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Inclusive intervention design for vulnerable road users: Applying co-design and behaviour change model in Bangladesh

M. Shaheen Sarker [a,1,*], Oliver Carsten [a], Yue Huang [a], Foroogh Hajiseyedjavadi [b]

[a] *Institute for Transport Studies, University of Leeds, LS2 9JT, UK*
[b] *School of Engineering and Built Environment, Birmingham City University, B5 5JU, UK*

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ABSTRACT

In 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. While the Safe System approach emphasises authorities' responsibility for safe facilities, understanding user needs and promoting behaviour change remain underexplored. This study investigates the current design practices in Bangladesh. It compares the impact of conventional design with co-design on intervention quality and examines the further benefits of integrating a behaviour change model 'COM-B'.

Local road agency professionals applied the design process and suggested interventions at four highway sites. Subsequently, four focus group sessions were conducted with students and workers, followed by four design workshops. In each workshop, participants were randomly assigned to two design groups (without and with the application of the behaviour change model), where they designed interventions facilitated by professionals. Lastly, perception ratings of stakeholders and safety assessments by four experts were conducted to evaluate the efficacy of all interventions.

The findings highlight major usability problems in conventional designs, while co-designed interventions demonstrate clear improvements. Notably, integrating a behaviour change model further enhances effectiveness. Stakeholder interviews reveal that co-design fosters shared responsibility and addresses the blame culture. The co-design approach and application of the behaviour change model can address design flaws and promote the proper use of facilities.

1. Introduction

Road traffic crashes result in approximately 1.19 million deaths and 20 to 50 million non-fatal injuries each year worldwide (WHO, 2023). Vulnerable Road Users (VRUs), including pedestrians, motorcyclists, and bicyclists, represent more than half of the global deaths due to road traffic crashes (WHO, 2021). Pedestrians, who lack protection against vehicles in the event of a collision, are among the most vulnerable road users. 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).

Unlike high-income countries (HICs), low and middle-income countries (LMICs) are experiencing a rise in the number of students and workers (Tiwari, 2020). They regularly commute to their educational institutions or workplaces on foot and face heightened vulnerability when crossing highways as pedestrians due to a lack of proper crossing infrastructure. In Bangladesh, roadside environments such as educational, industrial, and commercial activities adjacent to a road create the highest pedestrian crossing flow (iRAP, 2013). Consequently, crossing major arterial roads in Bangladesh for educational or work purposes puts their lives at stake.

Pedestrian safety is a major concern in Bangladesh, as the road traffic

* Corresponding author.
E-mail addresses: sarkermo@gmail.com (M. Shaheen Sarker), o.m.j.carsten@its.leeds.ac.uk (O. Carsten), y.huang1@leeds.ac.uk (Y. Huang), Foroogh.hajiseyedjavadi@bcu.ac.uk (F. Hajiseyedjavadi).
[1] Current Address: Additional Project Director (Superintending Engineer, RHD), Bangladesh Road Safety Project, Roads and Highways Department, Sarak Bhavan, Tejgaon, Dhaka-1215.

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fatality rate is 102.1 per 10,000 vehicles, more than ten times the South-East Asian average of 10.1 (The World Bank, 2020). The reasons for these incidents are complex and multifaceted, involving a range of factors, including institutional weaknesses in intervention design (Wegman, 2017; Bhalla and Shotten, 2019; Turner et al., 2020), violations of traffic laws by road users (Bhattacharjee et al., 2022; McIlroy et al., 2019), and a lack of shared responsibility among stakeholders (Shuey, 2013). In many cases, parties involved in the incident blame each other, leading to a culture of blame and finger-pointing (Job, 2012) rather than a collaborative approach to improving pedestrian safety. In 2018, school students demonstrated massive protests after two high school students were killed in a road crash (Podder et al., 2019). Highway agencies of Bangladesh usually provide at-grade crossings, such as zebra crossings and grade-separated facilities, such as pedestrian footbridges and underpasses. However, data shows that pedestrians' use of crossing facilities is very low in Bangladesh. They tend to cross the road along the shortest distance (iRAP, 2013). Such pedestrian behaviour indicates the crossing facilities' inherent design flaws or individuals' behavioural constraints.

Most of the evidence on effective interventions originated from high-income nations and focuses mainly 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, such as students and workers. A successful intervention depends on the know-how of injury patterns and the knowledge of who is affected (Butchart et al., 2000). The safety needs of VRUs (pedestrians, cyclists, etc.) are a focus of the WHO's Global Plan: Decade of Action for Road Safety 2021–2030. Ironically, less attention has been paid to the safety of vulnerable road users (Ameratunga et al., 2006).

The Safe System approach, despite its efforts to improve pedestrian safety, faces significant challenges, particularly for vulnerable road users exposed to high-speed traffic (Job, 2012). The guidance provided by the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) in the US emphasises various engineering and operational measures that agencies can adopt to enhance safety for pedestrians (FHWA, 2022). However, further work is required to ensure the safety of vulnerable road users and effectively implement the Safe System approach. Belin et al. (2012) highlighted the shared responsibility for safety in implementing Vision Zero, a road safety policy aiming to eliminate all traffic fatalities and severe injuries. The authors argued that system designers must take additional measures to prevent deaths or serious injuries, regardless of any shortcomings of road users.

