙ্গভঙ্গিটি তারা বেশিরভাগই করেছিল এবং আপনি কতবার তাদের যেতে দিয়েছিলেন? অনুগ্রহ করে ছবির উপরে একটি বাক্সে টিক(✓) দিন যা পথচারীদের অঙ্গভঙ্গির প্রতিনিধিত্ব করে।

☐	☐	☐	☐	আপনার যেতে দেয়া, টিক (✓) দিন-
				যেতে দেইনি ☐ কদাচিৎ যেতে দিয়েছি ☐ মাঝে মাঝে যেতে দিয়েছি ☐ ঘন ঘন যেতে দিয়েছি ☐ সবসময় যেতে দিয়েছি ☐

১০. ক্রসিং বা রাস্তা পারাপার শুরু করার পর, যখন এমন একটি পরিস্থিতি ছিল যা তাদের পারাপার সম্পূর্ণ করতে দেয়নি, তখন নিচের কোনটি তারা সবচেয়ে বেশি করেছিল এবং তা কতবার করেছিল?

শুধুমাত্র একটি বাক্সে টিক (✓) দিন	কতবার তারা করেছিল?, *শুধুমাত্র একটি বাক্সে* টিক (✓) দিন
থেমেছিল ☐ ফিরে এসেছিল ☐ দ্রুত দৌড়ে রাস্তা পার হয়েছিল ☐	কখনোই না☐ কদাচিৎ☐ মাঝে মাঝে☐ ঘন ঘন☐ সবসময়☐

১১. পথচারীরা রাস্তা পার হওয়ার সময় তাদের সাথে বুঝাপড়ার সময় প্রায় দুর্ঘটনার পরিস্থিতিতে আপনি কত ঘন ঘন পড়েছিলেন? দয়া করে একটি বাক্সে টিক(✓) দিন।

কখনোই না ☐ কদাচিৎ ☐ মাঝে মাঝে ☐ ঘন ঘন ☐ সবসময় ☐

সক্ষমতা, সুযোগ ও অনুপ্রেরণা

১২. কোভিড শুরু হওয়ার আগের পরিস্থিতি পুনরায় স্মরণ করে, আপনি কীভাবে পথচারীদের পার হতে দেন সে সম্পর্কে নিম্নলিখিত বিবৃতিগুলির সাথে আপনি কেমন মতামত পোষণ করেন? ডানদিকের স্কেল ব্যবহার করে প্রতিটি আইটেমকে একটি টিক (✓) দিয়ে রেট দিন।	**-২ মোটেই একমত না -১ একমত না ০ কোনোটিই না +১ একমত +২ পুরোপুরি একমত**			**স্কেল**	
	-২	-১	০	+১	+২
বিবৃতি: **আমি পথচারীদের যেতে দিয়েছি, যখন নিম্নলিখিত বাস্তব সুযোগ দেখেছিলাম-**					
সংক্ষিপ্ত ক্রসিং পথ এবং পথচারীদের জন্য নির্ধারিত অপেক্ষার জায়গা					
ট্রাফিক সাইন বা অগ্রিম রোড মার্কিং থাকা					
ট্রাফিক আইন অমান্যকারীর বিরুদ্ধে ব্যবস্থা					
একটি নির্দিষ্ট এলাকায় পারাপার নিশ্চিত করতে ফুটপাথ/মাঝে পথচারী বেড়া					
চালক এবং পথচারীর পারস্পরিক দৃশ্যমানতা					
রাস্তার মাঝখানে/পাশে যথেষ্ট অপেক্ষার জায়গা					
পথচারী পারাপারের আগে গতিরোধক					
গতিরোধক এর উপর পথচারী পারাপার					

স্কেল	-২	-১	০	+১	+২
বিবৃতি: **আমি পথচারীদের যেতে দিয়েছি, যখন নিম্নলিখিত সামাজিক সুযোগ লক্ষ্য করে ছিলাম-**					
অনেক পথচারী কর্তৃক ক্রসিং ব্যবহার করা					
ক্রসিং ব্যাতিত অন্য কোনো স্থান দিয়ে পার হওয়া ব্যক্তিদের মৌখিক বা অঙ্গভঙ্গির মাধ্যমে সতর্ক করা					
নির্দিষ্ট সময়ে দল বেঁধে পার হওয়া					
বিবৃতি: **আমি পথচারীদের পার হতে দিতে অনুপ্রাণিত হয়েছিলাম -**					
যখন তারা যত্রতত্র ক্রসিং না করে নির্দিষ্ট ক্রসিং এলাকায ছিল, যা আমার জন্য সুবিধাজনক ছিল					
যখন তারা পারাপারের সময় ভালো আচরণ করেছিল, যা আমার ইতিবাচক মনোভাবের সূচনা করেছিল					
কারণ তারা আবেগপ্রবণ আচরণ দেখাতে পারে, বা তাদেরকে যেতে দেয়া হবে এটা ভাবতে পারে, যা আমি সম্ভাব্য ঝুঁকি হিসেবে আগেই বিবেচনা করেছি					
যখন তারা ট্রাফিক সাইন/মার্কিং এর অর্থ জানত, যা আমি আশা করেছিলাম					
বিবৃতি: **আমি পথচারীদের পার হতে দিতে অনুপ্রাণিত হয়েছিলাম কারণ তাদের -**					
যে পেশা সেই একই পেশার সদস্য আমার পরিবারেরও আছে					
ঝুঁকিপূর্ণ জনগোষ্ঠী (শিশু/মহিলা) যাদের প্রতি আমি স্বাভাবিকভাবেই যত্নশীল					
দৃঢ়তা (রাস্তায় অপেক্ষা করা, দ্রুত হাঁটা বা ক্রসিংয়ের দিকে হাত বাড়িয়ে দেওয়া) যা আমাকে তখন থামতে তাড়িত করেছিল					
যানবাহনের আঘাত বা হতাহতের ভয় অভিব্যক্তি, যা আমাকে উদ্বিগ্ন করে তুলে					
বিবৃতি: **আমি পথচারীদের পার হতে দিতে শারীরিকভাবে সক্ষম ছিলাম ,যখন তারা -**					
দূরে ছিল কিন্তু আমার ভালো দৃষ্টিশক্তির জন্য দৃশ্যমান ছিল					
হাতের ইশারা/ চোখ দিয়ে যোগাযোগ করেছিল তখন ব্রেক করেছিলাম					
ব্যতিক্রমী রঙের পোশাক পরিহিত ছিল তখন সহজেই লক্ষ্য করেছিলাম					
বিবৃতি: **আমি পথচারীদের পার হতে দিতে মানসিকভাবে সক্ষম ছিলাম, যখন তারা -**					
আমার গাড়ির গতি/দূরত্ব ভালভাবে উপলব্ধি করেছিল যা আমাকে সময়মতো সিদ্ধান্ত নিতে উদ্‌বুদ্ধ করেছিল					
আগে ক্রসিং করার সময় বিভিন্ন ধরনের আচরণ করেছিল যা আমার মনে ছিল					
ট্রাফিক সাইন /মার্কিং এবং ক্রসিং টাইপের জন্য অগ্রাধিকার নিয়ম মেনে পার হয়েছিল যা আমার জানা ছিল					

