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Conceptualizing the mobility design gender gap: a scoping review and framework proposal

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ABSTRACT

The current transportation system lacks gender inclusivity, often reflecting the characteristics of an average, male body. This creates gender gaps by favoring male needs, leading to exclusivity by neglecting women's needs. Research has already identified gender gaps in the transportation system: the mobility gender gap, which reflects overlooked gender-specific mobility behavior; the decision-making gender gap, which considers gender-unfair mobility-related decisions; and the gender data gap, which highlights the lack of gender-specific mobility-related data. This paper defines a conceptual framework targeting an additional facet of inequality: the Mobility Design Gender Gap (MDGG). The MDGG describes the fact that the interior of transport modes in passenger transport is primarily designed to serve the needs of an average, male body. The MDGG is investigated with a scoping literature review in combination with a qualitative content analysis. We detected 70 relevant papers and identified four categories where the MDGG manifests: safety and security, sanitary needs, usability and comfort. These categories represent crucial areas to improve transport-mode interior-design, ensuring parity between women's and men's needs. We discuss future research directions and propose strategies to close the MDGG.

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Introduction

The interior of transport modes in passenger transport is primarily designed to serve the needs of an average, male body. For example, luggage storage in European trains is most of the time overhead. Women with average height struggle to store their luggage there. First, women's upper arms are often too weak to lift the luggage overhead. Second, they are often slightly too small to reach the overhead storage space comfortably without having to stand tiptoe. How do women help themselves in these situations? They ask someone who is taller and stronger to assist them, most of the time this is a man, who has no problem with lifting regular luggage into the overhead luggage storage space. It may remain arguable whether it can be traced back to biological reasons or societal convention, why a taller and stronger woman would be asked less frequently. However, this represents a well-known problem: many elements of the environment surrounding all of

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us have been and still are mainly designed for an average, male body (McKnight 1994; Parnell et al. 2022).

Although gender inequality in the transportation system has received some attention, one critical aspect remains underexplored: the interior design of transport modes. Current design practices often fail to adequately address the specific needs of women, resulting in a gender disparity. This conceptual framework is termed the Mobility Design Gender Gap (MDGG). This gap highlights the systemic oversight of integrating gender-sensitive considerations into the interior design of transport modes. Addressing the MDGG requires a thorough understanding of which specific aspects of the interior design of transport modes meet the needs of all genders and which fail to do so. To create a truly equitable transportation system, it is crucial to recognize that mobility is a basic need that should be accessible and inclusive for all. Accordingly, this paper investigates the research questions: How does transport-mode interior design reflect gender gaps and can the MDGG capture them systematically? And which dimensions and features reflect the MDGG? The research questions are answered with a scoping literature review in combination with a qualitative content analysis.

State of the art: gender gaps in the transportation system

Except for walking, vehicles play a pivotal role in mobility, because the majority of travel relies on vehicular transport modes. The interior design of vehicles not only influences their usage patterns but also determines who feels included or excluded from utilizing them effectively (Vöckler et al. 2023). Thereby, interior-design requirements are influenced by both physiological and societal role-related factors. Misalignment between design and user needs can result in restricted access or diminished user satisfaction, underscoring the importance of addressing these inequalities.

Since the 1970s, research has shed light on various aspects which describe differences between women and men concerning their mobility needs, gender-inequality in the transportation system and its resulting effects (Law 1999). Generally speaking, women and men have different mobility patterns (Miralles-Guasch, Melo, and Marquet 2016). These differences have been described thoroughly as mobility gender gap and debunk the assumption that mobility is gender-neutral (see, e.g. Gauvin et al. 2020; Miralles-Guasch, Melo, and Marquet 2016). The differences between men and women entail various aspects, e.g. women make more, but shorter trips compared to men and walk more often or use public transport (Miralles-Guasch, Melo, and Marquet 2016). Furthermore, women, on average, possess fewer economic resources, which narrows their range of transport options. Limited financial means reduce the probability of car ownership and increase reliance on public-transport services (Gauvin et al. 2020). As a result, mode choice for women is more likely dictated by necessity rather than preference. Moreover, women have less diverse destinations (e.g. the same workplace, grocery stores, leisure destinations) compared to men (Gauvin et al. 2020). We assume that these different mobility patterns also influence which interior design is needed in transport modes. For example, the tendency of women to undertake more frequent but shorter trips, often with less diverse destinations, may lead to highly specific design requirements tailored to the diverse tasks they perform during their travel. These requirements could include features such as enhanced lighting for

improved safety, customizable seating for individual comfort, intuitive navigation systems for easy wayfinding, or versatile storage solutions to accommodate a variety of personal items.

One reason, why the interiors of passenger transport vehicles are predominantly designed with the needs of an average, male body in mind, is that only a small share of people working in the transportation sector is female (Sansonetti and Davern 2021). This means that most decisions about mobility are made by men, which is defined as the Decision-Making Gender Gap (Pirra et al. 2021). Accordingly, women are underrepresented in the transportation sector, as is the female perspective in mobility-related decisions. Importantly, the decisions made by men form the foundation of transportation policies, planning and implementation (Pirra et al. 2021). Since only very few women are actively engaged in these initial stages, mobility fails to be equally responsive to the needs of women as it is to those for men (Queirós and Da Marques Costa 2012), resulting in an MDGG.

Another reason for the MDGG is that we currently do not know enough about the differences between men and women concerning their distinct mobility needs, referred to as the Mobility Data Gender Gap. This gap refers to the situation that there are not enough gender-disaggregated mobility data and data analysis of such (Gauvin et al. 2020). Accordingly, research only gradually reveals disparities in the mobility needs of women and men. This gap stems from data analysis predominantly conducted gender-aggregated, obscuring the differences between the mobility patterns of women and men (Gauvin et al. 2020) and standard trip purposes examined in empirical studies being designed for a working population (Queirós and Da Marques Costa 2012). In contrast, care-related travel purposes are often not explicitly queried or considered in data analyses, despite constituting a significant proportion of the trips undertaken by women (Sansonetti and Davern 2021). Work-related and recreational trips tend to dominate the analyzed datasets and are often used to characterize “average” mobility behaviors (Spitzner 2021). However, the activities we engage during travel significantly shape the interior design features we require. For instance, the design needs differ considerably when traveling for work compared to running errands like grocery shopping. For work-related travel, practical features such as stable surfaces for laptops or mobile devices and charging points may be crucial. In contrast, grocery shopping might necessitate accessible storage spaces.

As can be seen, while research is gradually advancing towards defining various gender gaps, the MDGG remains highly unexplored. There exists a significant gap in knowledge, research and practice. This paper synthesizes existing knowledge on gender-specific design requirements in transport modes and organizes it into the conceptual framework of the MDGG. Unlike the fragmented understanding of discrimination in the transportation sector, the MDGG emphasizes the systematic nature of discrimination against women in this context. Thereby, we integrate diverse causes (e.g. decision-making gender gaps) and aspects (e.g. gender-specific mobility patterns) of discrimination. By focusing on the object itself, transport modes interior, the MDGG aims to ensure a more inclusive and positive user experience for all. Drawing on existing literature, we assume that design has the potential to drive meaningful change (Vöckler et al. 2023). Considering that women comprise approximately half of the global population, transport modes should equally address their design needs as those of others.

