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Voices of the Vulnerable: Insights from A German Road Safety Co-Creation Workshop

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Abstract - Global Road traffic incidents account for approximately 1.19 million fatalities annually, with an additional 50 million people sustaining injuries. Vulnerable Road Users (VRUs) constitute a significant proportion of these statistics (almost half). The scenario is akin to Europe, where 70% of the overall road fatalities are attributed to VRUs. Initiatives like the European Commission's Vision Zero aim to eliminate road accident fatalities and enhance transportation safety. Therefore, understanding the specific challenges VRUs face is crucial to address this issue effectively. While prior studies have explored challenges among specific VRUs, this study comprehensively gathers a wide range of stakeholder groups and analyses the various attitudinal and subjective concerns of VRUs in Germany. By adopting a co-creation approach through online workshops, insights and common challenges faced by VRUs were identified. Key themes such as infrastructural issues, behaviour and attitude, requisite for training and awareness, law and regulation enforcement, personal safety concerns, leveraging technological advancement, environmental concerns, and potential solutions emerged from thematic analysis of qualitative data. This provides valuable information for those instrumental in driving change and for those delivering policy. Moreover, this study underscores the importance of involving end-users in planning mobility infrastructure to tailor safety measures to diverse VRU needs. Adopting a human-centric design approach is critical to reducing road injuries and fatalities and ensuring equitable access and safety for all VRUs in Germany.

***Keywords*:** Living Lab, Vulnerable Road User, Micro-mobility, Cyclists, Scooters, Pedestrians.

1. Introduction

According to statistics,1.19 million fatalities are attributed to road accidents globally, with more than half involving Vulnerable Road Users (VRUs) [1]. In Europe, the road safety landscape mirrors global concerns, prompting initiatives like Vision Zero proposed by the European Commission (EC), which seeks to eliminate road accident fatalities and set a precedent for worldwide efforts. In line with the EC's "Strategic Action Plan on Road Safety," the German road safety strategy 2021-30, urges to reduce the number of road fatalities in Germany by 40 % by 2030 [2]. In light of these, it is crucial to understand the challenges and concerns of the VRUs to create road safety solutions and action plans for the VRU. It is important for all stakeholder groups to have an equitable platform to articulate their challenges and influence decisions regarding mobility safety. Currently, there is a deficiency in comprehensive approaches that encourage local community engagement in decision-making and encourage proposals for enhancing safety. Embracing a community-driven approach that prioritises vulnerable and marginalised road users fosters socially inclusive urban development with significant impact [3]. Therefore, this study aims to employ a co-creation process to uncover insights and challenges faced by micro-mobility and VRUs in Germany and to identify various collaborative solutions to enhance the road safety for these groups by amplifying their collective voices.

2. Background

As highlighted in the Global Status Report of 2023, traffic-related injuries and fatalities remain a significant global concern. According to the report, traffic accidents rank as the 12th leading cause of death and disability worldwide [1]. VRUs, including pedestrians, motorcyclists, cyclists, and other micro-mobility users, constitute half of these fatalities. Child pedestrians are particularly at risk, with an alarming 30,000 deaths annually [4]. Recognising the severity of this issue, the

EC has prioritised pedestrians in its urban road safety initiatives, underscoring the need for tailored measures to protect VRUs. Moreover, global initiatives such as the UN's Decade of Action for Road Safety (2021-2030) aim to halve road traffic deaths and injuries by the end of the decade, emphasising the urgent need for comprehensive road safety strategies [5]. Furthermore, the European Union's (EU) road safety policy framework for 2021-2030 aims to eliminate road fatalities by 2050, focusing on enhancing safety for all road users, including VRUs [6]. These efforts are complemented by region-specific policies and legislation to promote safer road environments and reduce traffic-related fatalities.