মতামত ভিত্তিক প্রশ্ন ১৩. আমরা জানি, কিছু সুবিধা হাইওয়েতে নেই, যেমন ওভারহেড ফ্ল্যাশিং বীকন (রাস্তায় ওভারহেড লাইট যা জ্বলে-নিভে), বা সিগন্যাল/পুশ বোতাম-ভিত্তিক ক্রসিং। এই বিকল্পগুলিসহ বর্তমান বিকল্পগুলি (ট্রাফিক সাইন / রোড মার্কিং) বিবেচনায় নিয়ে, পথচারীদের পর্যাপ্ত পরিমানে যেতে দেয়া নিশ্চিত করতে আপনি হাইওয়েতে কোন সুবিধাগুলি দেখতে চান? অনুগ্রহ করে এক বা একাধিক বাক্সে টিক (✓) দিয়ে নির্বাচন করুন।

☐ ক্রসিংয়ের উপর ওভারহেড ফ্ল্যাশিং লাইট
☐ সংকেত/পুশ বোতাম-ভিত্তিক ক্রসিং
☐ বর্তমান বিকল্পগুলি (ট্রাফিক চিহ্ন/ ক্রসিংয়ের পূর্বে স্টপ লাইন)

সমীক্ষার সমাপ্তি এবং এটি সম্পন্ন করার জন্য আপনাকে ধন্যবাদ

Appendix C Participants information sheet for survey

This survey is a part of a research project named '---'. Please read the following information carefully and ask us if anything is still not clear to you.

1. Introduction
I am a PhD student at the University of Leeds in the UK, with financial assistance from the Bangladesh Government. I am researching pedestrian safety, intending to improve the design of crossing facilities and motivate pedestrians to use them.

2. Participation
Your participation in this survey is entirely voluntary. To take part, you need to physically collect the questionnaire or an online questionnaire link while visiting you or your institutional representatives. Completing a questionnaire will confirm your consent. However, if your age is below 18, you need to inform this information sheet to your parents and take verbal consent that you are participating in the survey. The questionnaire will ask about your gender, age, education, profession, road crossing type that you use, and your past (before COVID starts) road crossing behaviour (if you are pedestrian) or past yielding behaviour (if you are a driver). The questionnaire will also ask a few questions to understand your capability, opportunity, and motivation concerning your past behaviour.

3. Expected Risks and Benefits
There are minimal risks associated with your participation in this survey. In some questions regarding past behaviour, you may feel awkward to state your response. However, as the survey is anonymous, you do not need to mention your name or contact number in the survey form. However, suppose you are interested in participating in a total of twenty- mobile top-up/credit prize draw (total amount TK 20,000) as a reward. You will have a chance to win a mobile phone credit amount of TK 1,000 in each draw (1prize: 20 interested participants). In that case, ~~you~~ your contact number and questionnaire ID will be noted on a separate piece of paper. More importantly, as you are a road user, this research project will benefit you, especially pedestrians, by understanding the behaviour and improving the existing crossing facilities.

4. Data withdrawal, confidentiality and privacy
You can withdraw your data at any time by mentioning your questionnaire ID within two weeks of having completed the survey through sending a request to the researcher's e-mail (mentioned below). Upon getting such a request, the researcher will make confirmed by sending a receipt. This is because we will aggregate the data, and after two weeks, we will not be able to identify your data.

The survey is anonymous. You do not need to mention your name or contact number in the survey form. This survey will be used to understand the overall population's behaviour rather than individuals as it does not trace responses back to the participants.

The data will be secured and stored based on the University of Leeds guidance for good research practice and data protection.

QUESTIONS / FURTHER INFORMATION ABOUT THE RESEARCH PROJECT
For any questions or require further information:
Mohammad Shaheen Sarker, Lead researcher, Institute for Transport Studies (ITS)
E-mail: tsmss@leeds.ac.uk, Mobile no- 01713401810 (Bangladesh)
CONCERNS / COMPLAINTS REGARDING THE CONDUCT OF THE RESEARCH
For any concerns or complaints about the ethical conduct of the research project:
Dr Yue Huang, Associate Professor, Institute for Transport Studies (ITS)
E- mail: y.huang1@leeds.ac.uk, Work phone-+44-113-343-2254

Appendix D Participants information sheet for workshops

You are invited to participate in a workshop under a research project named **'-------------------'**. *Please read the following information carefully to decide whether or not you wish to take part*

1. Introduction
I am a PhD student at the University of Leeds in the UK, with financial assistance from the Bangladesh Government. I am researching pedestrian safety, intending to improve the design of crossing facilities and motivate pedestrians to use them.

2. Participation
Your participation in workshop is entirely voluntary. You are invited to participate in the participatory workshops at a convenient venue or using an online platform. You will get at least a week to decide whether you will take part in the workshop or not.