Human behaviour can be categorised as either unintentional or intentional. Unintended behaviour typically results from human error, while intentional behaviour involves violations and non-compliance (Edmonds, 2016). Rather than errors, violations are the primary contributing factors in pedestrian-related traffic crashes (Dıaz, 2002). Elvik (2023) warned that the widespread tolerance of road traffic law violations is inconsistent with the Safe System approach. Although the Safety System principle underscores the authorities' role in providing facilities for road users, little attention has been given to understanding users' safety priorities and willingness to adapt their behaviour to the available crossing facilities. The mere provision of pedestrian amenities in developing countries does not guarantee their utilisation if they fail to meet users' expectations. To effectively manage these expectations, a consensus must be reached on the type(s) of interventions and the expected degree of behaviour change they can induce (Nag et al., 2020). Involving users in the co-design process can help meet their expectations and foster behavioural change, as they provide valuable input into the design process. In the co-design process, designers can gain insight into users' attitudes and behaviours regarding available intervention options (person-based approach) or explore innovative solutions to modify external factors (system-based approach). Both person- and system-based approaches are recommended in developing countries (Batool, 2012).

"Co-design" refers to a participatory approach to designing solutions (Colapinto et al., 2022). Collaborative innovation practices have existed for over 50 years (Sanders & Stappers, 2008). Although co-design has been used in underdeveloped nations for over three decades (Simonsen & Robertson, 2012), its application remains limited due to several challenges such as the relationship between designers and participants, access to users and stakeholders, participants' capacity to participate, language barriers, allocating time for participants, trust, recognising the importance of the process, allocating resources, and organisational hierarchy (Hussain et al., 2012). These barriers are particularly relevant in the transportation domain, where road safety remains constrained by complex technical requirements, regulatory constraints, significant financial investments, a traditional top-down approach, a lack of awareness among transport professionals, and challenges in coordinating diverse stakeholder groups and managing differing interests. However, in developing country settings, especially community contexts, co-design has gained popularity among contemporary designers (DiSalvo et al., 2012).

In a developed country setting, a study on intervention design aimed at changing drivers' attitudes and behaviours has shown positive outcomes for this design approach (De Jong, 2009). Despite this, very few interventions have been designed and empirically tested, focusing on behavioural change techniques (Davidson et al., 2018). Combining behaviour change models and co-design can be a powerful approach to promote sustainable behaviour change within a community. In the healthcare sector, a study has demonstrated that the combined use of co-design and behaviour change is a promising strategy for formulating a shared vision of challenges and finding potential solutions with quality outcomes (Carvalho et al., 2017). Co-design, where system designers and users negotiate, can complement Vision Zero by offering a contract between system designers and road users (Belin, 2022). This contract can employ appropriate behaviour diagnosis tools or behaviour change models to ensure that if road users adhere to system limits, system designers guarantee they will not be killed or sustain permanent injury. A novel approach involving the integration of a suitable behavioural model into the co-design process could benefit system designers by minimising the uncertainty of system failure, especially in contexts where road users have a history of violations beyond the system limits.

While many behaviour change models have limited or weak theoretical foundation, "COM-B" performs as an overarching model of different health behaviour models such as the theory of planned behaviour, health belief model, social cognitive theory, protection motivation theory, self-determination theory, transtheoretical model, and the health action process approach (Michie et al., 2011). The three components of the COM-B, Capability (physical and psychological), Opportunity (physical and social), and Motivation (automatic and reflective) are all predictive of an individual's willingness to engage in a Behaviour (Michie et al., 2011; Varisco et al., 2020). By integrating the COM-B model, our study highlights a novel method for achieving behaviour change in road safety (Michie et al., 2011; Fylan, 2017; Chadwick, 2018), complementing existing research on comprehensive safety strategies (Aaron et al., 2020) and the benefits of community involvement (Lunetto et al, 2023). The COM-B model can be combined with co-design approaches to maximise the acceptability and feasibility of the co-designed intervention, such as oral care (Lievesley et al., 2022) and eating behaviour (Kalantari et al., 2024). This conceptual framework underscores the importance of a structured and specific goal-oriented approach to uncover the users' needs and what changes are needed to overcome barriers of a target behaviour to find effective interventions.

Understanding how institutional design practices in Bangladesh impact pedestrian safety is limited, particularly concerning intervention design. This study aims to examine the existing design practices in Bangladesh and compare them with the effects of co-design on the quality of outcomes (intervention 1). Subsequently, the study explores the potential improvements that can be achieved by incorporating the COM-B model into the co-design process (intervention 2). Finally, the study investigates the impact of co-design and a behaviour change model in enhancing shared responsibility among stakeholders.