Research questions

The research questions of this paper are as follows:

- (1) How does the current interior design of passenger-transport vehicles reflect a gender gap, and can this gap be systematically captured in the framework MDGG?
- (2) Which conceptual dimensions (e.g. safety) and which specific interior-design features (e.g. seats) of transport modes embody an MDGG?

The research questions are answered by a scoping literature review in combination with a qualitative content analysis. The methodology was chosen as scoping reviews allow the researcher to chart the extent, range and nature of existing literature thoroughly and effectively, while it is explicitly designed to identify research gaps and to generate conceptual frameworks (Arksey and O'Malley 2005). The qualitative content analysis was applied to extract and categorize the substantive content. This method is well-suited for inductively deriving themes from textual data and preserving the contextual nuances of topic-specific terminology (Mayring 2000). By coupling the scoping review's breadth with the depth of qualitative content analysis, we are able to map the state-of-the-art across multiple transport modes, systematically identify relevant recurring dimensions and ground the MDGG framework on empirically derived evidence.

Method

The methodology to answer the research question is trifold: first, we performed a scoping literature review to investigate which elements of transport-mode interior design inhabit the MDGG. This initial search led to very few relevant papers. Therefore, second, we conducted a qualitative content analysis, to deduce categories in which the MDGG becomes apparent and to enhance our search terms. Third, we conducted a second scoping literature review with the search terms found in the qualitative content analysis.

Initially, we consider all transport modes, while assuming that the MDGG is particularly relevant for public transport, as they are typically less able to incorporate individual preferences and needs, compared to individual transport modes like cars. Thereby, the focus lies on the functional aspects of design, leaving aesthetic considerations aside.

First scoping literature review

We conducted a scoping literature review (Arksey and O'Malley 2005), as shown in [Figure 1](#) (first literature search), and expanded it by recommendations for literature reviews (van Wee and Banister 2016).

After defining the research question (stage 1), we identified relevant papers (stage 2). We developed a search strategy within the research team. As recommended by Arksey and O'Malley (2005), the search terms were very broad to be able to get a quick overview of the research field (see Appendix [Table A1](#)). Six researchers, including the two authors of this paper, were involved in the literature search. The search was conducted simultaneously and supervised by the two authors.

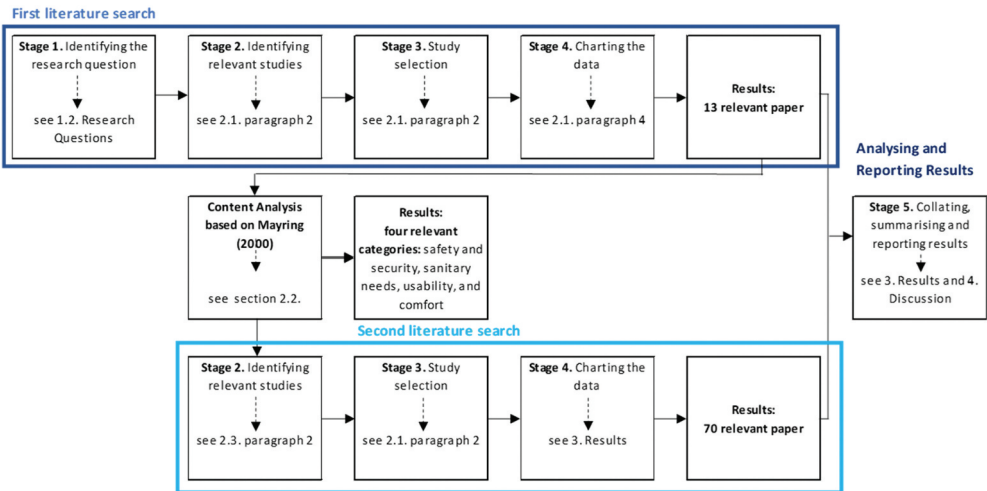


Figure 1. Adapted procedure of a scoping literature review (as in Arksey and O'Malley 2005) including the description of our work (illustration created by the author, inspired by Arksey and O'Malley 2005).

Table 1. Defined inclusion and exclusion criteria for the scoping literature review.

Inclusion criteria	Relevant papers had to provide: - insights into the specific needs of women - with focus on the design of transport modes or related aspects - while providing insights into specific design recommendations to meet women's specific needs
Exclusion criteria	The exclusion criteria were - papers about train or airplane cockpits of train conductors or pilots - papers about medical research topics, such as physical mobility or cell transportation - policy design recommendations - walking - transportation systems or transport modes not comparable to Western circumstances

Following the approach of Parnell et al. (2022), we limited the search to the first 100 papers for each search term. We used the databases Scopus, Google Scholar and ScienceDirect. We reviewed scientific papers from different disciplines and with different methodological approaches. We limited the search to English journal articles, literature reviews, project reports, university and conference publications. Furthermore, the reference lists of relevant papers were examined for additional literature. We did not limit the publication year. The search was conducted between March and December 2023.

For the study selection (stage 3), inclusion and exclusion criteria were defined (see Table 1). To determine whether the article should be included into the scoping literature review or not, the author team read the abstract and whenever necessary additional paragraphs.

To chart the data (stage 4), whenever we decided to include a paper, it was read in full and added into a literature database. Even though the search terms led to a very large number of results only 13 papers were relevant to answer our research question (see Appendix Table A2). This can be attributed to two main observations: (1) while the term "gender" appears frequently in studies, it does not necessarily imply an investigation of

gender differences; and (2) gender-specific needs in transportation design remain a significant research gap. This highlights the necessity of using broad search terms to identify the limited number of relevant studies. In contrast, more specific search terms (e.g. “gender + vehicle design”) yielded even fewer relevant results.

In the next step, the papers were subjected to a content analysis based on Mayring’s approach (Mayring 2000) to empirically derive and refine thematic categories.

Content analysis

We employed an inductive-deductive approach for the content analysis, aiming to identify themes or main ideas from the literature (Mayring 2000). The goal was to condense the data into overarching categories, sorting literature by related aspects and identifying relevant search terms for the second scoping literature review. Although qualitative content analysis is mainly used for interview or focus group data, it can be applied to various text-based data, like systematic literature reviews (Seuring and Gold 2012). It is particularly useful for examining consumer behavior, product reviews and trends (Kassarjian 1977). We also adhered to methodological guidelines for gender research (Neuendorf 2011).

The theoretical and conceptual basis for the content analysis was provided by Jordan’s Consumer Hierarchy Needs (CHN) (Jordan 2000). It posits that three hierarchically organized consumer needs, functionality, usability and pleasure, and determine whether a product is used or not. The CHN was applied, keeping a potential hierarchical structure of interior design needs in transport modes in mind. Its categories formed the basis for the MDGG, which was tested for suitability, necessity of additional categories and potential modifications. Additional categories were incorporated into the model when they appeared frequently and meaningfully enriched the model.

Based on the results of the content analysis (see Appendix Table A3), we decided to adapt the CHN in an iterative process. We expanded the proposed categories of the CHN by safety and security as the literature highlighted, transport modes are used less frequently and satisfactory, when individuals are or do not feel safe. Furthermore, sanitary needs appeared to be an important factor influencing the usage of transport modes. Furthermore, we changed the category pleasure to comfort, as this term was used in the relevant papers. Lastly, we decided to integrate functionality into usability as we understand functionality as part of usability. This led to four categories: safety and security, sanitary needs, usability and comfort.