As per ERSO [7], in Germany, the toll of traffic accidents in 2020 resulted in 2,719 fatalities. Despite a 25 % decrease in fatalities over the past decade, Germany's progress lags behind the EU average reduction of 36 %. Notably, cyclists comprised 16 % of these fatalities, a higher proportion than the EU average of 10 %. In addition, Germany saw an 11 % increase in cyclist fatalities over the past decade, contrasting with a rather stable change of -3 % observed across the EU. Pedestrian fatalities follow the average decrease of the EU although on a slightly lower level (-22 % vs. -25 %). These statistics underscore the persistent challenges and varied trends in road safety for VRUs in Germany compared to broader European trends but must also be seen in context of an increase of cyclists and simultaneous decrease of pedestrians within the modal split of Germany in particular within the age groups up to 19 years ("generation Z").

The statistics urge for a comprehensive action plan to enhance VRU safety, which primarily necessitates comprehending their day-to-day life challenges. As prevailing research continues to explore the complex interactions between humans, vehicles, infrastructure, and the environment within the road traffic system and influences official planning regulations, understanding the behavioural, infrastructural, regulatory, and environmental factors affecting VRU safety is crucial [8]. By addressing these multifaceted challenges and integrating findings especially into urban transportation planning, authorities can effectively enhance VRU safety and promote sustainable mobility systems accessible to all. An optimal approach to achieve this is to involve stakeholders and road users working together collaboratively to cultivate shared expertise for crafting solutions. Integrating users' perspective from the outset of innovation endeavours can attain a deep comprehension of user attitudes, values, lifestyles, habits, and motivations, maximising the likelihood of user adoption [3]. Such a collaborative value-creation process involving stakeholders from conception to use is termed co-creation. Co-creation encompasses collaborative activities of finding ideas ("co-ideation"), their evaluation ("co-assessment"), the design on how to bridge the gap between identified ideas and concrete solutions ("co-design", the improvement of prototype solutions ("co-testing"), and the final launch of a solution "co-launching", fostering a participatory environment throughout the innovation process [9].

Urban mobility living labs (LLs) epitomise a paradigm shift towards collaborative innovation, underscored by the principles of co-creation and robust end-user engagement. By integrating diverse stakeholders and actively involving end users in designing and testing mobility solutions, these LLs foster a dynamic ecosystem conducive to developing sustainable and user-centric urban mobility solutions [10]. Through continuous iteration, experimentation, and feedback loops, urban mobility LLs drive innovation and empower communities to shape the future of transportation in urban environments [11]. As cities grapple with complex mobility challenges, the collaborative approach exemplified by urban mobility LLs offers a promising avenue for co-creating solutions that are inclusive, efficient, and responsive to the diverse needs of urban dwellers.

3. Research design and Methodology

To address the aim of the study, an interpretivist philosophy was adopted because this paradigm focuses on understanding the subjective meanings and experiences of individuals within their social context.

3.1. World Café workshop

Given the adopted philosophy, a World Café workshop was employed. A world café workshop is a knowledge translation and mobilisation event designed to offer participants a relaxed, friendly, and welcoming café-style environment [12],[13]. In this setting, participants gather around tables to engage in facilitated discussions. Conversations are continuously shaped and reshaped during these interactions, with thoughts written down and sketches made on paper tablecloths. Participants then rotate between tables, sharing further insights and ideas, enriching the discussions, and transitioning individual knowledge and experience into collective understanding and actionable solutions [14].

In this study, a similar online approach was conducted via MS Teams, where participants were divided into four groups/rooms with a moderator in each to have an interactive discussion based on a specific question. The interactive discussions based on each question lasted for 20 minutes and focussed especially on perceived accident risk as one possible influence on the choice of travel mode.

The questions addressed in each group were.

Question 1: Does personal road safety and well-being influence the choice of mobility for the group(s) you represent, and the routes taken to travel between places?

Question 2: Thinking about the micro-mobility group(s) you represent, what are the possible road safety issues/risks considered before or when travelling?

Question 3: Thinking about the micro-mobility group(s) you represent, kindly describe any road safety issues or examples of any near misses/accidents you have experienced/witnessed or you have been told about.

Question 4: Thinking about the micro-mobility group(s) you represent, and no matter how obvious or obscure, what do you think are the potential solutions for improving the road safety of VRUs?