2. Methodology

This experimental study examines four research sites that serve as representative crossings within the road network of Bangladesh (Fig. 1), using a combination of methods. The key activities include key informant interviews and the collection of improvised prototype designs from the road agency, focus group discussions, co-design workshops (with and without using the COM-B model) to develop intervention prototypes, and evaluations through stakeholder feedback and expert assessments. The research sites include a zebra crossing in front of 'Dendabor School and College' (location/site-1) and a footbridge with an underpass nearby at 'Bipyl' (location/site-2) along the N540 highway. Furthermore, zebra crossings are in front of 'Narshingdi Abdul Kader Mollah College' (location/site-3) and the 'Morjal' marketplace area (location/site-4) on road N2.

The researcher and his team conducted the activities from December 2021 to March 2022. These experimental research activities are divided into three stages:

Stage I (December 2021): Before the design workshops, the lead researcher (first author) initially interviewed key informants (n = 3) from the Roads and Highways Department (RHD) and searched available RHD design guidelines. Three key informants from the Roads and Highways Department (RHD) were identified based on their roles and organisational positions related to design and implementation decisions. The key informants included the Executive Engineer of the road safety division and the Executive and Sub-Divisional Engineers of the Manikganj Road Division. These individuals were selected for their involvement in designing and implementing road safety interventions. The researcher reviewed the Road Safety Manual, Geometric Design Standard Manual, Road Safety Audit Manual, and Traffic Signs Manual to gather relevant design guidelines. The search criteria focused on identifying standards and practices related to pedestrian crossings, road safety measures, and traffic management. Content analysis, as outlined by Krippendorff (2018), was employed to extract data on best practices, regulatory requirements, and design specifications outlined in these manuals. Finally, as part of the experiments, the researcher gathered improvised prototype designs of the research crossing sites from road agency professionals.

Apart from the key informant interviews, the lead researcher also conducted interviews with a group of drivers (n = 19) to explore their attitudes toward yielding decisions and pedestrians' crossing behaviour. These drivers were recruited in collaboration with bus and truck drivers' associations, local three-wheeler stands, and the local road agency office, ensuring representation across various vehicle categories such as buses, trucks, cars, and three-wheelers. The insights from these interviews were recorded in audio and video formats. During the workshops, discussions commenced with an overview of pedestrian crossing behaviours around designated facilities, followed by specific inquiries into the drivers' decision-making processes regarding yielding to pedestrians in these areas. Before the workshop sessions began, the research team compiled and shared key comments from the drivers concerning their yielding intentions and views on pedestrians' behaviour.

Stage II (mid-December 2021 to January 2022): The lead researcher and his team visited schools, colleges, marketplaces, and garment factories near the N2 and N-540 routes to meet with institutional representatives. Meetings with institutional representatives were organised through direct outreach and collaboration. The institutional representatives included the head of the institution or their nominated person, with whom the lead researcher conducted discussions to explain the research objectives and criteria for participant selection. Notes were taken during these meetings to document key points and decisions, but the discussions were not audio recorded. Although the institutional representatives were not part of the research team, they played a crucial role in participant recruitment and engagement. The meetings were conducted primarily in the local language, ensuring clear communication. Collaborating with these representatives, suitable participants were selected based on their regular crossing of the research routes and their ability to provide insights. The research team did not count the crossings but relied on the representatives' insights and participant self-reports. A total of 40 participants, were divided into four focus groups

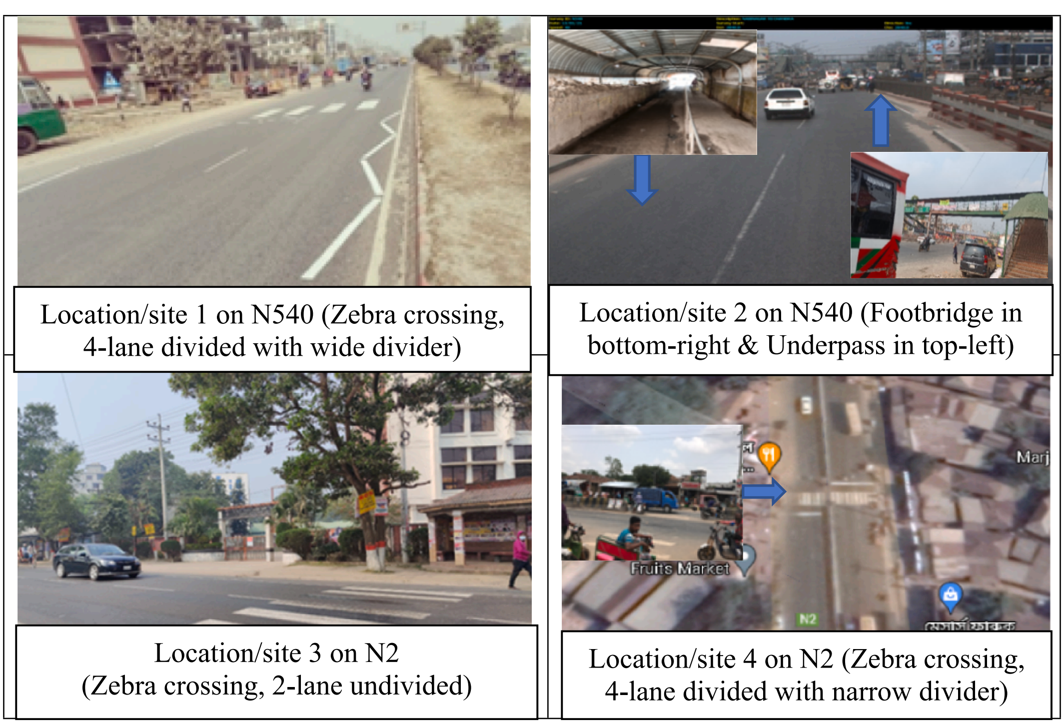

Fig. 1. Research sites.