Second scoping literature review

After the content analysis, we performed a second systematic literature review. The four categories were combined with the terms “gender”, “women” and “female” and “means of transportation design”. This resulted in 15 search-term combinations (see Appendix Table A4). All methodological framework conditions were the same as defined for the first scoping literature review. The second scoping literature led to 70 relevant papers (see Appendix A5). The content of these papers is presented in the subsequent results section. Furthermore, we validated the inductively developed MDGG categories, derived from the

first scoping literature review and content analysis, using the findings of the second scoping literature review.

Results

The integrated results are presented according to the four overarching categories, which structure the analysis of the MDGG: safety and security, sanitary needs, usability and comfort.

Safety and security

The first category in which the MDGG became apparent is safety and security. Even though many studies already investigated the relationship between gender and safety and security in different transport modes, only few studies translated the results into actual design principles. The literature clearly shows that the current design of transport modes does not meet the safety and security needs of women (e.g. Ceccato 2017; Linder and Svedberg 2019; Soto, Orozco-Fontalvo, and Useche 2022). Even though the dangers of women in public space cannot be eliminated by design, certain design improvements which align with the needs of women may improve the situation, despite the remaining necessity of societal changes.

Concerning safety, the literature shows that based on accident statistics women are less safe in cars compared to men (Linder and Svedberg 2019). Despite the fact that males are generally more frequently engaged in automobile accidents, females are more likely to be involved in crashes, which are followed by hospitalization (Cullen et al. 2021). In a comparable accident the probability that a belted female driver gets severely injured is 47% higher compared to a belted male driver (Bose, Segui-Gomez, and Crandall 2011). Furthermore, women tend to suffer more often from neck injuries in car crashes, compared to men (Welsh and Lenard 2001), like whiplash (Mordaka and Gentle 2003). Another study showed that current whiplash protection concepts favor men by a risk reduction of 60%, while only of 45% for women (Kullgren and Krafft 2010). Kullgren and Krafft (2010) also emphasize that women cannot be modelled as scaled-down men, but need a separate, female biochemical model. It has been shown, the male BioRID II crash-test dummy, representing a 50th percentile male, is an insufficient representation of an average female driver and fails as an adequate whiplash protection system testing dummy for female drivers (Carlsson et al. 2021). Moreover, in simulation tests male physiognomies are especially insufficient to represent pregnant women (Acar and Weekes 2006). It is inadequate to assume that the 95th percentile anthropometric data of a male represent the anthropometric data of a pregnant woman, only because the dimensions are larger. Chest, abdomen and hips can exceed those dimensions during pregnancy, endangering many women by their third trimester of pregnancy (Acar and Weekes 2006). This follows, current passive safety systems in cars seem not be designed to protect women as good as men. Linder introduced a dummy model representing an average female (Auto Motor Sport 2022; BBC 2022). However, current legislation still mandates only a male dummy; in fact, only one of the five EU occupant-safety regulations explicitly requires the use of female dummies (Linder and Svedberg 2019). But not only cars pertain a higher risk for women to be less safe compared to men, this holds also true

for public transport. One study showed that in buses in Belgrade women have a higher risk of non-collision related injuries, compared to men (Zunjic et al. 2012). The study revealed that women over 60 years are the most vulnerable group for those injuries.

Concerning security literature shows, in public transport sexual harassment is happening every day, which mainly concerns women and girls (Ceccato 2017). Ceccato (2017) follows that this situation substantially reduces women's and girl's freedom of movement. She describes, even though violence at home has been recognized as a human-rights violation, violence against women in public space, and especially sexual violence, with its many different forms of appearance, is still widely neglected. Sexual harassment can happen in overcrowded as well as empty public transport, by drivers as well as other passengers (Kaygan, Kaygan, and Keysan 2023). The authors report that women all over the world have identical strategies to face this danger: special public-transport clothing (wide and covering the body), unapproachable face expressions, showing verbal and physical resistance and carefully choosing specific routes and times to travel (Kaygan, Kaygan, and Keysan 2023). A high level of visibility through underground and train carriages, as well as gender-separated carriages, can enhance women's perceived and actual security (Duchène 2011; Pirra et al. 2021). Furthermore, the design of seats can influence how secure women feel. Seats with limited legroom that are positioned closely together can contribute to sexual harassment, as well as restricted visibility and blind spots (Kaygan, Kaygan, and Keysan 2023). Standing spaces located between seats along the carriage sides may increase feelings of entrapment, while seats facing strangers can lead to unwanted interactions, particularly for women (Matthewson and Kalms 2021). Kaygan, Kaygan and Keysan (2023) explain that women carefully choose where to sit or stand, therefore, a wide range of different standing and sitting options should be provided in public transport. For example, when standing, women often prefer to position themselves with their backs to the wall, near other women, to maintain visibility of the surroundings, enable a quick exit if needed and minimize unwanted eye contact, such as by looking out of a window (Kaygan, Kaygan, and Keysan 2023). Furthermore, certain postures, like holding onto high handrails can expose sensitive body parts (Matthewson and Kalms 2021). Duchène (2011) emphasizes that when women's safety is not ensured in public transport, women might choose individual modes, like cars. Research has shown that when women faced frightening situations, they avoid corresponding routes, destinations and travel modes (Stark and Meschik 2018).

Regarding perceived security, the literature reveals that women report higher levels of concern than men across various transport modes, even though the types of risks they perceive, such as darkness, are often similar (van Bekkum, Williams, and Morris 2011). In line with that, the strongest predictor of fear of crime in public transport is gender, and fear of crime is heightened by bad lighting, overcrowding, travelling alone and isolated places (Soto, Orozco-Fontalvo, and Useche 2022). Accordingly, women make less trips at night compared to men due to security concerns (Zhang, Zhao, and Tong 2022). Women feel more secure when actual security guards are present, visible and approachable (Kim 2021; Loukaitou-Sideris 2014; Pirra et al. 2021). However, Kim (2021) states that transportation companies tend to do the opposite and reduce actual safety guards and increase technological safety measures like CCTV. Few transport agencies actively consult women on what enhances their sense of security. Moreover, research has shown that women are highly skeptical of efforts to replace human staff with automated systems (Loukaitou-

Sideris 2014; Loukaitou-Sideris and Fink 2009). Additionally, security measures in public transport that women wish for include good lighting (Matthewson and Kalms 2021; Vanier and d'Arbois de Jubainville 2017) and panic buttons in carriages and stations (Loukaitou-Sideris 2014). When staff and panic buttons are provided, adequate and visible information about those security measures must be ensured (Kim 2021; Loukaitou-Sideris 2014), such as frequently displayed large help phone numbers (Molero et al. 2021). Furthermore, Kim (2021) points out that it is important to provide a close proximity of staff and a prompt reaction of security personnel, either in person or via digital communication options. Moreover, availability of Wi-Fi increases the feeling of connection and stability by the ability to contact friends, family or police when necessary (Kim 2021). Lastly, also the general appearance of space, e.g. trains, influences whether women feel secure or not (which represents a connection to sanitary needs), e.g. based on vandalism, large amount of concealed areas or cleanliness (Yavuz and Welch 2020).