In the workshop, you will take part in a focus group discussion. The research team will act as a facilitator to conduct several focus group discussions to understand the behavioural factors that influence the target behaviour (uses of crossing safely for pedestrians' group). During your discussion, the lead researcher will play short video clips of drivers' group interviews to understand drivers' attitudes in yielding towards pedestrians, including their yielding behaviour. Same focus group participants will be involved in a design team.

After selecting preliminary workshop participants, information sheets and consent forms will be supplied to the design participants earlier (a week before the main workshop). If you are a student of age below 18, you must show this information sheet to your parents for his/her sign in the consent form. The participants will have to submit the signed consent form to the lead researcher at the day workshop.

Each pedestrian's focus group consists of 5 (five) participants and will be accompanied by a local road agency (RHD) professional while designing interventions. Each focus group discussion will be recorded and transcribed. At the end of the design process, design teams for research sites will produce different design layouts or interventions. Other stakeholders and experts will also evaluate or give feedback on those interventions.

3. Expected Risks and Benefits
There are minimal risks associated with your participation. During the workshop, to understand the problem of the site, video recording using low resolution or putting a mask on the face will be displayed to avoid respondents' identity. Every participant who attends the workshop or trial run will get TK 500 at the workshop venue to cover conveyance and compensation costs for time. The online participant will also get the same monetary amount to cover the cost of internet data use. All participants will also get a certificate of participation. More importantly, as you are a road user, this research project will benefit you and other pedestrians by understanding the behaviour in-depth and improving the existing crossing facilities.

4. Data withdrawal, confidentiality and privacy
You may withdraw from the study at any stage during focus group discussions or may decline any question at the workshop without giving any reason. The data will be anonymised, and that pseudonyms will be used when the research is written up so that the participants cannot be identified. The data will be secured and stored based on the University of Leeds guidance for good research practice and data protection.

QUESTIONS / FURTHER INFORMATION ABOUT THE RESEARCH PROJECT
For any questions or require further information:
Mohammad Shaheen Sarker, Principal researcher, Institute for Transport Studies (ITS)
E mail: tsmss@leeds.ac.uk, Mobile no- 01713401810 (Bangladesh)

CONCERNS / COMPLAINTS REGARDING THE CONDUCT OF THE RESEARCH
For any concerns or complaints about the ethical conduct of the research project:
Dr Yue Huang, Associate Professor, Institute for Transport Studies (ITS)

Appendix E Consent Form

CONSENT FORM ***Research project -*** '------project name……. **Event name:** Workshop (venue or online based)	Tick (✓) if you agree
I confirm that I have read and understand the information sheet dated [............date] explaining the above research project and I have had the opportunity to ask questions about the project.	
I understand that my participation is voluntary and that I am free to withdraw during focus group discussion without any reason and any negative consequences. In addition, should I wish not to answer any question or questions, I am free to decline.	
I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. I understand that participants' comments will be treated as confidential.	
I understand that the data collected from me may be stored and used in relevant future research in an anonymised form.	
I understand that relevant sections of the data collected during the study may be looked at by individuals from the University of Leeds or from regulatory authorities where it is relevant to authorise my participation in this research.	
I agree to take part in the above research project and will inform the lead researcher should my contact details change.	

E mail: y.huang1@leeds.ac.uk, Work phone-+44-113-343-2254

Name of participant	
Participant's signature/Parent's signature (for the student of age under18 years participant)	
Date	
Name of lead researcher/ Research assistant	
Signature	
Date	

Appendix F Descriptives of predictors (pedestrian COM items)

Variable	ID	Range	Mean	Std. Dev.
short crossing time	PO1	4.0	3.507	1.0898
convenient location of crossing	PO2	3.0	4.054	0.6848
easy access & usable in all weather	PO3	3.0	4.060	0.6830
having traffic sign and road marking	PO4	4.0	3.972	0.7153
measures against traffic law violators	PO5	4.0	3.874	0.8952
pedestrian fences on footpath/median	PO6	4.0	3.671	0.9991
adequate right of way to meet peak flow	PO7	4.0	3.950	0.8073
visibility of drivers	PO8	3.0	3.962	0.7400
waiting area in the middle/at side of a road	PO9	4.0	3.904	0.7727
vehicle speed reducer before the crossing	PO10	3.0	3.977	0.7126
Education & support from family/institution	SO1	3.0	3.947	0.7271
many known people use the crossing	SO2	3.0	3.930	0.7235
parental safety alert reminders	SO3	3.0	3.997	0.7083
group crossings at specific times	SO4	3.0	4.036	0.7026
influential people use the crossing	SO5	4.0	2.625	1.1697
planning to improve crossing behaviour	RM1	4.0	3.833	0.9179
satisfaction to use the crossing	RM2	3.0	3.947	0.6799
benefit from avoiding risky crossings	RM3	4.0	3.894	0.7440
feeling confident in safe uses the crossing	RM4	3.0	3.921	.06724
prioritising safety over convenience	RM5	3.0	3.927	0.6480
persuasion from awareness campaign	RM6	4.0	3.186	1.1571
reward/praise for using the crossing	RM7	4.0	2.158	1.1610
uses of crossing seeing other pedestrians	RM8	4.0	3.317	1.1396
faith in God strengthens willingness to use	AM1	4.0	4.077	0.7887
habit formation from previous experiences	AM2	4.0	3.861	0.8236
feeling for using the crossing	AM3	4.0	4.077	0.8013
feeling self-protection for beloved ones	AM4	3.0	4.156	0.6614
fear of traffic injury/death	AM5	3.0	4.193	0.7078
ability to walk	PC1	3.0	4.179	0.7161
ability to use stairs if needed	PC2	3.0	3.931	0.7238
strength to overcome tiredness	PC3	4.0	3.813	0.9941
hand gesture or eye contact with drivers	PC4	3.0	4.030	0.7307
estimation of vehicle speed/distance	PsC1	4.0	3.871	0.7381
mood control in assertive crossing	PsC2	4.0	3.947	0.8801
paying attention or thought before crossing	PsC3	4.0	3.970	.07663
Knowledge of traffic signs, marking	PsC4	4.0	3.897	0.7599
knowing the provision of fines for violations	PsC5	4.0	3.387	1.0992