(college, school, marketplace, and garment industry) for the workshops, each representing distinct road user types. These categories were chosen to capture diverse perspectives and experiences related to road crossings, ensuring the data reflects the varied needs of different road user groups, and allowing for targeted intervention designs tailored to site users. The workshops, held on different days, began with a focus group discussion moderated by the lead researcher, with an assistant acting as a note-taker. In addition to the focus group discussions, intervention design sessions were conducted within design groups, where each focus group was divided into two design groups. The entire workshop activities and conversations were audio and video recorded, with the medium of communication being Bengali.

The discussions revolved around four key issues: pedestrians' crossing behaviour at designated crossing facilities, factors influencing their decision to use crossings safely, stakeholders' roles in addressing the blaming culture for road crashes, and potential solutions. The lead researcher also shared drivers' comments listed before the workshop. The focus group discussions aimed to raise awareness among participants about pedestrian safety and encourage active participation in workshop activities. Conducting focus group discussions before undergoing workshop tasks for intervention design with the same participants can result in better outcomes. According to La Pira et al. (2016), having a preliminary understanding of stakeholders' opinions and helping repeated interaction opportunities effectively arrange the participation process and smooth diverging opinions, leading to more cohesive and well-informed design interventions.

In the design workshops, participants were divided into groups (Group 1 and Group 2) to design each crossing site based on an odd–even registration system. The lead researcher provided materials and logistics, such as pencils, paper, and site information, to facilitate the design process. Due to COVID restrictions, one workshop (for site 3) was conducted online, where site information was uploaded. The lead researcher briefed the design workshop's mission before starting the design procedure of interventions. The local road agency professional facilitated the design team by creating low-fidelity sketch drawings of the research crossing sites, which offered a straightforward and user-friendly approach (Coyette et al., 2007). The local road agency professionals, who are not part of the core research team, facilitated the design sessions. These professionals were recruited through collaboration with the local road agency office responsible for the research site. Their involvement ensured expertise in road design and safety practices relevant to the intervention design process. The institutional designer and research team followed basic steps in prototype design, exploring the problem and deriving solutions (Fig. 2). A study found that the double diamond co-design strategy often saves the design process time (Saad et al., 2020). In Group 1, the COM-B model was applied by structuring the design process around it, while this model was not used in Group 2, serving as a control group for comparison. While comparing the online and in-person workshops, the online workshop faced more technical challenges and lower engagement but was accessible and easy to document. In-person workshops enabled richer interactions and a more intuitive design process with direct access to materials. Despite these challenges, the online format was viable, suggesting potential for future hybrid models.

Stage III (February 2022 to March 2022): After the workshops, the lead researcher reproduced intervention prototypes following design sketches and participants' recommendations for each site. Then, PowerPoint slides were prepared according to the site-specific experimental settings for the evaluation of prototypes through feedback from stakeholders and expert assessments through interviews separately on the convenient and mutually agreed schedule. Experiment 1 examined the differences between the reproduced intervention design by the road agency and the intervention design proposed by workshop participants. Experiment 2 compared Group 1 and Group 2 to assess the impact of using the behavioural model in the co-design process. Specifically, a site-specific experimental setup was created, where interventions for Site 1 were produced by combining suggestions from both Group 1 and Group 2, while for other sites, the interventions suggested by Group 1 and Group 2 were kept separate. This setup allowed for a clear analysis of the behavioural model's influence on design outcomes by comparing the integrated and independent intervention proposals.

The researcher formed an expert panel for intervention evaluation, considering criteria such as evaluation expertise, subject matter expertise, local knowledge, independence, and availability (Molund & Schill, 2004). The panel comprised a certified road safety auditor, an anthropologist, an Accident Research Institute (ARI) academic, and an international transportation specialist. These experts were contacted via email and phone calls, and their participation was confirmed based on their expertise and willingness to contribute voluntarily. In one-on-one interviews, the lead researcher presented slide presentations showcasing the prototypes and sought expert opinions on the experiments using Nielsen's severity rating (Nielsen, 1992), which employs a 5-point Likert scale. The scale ranges from 0 (no usability problem) to 4 (usability catastrophe) for evaluating the suggested interventions at the research site, with additional ratings for cosmetic (1), minor (2), and major usability (3) problems. However, the experts were also given the