Adopting this approach in this research asserts the application of an interpretivist epistemology [15], employing inductive reasoning. In order to effectively foster co-creation among such a diverse group, the project team must "configure user participation" [10]. Moreover, as Lohr *et al.* [13] highlight, involving a diverse range of participants in the research process is crucial to co-create knowledge that benefits both science and society. Implementing a world café model workshop approach in this research facilitated open and yet intimate discussions that drew on the perspectives, experience and knowledge of a wide array of individuals. In essence, this method serves as an exploratory data collection technique within a qualitative research framework, bringing together experts in a workshop to share their insights.

3.2. Participant recruitment

Sixteen stakeholders participated in the online workshop, encompassing citizens (as part of VRUs), interest groups, traffic planners, environmental officers, accident prevention and mobility trainers, police officers, and traffic transformation planners of the LL “Saxony”. In total, there were representatives from eleven different mobility forms (pedestrian, cyclist, skateboard user, pedestrian with troller, child pedestrian, motorist, motorcyclist, e-biker, e-scooterist, scooterist, mobility impaired), with five female participants.

3.3. Data collection and analysis

Discussions held on the MS Teams platform were recorded and later transcribed and translated (to English). Reflexive thematic analysis was conducted using NVivo software to identify a range of themes through inductive coding (Figure 1).

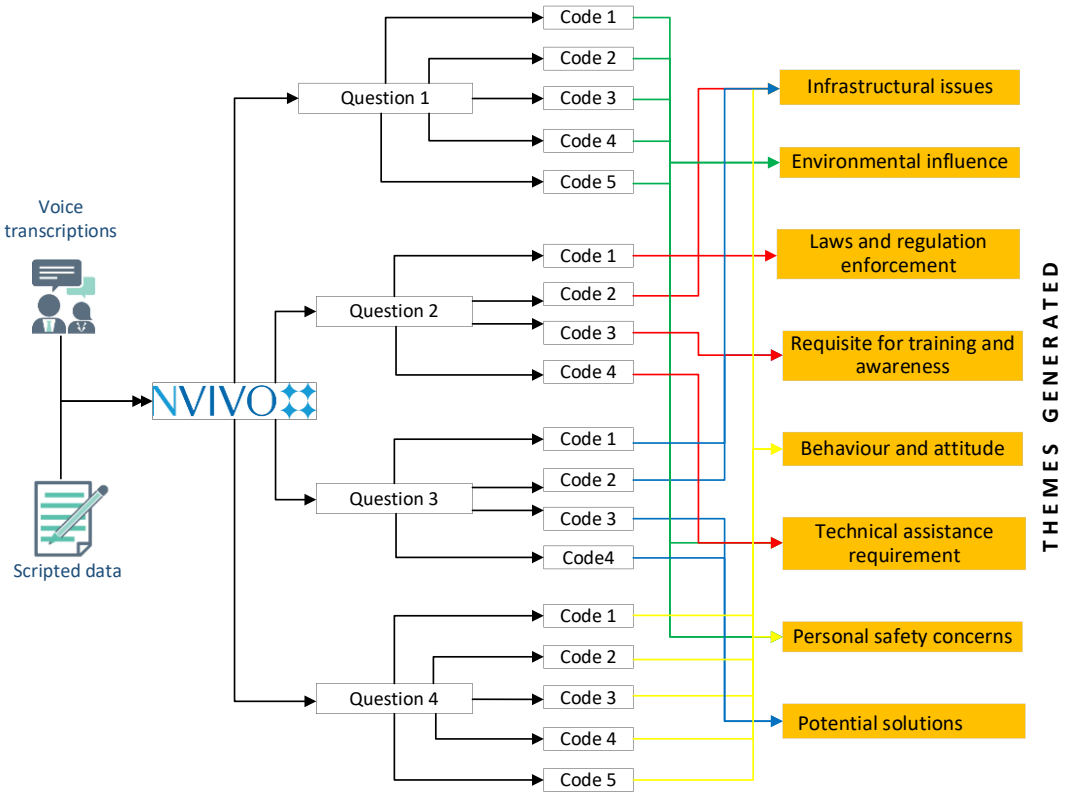

Fig. 1: Theme generation based on the inductive data analysis.