Appendix G Multigroup analysis output

(A) Multigroup analysis between males and females

Path	Original β (Males)	Original β (Females)	Original difference	95% CI Range	Permutation p-value
Motivation -> Safe crossing use	0.403	0.135	0.268	-0.228 0.223	0.018
PC -> Motivation	0.122	0.208	-0.085	-0.215 0.215	0.444
PC -> Safe crossing use	0.224	0.039	0.185	-0.223 0.203	0.087
PO -> Motivation	0.245	0.182	0.064	-0.256 0.215	0.638
PO -> Safe crossing use	0.207	0.375	-0.168	-0.162 0.174	0.053
PsC ->Motivation	0.174	0.248	-0.073	-0.247 0.24	0.554
SO -> Motivation	0.312	0.314	-0.001	-0.218 0.231	0.993
SO -> Safe crossing use	0.164	0.344	-0.179	-0.201 0.211	0.092

(B) Multigroup analysis between students and workers

Path	Original β (Students)	Original β (Workers)	Original difference	95% CI Range	Permutation p-value
Motivation -> Safe crossing use	0.385	0.242	0.143	-0.225 0.25	0.222
PC -> Motivation	0.205	0.084	0.122	-0.219 0.219	0.304
PC -> Safe crossing use	0.079	0.207	-0.127	-0.203 0.203	0.238
PO -> Motivation	0.326	0.044	0.282	-0.251 0.252	0.024
PO -> Safe crossing use	0.275	0.298	-0.022	-0.174 0.182	0.8
PsC ->Motivation	0.24	0.267	-0.027	-0.24 0.251	0.822
SO -> Motivation	0.201	0.387	-0.186	-0.222 0.233	0.12
SO -> Safe crossing use	0.207	0.123	0.084	-0.216 0.191	0.423

Appendix H Summary notes for pedestrian behaviour and drivers' yield

Question 1. "What are the pedestrians crossing behaviours often you have seen in or around a designated crossing of a road?"

Drivers' comments	Drivers' notable quotes
- Workers use crossings more (M) - From eight in the morning to five in the afternoon (DS) - They run/walk under the footbridge & cross a road diagonally (MW) - The phone conversation is too much, especially in the afternoon, not paying attention to vehicle horns, even not hearing (M) - They come towards the street with raising hands (right hand)/ Students do more (M) -Workers cross with the help of a guard showing the red flag to the drivers (DS, MW) - Market workers are not educated enough. They are careless and force the car has to brake (MW) - Pedestrians often do not see the vehicle come from the opposite direction while crossing a road (M) -. Pedestrians don't see their fault but blame drivers and even show power. They beat, abused, and talked differently in some instances (D) - they don't cross at a designated point. Instead, they show rush / hurry up when school or office time is over (in the afternoon) /They run or cross haphazardly (M) - The market is more of a general public movement where hawkers do not obey crossing rules at all (MW) - The market is more of a general public movement where hawkers do not obey crossing rules at all - School friends cross the road, tell stories and look back sometimes (MS) -usually, village people do not know how to cross (DW)	" As a bus driver, I have seen everywhere in Bangladesh that maximum pedestrians do not know how they should cross. Most of them don't know…even do not know what zebra crossing is." (MW) "Around 80% cases, they do not use footbridge despite having it."(there is some reason behind it) (MW) "It is often seen for many. ………someone raises a hand, others follow and do run from the back."(M) "They cross a road with mobile phones talking without following me that I am driving. When I press the horn at a closer point, pedestrians get fear and take action by moving forward or backwards. This situation happens mostly in mobile phone talking" (M) "We normally maintain normal speed in front of the school with keeping attention and slowing our vehicles." (D)

Notes: All statement/quote in table refer general agreement of pedestrians unless the followings are added at the end:
Major agreement by all denoted by (M)
- Agreement by students only denoted by (MS)
- Agreement by workers only denoted by (MW)
Major disagreement by all denoted by (D)
- Disagreement by students only denoted by (DS)
- Disagreement by workers only denoted by (DW)

Question 2. From your experiences, what situations decide your willingness or intentions to yield pedestrian, whether you will give or not in or around a designated crossing of a road?

Drivers' comments	Drivers' notable quotes
Drivers yield to pedestrians when they - • think that they will not fall into a problem for letting them go (DS) • do not need to wait for a long time • see hand gestures of pedestrians, seeking attention for yielding, from a long distance to brake or control vehicle (MW) • see old people/women/blind/disabled/deaf not hearing horn/person moving with children (MW) • see long time waiting with bags in hand etc. (DS) • drive during school class hours; otherwise, students will be late /closing time/tiffin time (DS) • see from a distance that someone reaches the middle portion of a road while crossing (MS) • memorise the location of the frequent crossing • see the traffic sign/signboard on the highway **Drivers do not yield to pedestrians when -** • Their mood change usually happens in the afternoon (MW) • They do overtime duties • They are in a hurry	"Having footbridge, but someone is crossing the underneath. In that case …….. feeling angry to get no logic behind such crossing despite having a footbridge." (MW) "Nobody intentionally runs their vehicle over someone. We also have kids go to school''. "If it is seen that someone does run for crossing a road, but the situation does not permit to yield, there could be a danger for the vehicle passenger or driver if the driver yield''. (MW) "We are willing to yield to pedestrians even who cross the road at a location where no designated crossing nearby, but don't have the willingness to whom try to cross a road despite having footbridge nearby''. "As a driver, I try to understand the crossing motives of pedestrians and decide whether I should go or not.'' (D) "One accident cost a lot with miseries, not because we don't want to yield." "Pedestrians don't read the mind of a driver. When a vehicle is riding over the night……. pedestrians need to judge the origin of the vehicle from where it came…if they fail to do so, an accident occurs.'' (D)

Notes: All statement/quote in table refer general agreement unless the followings are added at the end:
Major agreement by all denoted by (M)
- Agreement by students only denoted by (MS)
- Agreement by workers only denoted by (MW)
Major disagreement by all denoted by (D)
- Disagreement by students only denoted by (DS)
- Disagreement by workers only denoted by (DW)

Appendix I Descriptives of predictors (driver COM items)