Sanitary needs

The second category in which the MDGG became apparent is sanitary needs. Differences in sanitary needs between men and women necessitate gender-responsive design solutions in public transport interiors, including dedicated sanitary facilities. However, current design practices predominantly reflect the needs of men, while those of women remain underrepresented. This is particularly concerning, as hygiene and sanitation are fundamental to personal safety and well-being. Therefore, sanitary needs is another category in which the MDGG becomes apparent.

First, literature shows that women tend to have stricter views on hygiene (Eriksson, Dickins, and Strimling 2023) and are more sensitive towards disgust compared to men (Druschel and Sherman 1999; Tybur et al. 2011). This concerns transport modes in general but also their toilets to be more specific. Accordingly, women wash their hands more often than men (Anderson et al. 2008). Furthermore, women have a higher risk for urinary illness like bladder infections (Foxman 2002) and therefore have higher hygienical demands in sanitary facilities to stay healthy. Men tend to stand while urinating in trains, which causes hygienical difficulties for women having to sit on said toilettes (Loth 2021) as well as in airplanes (Westwood, Pritchard, and Morgan 2000). Accordingly, women worry about hygiene of sanitary facilities (Parnell et al. 2022) and adapt their behavior, with e.g. different toileting postures, unhealthily delaying toileting (Wu, Xue, and Palmer 2019), or avoiding public toilets at all (Kowalik et al. 2019). One study revealed that 41% of the female participants indicated that they do not drink before traveling by train to avoid the train toilet (Loth and Molenbroek 2011).

Second, women place greater emphasis on the cleanliness and tidiness of transport modes as well as of public space. Women tend to feel uncomfortable, unsatisfied and unsafe when their neighborhood is vandalized and loud, when there is graffiti and garbage (Alvi et al. 2001). Accordingly, when bus stops are kept neatly, women feel more comfortable and safer (Loukaitou-Sideris 2014). A stated preference analysis revealed that for women the cleanliness of a bus is more important than for men (Dell'olio, Ibeas, and Cecin 2011). Thus, "cleanliness and maintenance" is an important factor to ensure public transport to be inclusive (García-Jiménez et al. 2020). One explanation for this need can be the broken-window theory. This theory assumes that once "one

window is broken”, more “broken windows” will follow, meaning disordered environments tend to get disordered even more (Kelling and Wilson 1982). As women tend to have more fear of crime compared to men, especially of sexual harassment (Jiang et al. 2017), “broken windows” may cause more discomfort in women as more “broken windows” are expected. Therefore, unhygienic transport modes may lead to lower satisfaction, higher stress and anxiety levels among women (Pirra et al. 2021). This is especially striking as public transport, in particular, often suffers from cleanliness issues and, at times, vandalism.

Third, literature shows, women have different toilet design needs compared to men because, e.g. women empty their bladder more frequently (Mueller et al. 2005) and need more time when using the toilet (Greed 2019). This stands in contrast to the situation that often more sanitary facilities are provided for men (urinals) compared to women (stalls) (Greed 2004). Urinals need less space, stalls need more space, but the space for toilets for men and women are often evenly distributed. Supposed equality leads here to obvious inequality, often resulting in half as many facilities for women than for men (Greed 2019). In a qualitative study, focus group discussions revealed that the general availability of bathroom facilities does not meet women’s needs (García-Jiménez et al. 2020). Additionally, Greed (2019) emphasizes, due to women’s prevalent caring tasks, they are accompanied more often by persons who have to use toilets more frequently or with greater urge, e.g. children or elderly. Furthermore, due to menstruation, pregnancy or menopause women have specific and more complex design needs in sanitary facilities (Greed 2019). Women tend to carry (more) hand luggage than men, which represents a barrier to use the bathroom due to not enough storage space, e.g. in train toilets (Loth, Molenbrock, and van Eijk 2018) and also the design of toilets on planes, does not cater women’s (hygiene) needs (Westwood, Pritchard, and Morgan 2000). Women necessitate a larger spatial allocation within sanitary facilities to accommodate their multifaceted sanitation routines, increased storage capacity for their personal belongings and hygienic storage solutions for potential sanitary supplies. Only changing the label on the doors negates gender-specific spatial, temporal, biological and social differences in sanitary needs (Greed 2019). Female-friendly toilets should enable women to feel confident, safe and dignified and include specific design measures which account for their menstrual hygiene, personal safety and other relevant needs (Schmitt et al. 2018).

Usability

The third category in which the MDGG became apparent is usability. Usability has received increasing attention in transportation research. However, gender-specific aspects of usability remain underexplored, particularly in the interior design of passenger transport modes. While men and women often have different usability needs, these differences are rarely integrated into design practices. This is particularly striking as research in software design has shown when incorporating usability considerations tailored to women’s needs not only benefits female users but also enhances overall usability, leading to reduced error rates for both women and men when interacting with the software (Vorvoreanu et al. 2019). Furthermore, it is not enough to serve gender stereotypes and to assume women simply want smaller and more colorful versions of e.g. automobiles, but a thorough understanding of women’s usability needs in transport-

mode design has to be compiled. Therefore, usability is another category in which the MDGG becomes apparent.

Concerning effectiveness, the literature reveals that women and men still have different social roles and therefore have to solve different problems and tasks during their days (Duchène 2011). Currently, interior design of transport modes mainly focuses on the tasks of an average, healthy man (McKnight 1994; Spitzner 2021): a full-time job and a commute in the morning and in the evening, resulting in comparatively simplified travel routines with fewer intricate mobility demands. In contrast, individuals with caregiving responsibilities, often assumed to be women (Babbar et al. 2022), frequently balance both unpaid caregiving duties and paid employment, thereby accruing, for example, additional luggage and logistical complexities. This brings along distinct design-needs, like greater spatial accommodation, lower steps, toilets (Duchène 2011; McKnight 1994), dedicated space for children, availability of, e.g. car seats for children in shared cars or taxis (Pirra et al. 2021) and seats for two people at the same time (Umaña-Barrios and Gil 2017). Moreover, the utilization of strollers introduces further design imperatives (McKnight 1994), including multifunctional handles at varying positions and heights, providing sufficiently wide doors, adaptable seating configurations (Duchène 2011) and free space next to the seat, avoiding obstructions of the passage (Molero et al. 2021; Umaña-Barrios and Gil 2017). Addressing these multifarious design requirements is imperative for ensuring effective transport-mode interior design and providing equitable and inclusive access for all members of society.

Another important aspect of effective transport-mode interior design is sufficient information. Especially when accompanied by children, elderly, or people with disabilities, the caregiver has to have all necessary information at hand, e.g. when a train comes, where it is possible to enter barrier-free, where the toilets are, and much more. Therefore, maps, information on routes and timetables with sufficient information labeling in free visual sight are necessary (Umaña-Barrios and Gil 2017). Right now, transport modes often only provide the bare minimum of necessary information, if at all, making especially public transport less effective for individuals with complex daily tasks.