According to Braun and Clarke [16], reflexive thematic analysis procedures reflect the values of a qualitative paradigm, centring researcher subjectivity, organic and recursive coding processes, and the importance of deep reflection on and engagement with data. The data were sorted, plotted, and analysed with the aid of five steps. These included an initial sight at the data and taking first notes ("data familiarisation"), highlight and label significant text phrases ("coding"), combine codes to broader themes ("theme generation"), review the used themes with regard to their usefulness and accurate representation of the text ("theme review"), and the final "definition and naming" of themes to clarify their exact meaning and ensure their use to understand the data.

3.4. Ethical consideration

Ethics, moral standards, and GDPR compliance were crucial throughout the planning and execution of co-creation workshops [17]. Ethical approval for the research was granted by an independent ethics committee before data collection was embarked upon. This approval means the consent of all participants was sought prior to them joining the workshop; whereby, participants were informed of their voluntary involvement, data usage/storage details, and data confidentiality. Further, participants were given a cooling-off period (two-weeks from the date of their involvement) in case they wanted to withdraw their responses.

4. Results

Analysis of the qualitative data has established hierarchical rankings of codes for all four questions. Tree maps were created to represent the hierarchy between labels and themes (by colour and position of rectangles), as well as their amount of coding references via their size. From this analysis, eight overarching themes have been identified and are detailed next.

4.1. Infrastructural issues

Road crossings and intersections pose significant threats to VRUs, particularly child pedestrians and cyclists. The Beetle Crosswalks in general and intersections in specific cities are frequently cited as hazardous, with safety concerns exacerbated by the time-consuming nature of crossing, insufficient crossing time, and the chaotic interference from mixed traffic. Red markings on all road bike lanes, especially at intersections, are implemented to alert motorists and VRUs. However, the lack of designated bike lanes and clear separation from heavy traffic remains a significant risk. Participants emphasised the need for less mixed traffic, fewer traffic lights, and dedicated bike lanes to enhance travel quality. Poor surface conditions negatively impact cyclists' riding comfort, often prompting a switch to cars, though pedestrians are less affected by these conditions. Adequate street infrastructure, such as proper streetlights and ample footpaths, is crucial for reducing travel risks. Infrastructural deficiencies are a primary cause of accidents or near-misses, particularly during turns where blind spots and undisciplined behaviour prevail. Participants also noted poor road design, such as the absence of designated parking spaces, which leads to dangerous parking on bike lanes. City planning is often criticised as car-oriented rather than VRU-focused, with traffic lights providing insufficient crossing time for VRUs. Nonetheless, recent developments, such as widened bike paths and parking removal, received mixed reviews from participants.

4.2. Behaviour and attitudes

The behaviour of co-road users highly impacts the safety and experience of VRUs, particularly cyclists. Participants frequently complained about motorists driving over cycling lanes, undermining the discipline necessary for a safe road-sharing environment. Dangerous overtaking manoeuvres by motorists present a severe threat, often forcing cyclists out of designated bike lanes. In addition, improper parking practices create visibility issues for VRUs, exacerbated by motorists' neglect of their environment and poor blind spot observation. "Dooring" incidents, where car doors are opened into the path of oncoming cyclists, and general negligence of traffic rules are frequently cited as primary causes of incidents.

4.3. Requisite for training and awareness

Unawareness of existing traffic rules and recent updates are a significant concern for the safety of VRUs. It is crucial to impart awareness of these rules and implement measures to control dooring incidents and hazardous vehicle turning situations. Co-road user behaviour, particularly motorists' negligence and ignorance of traffic laws pose a substantial safety threat to VRUs.

4.4. Laws and regulation enforcement

The lack of enforcement of regulatory measures places VRUs in dangerous situations, particularly at crossings where traffic light timing is underestimated, and red-light violations are common. There is a pressing need for regulations to control lane interferences, prevent parking at intersections, sidewalks, and bike lanes, regulate speeds to avoid rear-end collisions at red light signals, remove temporary obstacles, and reduce heavy traffic in downtown areas. Moreover, the widespread unawareness of existing traffic rules and updates exacerbates these issues. One participant even reported feeling compelled to break safety rules due to these unsafe conditions, emphasising the need for stringent enforcement and widespread education to improve road safety for all users.