Variable	ID	Range	Mean	Std. Dev.
short crossing path & designated waiting area	PO1	4	3.47	1.003
traffic sign or advance road marking available	PO2	3	3.56	0.834
measures against traffic law violators	PO3	4	3.49	1.013
pedestrian fences on footpath/median	PO4	3	3.76	0.905
drivers & pedestrians are visible to each other	PO5	3	3.78	0.818
enough waiting area in the middle/at side of a road	PO6	4	3.00	0.933
having speed reducer before crossing	PO7	4	3.55	0.972
crossing on speed reducer	PO8	4	3.28	1.010
many pedestrians use the crossing	SO1	3	3.95	0.780
warning against random crossers	SO2	4	3.34	0.808
crossing in groups at specific times	SO3	3	4.07	0.795
avoiding random crossing	RM1	3	4.15	0.685
good crossing behaviour	RM2	3	4.04	0.697
potential risks from impulsive behaviour	RM3	3	4.19	0.694
know the meaning of traffic signs/marking	RM4	4	3.15	0.931
profession, similar to drivers' family members	AM1	4	3.84	0.933
vulnerable group (children/women)	AM2	3	4.24	0.721
assertiveness	AM3	3	3.99	0.870
fear expression of traffic injury or casualties	AM4	4	4.09	0.767
visible for good eyesight	PC1	3	4.20	0.740
hand gesture/eye contact	PC2	3	4.01	0.810
dress in unique colours	PC3	3	3.99	0.816
well-judgement of vehicle speed/distance	PsC1	4	4.16	0.682
remembering different past crossing behaviour	PsC2	4	4.20	0.713
known traffic signs/marking & crossing priority rules	PsC3	4	2.92	1.071

Appendix J Multigroup analysis of bus and light vehicle drivers

Path	Original β (Bus)	Original β (Light vehicle)	Original difference	95% CI (range)	Permutation p-value
Motivation -> Yield	0.412	0.668	-0.256	-0.219 0.221	0.056
O1 -> Motivation	-0.006	0.276	-0.282	-0.309 0.306	0.131
O1 -> Yield	0.367	0.189	0.178	-0.206 0.223	0.164
O2 -> Motivation	0.218	0.36	-0.142	-0.251 0.216	0.358

Appendix K Thematic code analysis for drivers’ yield

Code (no. of reference/ participants)	**Factors** (+ for positive and – for negative role/attitude)
Social/ professional role (2/2)	Same profession in driver’s family (+)
Attitude/belief about consequences (14/11)	Specific time (+) Attitude to kids (+) Long queue/waiting time (-) Perceived danger for the vehicle passengers (-) Pedestrians in a dangerous position on the road (+) Zebra crossing is pedestrians’ right (+) Crossings nearby but no use (-) Fear from possible aggression (+) Cautiousness of rural pedestrians (+) Risk perception (+) Physically challenged or disabled person (+) Meeting expectations from pedestrians (+)
Barriers (17/11)	Crossing under footbridge Crossing without looking properly Showing hurries and choosing a shortcut Indecision in the middle of the road Drivers vision constraint Unpredictable response on vehicles horn while using a phone Office start and finish Peak flow time Sudden running without giving time to brake More duties become mood change Less road signage Diagonal crossing instead of zebra Drivers hurries Unpredictable crossing action or move
Capability/Control (6/4)	Judging pedestrians capability Adjusting pedestrians Behaviour Memorising earlier actions Understanding motives
Communication and decision-making (4/3)	Raising hands by pedestrians Notice from a reasonable distance Mutual understanding
Emotions (6/5)	Older adults, women or disabled people, kids
Env. Restructuring /Facilitator (5/3)	Crossings in front of key places (schools, mosques) Crossing signs and markings
Social influences (2/2)	Platoon size Specific times of a day

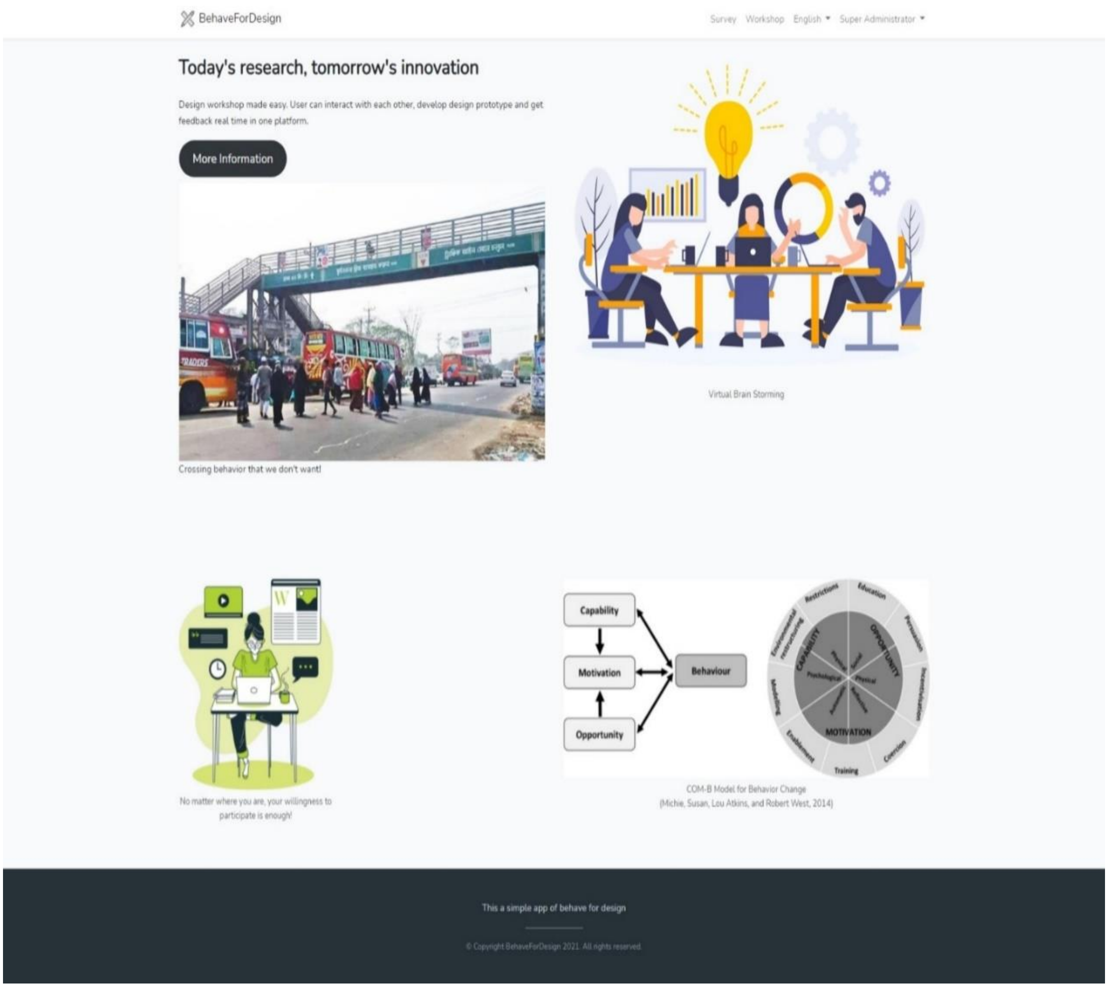
Appendix L Thematic code analysis for pedestrians' safe use of crossings