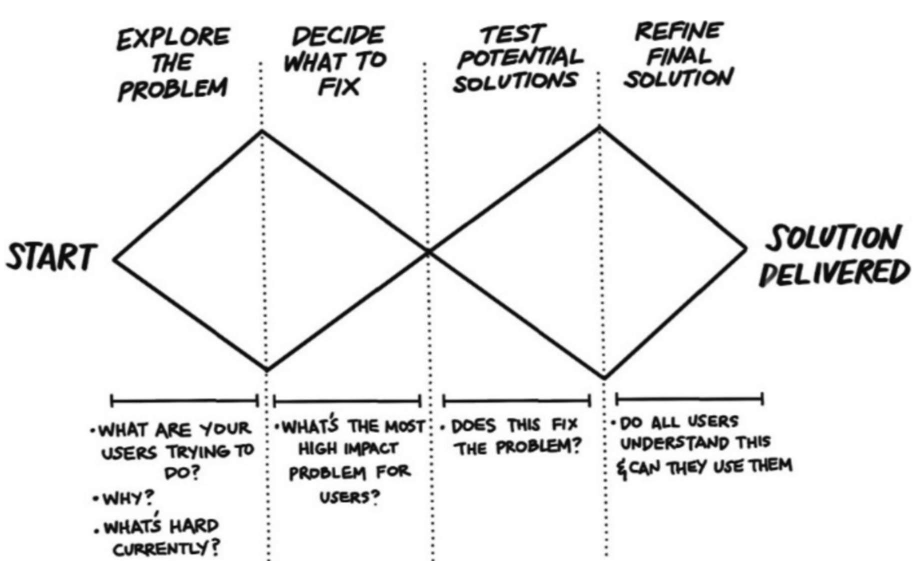

Fig. 2. Prototype design steps in co-design (Aethelyon, 2022).

option to use their preferred scale for evaluation. The interview sessions were conducted in English and audio recorded.

In stakeholder interviews, the researcher interviewed nine stakeholders representing various institutions, including RHD, Bangladesh Road Transport Authority (BRTA), Highway police, Road Transport and Highways Division (RTHD), a drivers association leader, a school teacher, a garments industry manager, a student activist, and the leader of a pedestrians welfare association. During the one-on-one interviews, the researcher presented slide presentations and sought opinions on the experiments using perception ratings based on safety and practicability. The safety rating utilised a 5-point Likert scale, where 1 represented the lowest and 5 represented the highest probability of pedestrians' safety and conflict resolution with vehicles if the suggested interventions were implemented. Similarly, the practicability rating assessed the value for cost and feasibility of implementation, with 1 representing the lowest and 5 representing the highest probability. Perception ratings were used as an analytical tool to quantify stakeholders' evaluations of both safety and practicability, providing a structured way to assess and compare the proposed interventions. At the end of the presentation, qualitative insights were gathered through semi-structured interviews where interviewees were asked four questions (Q1-Q4). All interview sessions were conducted in Bengali language and audio recorded.

Q1. Do you find participatory design effective in achieving safe infrastructure? Will you advocate participatory design within your organisation or support stakeholders who provide infrastructure?

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

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

Q4. What are your suggestions for resolving the so-called "blaming game" among pedestrians, drivers, and authorities?

After the interviews were completed, all audio recordings were transcribed in Bengali using an online transcription service called 'Transkriptor,' which had a 90 % accuracy rate (https://transkriptor.com/support/). The lead researcher then listened to the recordings and corrected errors in the transcribed documents. Subsequently, all verified Bengali documents were translated into English using the Google Docs translation service. The lead researcher also reviewed the translated interview transcripts to ensure the final corrected transcription. Thematic analysis was employed to identify key themes related to the questions (Q1-Q4), exploring perspectives on participatory approaches, behavioural insights, policy implications, and strategies for fostering collaboration and safety improvements in road infrastructure. While the questions directed the analysis, the thematic analysis adhered to the six-step approach based on Braun and Clarke (2012) and Braun et al. (2017). The steps included: (1) familiarising oneself with the data through repeated reading, (2) systematically generating initial codes across the dataset, (3) collating codes into potential themes, (4) reviewing themes to ensure they accurately represented the data, (5) defining and naming themes, and (6) producing the final report by integrating the analysis with data extracts.

3. Results and discussions

3.1. Experts' evaluation

For research site 1, the local engineers of the road agency identified three interventions based on their assessment using standard engineering practices within their institutional capacity and guidelines. The interventions included widening the zebra crossing to accommodate peak flow, installing a median barrier to protect against random crossing, and placing traffic signs to provide information to users. Upon combining the interventions suggested by the two groups, it was observed that the participants also identified these three interventions. In addition, they offered several other interventions, including removing the median height to facilitate easier crossing, implementing plantation to protect shops and prevent encroachment, installing speed reducers to ensure a manageable speed, incorporating flashing light signals to warn drivers, and installing CCTV cameras for monitoring purposes.

For research site 2, the local engineers identified three interventions: closing the median gap to protect pedestrians, relocating the median gap to a safer location, and installing traffic signs to inform users. The co-design participants from Group 1 and Group 2 also identified these three interventions. Additionally, they suggested several other interventions. Group 1 suggested interventions such as displaying billboard messages regarding rules, fines, and attention, installing CCTV cameras for monitoring and safety purposes, incorporating motivational persuasive messages, and integrating safety messages into institutional routines. Group 2 suggested interventions, including providing dustbins and drainage facilities to maintain cleanliness in the underpass and improving lighting to address the issue of darkness in the underpass.