4.5. Personal safety concerns

Most participants expressed that personal safety and well-being heavily influence their choice of routes, emphasising the importance of physical and mental health for travellers. Despite this, due to day-to-day practicalities, many individuals opt for unsafe routes along motorised roads over off-road recreational paths. Time and safety are critical factors, with many avoiding cycling or walking during peak traffic hours or in darkness. Cyclists particularly avoid busier routes at night and in the rain due to visibility concerns. Participants generally agree on steering clear of busy downtown routes, while opting for the shortest path to their destination as well. Safe route planning becomes especially crucial when accompanying children, with some participants appreciating systems like the walking bus. The purpose of travel, safety preparations such as using personal protective equipment (PPE), familiarity with routes, and choosing safer, well-lit paths—especially for women—are

key considerations for personal safety and well-being. Additional travel risks identified include navigating on busy routes or passing construction sites, mental stress, dooring incidents, and other conflicting spots.

4.6. Leveraging technological advancement

Most participants rely on apps like “Komoot” and “Google Maps” to find routes off the busier streets to ensure safe travel. However, despite the technical advancements in road user safety, some participants raised concerns about these innovations posing a threat. The primary issue is that navigation apps can become a source of stress and distraction, potentially leading to unsafe situations as users focus on their devices instead of the road. In contrast, other participants find smart navigation devices mounted on handlebars beneficial, especially when travelling through unknown routes. These devices enhance safety by providing clear directions and aid in efficient route planning before travel.

4.7. Environmental concerns

Cycling and walking are frequently favoured for leisure and pleasure, offering individuals a sustainable means of travel that promotes physical activity and enjoyment of the outdoors. One participant explicitly highlighted a river cycling path, showcasing the appeal of well-established routes for cyclists. However, concerns over noise and air pollution often discourage road users from opting for these sustainable modes of travel. Additionally, the unpredictability of weather and climate plays a significant role in mobility choices, with adverse conditions like rain or extreme temperatures affecting the feasibility and comfort of cycling and walking. Moreover, regulatory measures in downtown areas are scrutinised, as congestion frequently deters participants from choosing sustainable transport options through city centres.

4.8. Potential solutions

Efforts to enhance road safety for VRUs, particularly cyclists and pedestrians, have prompted suggestions for redesigning road lanes to prioritise their safety. Planners advocate for intelligent traffic light control systems, the Vision Zero initiative aimed at eliminating road fatalities, and minimising space allocation for vehicles at intersections to accommodate all users safely. Urban planning must also anticipate and manage the challenges of overcrowded cities, which can impact road users psychologically. Recommendations include developing a comprehensive bike path network with speed limits and small speed bumps, ensuring complete segregation of VRUs from motorists at intersections, and implementing regulations such as one-way streets for safer turning and designated pedestrian zones. Stakeholders propose bicycle-focused smart traffic lights and adequate parking space at traffic lights to prevent conflicts among pedestrians and cyclists waiting to cross. Additionally, standardising the colour distinction of bike lanes and ensuring regional traffic infrastructure improvements are crucial. Implementing traffic calming zones near schools and maintaining road surfaces, including snow removal and well-illuminated crosswalks, are also essential for improving safety. Enforcing regulatory measures, such as prosecuting speed violations and controlling lane interference, while raising awareness of traffic rules and promoting proper vehicle maintenance and PPE use, are equally vital steps toward ensuring VRU safety. Measures to mitigate air, noise, and light pollution are also recommended, highlighting the multifaceted approach required to create safer and more sustainable urban environments for all road users.

5. Discussions

Analogous to the statistical data of road fatalities in Germany, the challenges faced by cyclists and child pedestrians predominate the result in the LL “Saxony”. This emphasises the need for safe and inclusive integration of active modes of transport to current mobility paradigms, stipulating cohesive infrastructure planning and safety applications.