Concerning efficiency, a qualitative study investigated mobility barriers of older women in Oslo and revealed that the main barriers concern the built infrastructure, namely, e.g. difficulties boarding, lack of seats, uneven grounds, high steps, anxiety about overcrowding and potential accidents (Nordbakke 2013). The author of the study emphasizes the way modes are designed defines how and if they are used. McKnight (1994) reported comparable issues already way earlier. Another study found that the accessibility of modes is influenced by “furniture and other facilities” and “design options” (García-Jiménez et al. 2020).

Furthermore, Parnell et al. (2022) assume that women’s needs are neglected concerning ergonomics. The authors of the study emphasize, even though a lot of effort is taken to improve ergonomics of modes, the dominant default male perspective persists, which leaves women with a higher risk of usability problems. One example for this is the Directive 2001/85/EC (2001) of the European Parliament and of the Council, which defines that in public transport, only handrails and grab handles between a minimum of 80 cm and a maximum of 190 cm above the floor are considered. However, a holding option at a height of 190 cm is difficult to reach for the majority of women. Zunjic et al. (2012), revealed the optimal grip height for women to be at a height of 176 cm. Taking into

account larger body heights as well, they recommend installing handholds at a height of 183 cm (Zunjic, Sofijanic, and Stojiljkovic 2016). Research findings indicate that women exhibit a lower frequency of grasping higher positioned bus handles when compared to men (Hwangbo et al. 2015). The same study showed that women try to stabilize themselves with lower options like seats, which leads to less stability. Above that, women not only reach high handrails worse compared to men, women also have on average smaller hands and a weaker grip. A study showed that female national elite athletes rarely surpass the 50th percentile of untrained or not specifically trained men (Leyk et al. 2007). This could imply that the concept of handrails and handles is less efficient for women as it is for men. Another issue concerns luggage storage. As already described in the introduction, over-head luggage storage is not as efficient for women as it is for men (Alberda et al. 2015). Other authors propose additional lower lockable luggage storage, e.g. in trains (Forsberg, Holgersson, and Bodén 2017).

As literature shows, different effectiveness and efficiency requirements of men and women exist, and right now mainly the requirements of men are met. This follows from the fact that user satisfaction currently varies between men and women, supposedly to the detriment of women. For example, many products originally designed without consideration for women are reconfigured using the “pink it and shrink it” approach (von Tilburg et al. 2015), reducing size and applying more color. While marketed as solutions for women, these adaptations often fail to address their actual functional needs. Simply making a product smaller or more visually feminine does not ensure it meets women’s practical requirements. This illustrates a broader issue: the mere inclusion of women as a target group in design does not guarantee that their needs are adequately addressed, often resulting in low satisfaction and limited usability and reproduction of gender stereotypes.

Comfort

The fourth category in which the MDGG became apparent is comfort. Although the total daily travel-time budget in Germany has remained essentially unchanged over the past three decades, the average trip distance has increased (Bundesministerium für Verkehr 2025). Consequently, passengers now experience longer continuous periods inside a vehicle, which raises expectations for comfort (Da Gameiro Silva 2002). Thus, passenger comfort gains more and more attention. A fuzzy-based linguistic approach identified the most important comfort aspects in high-speed rail in China to be temperature suitability, seat comfort, and air quality (Chen et al. 2020). For planes, researchers showed that to increase passenger comfort, future design efforts should consider well-being, aesthetics, privacy and autonomy as well as pleasure (Ahmadpour et al. 2014). However, what was largely neglected up until now are gender differences in passenger comfort. Literature shows women and men have different comfort needs in transport-mode interior design due to different physiological preconditions and physiognomies or private-space needs. Those differences are currently not addressed, mainly neglecting women’s comfort needs. To make different modes equally comfortable for everyone, those aspects have to be incorporated into design considerations. Therefore, comfort is another category in which the MDGG becomes apparent.

First, due to differences in body size and physiological characteristics women and men have distinct comfort requirements in transport interiors. One example is thermal comfort. Women and men have different perceptions of cold and warmth (Karjalainen 2007), as women are e.g. more sensitive to temperatures below 24 °C (Qiao et al. 2023). Following this, when public transport has an average temperature of 22 °C, women will experience less comfort compared to men as they would feel too cold.

Furthermore, by testing different ventilation systems, researchers found that women experience less comfort with such ventilation systems because they feel colder compared to men and experience higher air draught (Chen et al. 2020). When asking women and men which comfort aspect is most important in train carriages, for women it is temperature and air quality, and for men, it is vibration (Mohammadi, Amador-Jimenez, and Nasiri 2020). Supposedly, current temperature and ventilation circumstances in public transport are less aligned to the needs of women as to men's, despite gender differences and resulting loss of comfort.

Additionally, women and men experience traffic noise differently. One study showed that women are more sensitive towards traffic noise annoyance compared to men, which is directly negatively linked to health-related quality of life (Dratva et al. 2010). Accordingly, women need more traffic noise protection, compared to men.

Moreover, varying body shapes and physiognomies of women and men lead to different passenger comfort experience within modes. Seats, for example, in automobiles are not tailored for the distinct female physique, but for the average male physique (Linder and Svensson 2019). One paper investigated comfortable passenger seats in the Netherlands (Hiemstra-van Mastrigt 2015). They showed Dutch men are on average 161 mm taller than Dutch women, while the hip breadth of Dutch women is on average 82 mm wider, compared to Dutch men (Hiemstra-van Mastrigt 2015). Right now, seats do not account for such gender differences enough to ensure seat comfortability for women as for men (Molero et al. 2021; Tetteh, Bowen-Dodoo, and Kwofie 2017).

Second, having to share space with men sometimes produces discomfort for women. A study found that flying is less comfortable for women compared to men due to sharing sleeping space with unfamiliar men on long-distance flights (Westwood, Pritchard, and Morgan 2000). Women report the inconvenience of having to climb over unfamiliar men when e.g. needing to access the restroom at night. In contrast, surveyed men did not report discomfort in sleeping next to unknown women (Westwood, Pritchard, and Morgan 2000). Furthermore, women are more sensitive when their personal space is invaded by unknown persons, especially when those are males and approaching from the side (Molero et al. 2021). At the same time, the personal space of women is invaded more often compared to men's personal space (Wang et al. 2021).

Lastly, bike saddles serve as a positive example of gender-neutral comfortable transport-mode design. Research indicates distinct pressure centers for women and men on bike saddles, attributed to gender-specific driving styles and pelvic shapes (Potter et al. 2008). Furthermore, on average women seek more comfortable saddles (Kuo, Chen, and Roberts 2017). Acknowledging these differences, the bicycle industry manufactures saddles tailored to each gender. Contrasting this with other transport modes reveals a metaphorical dominance of male-centric designs, neglecting gender-specific comfort needs. Therefore, comfort is another category in which the MDGG becomes apparent.

Discussion

This paper represents the first effort to describe a conceptual framework, which assumes that currently the design of transport modes predominantly address the needs of an average, male body: the Mobility Design Gender Gap (MDGG). With a scoping literature review in combination with a qualitative content analysis, the present paper identifies four key categories where the MDGG is most evident: safety and security, sanitary needs, usability and comfort. By analyzing the interior design of transport modes through this analytical lens, the MDGG provides a novel approach to addressing gender inequities in transportation.

