

Regional rail interior design: assessing the Mobility Design Gender Gap (MDGG) in Germany

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ABSTRACT

The design of different modes of transport has been criticized for insufficiently addressing the diverse needs of different user groups, in particular women. This gender-based disparity is referred to as the *Mobility Design Gender Gap* (MDGG). Previous research suggests that the MDGG is particularly pronounced in public transport, primarily due to its limited adaptability to individual needs and current focus on male mobility behavior. However, it remains insufficiently understood which specific interior design aspects of modes of public transport contribute most to the MDGG. In the present paper we identified the key design features associated with gender differences in user satisfaction with regional train interiors and developed the MDGG questionnaire on the basis of an extensive literature review and focus group discussions. The MDGG-Q was administered online and completed by 542 participants. An exploratory factor analysis retained 23 items that best fitted a five-factor structure. Additionally, the questionnaire revealed that men show higher satisfaction with the subscales (1) space and privacy, (2) sanitary facilities, (3) usability, (4) grab handles, and (5) comfort in regional trains. Finally, the total score of the MDGG-Q showed higher values for men than for women, revealing men's greater overall satisfaction with the interior design of regional trains. Even though effects were small, public transport providers should consider respective items in future design processes with deliberate inclusion of diverse user perspectives, to improve user satisfaction for all.

Introduction

The design of transport systems has been criticized for insufficiently addressing the diverse needs of different user groups, in particular those of women (Babbar et al., 2022; Gauvin et al., 2020; Uteng, 2021). This inequality is referred to as the *Mobility Design Gender Gap* (MDGG) for the sub-facet of the transport system concerning the interior design of different modes of transport (Gebhardt et al., 2025; Nägele and Gebhardt, 2026). The MDGG is defined as the tendency to inadequately consider gender-specific needs in the interior design of modes of transport. Gender specific design needs can be traced back to different physiognomies, social roles, daily tasks, and more (Martínez-Díaz and Badia, 2024; Pirra et al., 2021).

Importantly, “gender” is a socially constructed concept that embodies culture-specific expectations and perceived differences between men and women, shaping phenomena such as the division of labor and access to resources (Law, 1999). By contrast, “sex” denotes the biological differences between individuals. For analytical purposes, however, we relied on participants’ self-identification into male, female, or

diverse, recognizing both the limitations and the inclusivity of this operationalization (Fraser, 2018). This enables us to address gender-related differences in design needs without reducing them to biological determinism.

Indeed, prior research has shown that vehicle design plays a crucial role in ensuring gender-equitable mobility (Hail and McQuaid, 2021). For instance, if barrier-free access to public transport is lacking for individuals with strollers, if luggage racks are placed too high, or if waiting at a dimly lit stop feels unsafe, these factors directly impact mobility, especially for women. Thus, the design of modes of transport can either reinforce existing barriers or serve as a lever for greater gender-equity (Borker, 2024; Jensen and Lanng, 2017; Jensen et al., 2020; Martens, 2017). However, despite growing attention, it remains unclear which specific aspects of the interior design of modes of transport are influenced by the MDGG and are particularly prone to neglecting gender-specific design needs. Given that women constitute approximately half of the global population, it is imperative that the interior of modes of transport is designed to address their needs on an equal level with those of men.

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Gender-inclusive design of regional-rail interiors is regarded as a means to improve passenger experience and ensure equitable access. However, evidence on which specific interior features contribute to the MDGG is still missing, leaving manufacturers and designers without clear guidance. The present study therefore investigates which regional rail interior-design factors contribute to the MDGG, using the newly developed MDGG questionnaire (MDGG-Q) to provide actionable information for planners and manufacturers.

State of the art in gender-inclusive train design

The history of train design reflects a compelling narrative of technological advancement, engineering innovation, and cultural as well as societal change. From the earliest steam-powered locomotives to today's streamlined high-speed trains, this evolution has profoundly influenced patterns of travel and human connectivity. Despite these remarkable developments, one important aspect has long been neglected: gender-specific design needs in trains. The design process of trains is highly regulated, for example through the European Unions' standards for rail vehicles, the "Technical Specification for Interoperability" (TSI) and other directives. While these standards address accessibility and general safety, they do not explicitly consider gender differences (VO (EU) Nr. 1300/2014 2014; RL 2001/85/EG 2001). Similarly, the European Union Agency for Railways has integrated human and organizational factors into its safety management system requirements, but gender-specific considerations remain absent (Eisenbahnagentur der Europäischen Union, 2021). On a national level, the German Institute for Standardization (DIN) sets quality and safety standards. In recent years, gender fairness has gained attention, with a working group established in March 2022 and a draft standard titled "Guidelines for Promoting Gender Equality and Empowering Women" published in April 2023 (DIN e. V., 2022; DIN e.V., 2023). However, this draft focuses on internal and external organizational measures rather than incorporating gender considerations into mode design. Guidelines for vehicle procurement by the German Association of Regional Rail Transport (Bundesverband SchienenNahverkehr, 2023; nvbw Nahverkehrsgesellschaft Baden-Württemberg mbH, 2014, May 22). Generally speaking, while substantial time and effort are dedicated to car design, relatively little attention is paid to train design, which is primarily driven by technical constraints and structural implementation (Hofmann, 2018). Importantly, the interior design of vehicles not only influences usage patterns but also determines who feels included or excluded from using these services (Vöckler et al., 2023). This suggests that achieving gender-inclusive train design requires a cultural shift within the procurement and design process itself, comparable to the historical changes in train design that have shaped mobility over time.

Gender-inclusive train design represents a particularly pressing gap, as women disproportionately rely on public transport compared to men (Babbar et al., 2022). In this context, regional rail plays a crucial role by providing essential mobility in rural areas, linking smaller communities with urban centers, and facilitating intra-regional connectivity (Sieber et al., 2020). However, currently, many users are dissatisfied with regional rail services. For example, one study reported in Germany an average school grades ratings of 4.5 (on a scale from 1 to 6, with 1 being the best) in rural areas (Norddeutscher Rundfunk [NDR], 2023). However, gender-specific analyses are scarce. Crucially, gender-inclusive design principles benefit everyone diverging from the normative "average male", which includes many male users as well. These principles primarily aim to design vehicles, regional trains in the present study, that are more inclusive for everyone in all relevant dimensions (Gebhardt et al., 2025; Nägele and Gebhardt, 2026).