Code (no. of ref. /participants, Student: Worker)	**Factors** (+ for positive and – for negative role/attitude)
Social/ professional role (1/1, W)	Own responsibility (+)
Attitude/belief about consequences (11/9,4:7)	Lesson learning for the previous accident due to violation (+) Threats from addicted people (-) Feeling unsafe for traffic movement (-) Security concern in the evening (-) Fear of accident (+) Drivers' unwillingness to slow down unless forced (-) Feeling safe for a distance of vehicles (+) Negative past experiences on drivers yielding (-)
Barriers (28/17,16:12)	18-26 years people don't obey traffic laws and do risky crossing Less knowledge and crossing skills Drag-addicted people occupy crossings Avoid footbridge in hurries Drivers unyielding Crossings are not visible due to the road side shop/garages Peer pressure in a group Less security in the evening, especially for women Small size NMV or motorbikes don't want to stop Congestion within the footbridge at the weekend Running or stopping in the middle of the road Preferring convenience rather than safety Drivers' knowledge of traffic rules limited Distracted mind
Capability/Control (2/2,1:1)	Estimation of vehicle speed and distance Believing in the ability to cross
Communication and decision-making (3/2,0:3)	Raising hands Waiting for suitable moments
Benefit (1/1, 0:1)	Convenient location
Env. Restructuring (6/5,5:1)	Highly visible zebra crossing Crossing signs and markings Light signal system having a speed reducer
Facilitator (8/8,5:3)	Presence of traffic police Having time in hand Less traffic on the road Road lamppost
Social influences (5/5,3:2)	Following others In group In a group, forcefully stop a vehicle

Appendix M Needs identification form

COM-B components (Associated Intervention functions)	What needs to happen for users to use the designated crossing facility safely?	Is there a need for change?
Capability		
(*Training/Enablement/Education*)		
Opportunity		
(*Training/Enablement/Restriction/Env. Restructuring/Modelling*)		
Motivation		
(Education/*Persuasion/Incentivisation/*		
***Training/Coercion/ Enablement/Env. Restructuring/Modelling*)**		
Behavioural diagnosis on the relevant COM-B component		

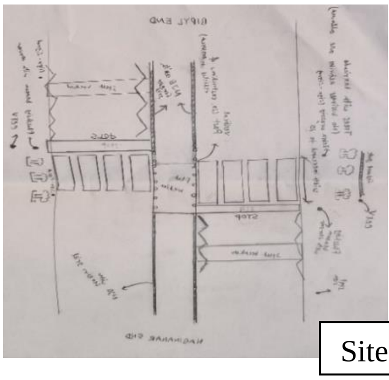
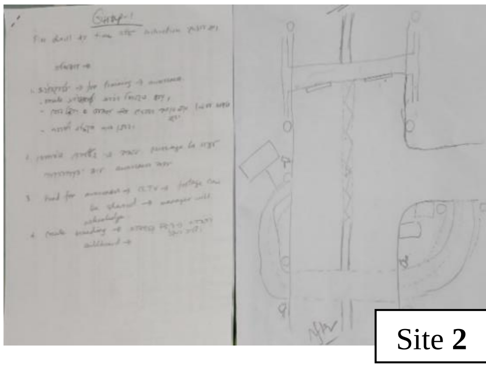
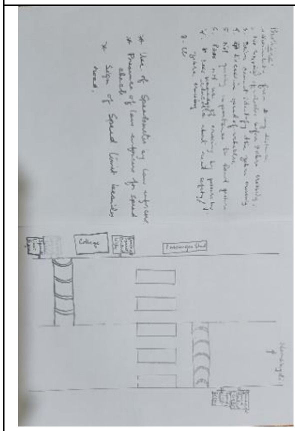
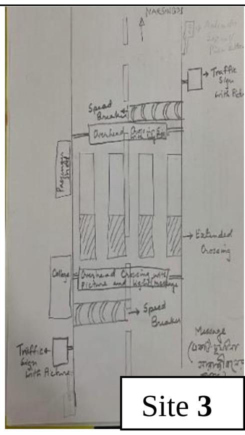
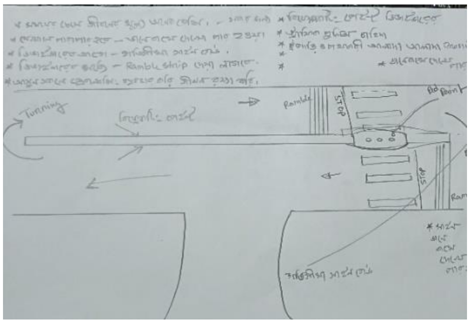
Appendix N BehaveForDesign