It is the goal of the UN (Directorate-General for Employment, social affairs and inclusion 2023, November) and the UNDP (Directorate-General for Employment, social affairs and inclusion 2023, November; UNDP 2015) to “provide access to safe, affordable, accessible and sustainable transport systems for all, [. . .], with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons”. Yet, current design practices in passenger transport often reflect gender biases, undermining this commitment. While research consistently underscores the necessity of integrating women’s needs into transport systems (e.g. Parnell et al. 2022), implementation remains limited, suggesting persistent resistance to gender-responsive design. Crucially, vehicle design shapes not only how transport is used but also who uses it (Vöckler et al. 2023). Given that women frequently rely on public transport out of necessity (Gauvin et al. 2020), a gender-responsive redesign could transform it from a functional obligation into a preferred and empowering mobility option, thereby supporting a more inclusive and sustainable transition to future transport systems.

The four dimensions of the MDGG partially align with the consumer hierarchy of needs (CHN) of Jordan (2000). However, Maslow (1943) already discussed that hierarchical structures of needs can never be fixed, as higher order needs can arise when lower order needs are not satisfied (Maslow 1943). Consequently, at this point we do not assume a strict hierarchy among the MDGG dimensions. Establishing such a hierarchy will require further empirical work. Although safety and security might be interpreted as the most pressing category and its improvement most promising to eliminate large usage barriers, the other aspects should not be neglected or understood as less important or relevant. The salience of each dimension is context dependent, and overcoming the MDGG requires attention to all categories with equal priority. Simultaneously, the identified categories stem from, e.g. physiological differences (e.g. height) or societal influences (e.g. social roles and responsibilities), each operating at different levels. In this paper, these factors are described but not ranked, weighed or assessed for their predictive power or relative importance. Future research should explore this in greater depth.

Furthermore, future work should validate the MDGG. Literature clearly leads to the assumption that our proposed concept exists. However, research needs to act to further investigate and validate it with quantitative research. It is important to note that the MDGG could potentially manifest also in other categories, which future research should investigate as well.

Thereby, specific attention should be given to the different daily tasks arising from socially dominant gender roles. As per statistics in Germany, women continue to bear a larger portion of caregiving responsibilities (Statistisches Bundesamt 2024),

notwithstanding the fact that there are also men who push strollers. This not only influences trip purposes but also what individuals carry during rides with e.g. public transport and the amenities they require. This affects usability aspects but might also influence design needs of other categories. Accordingly, in future, the influence of the number of care-related tasks someone has should be explored in combination with vehicle interior design needs. Additionally, it is unclear how the predominantly male decision-makers in the transportation sector influence vehicle design and transportation infrastructure through gender-stereotypical role assignments, as well as their own reality and daily tasks.

Moreover, we want to particularly emphasize the importance of women's perceived low security in public transport. As long as women do not feel secure in public transport, it cannot be assumed that their usage is equally enjoyable as those who do feel secure. We argue, that not only should precise attention be given to ensuring that women are as secure as men, but also that they feel equally secure. This is currently not the case and represents an unsatisfying compromise. Moreover, there might be women who are so deeply concerned about their security to the extent that they completely avoid using public transport (Mers, Watkins, and Hunter 2023). Consequently, their perspectives are absent when current public transport users are surveyed about their feelings of safety and security. Accordingly, investigating the concerns of women who do not utilize public transport is of particular interest. It can provide valuable insights into what would be necessary to make them feel secure enough to use these services in future. Importantly, since the completion of our systematic literature search, further work has examined gender-related security issues in public transport, like Lewis (2024), who analyses sexual harassment on the London Underground from a mobilities perspective (Lewis 2024).

Overall, the proportion of studies dealing with gender-specific needs in transport mode design seems to be in a niche. While the Mobility Gender Gap gains increasing attention, the scarcity of relevant papers concerning the Mobility Design Gender Gap indicates a glaring knowledge and research gap. One part of the explanation might be the Decision-Making Gender Gap, leading to mainly male-oriented research projects and papers. Accordingly, relevant data are collected only scarcely, which is in line with the existence of the Gender Data Gap (Gauvin et al. 2020; Queirós and Da Marques Costa 2012).

Furthermore, the rare literature falls short in proposing tangible design implications. Only a few studies formulate actual design recommendations to address women's specific design needs (e.g. Duchène 2011; Pirra et al. 2021). Additionally, when design implications are formulated, those often still necessitate further design research or conceptualizing to introduce actual changes in the design of transport modes. Future research should focus on practical, ready-to-implement design solutions that support the reduction of the MDGG. In a prior study, we synthesized existing design implications for practitioners, including designers, public transport providers and policymakers and presented them in a dedicated publication (Gebhardt, Nägele, and Brost 2025).

Taken together, we identify a critical gap in current research: despite extensive studies on various aspects of transport design, four key dimensions remain underdeveloped. First, gender differences are frequently overlooked. Second, when categories such as comfort are examined, findings are often limited to descriptive analysis without translating them into actionable design principles. Third, even when insights are generated, they are rarely

operationalized into specific design implications. Fourth, these proposed solutions have not yet been empirically tested in real-world settings. Addressing these gaps is essential to move from theoretical guidelines to practical, gender-responsive transport design.

Especially, when thinking about developing and designing (new) transport modes, we need to understand the design needs of all users. Only then new transport modes will gain broad user acceptance and the reproduction of the MDGG is prevented, e.g. for automated vehicles (Grosso et al. 2022). Our analysis has shown that particularly public transport, which is used by a wide range of individuals, is susceptible to neglect design requirements diverging from those of an average, male body. This gap needs to be closed, to fulfill the promise of public transport being usable for the entire public. Not only the group of women deviates from the widespread norm of the average, abled-body male. There are many more individuals and groups who do not necessarily need to identify as female who are equally disadvantaged in the design of transport modes. Accordingly, the univariate approach which only covers the 5th female percentile to 95th male percentile is criticized nowadays. It is necessary to consider deeper anthropometric measurements and multivariate methods in engineering anthropometry. Therefore, future research should address the extent to which not only an MDGG exists but possibly an overarching Mobility Design Norm Gap. A gap that describes the insufficient consideration of the requirements of individuals deviating from the average, abled-body male norm in transportation.

The present paper pertains some limitations which need to be addressed. First, even though we call the conceptual framework the Mobility Design Gender Gap, it does not refer to the terminology “gender” but to “sex”. We did so as “gender” is the label most commonly used in transportation-research, even though the majority of the referenced studies investigated biological sex. This conflation introduces an interpretive bias: the reported differences are largely driven by sex, not by socially constructed gender roles. However, this reflects the purpose of a scoping review to present the state of the existing evidence as it is currently reported. Future work should adopt an extraction schema that separates sex from gender. This would enhance transparency and reduce the risk of misinterpretation. Deliberate reflection and the systematic incorporation of gender are essential to meet the mobility needs of all population groups.

Furthermore, our analysis was restricted to studies that examined gender differences using a binary classification framework. It is important to emphasize that the use of the terms “woman” and “man” in this context reflects the categorical structure employed in the original studies, which constrains this synthesis. We acknowledge the diversity of gender experiences and identities beyond the binary (see e.g. Ivanova and O’Hern (2024) publishing, the first systematic literature review about the mobility of non-binary and gender-nonconforming individuals). As such, our findings represent the state of evidence as it stands, while highlighting the need for future research to incorporate more inclusive and intersectional approaches to gender measurement (Ivanova and O’Hern 2024).