Relevant dimensions literature has already revealed are safety and security, sanitary needs, usability, and comfort (Nägele and Gebhardt,

2026). However, the evidence is primarily conceptual rather than quantitatively specific. More specifically, the literature highlights that trains are associated less with safety risks than with security concerns, primarily linked to the fear of harassment (Day, 2001; Pain, 2001). While such concerns are not exclusive to individuals identified as women, they disproportionately affect them. Indeed, at night, perceived safety drops by 30% for women versus 10% for men (Krauß and Schwimmer, 2021), limiting their mobility (van Bekkum et al., 2011; Zhang et al., 2022). Furthermore, many individuals have diverging sanitary needs from those of normative "average male" individuals. Women, for example, have distinct sanitary needs due to menstruation, menopause or physique and higher hygiene needs and expectations, aspects which are often overlooked in mode of transport design (Eriksson et al., 2022). Generally speaking, perceived unhygienic environments, common in regional trains, can cause significant discomfort and lead to unhealthy behaviors such as avoiding toilet use, reducing fluid intake (dell'Olio et al., 2011; Loth and Molenbroek, 2011; Palmer et al., 2019; Sjögren et al., 2017), or even avoidance of regional trains (Greed, 2015; Mueller et al., 2005). Additionally, current vehicle designs often constitute usability challenges for people traveling with strollers, wheelchairs, or additional baggage, circumstances which disproportionately affect women (Babbar et al., 2022). Moreover, physical factors such as shorter average height and weaker grip strength reduce accessibility to handrails, and straps for many users, increasing their risk of injury during sudden vehicle movements (Bishop et al., 1987; Leyk et al., 2007; Statistisches Bundesamt, 2021; Zunjic et al., 2012). Lastly, sex specific differences in thermal preferences can lead to discomfort when vehicles are designed around "average male" needs (Dratva et al., 2010; Karjalainen, 2007; Marggraf-Micheel et al., 2010; Statistisches Bundesamt, 2021). Furthermore, Dunk and Callaghan (2005) found significant gender differences in seated postures: males exhibited more flexed lumbar spines (65.4°) than females (49.6°), suggesting seat design based on male postures may not accommodate female bodies (Dunk and Callaghan, 2005). Moreover, social factors such as harassment further compromise comfort, especially for female passengers which negatively influences public transport usage frequency (Useche et al., 2024). Importantly, the aspects may not always be perceived as distinct. For example, a negative social interaction can lead not only to discomfort but also to anxiety. Similarly, handrails that are too high may create usability issues while also causing uncomfortable postures or safety risks if individuals trip. Likewise, unhygienic sanitary facilities primarily affect sanitary needs but can also reduce comfort, as people may avoid using them.

While the available evidence points to disadvantages for women who travel by (regional) train, gender-specific data on usage shares and detailed temporal patterns are still scarce, especially for regional rail in Germany or Europe. For example, the large, Germany-wide mobility survey *Mobilität in Deutschland* (Mobility in Germany; MiD) does provide gender-disaggregated information on public transport use, but it does not differentiate between modes (train, bus, tram, etc.). The MiD shows that, for the 20–60 year-old age group, women use public transport slightly more often than men. This can be explained by the fact that women are less likely to own a car and generally have fewer financial resources, which increases their overall dependence on public transport (infas et al., 2025). Jin and Yu (2021) examined U.S. transit usage in general but did not isolate train travel (Jin and Yu, 2021), and Buehler and Pucher (2012) compared overall transit demand in Germany and the United States, but without gender disaggregation (Buehler and Pucher, 2012). The only study that explicitly addressed gender-specific train usage patterns found no gender difference in the overall proportion of public transport users, but women reported significantly higher feelings of insecurity (37 % of women vs. 22 % of men overall; 68 % vs. 46 % at night) of 366 residents near Melbourne, Australia (Carver et al., 2019). Rosenbloom (2006) argues that, although some aggregated mobility patterns (e.g., labor-force participation, share of single-person households) are converging between men and women, women's societal

roles, and particularly the higher share of care work and limited resource availability, continue to generate distinct travel preferences, values, and concerns (Rosenbloom, 2006). Consequently, a gender-inclusive design of regional rail interiors cannot rely on generic public transport literature alone. It requires train-specific, gender-disaggregated evidence that is currently missing.

Research objectives

Gender-inclusive design of transport mode interiors is increasingly recognized as a means to improve overall passenger experience and to promote equitable access to public transport (Nägele and Gebhardt, 2026). Nevertheless, empirical evidence is lacking on which specific interior elements actually contribute to the MDGG. Consequently, designers have no evidence-based guidance on how to modify interiors so that they do not unintentionally disadvantage female-identifying passengers. The present study therefore identifies the interior-design features that contribute to the MDGG and quantifies their impact using the newly developed MDGG-Q. By pinpointing these drivers, the research provides actionable information for transport planners and vehicle manufacturers aiming to create truly inclusive rail environments.

Method

To identify interior design factors in regional trains which contribute to the MDGG, first, four focus group discussions (FGDs) were carried out, based on a comprehensive literature review conducted in earlier work (Nägele and Gebhardt, 2026). The FGD guidelines were developed based on insights from the literature review published in this earlier paper, ensuring a grounded and theory-informed discussion. Second, drawing on findings from both literature review and FGDs, a questionnaire was developed, the MDGG-Q, to assess the MDGG in regional trains interior design in Germany. The items reflected recurring themes and statements, which were mentioned during the FGDs as well as were supported by the literature. An exploratory factor analysis was conducted to identify the underlying structure and validate the item groupings.

Preliminary study

We conducted four FGDs, two with only self-identified female participants, two with only self-identified male participants. In total 24 individuals participated in the FGDs (see Table 1).

The participants of the FGDs were recruited by a market research company. The FGDs took place in July, 2023. All four FGDs were held online and took a maximum of two hours. Informed consent was obtained from all participants, who were advised that participation was voluntary and that they could withdraw at any time without

explanation. The implementation of the FGDs as well as the subsequent survey were assessed as ethically unobjectionable by the Office of Research Ethics of DLR e.V. During the FGDs, discussions were systematically guided by a protocol with visual aids that incorporated a comprehensive user journey analysis (Oliveira et al., 2017), while special attention was given to aspects that the literature review (Nägele and Gebhardt, 2026) identified as relevant: (1) safety and security, (2) sanitary needs, (3) usability, and (4) comfort (see Figure 1).

All FGDs were recorded in audio format, transcribed, and subjected to analysis using MAXQDA software. The data were analyzed using qualitative content analysis (Mayring, 2021). This method enables the systematic identification, summarization, and description of relevant content (Mayring, 2021). Relevant content was captured as categories within a content-analytical category system, and text segments were assigned to these categories. The category system was developed using a deductive-inductive approach: main categories were formed deductively based on the literature review and interview guide and supplemented inductively based on the statements of the FGD participants. In total, 471 codes were assigned to the main categories.