The co-creative approach continues to be integral for gathering the demands, suggestions, and daily challenges of VRUs, fostering a participatory environment throughout the innovation process. Infrastructural challenges are frequently cited as a key factor impacting VRU's mobility safety during interactive discussions. According to stakeholder opinion, road infrastructure design should prioritise comprehensive consideration of various road users, particularly those in vulnerable categories, instead of car-oriented planning. An optimal solution is adopting a public engagement approach for a co-creative urban transition to resolve planning uncertainties and enhance travel quality and user satisfaction.

Crossings and intersections are frequently cited as critical to VRU hazards among various urban infrastructural components. The EC road safety thematic report highlights that most pedestrian accidents occur at crossings [18]. Since the goal of Vision Zero also hinges on adequate infrastructure as its primary foundation, infrastructural interventions should be a preliminary step for a safety revolution. In addition to infrastructural shortcomings, pedestrian behaviour plays a crucial role in safety at crossings. Through meticulous planning and active participation of users in design, current hazardous situations at crossings and intersections can be effectively resolved. Moreover, a high-quality road infrastructure facilitates traffic safety by encouraging safe behavioural practices [19]. Thus, a well-planned infrastructure can mitigate behavioural issues and accidents to a significant extent. Previous research suggests assessing road user behaviour and attitudes before designing and implementing infrastructure for VRUs [20]. The extensive findings from previous studies align with the workshop results.

The general behaviour-related to road safety issues stem from both intentional and unintentional disregard. For example, the results highlight the urgent need for more disciplined and considerate driving practices to protect cyclists and other VRUs. Hence, in addition to infrastructural improvements, implementing rigorous training and awareness programs from the school level can significantly impact the behaviour of road users. The training should effectively inform traffic rules and regulations, unintentional misconducts such as dooring, which can lead to serious incidents, and the importance of respecting behaviour within the traffic environment.

The road users' lack of awareness about current traffic rules and updates has profound implications for road safety. By increasing knowledge and adherence to traffic regulations among all road users, the frequency of accidents involving VRUs can be reduced, creating a safer and more predictable road environment for everyone.

The dangers VRUs face due to lax enforcement of traffic regulations, particularly at intersections with issues such as inaccurate traffic light timing and disregard for red lights. It emphasises the necessity for stricter regulations to control lane usage, prevent inappropriate parking in sensitive areas like intersections and bike lanes, and regulate speeds to reduce rear-end collisions at red lights. The results also emphasise the necessity to identify organisational and regulatory measures to enforce micro-level road to macro-level regulations. The results also stress the importance of addressing temporary obstacles and downtown traffic congestion. As per the previous study, a comprehensive regulatory strategy is lacking despite promoting various solutions [21]. Achieving the goals of Vision Zero, the UN Decade of Action for Road Safety, and the UN Sustainable Development Goals requires road safety strategies, policies, and development plans along with infrastructural improvements, behavioural changes, extensive training, and awareness. With focus on the effect of violating traffic rules on traffic safety, educating children, especially of the so-called “generation Z”, on the risks and different causes of accidents in their daily mobility could contribute to a higher willingness to meet regulations as future car drivers, as well as pedestrians and cyclists.

While personal safety and well-being are crucial considerations for travellers, there is a significant tension between ideal safety practices and practical necessities. Due to time constraints, travellers often compromise safety for efficiency, especially in daily commutes. Avoiding risky conditions like peak traffic hours and poorly lit routes indicates a high awareness of safety risks among travellers. However, the necessity to traverse busy city centres or motorised roads suggests a lack of sufficient, safe infrastructure to support safer, more desirable travel choices. This compromise is more pronounced when accompanied by children, where safety becomes even more critical, yet logistical challenges persist. The emphasis on preparedness, including using PPE, familiar routes, and safer options for women, reflects a proactive approach to mitigating risks. The identified additional risks, such as busy routes, construction sites, and mental stress, further underscore the need for improved infrastructure and policies that prioritise the safety of VRUs. This study suggests that enhancing travel safety requires a multifaceted approach, addressing infrastructural inadequacies and the practical realities of travellers' daily lives.