Appendix O Key information from field unit

Question-1. Describe how you involve the designing process in developing interventions?
Feedback- Initially field unit observe practical field condition to understand the necessity. The unit also visits sites to ask a few road users to know the problems and analyse accident data. Then, intervention type and dimensions are selected following the road sign manual before fixing location and intervention. Later, when funds become available, then intervention is implemented.
Question-2. How do you fix the priority in the number of crossings and types such as zebra and footbridge? Say, within the fund, what number of crossings do you usually give in a 10 Km stretch of road?
Feedback- Field unit could manage about 50% of the required Zebra crossing; however, it could not provide a footbridge or underpass due to the high cost. The field unit decides the crossing type and location based on the highest priority and funds available. For example, in 10 Km of the road, it could not be possible to provide one footbridge even due to the scarcity of funds.
Question-3. How have you designed or involved your crossings of research sites?
Feedback- Field units usually design crossing without adequate analysis on the spot-based dataset. Instead, it relies on type design. Footbridges designs are replicated following the design of footbridges that were implemented in a similar condition in other places. However, field units take the design from the central design office (for example, the bridge management wing). For the research sites, type designs are followed. A footbridge is provided in one research location without surveying or analysing data. However, as this location has a T-type intersection and many people cross, it could be assumed the high demand for such facility on that location.
Question-4. New transport act has scope to share the responsibility even to the designer. How could a blaming game between service delivery authority and road users (pedestrians and drivers) be addressed?
Feedback- It is a reality that due to the shortage of workforce; it could not be possible to visit the site and take data from the design team (central) before designing. For that reason, software or any mechanism are needed that can act as a platform of data exchange from the field unit to the design unit where the data could be stored and could be utilised if required for design. Regarding blaming culture, the field unit believes that every party has their personal views. However, several motivational campaigns involving all parties could solve such blaming to some extent. Simultaneously, strict law enforcement should be more focused and implemented to ensure the traffic rules.
Question-5. You advocate data management or analysis on one side; similarly, you are following type design. In such a contradictory situation, how the behavioural data could be managed?
Feedback- The behavioural data are changed on a temporal scale. Therefore, a separate arrangement of doing a survey could be more pragmatic. Such dataset could be stored and renewed after 2-3 years of interval.
Question-6. Why are the users still not encouraged enough to use crossing facilities?
Feedback- From the experiences, it could be stated that they would not use a footbridge until the users are forced, for example. Sometimes, new jersey barriers are provided to protect random crossing behaviour. However, the users try to cross over the new jersey barrier; in such cases, the field unit often relies on a trial-and-error method where more fencing or restrictions are provided to compel the user to follow the crossing path in the designated point. Other issues observed are that the unruly behaviour is more pronounced on highways compared to city areas where law enforcement agencies are present.
Sometimes, various opinions generate from different groups of people, and in some cases, influential persons or other institutions dictate the position of crossing facilities before implementation. In such power pressure, the original design and layout had to be changed or adjusted in some cases.

Appendix P Workshop design sketches

 Site **1**	 Site **2**
  Site **3**	 Site **4**

Appendix Q Experts' evaluation of interventions

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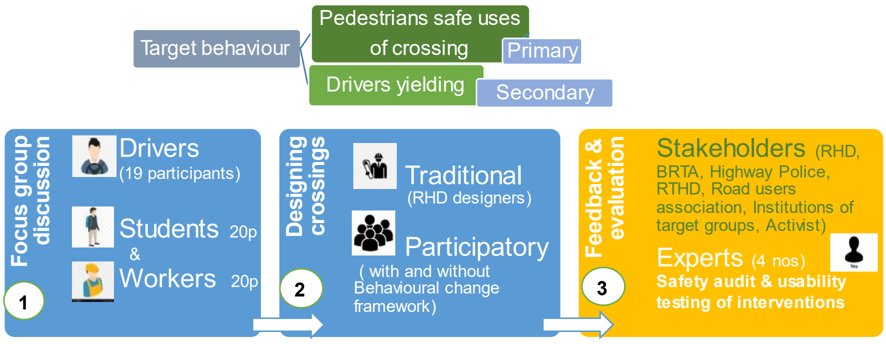
Research Project - **Safety evaluation of protection measures at road crossing to encourage safe road user behaviour in developing countries**



Experiment-combined: Zebra crossing,N540

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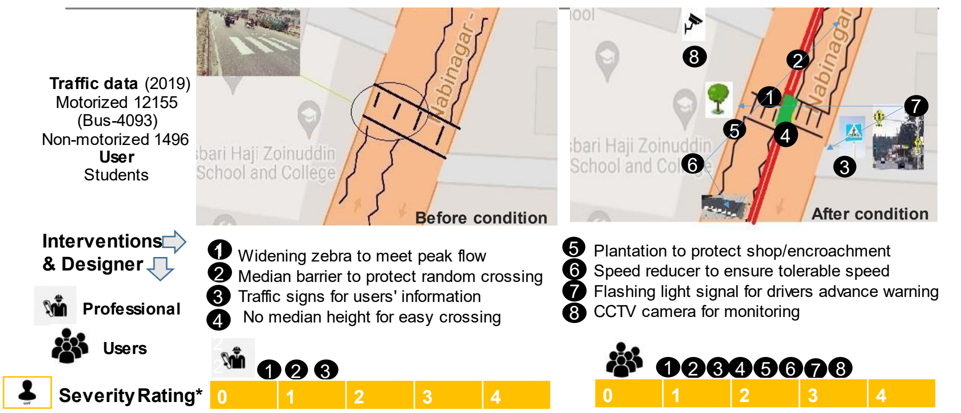

* **0** = No usability problem at all **1** = Cosmetic problem only **2** = Minor usability problem **3** = Major usability problem **4** = Usability catastrophe

Experiment-1&2: Underpass & Footbridge,N540

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Traffic data (2019)
Motorized 12155
Non-motorized 1496
Major users
Garments workers

Professional

Design group

Group-1
Group-2

1 Closing median gap to protect pedestrians
2 Shifting median gap to safe location
3 Traffic sign for informing crossings to users
4 Billboard message on rules/fines/attention
5 CCTV camera for monitoring and safety
6 Motivational persuasive message
7 Embedding safety message into Institutional routine
8 Dustbin & drainage facility for underpass cleanliness
9 Light for remove darkness inside of underpass