Main study

Item development

Based on the systematic literature review (Nägele and Gebhardt, 2026) and the results of the FGDs we formulated items for a questionnaire to assess relevant factors of the MDGG in regional trains. We developed the questionnaire in an iterative process with multiple feedback loops involving the authors as well as additional researchers from the authors' institute. These experts provided input on clarity, wording, and appropriateness of terminology, which led to increasingly refined item formulations. The items were answered on a six-point Likert scale (1 = I do not agree at all, 6 = I totally agree). All negatively formulated items were reverse scored.

Due to the highly specific design aspects of regional train interiors investigated in this study, existing standardized e.g. usability questionnaires (SUS, UEQ) were not fully suitable to capture relevant attributes identified in the literature and in the FGDs. Following recommendations by Creswell and Plano Clark (2011) and Sauro and Lewis (2016), we therefore developed a tailored item set to ensure content validity and contextual relevance (Creswell and Clark, 2017; Laugwitz et al., 2008; Sauro, 2016).

Initially 36 items were formulated (see Table A1 in the Appendix), grouped by the aspects which the literature review (Nägele and Gebhardt, 2026) identified as most relevant: (1) safety and security, (2) sanitary needs, (3) usability, and (4) comfort. For the initial questionnaire a pretest was conducted with five researchers from the author's institute who were not part of the author team. They completed the questionnaire and provided detailed feedback on comprehensibility, item clarity, and technical functionality. Their comments were used to further refine the wording and structure of the survey.

Participants

Participants were recruited through an established German online panel provided by a market research company. Eligibility was restricted to individuals who reported using regional or intercity trains at least 1–3 times per month. Thus, the study relies on a non-probabilistic panel sample with targeted screening. Although the original survey sample was drawn to be representative of the German population, the analytical subsample, which was limited to respondents who use regional-train services on a regular basis, cannot be assumed to be representative of the overall population. It took about 15–20 minutes to fill out the questionnaire, which was sent out to potential respondents by a market research company during 11.12.-25.12.2023.

A total of 542 individuals who use regional trains at least 1–3 times per month filled in the online-questionnaire, 49.82% self-identifying as female, 50.18% as male, none identified as diverse. Table 2 shows

Table 1
Sociodemographic information and regional rail usage frequency of the focus group discussion participants.

Self-identified gender	54.17% female participants 45.83% male participants
Age	21–70 years
Monthly net household income	Range = 1,500 – 6,000 MW = 2,833.33 €
Education	17.33% basic secondary education 23.34% intermediate secondary school certificate 35.78% (Applied) University entrance qualification 23.55% higher education degree
Working status	16.67% students (in school or university) 8.33% part-time (less than 35 hours per week) 62.50% full-time (more than 35 hours per week) 12.50% retired
Regional Rail Usage Frequency	37.50% one to three times per month 29.17% one to three times per week 33.33% on a daily basis

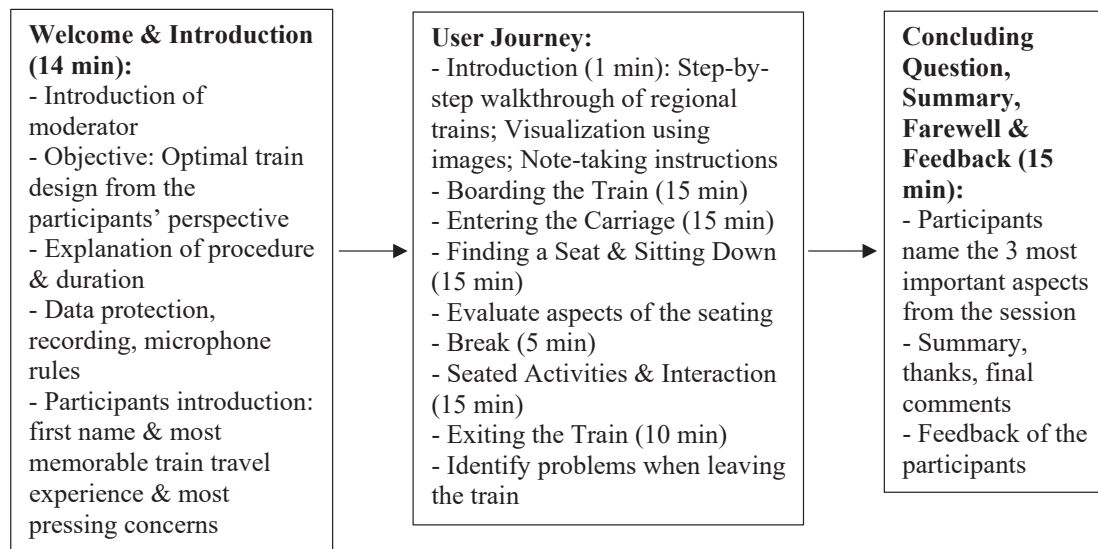


Figure 1. Flow chart of focus group discussions.

gender specific characteristics.

Data analysis

The data was analyzed with the software environment R (version 4.3.1). First, the data were prepared for an exploratory factor analysis (EFA), based on the recommended procedure of Bühner (2021) with six iterative steps: The analyses started with the test for implausible numbers, which revealed none. Next, outliers for each item were identified using a ± 3 standard deviation criterion. To limit their influence on the analysis while retaining all cases, extreme values were replaced with the respective item mean. This approach was chosen for simplicity, but we acknowledge it may slightly reduce item variance. Next, the correlation plot revealed no visible multicollinearity. Bartlett's test of sphericity was significant and the correlation matrix accordingly not random, $\chi^2(630) = 7309.44$, $p = 0$. Based on the Kaiser-Meyer-Olkin statistic (threshold below 0.80) three items were excluded, which resulted in all items being ≥ 0.80 and a general KMO statistic of 0.92. Missing values were replaced using mean imputation, with each missing value substituted by the mean of its respective item. Across the 36 items that entered the EFA, the overall missing-data rate was 6.46 %. Item-wise missingness varied between 0 % and 12.36 % (Table 3). The amount of missing data was modest and there was no systematic pattern of missingness (visual inspection of the missing-value matrix showed a random distribution).

Second, after confirming that the correlation matrix was factorable, the EFA was conducted (Bühner, 2011). The goal of an EFA is, to identify the common factors that explain the order and structure among measured variables (Watkins, 2018). The scree plot suggested a break

after the fourth factor, but the elbow was shallow and therefore ambiguous. However, parallel analysis indicated that six factors should be retained, as the first six eigenvalues exceeded the corresponding eigenvalues from randomly generated data. Due to theoretical considerations (see 1.2. Research Objectives), it was assumed that the factors are correlated, therefore oblimin rotation was employed.