Fig. 3 showcases the workshop participants' settings and designs, illustrating specific physical infrastructure components of the interventions for each site of N540.

For research site 3, the co-design participants (Group 1 and Group 2) identified common interventions, including speed reducers to ensure safe speeds and push button/sensor signals with overhead signs. In addition, Group 1 identified interventions such as widening zebras to accommodate peak flow, billboard messages on rules/fines/attention, motivational messages, and off-site education/hiring of a resource person. Group 2 identified interventions such as *retro*-reflective paint for crossing visibility, overhead speed limit signs for drivers, and police enforcement.

For research site 4, local engineers identified four interventions: closing divider gaps to protect pedestrians, shifting crossing gaps to safer locations, installing traffic signs for road users, and using rumble strips for driver speed/awareness. Group 1 also identified these interventions and suggested additional interventions such as billboard messages on rules/fines/attention/motivation, increasing pedestrian refuge areas with safety measures, and police enforcement. Group 2 suggested increasing pedestrian refuge areas with safety measures, including a few interventions identified by engineers.

Fig. 4 showcases the workshop participants' settings and designs, illustrating specific physical infrastructure components of the interventions for each site of N2.

4.

A total of four experts evaluated all interventions, with three experts using Nielsen's severity rating (see Table 1) and one expert providing a qualitative evaluation.

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). Experts positively commented on the co-design and behaviour change model. The international transportation specialist stated:

Embedding safety messages into the daily routines of garment industry workers is a great idea by co-design participants. Incorporating these messages into regular activities can significantly improve adherence to safety practices and overall awareness.

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. Experts favoured various interventions suggested by both groups, particularly emphasising the benefits of speed-reducing measures and

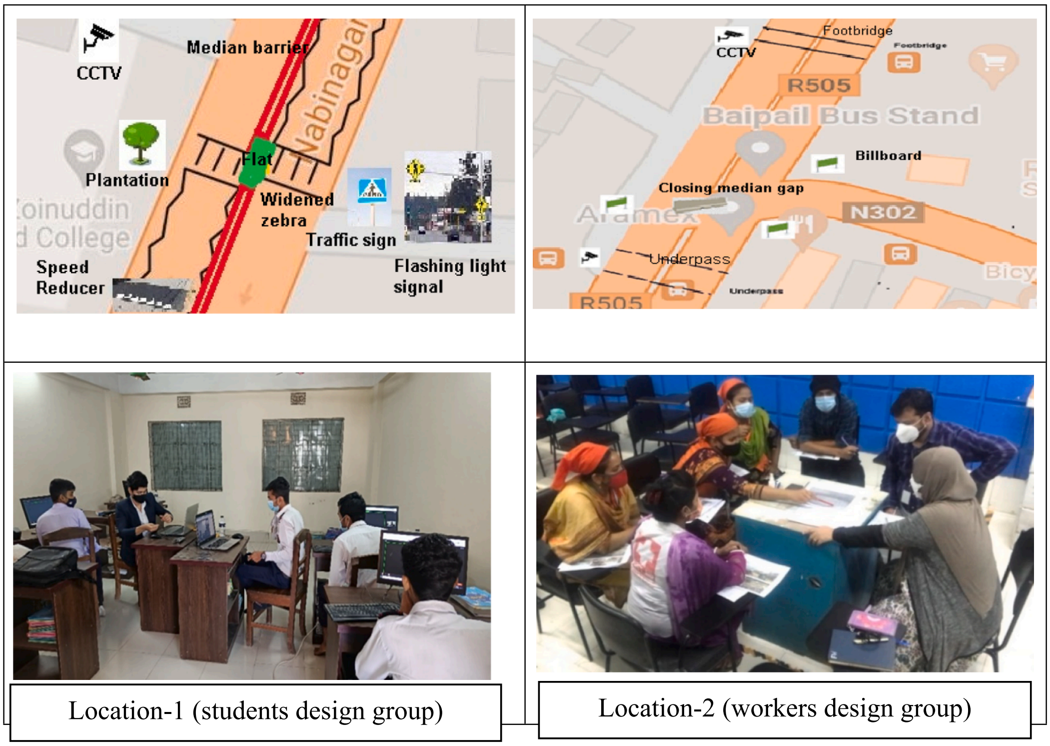

Fig. 3. Workshop settings and design for site 1 (left-top) and site 2 (right-top) on N540.

Fig. 4. Workshop settings and design for site 3 (left-top) and site 4 (right-top) on N2.

signals. The international transportation specialist also highlighted flaws in the existing educational curriculum and praised the people-centred approach implemented by the World Bank in countries like Tanzania:

The current educational curriculum has significant flaws. The people-centred approach implemented by the World Bank in countries like Tanzania is commendable and could serve as a valuable model.

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

Table 1
Experts' ratings of road safety interventions by site.