Lastly, this review focuses exclusively on the gender gap in mobility design needs and therefore does not examine how race, class, disability, or other intersecting identities shape those needs. The existing literature itself is largely confined to “average, healthy” female body, mirroring the historic male-default bias in transport design (Kusters 2019). Consequently, the samples we analyzed rarely incorporate intersectional variables, which reproduces this limitation. We acknowledge that intersectionality is crucial: recent work shows that women of color depend more on public transport (Brozen 2021), that

disabilities impact transport and mobility needs and there is a lack of quantifiable evidence to fully understand this impact (Kett, Cole, and Turner 2020), that policies often adopt a unitary view of users and miss structural inequities (Kakar, Peden, and Jagnoor 2021) and that socioeconomic status, education and the built environment influence mobility behavior (Spray et al. 2022; Yuan et al. 2023). Incorporating these dimensions would have exceeded the predefined scope of our scoping review and was therefore omitted deliberately. Future research should extend the analysis to include race, class, disability and other intersecting axes (Kett, Cole, and Turner 2020) to improve transparency, reduce misinterpretation and inform mobility planning that serves all users.

Conclusion

The present paper underlines the existence of an unsolved facet of inequality in the transportation system: the Mobility Design Gender Gap. The results show different transport modes have been and still are mainly designed to serve the needs of an average, male body. Those gender-specific design requirements get visible in the categories: safety and security, sanitary needs, usability and comfort. The MDGG leads to less satisfying transport modes for women compared to men, revealing an unjust disparity that undermines the principle of equal access to and enjoyment of mobility for all. It is imperative to recognize that addressing this gender gap does not imply favoritism toward women but rather advocates for an inclusive approach that accommodates the diverse needs of all in transportation design. Closing the MDGG is an opportunity to construct a more accessible and inclusive transportation system that caters to the varied needs of all individuals, transcending gender boundaries. To realize this vision, it is paramount to bridge knowledge and research gaps, fostering a deeper understanding and heightened awareness of the unique challenges faced by women in the current design of transport modes. Equally pivotal is the imperative to translate this knowledge into action, effecting tangible changes in the design landscape of transport modes and reshaping current design frameworks. The time is ripe for a concerted effort to transform the reality of transport mode design, ensuring a future where everyone equally enjoys inclusive mobility and is able to store luggage easily, safe and comfortably and not only over-head, with help of others.

Author contributions

- **Sophie Isabel Nägele:** Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, visualization, writing – original draft and writing – review and editing.
- **Laura Gebhardt:** Conceptualization, data curation, funding acquisition, project administration, resources and writing – review and editing.

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Declaration of generative AI and AI-assisted technologies in the writing process

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Appendix A. A search terms and findings of the first literature search

Table A1. Total findings, relevant and included papers for each search term, separate for each search platform.

Search terms:	Google Scholar			Scopus			ScienceDirect		
	total findings	Relevant	Included	total findings	Relevant	Included	total findings	Relevant	Included
gender + mobility	4.540.000	3	0	10.923	0	0	82.879	2	0
women + mobility	5.020.000	2	1	17.791	2	1	122.900	1	0
female + mobility	5.440.000	0	0	80.488	0	0	153.578	3	0
gender + transportation design	2.930.000	14	6	554	4	0	49.675	4	0
women + transportation design	2.990.000	12	0	742	3	0	52.292	0	0
female + transportation design	2.210.000	0	1	3.317	2	0	61.127	0	0
gender + means of transportation design	1.970.000	0	0	83	6	0	32.972	0	0
women + means of transportation design	2.320.000	3	2	134	2	2	33.117	1	0
female + means of transportation design	1.650.000	2	0	541	2	0	38.115	0	0

A2. Relevant papers

Table A2. Relevant papers of the first systematic literature search.

NR	Search platform	Search term	Source
1	Google Scholar	women + mobility	Nordbakke, S. (2013). Capabilities for mobility among urban older women: barriers, strategies and options. <i>Journal of Transport Geography</i> , 26, 166–174. https://doi.org/10.1016/j.jtrangeo.2012.10.003
2	Scopus	women + mobility	Stark, J., & Meschik, M. (2018). Women's everyday mobility: Frightening situations and their impacts on travel behaviour. <i>Transportation Research Part F: Traffic Psychology and Behaviour</i> , 54, 311–323. https://doi.org/10.1016/j.trf.2018.02.017
3	Google Scholar	gender + transportation design	Qiao, R., Wu, Z., Gao, S., Jiang, Q., Liu, X., Huang, C., Xia, L., & Chen, M. (2023). Towards inclusive underground public transportation: Gender differences on thermal comfort. <i>Building and Environment</i> , 242, 110,569. https://doi.org/10.1016/j.buildenv.2023.110569
4	Google Scholar	gender + transportation design	Duchène, & Chantal (2011). Gender and Transport. <i>International Transport Forum Discussion Papers</i> , 2011(11), OECD Publishing, Paris. https://doi.org/10.1787/2223439X
5	Google Scholar	gender + transportation design	Pirra, M., Kalakou, S., Carboni, A., Costa, M., Diana, M., & Lynce, A. R. (2021). A Preliminary Analysis on Gender Aspects in Transport Systems and Mobility Services: Presentation of a Survey Design. <i>Sustainability</i> , 13(5), 2676. https://doi.org/10.3390/su13052676
6	Google Scholar	gender + transportation design	Parnell, K. J., Pope, K. A., Hart, S., Sturgess, E., Hayward, R., Leonard, P., & Madeira-Revell, K. (2022). "It's a man's world": a gender-equitable scoping review of gender, transportation, and work. <i>Ergonomics</i> , 65(11), 1537–1553. https://doi.org/10.1080/00140139.2022.2070662
7	Google Scholar	gender + transportation design	Umaña-Barrios, N., & Gil, A. S. (2017). How Can Spatial Design Promote Inclusivity, Gender Equality and Overall Sustainability in Costa Rica's Urban Mobility System? <i>Procedia Engineering</i> , 198, 1018–1035. https://doi.org/10.1016/j.proeng.2017.07.147
8	Google Scholar	gender + transportation design	García-Jiménez, E., Poveda-Reyes, S., Molero, G. D., Santarremigia, F. E., Gorrini, A., Hail, Y., Abibio-Donkor, A., Leva, M. C., & Mauriello, F. (2020). Methodology for gender analysis in transport: Factors with influence in women's inclusion as professionals and users of transport infrastructures. <i>Sustainability</i> , 12(9), 3656. https://doi.org/10.3390/su12093656
9	Google Scholar	female + transportation design	Carlsson, A., Davidsson, J., Linder, A., & Svensson, M. Y. (2021). Design and Evaluation of the Initial 50th Percentile Female Prototype Rear Impact Dummy, BioRID P50F – Indications for the Need of an Additional Dummy Size. <i>Frontiers in Bioengineering and Biotechnology</i> , 9(687058). https://doi.org/10.3389/fbioe.2021.687058
10	Google Scholar	women + means of transportation design	Kim, H. (2021). Service design for public transportation to address the issue of females' fear of crime. <i>Transportation</i> , 48(1), 167–192. https://doi.org/10.1007/s11116-019-10043-5
11	Google Scholar	women + means of transportation design	Kaygan, P., Kaygan, H., & Keysan, A. (2023). Gendered interactions Mediated by Design: Sexual Harassment on Public Transport. <i>Design and Culture</i> , 15(3), 345–366. https://doi.org/10.1080/17547075.2022.2141159
12	Scopus	women + means of transportation design	Zunjic, A., Sremcevic, V., & Sijacki, V.Z., Sijacki, A. (2012). Research of injuries of passengers in city buses as a consequence of non-collision effects. <i>Work</i> , 41, 4943–4950. https://doi.org/10.3233/WOR-2012-0790-4943
13	Scopus	women + means of transportation design	Kuo, J.-Y., Chen, C.-H., & Roberts, J. (2017). The Subjective Impression of Bicycle Saddles in Different Contexts. <i>Transdisciplinary Engineering: A Paradigm Shift</i> . Advance online publication. https://doi.org/10.3233/978-1-61499-779-5-303

A3. Content analysis

Table A3. Content analysis of the 13 relevant papers to deduce relevant categories for the *MDGG*.