Third, the Shapiro-Wilk test showed significant deviations from normality for all variables (W range = 0.83 – 0.94, all $p < .05$). Therefore, we chose a more robust estimation method, weighted least square, as e.g. maximum-likelihood is more sensitive to non-normal distributed data.

Lastly, we analyzed whether the MDGG-Q reveals gender differences in the design needs for regional trains. To examine gender-specific differences, regression analyses were calculated exploratively with gender as the predictor for the six subscales and the overall score of the developed questionnaire.

Results

Preliminary study

The results of the FGDs will be presented along the aspects which the literature review (Nägele and Gebhardt, 2026) identified as most relevant: (1) safety and security, (2) sanitary needs, (3) usability, and (4) comfort. First, the FGDs revealed that female participants prioritize their foremost concerns in the following order: hygiene, accessibility, and comfort. In contrast, male participants place importance in the following order: accessibility, storage space, and hygiene. Especially hygiene seemed more important to female respondents, compared to male respondents.

Following this, female participants expressed a desire for an increased presence of safety personnel and the installation of emergency buttons, preferences not shared by any of the male participants. "I would very much like to have contact persons in the regional train (...) or simply a presence of security guards or something, especially at night. Sometimes there are situations where you really feel at the mercy of others, as a woman [travelling] alone." (self-identified female participant); "I don't travel by train too often at night or in the evening either, but maybe I would do it more if there was such a thing [as security guards]" (self-identified female participant). Nevertheless, both male and female participants expressed concerns about safety related to train stability, insufficient handholds, and substantial gaps between trains and platforms.

Second, mainly female participants expressed negative evaluations

Table 2
Gender-specific characteristics of survey participants.

	Overall	Women	Men
Age	$M = 49.9$ years ($SD = 17.2$)	$M = 49.9$ years ($SD = 18.0$)	$M = 49.9$ years ($SD = 16.4$)
Height	$M = 1.73$ m ($SD = 0.10$ m)	$M = 1.66$ m ($SD = 0.07$ m)	$M = 1.80$ m ($SD = 0.08$ m)
Weight	$M = 80.2$ kg ($SD = 20.0$ kg)	$M = 70.7$ kg ($SD = 16.6$ kg)	$M = 88.6$ kg ($SD = 19.9$ kg)
Regional rail usage frequency	$M = 2.51$ ($SD = 0.85$)	$M = 2.47$ ($SD = 0.83$)	$M = 2.54$ ($SD = 0.86$)

Note. Usage frequency of regional rails was assessed with a five-point Likert scale: 1 = never/ nearly never; 2 = <1/month; 3 = 1–3/month; 4 = 1–3/week; 5 = daily/nearly daily.

Table 3

Missing-data rate per item entering the EFA.

Item	1	2	3	4	5	6	7	8	9
Missing data rate	5.72	4.06	5.90	4.06	4.24	4.06	4.24	8.12	5.98
Item	10	11	12	13	14	15	16	17	18
Missing data rate	4.61	8.67	6.27	9.96	7.20	9.04	11.07	6.46	7.56
Item	19	20	21	22	23	24	25	26	27
Missing data rate	7.75	7.01	12.36	12.36	0.00	11.25	5.35	4.24	3.87
Item	28	29	30	31	32	33	34	35	36
Missing data rate	8.30	7.38	7.75	5.72	9.23	8.12	6.09	6.64	5.90

of the current sanitary conditions in the interior of regional trains. In the context of restroom facilities, both male and female participants raised similar concerns. However, they seemed more important to female participants. The concerns centered around the cleanliness and limited size of train restrooms: *"I have never seen a clean train toilet."* (self-identified female participant); *"I only use toilets in case of an emergency."* (self-identified female participant). Notably, discussions around general hygiene of regional trains occurred only among female participants, who primarily voiced concerns about unclean cushion and chair covers, push buttons, and the condition of the carpeting. *"I don't know why upholstery and carpets are used at all on a train, where everyone sits on them: it's so disgusting and nonsensical."* (self-identified female participant).

Third, related to usability issues, female participants complained about too high handles, while male participants wished for additional handles in the whole carriages as well as on seats. The interior space in regional trains is, regardless of self-identified gender, perceived as too cramped with aisles that are too narrow. *"I frequently encounter situations in crowded trains where people block the aisle with their luggage."* (self-identified male participant). Regarding luggage storage, mainly female participants reported obstacles with current design solutions. The primary concerns pertain to the presence of too high storage spaces that are out of reach, as well as the inability to monitor luggage due to it being stored at a distance from the seat, which simultaneously represents a safety concern *"If I want to put my luggage into the high storage spaces, I often can't get them up there and have to ask someone else if they can help me, because I am relatively short."* (self-identified female participant). Regarding the information displays participants complained about them being too small, uninformative and chaotic: *"That jumble of signs somehow reminds me of a space station where you have to read a phone book of operating instructions. Who reads through that?"* (self-identified male participant). Especially the information about the compartment and seat number including reservation indications should be easier to find. Female participants also suggested installing a touch screen where one can search for information themselves. Furthermore, male and female participants stated great dissatisfaction with regional train entrances with stairs and pronounced the necessity of barrier-free train carriages. Furthermore, doors open too slow or late and are sometimes difficult to open at all. Many participants therefore requested automatic door opening, ramps and separate doors for boarding and exiting passengers: *"I would like (...) a traffic light (...), because when I have to get out [of the train] as a cyclist, it's impossible to get out sometimes. Once I even had to ride to another station and then change trains and ride back again because they wouldn't let me out with my bike."* (self-identified male participant). Some male participants reported lacking sockets to be able to work during driving with the train and not having enough legroom.

Lastly, as an aspect of comfort many participants complained about current seating solutions: *"I find the seats on regional trains extremely uncomfortable. I have back problems and (...) unlike many people who have used the Deutschland Ticket, I couldn't travel around on regional trains, because I simply can't sit in a seat like that for five hours."* (self-identified female participant). Furthermore, mainly female participants expressed discomfort with the idea of sitting next to strangers: *"Personally, I prefer the four-seater. Because, as you mentioned earlier, it's always awkward when you're in a two-seater and someone sits next to you. Yes, it depends who sits*

next to you, but it can be very uncomfortable." (self-identified female participant). Additionally, many female participants reported experiencing motion sickness when being unable to sit facing the direction of travel *"I think sitting in the direction of travel would also be brilliant. (...) Otherwise, I get sick relatively quickly."* (self-identified female participant). Additionally, many female participants perceive regional trains as too crowded, too warm or too cold.