Mixed perceptions of technological advancements in route planning and navigation reflect the dual nature of these tools in enhancing road user safety. While apps like “Komoot” and “Google Maps” are popular for their ability to help users find and plan subjectively perceived safe routes, there is a significant concern about the potential for distraction, which can turn these aids into stress factors and safety hazards. This highlights a critical challenge in integrating technology into daily travel: balancing the benefits of enhanced navigation and pre-travel planning against the risks of device-induced distraction. The

study further underscores the need for thoughtful design and usage strategies to fully realise the safety benefits of navigation technology while minimising its potential drawbacks.

The analysis of participants' mobility choices emphasize the need for a delicate balance between the appeal of cycling and walking for leisure and the practical challenges urban environments pose. The findings underline the multifaceted nature of mobility decision-making and the critical need for cohesive urban planning strategies and environmental policies to foster more sustainable and appealing transportation choices for urban residents and visitors alike.

The potential solutions presented in the result reflect a comprehensive approach to addressing road safety and urban mobility challenges. By prioritising VRUs such as cyclists and pedestrians through redesigned road infrastructure and intelligent traffic management systems, the recommendations aim to create safer and more inclusive urban environments. The emphasis on segregated bike paths, speed management measures, and clear regulations at intersections suggests a strategic shift towards improving subjective perceptions of safety among road users. Moreover, the proposed initiatives encompass physical infrastructure improvements and maintenance and enforcement strategies, highlighting a holistic approach to mitigating risks and enhancing urban mobility. Additionally, the focus on awareness campaigns and behavioural education underscores a proactive stance in promoting responsible co-road user behaviour and reducing conflicts on the road. Ultimately, these solutions suggest a recognition of the complex interplay between infrastructure design, regulatory frameworks, environmental considerations, human behaviour and community engagement in fostering safer and more sustainable urban transportation systems.

6. Conclusions

The study used a reflexive thematic analysis approach to highlight the importance of critical themes in the context of perceived safety issued hindering the use of active modes of transport stated in co-creation workshops. Although they must be seen as a subjective perceived risks the study clearly highlights significant challenges faced by cyclists, pedestrians and child pedestrians, emphasising the urgent need for safer and more inclusive integration of active modes of transport within current urban mobility frameworks. The findings underscore the critical importance of cohesive infrastructure planning, the application of safety technologies tailored to “generation Z”, and comprehensive educational efforts to increase children's awareness of accident risks in daily mobility within the short term and their traffic behaviour as future road users. The co-creative approach is essential for gathering and addressing the diverse demands, suggestions, and day-to-day challenges of VRUs, fostering a participatory environment throughout innovation processes. Stakeholder discussions frequently highlighted infrastructural challenges as a critical factor impacting mobility safety, advocating for designs prioritising all road users over traditional car-centric planning. Crucially, intersections and crossings were identified as high-risk areas for VRU accidents, aligning with EC reports that underscore the foundational role of adequate infrastructure in achieving Vision Zero goals. Recommendations emphasise meticulous planning and user involvement in design processes to mitigate hazards at these critical points effectively.

Additionally, the study advocates for enhanced urban infrastructural components such as bicycle-focused traffic lights and improved surface maintenance to foster safer and more accessible urban environments. It underscores the importance of enforcement measures targeting behaviours like speeding and lane interference alongside initiatives promoting awareness of traffic rules and safety practices among VRUs. Achieving sustainable urban mobility and reducing VRU risks necessitates integrated strategies that address infrastructure deficiencies, promote behavioural changes, and prioritise community engagement in urban planning and development.

Furthermore, employing an online workshop method instead of an in-person world café model workshop presents a significant drawback in this study, as direct interaction and the scribblings on tablecloths could have made the discussions more engaging and productive. As a future step, it is recommended to address concerns raised in this workshop through interventions exclusively for each category of VRUs, such as secure cyclist infrastructure and awareness programs focussing on “generation Z”.

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