Experts	Site 1		Site 2			Site 3		Site 4		
	p	u	p	u1	u2	u1	u2	p	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					

Note: p = professional engineers' interventions; u = interventions combined of Group 1 & 2;
u1 = interventions of Group 1; and u2 = interventions of Group 2.

intervention of Group 1 received a severity rating of 0, and the intervention of Group 2 received a severity rating of 2.

Overall, the interventions proposed by Group 1 generally had fewer usability problems than Group 2, suggesting that the inclusion of the behaviour change model in the co-design process contributed to the development of more effective and user-friendly interventions. However, it is essential to note that Group 1 and Group 2 co-design interventions outperformed the engineers' interventions across all four research sites. These findings underscore the critical importance of the co-design process in addressing the challenges outlined in the introduction. Unlike the traditional top-down approach, co-design actively involves vulnerable road users (VRUs), such as pedestrians and cyclists, in the design process. Therefore, the co-design practice can tackle the inherent institutional weaknesses in intervention design. The designers can use the appropriate behavioural model as a diagnosis tool for the co-design participants, especially in the context of VRUs or where the violations of traffic laws by road users are predominant. This involvement ensures that the designed interventions are technically sound and aligned with the users' needs and behaviours.

4.1. Perception rating on interventions

Stakeholders evaluated the design prototypes using a perception rating, considering their perceived safety and practicability. Table 2 displays the stakeholders' assessments, indicating each design prototype's safety and practicability rating.

In the safety ratings, the interventions of Group 1 generally received higher scores than the engineers' intervention, indicating that they were perceived to be safer. For example, at Site 1, the combined intervention of both groups received an average score of 4.11, while the engineers' intervention received an average score of 2.88. Similarly, at Site 2, the intervention of behavioural model users received an average score of 4.0, while the engineers' intervention received an average score of 2.62. Overall, using the behavioural model in co-design positively impacted stakeholders' safety perceptions.

On the other hand, the practicality ratings show that both groups received mixed scores compared to the engineers' intervention. For instance, at Site 1, the combined intervention received a slightly higher average score of 3.75 than the engineers' intervention, which received an average score of 3.0. At Site 4, the intervention of behavioural model users received a slightly higher average score of 3.8, compared to the engineers' intervention, which received an average score of 2.8. However, at Site 2, the engineers' intervention received an average score of 2.75, which was only slightly lower than that of behavioural model users, which received an average score of 4.0. The practicability ratings varied, with some interventions from both groups receiving higher scores than engineers' interventions, while others received slightly lower scores.

4.2. Shared responsibility

The stakeholders unanimously agreed that co-design, also known as participatory design, is a practical approach to achieving safe infrastructure. During the interview, RHD designers stated that they adhered to the Road Sign and Geometric Design Manual of RHD. The RHD representative appreciated the participatory approach and emphasised the importance of considering users' comfort and viewpoint:

In order to take into account users' comfort and viewpoint, I would appreciate the participatory approach. – RHD representative.

The importance of understanding user needs during design was a recurring theme. As the Police representative noted, "Participatory design helps victims understand how to enhance their security." This sentiment was echoed by activists who highlighted the problems with neglecting user perspectives: "Projects without user perspectives lead to inadequate amenities and issues," they remarked. The Garments manager offered a solution: "Participation in crossing design leads to more users utilising the facilities," underlining the value of user buy-in.

The COM-B model emerged as a valuable tool for facilitating discussions about behaviour change. Stakeholders saw its potential in helping participants understand their limitations and the consequences of their actions. The RHD representative highlighted this benefit: "The COM-B model helps participants estimate consequences and understand engineers' limitations." The model's ability to identify areas for improvement was also appreciated. The RTHD representative stated, "The model helps participants identify their flaws and understand where to change." The Police representative saw the model as a tool for ensuring comprehensive discussions: "The model helps check if any points are missed and synchronise discussion." The School teacher emphasised its role in problem identification: "The model helps identify problems among participants".

The stakeholders also discussed the potential impact of this work on future policies. They agreed that involving road users in the design process and using the COM-B model can help inform future policies. The RTHD representative believed that the participatory design should be an effect of the feature policy and benefit both users and policymakers. The BRTA representative highlighted the importance of reaching the

Table 2
Perception rating of road safety interventions by site.

Stake-holders	Site 1 (S, P)		Site 2 (S, P)			Site 3 (S, P)		Site 4 (S, P)		
	p	u	p	u1	u2	u1	u2	p	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)					
Student leader	(2,2)	(3,3)	(2,2)	(3,3)	(3,3)	(3,3)	(2,3)			
Garments manager	(4,3)	(5,4)	(4,3)	(5,4)	(5,4)					
Drivers' leader	3, n/a	4, n/a								

Note: S = safety rating; P = practicability rating; p = professional engineers' interventions;
u = interventions combined of Group 1 & 2; u1 = interventions of Group 1; and.
u2 = interventions of Group 2.

relevant audience to maximise the influence of the findings on policy development:

By involving users in the process, we can ensure that their needs and perspectives are considered, which can benefit both the users and policy-makers. – RTHD representative.