Discussion of preliminary study

We conducted four preliminary FGDs to identify interior design factors in regional trains which contribute to the MDGG. In line with previous research (Day, 2001; Krauß and Schwimmer, 2021; Pain, 2001), participants mentioned security concerns related to unpredictable behavior of other travelers and heightened anxiety during night time. Above that, the FGDs revealed male as well as female participants have safety concerns related to handles, stability and gaps between train and platform. Furthermore, as previous research has shown (dell'Olio et al., 2011; Eriksson et al., 2022; Loth et al., 2018; Palmer et al., 2019; Sjögren et al., 2017) many participants reported difficulties using regional train toilets, due to size, and hygiene. Additionally, general regional train appearance, e.g. floor or cushions were discussed. Both aspects seemed to be more important to female, compared to male respondents. Additionally, step-free level boarding, and usability difficulties for smaller individuals were found in the FGDs, similar to previous work (Babbar et al., 2022; Leyk et al., 2007; Zunjic et al., 2012). Above that, the FGDs revealed difficulties with overhead luggage storage, narrow train carriages, alighting and embarking, information provision as well as difficulties with door operation. Lastly, as previous research (Dratva et al., 2010; Karjalainen, 2007; Marggraf-Micheel et al., 2010), the FGDs revealed, comfort issues for individuals with smaller body size, in this case mostly female participants. Respondents reported uncomfortable seats and problems with not facing the direction of travel. Additionally, closeness to strangers produce discomfort for some female participants, crowdedness, as well as too warm or too cold carriages.

During the FGDs it got visible that it is not possible to separate effects of gender, body size, social role and sex. Making it even more important to investigate gender effects on satisfaction about regional train interior aspects. Our results guide us to the development phase of the questionnaire to assess the MDGG. Therefore, the following aspects were taken into further consideration for the item development phase of the questionnaire (see Table 4).

Main study

Factor structure

The original 36 items (see Table A1) were submitted to an EFA. In the process of finding the best factor solutions 11 items were excluded due to (1) factor-loadings < .30, (2) cross-loadings > .30, (3) considerations about internal consistent and logical, meaningful factors. The EFA revealed a six-factor solution with 25 items as the best-fitting and most appropriate model for the data. However, one factor comprised only two items, one of which showed an insufficient factor loading (< .30). This

Table 4

Results of the FGDs for further consideration in the item development phase.

Safety and Security	• Security concerns due to other passengers, lacking security guards or emergency buttons • Safety concerns due to lacking handholds, instability, gaps
Sanitary Needs	• Too narrow sanitary facilities • Unhygienic regional rail interior, including sanitary facilities
Usability	• Too high handles and luggage storage • Too narrow train carriages • Entrances with stairs • Information provision • Difficult door operation
Comfort	• Personal space, forced closeness to strangers • Too cold or too hot • Uncomfortable seats

factor was therefore discarded, and a five-factor solution was considered more appropriate with 23 items being included.

The final solution explained 40% of the variance and exhibited a total Cronbach's Alpha of 0.89. The five factors were interpreted and labeled according to the content of their constituent items. The proportion of variance each factor accounted for, and their internal consistency as indicated by Cronbach's alpha was calculated and can be found in Table 5. As an oblimin rotation was applied, the resulting factor intercorrelations became apparent (see Table 5). Table A2 in the Appendix shows the descriptive statistics of each item and factor of the final factor solution. Table A3 constitutes of the final MDGG-Q.

Gender analyses with five-factor structure

To analyze whether the MDGG-Q reveals gender differences, the items of each factor were summarized to a sum score and integrated into linear regressions with gender as the only explanatory variable (a total of 7 tests). For robustness, factor scores were also computed due to the notably different factor loadings, but they yielded very similar results to the sum scores. To account for the inflation of the Type I error rate due to multiple testing, a Bonferroni correction was applied (adjusted significance level: $p = 0.0071$). Higher values in the MDGG-Q indicate higher satisfaction levels.

Space and privacy. This factor captures passengers' perceptions of personal space, seating distance to strangers, storage availability, and general comfort regarding spatial and privacy-related conditions on regional trains. A linear regression revealed a significant effect of gender on *space and privacy*, $F(1, 540) = 8.11, p = .005$. The results indicate that self-identified male participants ($M = 3.40$) compared to self-identified female participants ($M = 3.21$) showed significantly higher satisfaction concerning *space and privacy* in regional trains ($B = 0.20, SE = 0.07, t(540) = 2.85$), with a small effect size ($Cohen's f^2 = 0.015$).

Sanitary facilities and hygiene. This factor reflects passengers' perceptions of cleanliness and hygienic conditions in regional trains, including the state of toilets, seating areas, and the overall interior. A linear regression revealed a significant effect of gender on *sanitary facilities and hygiene* $F(1, 540) = 9.83, p = .002$. The results indicate that self-identified male participants ($M = 3.07$) compared to self-identified

female participants ($M = 2.83$) show significantly higher satisfaction concerning *sanitary facilities and hygiene* in regional trains ($B = 0.25, SE = 0.08, t(540) = 3.14$), with a small effect size ($Cohen's f^2 = 0.018$).

Usability. This factor captures passengers' perceptions of the accessibility, ease of movement, and perceived safety related to the design of regional train features such as entrance and interconnecting doors. A linear regression revealed a significant effect of gender on *usability* $F(1, 540) = 12.51, p < .001$. The results indicate that self-identified male participants ($M = 4.25$) compared to self-identified female participants ($M = 3.98$) show significantly higher satisfaction concerning *usability* in regional trains ($B = 0.27, SE = 0.08, t(540) = 3.54$), with a small effect size ($Cohen's f^2 = 0.023$).

Grab handles. This factor reflects passengers' evaluations of the availability, accessibility, cleanliness, and functional adequacy of handrails and similar support elements in regional trains. A linear regression revealed a significant effect of gender on *grab handles* $F(1, 540) = 15.57, p < .001$. The results indicate that self-identified male participants ($M = 3.65$) compared to self-identified female participants ($M = 3.35$) show significantly higher satisfaction concerning *grab handles* in regional trains ($B = 0.29, SE = 0.07, t(540) = 3.95$), with a small effect size ($Cohen's f^2 = 0.029$).

Comfort. This factor encompasses passengers' perceptions of physical comfort and environmental conditions in regional trains, including seating, temperature, floor stability, availability of trash bins, and perceived safety. A linear regression revealed a significant effect of gender on *comfort* $F(1, 540) = 7.46, p = .007$. The results indicate that self-identified male participants ($M = 3.76$) compared to self-identified female participants ($M = 3.57$) show significantly higher satisfaction concerning *comfort* in regional trains ($B = 0.20, SE = 0.07, t(540) = 2.73$), with a small effect size ($Cohen's f^2 = 0.014$).