NR	Source	Category CHN	Additional optional categories
1	Nordbakke (2013)	usability (doors closing to fast, information for route planning)	
2	Stark and Meschik (2018)		(perceived) security (frightening situations)
3	Qiao et al. (2023)	pleasure (thermal comfort)	
4	Duchène (2011)	usability (care-work unevenly distributed, e.g. wide-doors, storage space, lower steps)	perceived security (high visibility)
5	Pirra et al. (2021)	usability (information; modifications for care-work)	security (good lightning, surveillance); cleanliness
6	Parnell et al. (2022)	usability (due to ergonomic needs, e.g. grab handles, needs due to social roles)	sanitary needs (toilets and hygiene not satisfactory for women)
7	Umaña-Barrios and Gil (2017)	usability (enough space for strollers, larger seats)	
8	García-Jiménez et al. (2020)	usability (accessibility, facilities and furniture, information)	security; comfort (facilities and furniture)
9	Carlsson et al. (2021)		safety (development of a first rare impact crash-test dummy representing a 50th percentile female)
10	Kim (2021)		(perceived) security (good visibility, CCTV not as helpful as actual safe guards, flight options in train carriages, Wifi as important connection)
11	Kaygan, Kaygan, and Keysan (2023)		(perceived) security (seats side-by-side, little legroom, bad visibility)
12	Zunjic et al. (2012)		safety (injuries due to deceleration/ acceleration, unsafe interior, boarding/ disembarking)
13	Kuo, Chen, and Roberts (2017)	pleasure (female needs for a comfortable bike saddle)	

A4. Compilation of search terms for the second scoping literature review

Table A4. Compilation of search terms for the second scoping literature review.

gender aspect	AND	design aspect	AND	different categories
gender		means of transportation design		safety
women				security
female				sanitary needs
				usability
				comfort

A5. Bibliometric analysis of the findings of both scoping literature reviews

First, the results of the three different search platforms were investigated more closely based on the PRISMA model (Moher et al. 2010). Second, we analyzed the scope and quality of the papers found by the literature search. Third, we investigated the findings related to the four categories in which the *MDGG* became apparent.

A5.1. Number of retrieved papers

The three search platforms produced highly varying numbers of potential as well as relevant papers (see Figure A5). Google Scholar was the first platform we used, then Scopus and ScienceDirect.

A5.2. Number, scope and quality of papers

The number and scope of the reviewed studies were limited, suggesting a significant gap in knowledge related to gender-specific needs for the design of means of transportation. Thereby, we identified some patterns of existing literature which more or less deals with the topics gender and mobility but not with the topics gender in combination with the design of means of transportation (see Table A5):

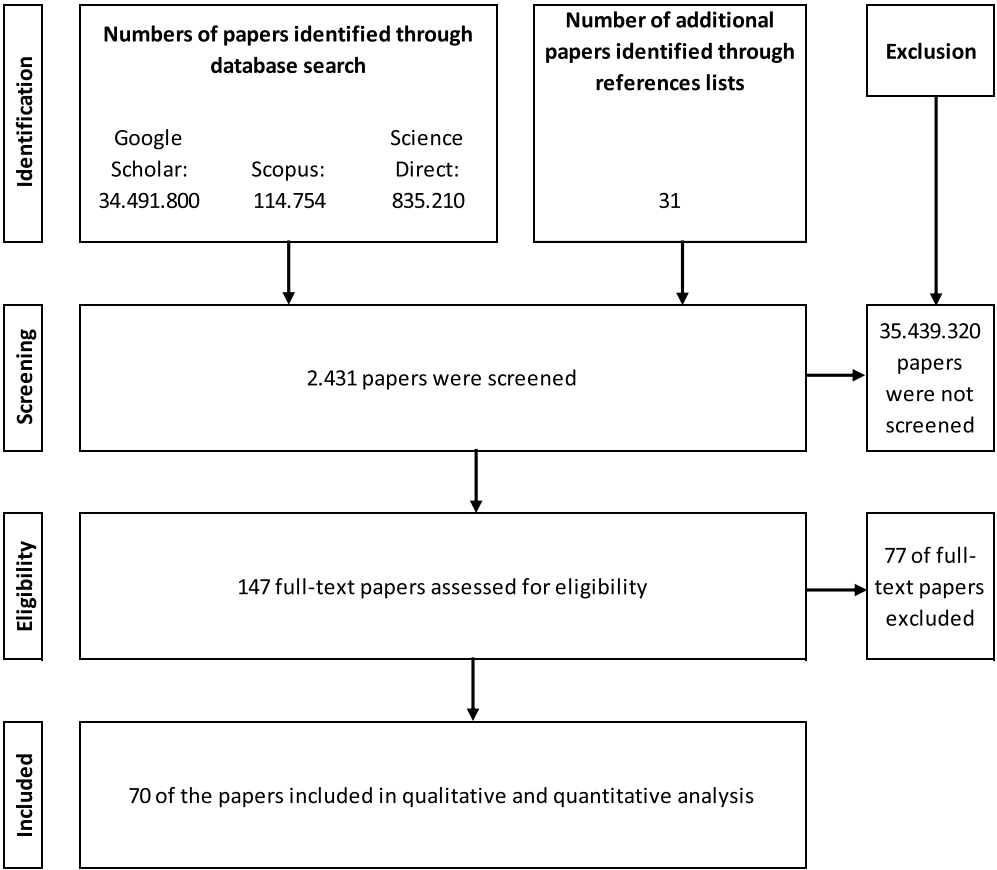


Figure A5. Number of findings per search platform, and based on the reference lists of relevant papers and the total number of included papers in the scoping literature review based on the PRISMA model (Moher et al. 2010).

Table A5. Patterns of existing literature about the specific needs of women for the design of means of transportation.

Design studies	Existing literature predominantly emphasizes - spatial and urban planning and design, - the design of public transport stations, - and policy design,yet tends to overlook the design aspects of the means of transportation itself
Comparability	Numerous papers lack comparability with Western transportation systems and design due to - cultural disparities and - variations in transportation system or means of transportation design The focus in the present paper lies specifically on the Western transportation system
Design implications	Despite the prevalence of discussions about the design of means of transportation in some papers, - actual design implications and - design recommendations are often lacking