It will definitely have an impact if it is disseminated in an appropriate forum for those who design or are policymakers. – BRTA representative.

The issue of blame was a central concern for many stakeholders. They overwhelmingly agreed that involving all parties in the design process could foster a more collaborative environment. The RHD representative believed, "Involving users eliminates blaming as they would willingly follow the design." The Police representative echoed this sentiment, stating, "Involving all stakeholders decreases blaming by fostering an understanding of everyone's limitations." The activist suggested a broader approach: "Discussing government policy decisions involving the media can shift away from blaming." Additional suggestions included implementing the Safe System Approach (RHD representative) and providing more training and shorter working hours for drivers (Student leader). Ultimately, the Drivers' leader emphasised the importance of identifying the root cause: "It's not right to blame someone until the culprit is determined".

The stakeholders' interviews revealed the importance of shared responsibility in achieving safe road infrastructure. Participatory design was identified as a key approach involving all stakeholders in the design process, fostering a sense of shared responsibility for infrastructure development. By giving everyone a voice and ensuring their involvement, stakeholders feel accountable for the final product and are more invested in its success. Using the COM-B model further promotes shared responsibility by structuring discussions on behaviour problems and solutions, encouraging participants to take ownership of their actions and make necessary changes. Involving all stakeholders in the design process also helps reduce the culture of blaming, as understanding each other's challenges and limitations fosters shared responsibility for the success of the infrastructure. Furthermore, this collaborative approach informs future policies, creating a shared responsibility for their effectiveness. By involving all stakeholders in policy formulation, everyone could feel responsible for their success, emphasising the importance of collaboration and shared responsibility. Overall, the stakeholders recognise that achieving safe road infrastructure requires active participation and shared responsibility from all stakeholders.

5. Conclusions and implications

The findings of this study indicate that interventions developed through co-design and the application of behaviour change models were better received in terms of usability compared to those developed solely by engineers. Stakeholder interviews provided valuable insights into the effectiveness of co-design involving road users and the usefulness of the COM-B model in addressing behavioural issues. The stakeholders acknowledged that involving all relevant parties in the design process and adopting a participatory approach could help reduce the tendency to blame others and foster a collaborative environment. Moreover, they recognised the potential impact of this work on future policies, benefitting both road users and policymakers. The stakeholders' responses underscore the significance of shared responsibility in achieving safe road infrastructure. They acknowledged that every stakeholder has a role in ensuring safety, and that collaboration is essential in attaining this shared goal. This study demonstrated how experts and road users can be brought together to evaluate infrastructure and interventions for VRU safety, highlighting the importance of inclusive co-design processes. By involving diverse stakeholders in the design and evaluation stages, future interventions can be more effectively tailored to meet the needs and preferences of all road users, ensuring more comprehensive and practical safety solutions. Future research should explore the long-term impacts of these interventions and investigate their scalability in other LMIC contexts, thereby contributing to global efforts to improve road safety for vulnerable road users.

In conclusion, the study's findings contribute to the existing knowledge by demonstrating the effectiveness of combining co-design with behaviour change models in improving pedestrian safety. By diagnosing behaviour problems and facilitating targeted behaviour changes, the COM-B model enhances the overall effectiveness of the interventions. This structured and novel approach ensures that interventions are effective and practically viable, as evidenced by the higher safety and usability ratings from stakeholders. The co-design approach fosters a sense of ownership and accountability among stakeholders, leading to more sustainable and effective road safety interventions. Therefore, the authorities should consider the following steps:

(1) The study found that involving pedestrians, drivers, and other vulnerable road users in the design process significantly improves road infrastructure safety, encourages user behaviours, and builds trust among stakeholders. Therefore, the road designer can adopt a co-design approach with an appropriate behaviour change model for diagnosis the problems and finding solution by involving vulnerable road users. The involvement of stakeholders in the design process is crucial for achieving safer road infrastructure and promoting sustainable behaviours.
(2) Share the study's findings with policymakers, road safety committees, and relevant government agencies. They can organise workshops or conferences, 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. This process should include local officials, traffic police, urban planners, road safety experts, community leaders, and representatives of vulnerable road users. Ensuring accessibility and support for marginalised groups and individuals with disabilities will be crucial to fostering an inclusive dialogue.
(3) Invest in comprehensive driver training programs focusing on safe driving practices, awareness of vulnerable road users, and campaigns for 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. This study highlighted the need for better education and training. Research, such as the BRAC (2016) driver training program in Bangladesh, has shown that such programs can improve attitudes and behaviours.
(4) Promote responsible road safety reporting through media engagement, using press conferences, campaigns, and interviews to discuss government policies. Research indicates that media engagement can effectively promote road safety and influence public attitudes (Saporito et al., 2023; Delaney et al., 2004).

Ethical approval

The University of Leeds Research Ethics Committee has given ethical approval for this study (Ref: AREA 20–103). All ethical protocols, including the Participant Information Sheet and Consent Form, were provided to the participants during this research.

CRediT authorship contribution statement

M. Shaheen Sarker: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Oliver Carsten:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Yue Huang:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Foroogh Hajiseyedjavadi:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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