MDGG-Q total score. A linear regression revealed a significant effect of gender on the *MDGG-Q total score* $F(1, 540) = 19.40, p < .001$. The results indicate that self-identified male participants ($M = 3.62$) compared to self-identified female participants ($M = 3.38$) show significantly higher satisfaction concerning the *MDGG-Q total score* in regional trains ($B = 1.05, SE = 0.24, t(540) = 4.41$), with a small effect size ($Cohen's f^2 = 0.036$).

Discussion

The present study identified interior design factors in regional trains which contribute to the Mobility Design Gender Gap (MDGG), drawing on an extensive literature review conducted in earlier work (Nägele and Gebhardt, 2026) as well as four FGDs. Based on these findings, we developed the MDGG-Q for regional train interior design, to assess gender-specific user satisfaction with relevant factors. Using exploratory factor analysis (EFA), this study identified 23 suitable items with five factors: (1) space and privacy, (2) sanitary facilities and hygiene, (3) usability, (4) grab handles, and (5) comfort. These factors together reflect the multifaceted nature of gender-specific regional train travel, where physical design and psychological perceptions interact to influence user satisfaction. Above that, the results showed that self-identified male participants scored significantly higher than female participants across all subscales and in the total score of the MDGG-Q for regional trains, although the effect sizes were small. While literature and FGDs suggested higher dissatisfaction among self-identified females, the trend was less pronounced in our data than expected. Even though, considering a wide range of user subgroups in the design of regional train interiors is valuable. It can help uncover previously underappreciated factors, such as sanitary needs and hygiene, which appeared to be highly relevant, as a way to make public transport interior design more satisfying for all.

Our EFA confirmed the multidimensional structure of usage barriers in train interior design identified in previous studies (see e.g. Babbar et al., 2022; dell'Olio et al., 2011; Evans and Wener, 2007; Hwangbo et al., 2015), suggesting that the core dimensions (e.g., comfort,

Table 5

Factor names, explained variance and Cronbach's alpha respectively as well as factor intercorrelations.

Factor	Explained Variance	Cronbach's Alpha	Factor Intercorrelation Matrix			
			1	2	3	4
Space and privacy	11%	0.75				
Hygiene	8%	0.74	0.48			
Usability	8%	0.72	0.29	0.07		
Grab handles	8%	0.70	0.10	0.24	0.39	
Comfort	5%	0.66	0.20	0.16	0.14	0.32

usability) are robust across contexts. However, while prior studies highlighted comfort as the dominant factor (Mohammadi et al., 2020), our data suggest that space and privacy is the most salient factor, possibly reflecting rising passenger expectations post-pandemic (Awad-Núñez et al., 2021; Yap et al., 2025). Indeed, not density per se leads to heightened stress, but personal space invasion (Evans and Wener, 2007). This has implications for design strategies that allow passengers to regulate social contact, for example through flexible seating arrangements or clearer demarcation of personal space. Consistent with this trend, the factor related to sanitary needs and hygiene received the lowest satisfaction rating of all factors (self-identified male participants $M = 3.07$, female $M = 2.83$) and ranked second overall, although it accounted for the same amount of shared variance as the factors usability and grab handles. Importantly, satisfactory hygiene levels and sanitary facilities are a basic need rather than a comfort feature (WHO Europe, 2024). Thereby, perceived cleanliness can shape broader trust in service providers and even influence passengers' emotional state and willingness to re-use services (Eboli and Mazzulla, 2012). Interestingly, perceived hygiene often influences affective responses (e.g., disgust, anxiety) more strongly than objectively measured cleanliness (Lewis et al., 2008), highlighting the importance of both actual cleanliness and hygiene, but also of appearance and design. Additionally, as reported in previous work (Veisten et al., 2024), boarding and alighting still brings major usability barriers. The same authors demonstrated that improvements in boarding and alighting can benefit all users, not only those with more complex design needs. Barriers to boarding, moving, or feeling safe in motion directly affect functional accessibility but also feelings of autonomy and competence (Iwarsson and Ståhl, 2003). This underlines that usability is psychologically significant beyond mere efficiency: it can foster or undermine passengers' sense of agency. Beyond this factor, another usability issue appeared, which was sufficiently influential to constitute an independent factor on its own: grab handles. The current design of grab handles in regional trains seems to not adequately meet the needs of a considerable share of passengers. Many respondents indicated difficulties in maintaining a secure hold, which raises concerns about both usability and perceived safety. This can be explained, at least in part, by the heterogeneous passenger population in regional rail, which often includes elderly travelers, children, females, or passengers carrying luggage. For these groups, the positioning, design, or ergonomics of grab handles may not provide sufficient support, which has been highlighted before (Zunjic et al., 2012). Inadequate grab handle design may therefore not only reduce comfort but also discourage regular use of public transport, especially in situations of crowding or sudden vehicle movements. Addressing these shortcomings through more inclusive design solutions could substantially improve both user satisfaction and perceived safety.

Concerning gender effects, results showed only small effect sizes, even though a pattern emerged. This pattern revealed significant, but only slightly higher dissatisfaction levels of self-identified female participants, compared to self-identified male participants. Possible explanations of the small effects sizes warrant consideration. First and foremost, the distribution of responses was strongly clustered around the midpoints of the scale, with relatively few extreme values. Furthermore, as mentioned before, extreme values were replaced with the respective item mean, which may have contributed to item variance reduction. Such restricted variance naturally constrains the maximum detectable effect size, as there is limited spread in the data on which associations can build. Second, social desirability bias could have played a role. Particularly women might be less inclined to express dissatisfaction or articulate specific design needs in the questionnaire format. In some contexts, women have been socialized to be more accommodating, less confrontational, or less likely to express critique (Bayerl et al., 2025). Studies on online reviews, for example, indicate that women are more likely than men to use emotionally expressive language, such as words conveying strong positive feelings (Abdul-Ghani et al., 2022). At the same time, evidence from scientific publishing shows that women are