Rating* — Professional: 1 2 3 | 0 1 2 3 4 — Group-1: 1 2 3 4 5 6 7 | 0 1 2 3 4 — Group-2: 1 2 3 8 9 | 0 1 2 3 4

* **0** = No usability problem at all **1** = Cosmetic problem only **2** = Minor usability problem **3** = Major usability problem **4** = Usability catastrophe

Experiment-1&2: Zebra crossing (narrow median),N2

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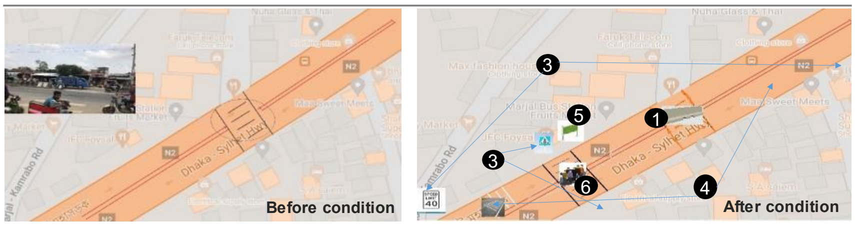


Traffic data (2019)
Motorized 14361
Non-motorized 1175
Users
Marketplace worker

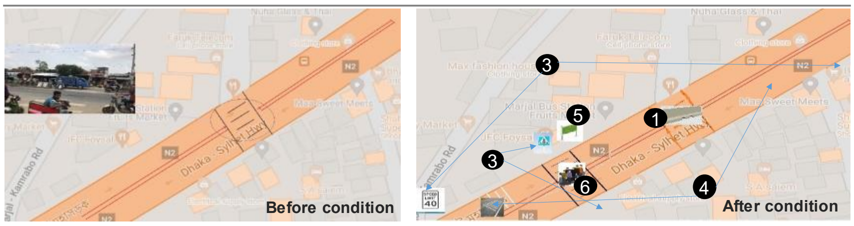
1 Closing divider gap to protect pedestrians
2 Shifting crossing gap to safer location
3 Traffic signs for road users
4 Rumble strips for driver speed/awareness
5 Billboard message on rules/fines/attention/motivation
6 Pedestrian refuge area increasing with safety
7 Police enforcement

Rating* — Professional: 1 2 3 4 | 0 1 2 3 4 — Group-1: 1 2 3 4 5 6 7 | 0 1 2 3 4 — Group-2: 1 2 3 6 | 0 1 2 3 4

* **0** = No usability problem at all **1** = Cosmetic problem only **2** = Minor usability problem **3** = Major usability problem **4** = Usability catastrophe

Experiment-1&2: Zebra crossing (narrow median),N2

UNIVERSITY OF LEEDS



Traffic data (2019)
Motorized 14361
Non-motorized 1175
Users
Marketplace worker

1 Closing divider gap to protect pedestrians
2 Shifting crossing gap to safer location
3 Traffic signs for road users
4 Rumble strips for driver speed/awareness
5 Billboard message on rules/fines/attention/motivation
6 Pedestrian refuge area increasing with safety
7 Police enforcement

Rating* — Professional: 1 2 3 4 | 0 1 2 3 4 — Group-1: 1 2 3 4 5 6 7 | 0 1 2 3 4 — Group-2: 1 2 3 6 | 0 1 2 3 4

* **0** = No usability problem at all **1** = Cosmetic problem only **2** = Minor usability problem **3** = Major usability problem **4** = Usability catastrophe

Appendix R Summary notes for addressing blaming culture issue

Question: ”In the event of traffic injury or causalities, how so-called ‘blaming game’ among pedestrians-drivers-authority could be minimised?”

Drivers’ comments	Drivers’ notable quotes
- Administrative organs need to have functioned (M) - Engineers often put intervention in places where there is no need and don’t put it where needed! (M) - BRTA often certify unfit vehicles/irregularities in giving license (M) -When traffic week observes, then discipline increases on the road (M) - Whenever there is a danger. Then check on the street in different places (M) - Road Safety Day is observed Just in Dhaka(capital)-centered (M) - Rural pedestrians have no idea about the law on highway rules or fines. / Police administration could offer training to control. - Information should be disseminated. The police have to apply rules in the country. Everything will be fine if everyone respects the existing laws fully. The fact is, having laws but lack implementation equally for all. (MS added -*rules for poor but not for rich, that is a problem*; MW added- *rules for poor but not for rich, that is a problem*) - There are police in a place within fifty to a hundred kilometers that are recording the speeds of vehicles. Not in the rest of the site. (MS) - Needs a lot of driving training centers for safe roads	“Foreign (traffic) system is different! In any accident. . . . they consider who’s involved in it ... In our country,…. The public doesn’t see it….. I am being attacked being fired at my vehicle. Not only mine but also five more cars burned in the back.” (M) “The people of the village don’t know how to walk, and on which side of the road, how much speed a car has.” “ There was no traffic sign/signal, board, lighting in the black spots. Nothing is given at all! Many accidents happened. You wouldn’t have missed the day that the truck or bus toppled over the island ………… At last, all things are installed including traffic signs/signals, board, lighting, and even road marking in those spots. This has greatly benefited the people. However, what the accident happened in between- no one took responsibility for it.” (MS added-*Administration should be taken care of the responsibility*: MW added-*lack of facilities on the road, if those facilities were there, the drivers would stop*) “In most cases. . . . Pedestrians don’t find their fault.” (D) (Students commented- *In most cases, drivers are responsible. In some cases, true, but drivers are also responsible in other cases. All need to be more aware and understand the vehicle speed, attitude, need to read the mind of each other;* MW added- *In some cases true, but drivers are also responsible in other cases. All need to be more aware and understand the vehicle speed, attitude, need to read the mind of each other*.) “I should rectify it first. If I’m not right, none can fix it. I have to be right.”

Notes: All statement/quote in table refer general agreement of pedestrians unless the followings are added at the end:
Major agreement is denoted by (M), Agreement by students only denoted by (MS), Agreement by students only denoted by (MW), and Major disagreement is denoted by (D)