less likely to author post-publication criticisms (Imtiaz et al., 2019; Klinowski, 2023). This suggests that gender differences in communication are not simply a matter of personal style, but are intertwined with societal norms and constraints. Additionally, some women hesitate to report discomfort with design features altogether if they are unsure whether their experience is "valid" or "important enough" (Bartky, 2015; Ridgeway, 2011). Third, women might not be aware that more suitable options exist (Leahy et al., 2020; Perttula and Lassi, 2006; Sridhar and LaVoie, 2007), and could thus perceive existing design practices as fixed and unchangeable. In general, it is difficult for people to imagine possibilities beyond what they already know, especially when these differ from the status quo, because imagination is guided by familiar and plausible variations of what is (Byrne, 2007). Moreover, it is challenging to recognize injustices if one is unaware of their existence, let alone articulate or challenge them (Turner-Zwinkels et al., 2016). Lastly, as in the present study gender differences were small (on the Likert scale 0.2–0.3), it has to be considered that the predominant source of dissatisfaction about regional rail interior design could be universal and misaligned with many user expectations and needs, beyond gender effects. This could imply that dissatisfaction with regional rail interior design points to a general need for improvement, as the current design fails to accommodate a wide spectrum of passengers. Importantly, small gender effect sizes are not unusual in the humanities and transport research (Granié et al., 2020; Ng and Acker, 2018; Silveira et al., 2019), yet they can still have significant implications for design decisions, particularly because millions of people use public transport daily. Even subtle gendered differences may create specific needs that are overlooked when the baseline environment is dissatisfying (Parnell et al., 2022). Future research should therefore isolate gender effects by examining individual facets of satisfaction (e.g., safety, cleanliness, accessibility) in relation to trip purposes and mobility patterns.

Limitations and future work

Some limitations have to be considered when interpreting the present results. First, while the questionnaire demonstrated generally acceptable psychometric properties, areas of further refinement occurred. The EFA partly confirmed the hypothesized structure, identifying hygiene, usability, and comfort as key factors, while safety and security did not emerge as a distinct dimension. The additional factors privacy and personal space, as well as grab handles were observed. Cross-loadings were not perfect, but acceptable (all $< .40$; Costello and Osborne (2005)), and internal consistencies were satisfactory (Cronbach's $\alpha = .89$ overall; lowest factor comfort = .66; Hussey et al. (2025)). Although the cumulative explained variance was 40%, below the typical benchmark of 56% in behavioral research (Peterson, 2000), the oblique rotation was appropriate given low-to-moderate factor intercorrelations (Brown, 2009). This modest proportion suggests that a substantial share of passengers' satisfaction is driven by constructs that are not captured by the current MDGG-Q. Possible reasons are (i) the omission of broader service-level attributes (punctuality, ticket-price perception), (ii) the exclusion of psychosocial factors (sense of safety, perceived crowding, social-interaction expectations), and (iii) the limited scope of the original FGDs, which concentrated primarily on physical-design aspects. Overall, the scale offers a first-step, systematic insight into how users perceive regional-rail interior design in Germany. While it already shows acceptable reliability and interpretability, further refinements and validation work are still needed. Future work should therefore (i) extend the questionnaire with items that explicitly address additional domains, and (ii) test multivariate models (e.g., hierarchical regression or structural-equation modelling) to quantify the incremental variance explained. Moreover, the rich qualitative material collected in the FGDs suggests that context-specific safety concerns (e.g., night-time travel, crowded platforms) may act as a meta-factor that shapes the interpretation of several design items. A mixed-methods approach, combining additional survey items with targeted interviews,

could uncover how such meta-factors interact with the six design dimensions identified in the present study.

Second, although safety and security are repeatedly identified in the rail-transport literature as central concerns for female passengers (Useche et al., 2024), they did not emerge as an independent factor in our EFA. We interpret this result in two, non-exclusive ways. (i) Safety-related items may be subsumed within the other four factors (e.g., space & privacy, grab handles), acting as a meta-factor that is expressed through more concrete design attributes rather than as a stand-alone construct. (ii) The wording of our items may not have been sufficiently salient to capture a separate safety dimension; consequently, respondents may have evaluated safety implicitly while rating the surrounding design features. Because of this methodological limitation, the present version of the MDGG-Q cannot be used to assess safety and security as a discrete outcome. Future research should explicitly target perceived safety and security and examine whether safety operates as an overarching latent construct or remains embedded within other design dimensions. Such work will clarify to what extent interior-design interventions can directly influence passengers' safety perceptions, or whether safety is primarily a contextual, non-design-mediated concern that must be addressed through complementary policies and operational measures.

Third, based on methodological considerations we decided not to use a standardized e.g. usability or user satisfaction questionnaire. Instead, we prioritized tailoring the instrument to context-specific needs identified through literature and FGD data. This approach enabled the identification of highly relevant, domain-specific factors, even though they might be transferable to other types of trains or even public transport modes in general. However, this decision limited comparability with established measures and validation options. Nevertheless, future research should consider testing the MDGG-Q alongside validated instruments to assess convergent validity and to explore whether established measures might yield stronger or more differentiated effects. It is important to note that the MDGG-Q is still in its early development phase. The current findings provide a promising starting point, but further validation, both in terms of psychometric properties and across diverse populations, is essential. Particular attention should be given to reassessing the factor structure in confirmatory analyses, and exploring longitudinal applications to assess the stability and sensitivity of the instrument. Above that stratified or interaction analyses should be considered for gender and frequency of train use, as well as gender and trip purpose or time of day.

Fourth, the MDGG-Q was developed with a German sample ($N = 542$) and therefore reflects the cultural, regulatory and operational characteristics of regional rail in Germany. While the internal consistency of the five factors (Cronbach's $\alpha = 0.66$ – 0.75 , overall Cronbach's $\alpha = 0.89$) were satisfactory, the questionnaire might not be applied "as-is" in other regions without further adaptation. Factors such as gender-role expectations, typical train interior layouts, ticketing systems, and service standards differ across countries and can alter respondents' interpretations of several items. Consequently, the questionnaire should be regarded as a template rather than a ready-to-use instrument for all regions. To use the MDGG-Q in a new context, we recommend a systematic cross-cultural adaptation process. The Germany-specific version of the MDGG-Q provides transport planners and vehicle manufacturers with actionable insights (e.g., the importance of lighting, seat ergonomics, and luggage storage).

Practical implications

The findings of the present study yield several important practical implications for the design of gender-inclusive regional train interior design and for the future application of the MDGG-Q. First and foremost, the observed gender differences in perceived design dimensions, though statistically small, consistently indicate a lower level of satisfaction among self-identified female participants in the identified factors. Public

transport providers and vehicle manufacturers should systematically integrate female perspectives into future design processes. At the same time, the considerable dissatisfaction voiced by self-identified male participants indicates that current regional rail interior design requires broader improvements to meet the needs of diverse user groups. In this regard, the deliberate inclusion of different user groups is essential: while the simplest design solutions often cater to only a narrow range of passengers, this study shows that such approaches may ultimately lead to widespread dissatisfaction. A more inclusive design strategy can therefore not only address specific gender-related concerns but also enhance the overall user satisfaction of regional rail. Based on the questionnaire, Table 6 presents concrete, design level implications per factor.

Furthermore, in practice (perceived) safety and security should not be addressed solely through explicit measures (e.g., emergency systems), but also through subtle design features that contribute to passengers' overall sense of security (e.g. spatial layout, personal space protection, lightning, visibility). A more holistic approach, which integrates (perceived) safety and security into multiple facets of the interior design, appears especially promising in this regard. Beyond design considerations, safety and security should be addressed within a broader societal framework. Although design interventions can enhance (perceived) safety and security, they are insufficient to bring about deeper societal change, which might be necessary to make all individuals feel safe in public transport. Thoughtful design can reinforce actual and perceived safety only in combination with initiatives fostering a culture of respect and shared responsibility of and for every public transport user.

Table 6

Design level implications per factor of the MDGG-Q.

1. Space and privacy

- Provide enough personal-space that accommodates passengers with luggage, shopping bags, strollers or accompanying children.
- Design seat layouts and standing-area configurations that minimize involuntary close contact to other travelers (e.g., staggered seats, wider aisles).
- Offer luggage-storage solutions that are reachable for users of smaller stature while delivering the same perceived safety as overhead racks (e.g., low-level compartments with secure locks).

2. Sanitary facilities and hygiene

- Raise cleaning standards for all sanitary units (toilets, wash-basins), document and display the frequency of cleaning cycles.
- Redesign toilet interiors to meet diverse needs, e.g., space for pregnant passengers, easy access for users carrying personal items, and provision of hygienic storage for toiletries.
- Apply a consistent, high-level cleaning regime to the entire carriage (floors, handrails, door handles).

3. Usability

- Install automatic-opening doors and low-floor ramps that enable barrier-free boarding and alighting for all users (including wheelchair users, parents with strollers, and passengers with heavy bags).
- Ensure intra-carriage movement is unobstructed: no steps, no narrow bottlenecks, no heavy doors between carriages, and sufficient width for two-way traffic.
- Eliminate slip-hazard zones (e.g., wet floors, uneven surfaces) and provide non-slip flooring throughout the carriage.

4. Grab handles

- Provide an ample number of handrails positioned at different heights to suit a wide range of body heights.
- Design handrails with multiple grip options (horizontal, vertical, angled) so users can choose a comfortable holding or leaning posture.
- Use antimicrobial materials and display a regular sanitization schedule for all touch surfaces (handrails, door handles, seat backs).

5. Comfort

- Offer seats with adjustable features (e.g., lumbar support, seat-depth, recline) that can be customized by individual passengers.
- Place sufficient waste receptacles in each carriage to avoid overflow and maintain a clean environment.
- Provide climate-control that can be individually adjusted (e.g., seat-integrated ventilation or personal air-diffusers) so that temperature feels comfortable for both heat-sensitive and cold-sensitive users.

Finally, at the policy level, the MDGG-Q may serve as a valuable tool for evidence-based planning and funding decisions in the realm of gender-equitable mobility. Integrating gender-specific user experiences into design guidelines and public transport strategies can contribute to a more inclusive and responsive mobility system, ultimately enhancing the attractiveness of regional train travel for all user groups.

Conclusion

This study presents interior design factors in regional trains which contribute to the Mobility Design Gender Gap (MDGG). Based on the findings of an EFA we developed the MDGG-Questionnaire (MDGG-Q) for regional train interior design, to assess user satisfaction with relevant factors: we found 23 suitable items within the five distinct factors (1) space and privacy, (2) sanitary facilities and hygiene, (3) usability, (4) grab handles, and (5) comfort. The findings highlight key dimensions influencing user experience and reveal consistent, albeit small, gender differences in satisfaction, with self-identifying male participants reporting higher overall satisfaction with regional rail interior design. Nevertheless, it must be acknowledged that current regional rail interior design leaves many passengers dissatisfied regardless of gender, indicating that gender-inclusive approaches should first and foremost be embedded within a broader effort to better address overall user needs, an issue that constitutes an immediate call to action for transport providers. Therefore, the MDGG-Q provides a valuable foundation for further research, offers practical insights for improving interior design of regional trains as well as public transport modes altogether and for all users.

CRediT authorship contribution statement

Sophie Isabel Nägele: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal

analysis, Data curation, Conceptualization. **Laura Gebhardt:** Writing – review & editing, Supervision, Resources, Project administration.

Declaration of competing interest

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

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Declaration of generative AI in scientific writing

During the preparation of this work the authors used Generative AI (GPT-5) in order to improve the readability and language of the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Ethical statement

Approval was given by the Ethics Board of the German Aerospace Centre on the 18.11.2025. Participants gave informed consent and were informed about their rights by the [market research agency](#) who administered the questionnaire.

Appendix

Table A1

Initial 36 items (translated from German) with respective sources beyond FGD results.

Construct	Item	Source
Safety and Security	1. I feel sufficiently protected from potential dangers (e.g., accidents, falls) in regional trains as they are designed.	(Ceccato, 2017; Cullen et al., 2021; Forsberg et al., 2017; Kim, 2021; Loukaitou-Sideris and Fink, 2009)
	2. As regional trains are currently designed, I sometimes feel threatened by other people.	(Ceccato, 2017; Kaygan et al., 2023; Kim, 2021; Loukaitou-Sideris, 2014; Matthewson and Kalms, 2021)
	3. There are not enough security personnel (e.g., police officers, Deutsche Bahn security staff, etc.) in regional trains.	(Ceccato, 2017; Forsberg et al., 2017; Kim, 2021)
	4. If security cameras are installed in regional trains, I feel safer because of them.	(Forsberg et al., 2017; Loukaitou-Sideris, 2014; Soto et al., 2022)
	5. There are not enough handrails in regional trains for me to hold on to at all times.	(Babbar et al., 2022; Chen et al., 2020; Hwangbo et al., 2015; Mohammadi et al., 2020)
	6. When I have luggage, I store it in a luggage rack outside my field of vision without concern in regional trains.	(Ceccato, 2017; Cullen et al., 2021; Forsberg et al., 2017; Kim, 2021; Loukaitou-Sideris and Fink, 2009)
	7. In regional trains, I often find the floor either too slippery, uneven, or wobbly.	(Babbar et al., 2022; Forsberg et al., 2017; Hiemstra-van Mastrigt, 2015; Mohammadi et al., 2020)
Sanitary Needs	8. The way the toilets in regional trains are designed meets my needs (e.g., they are spacious, provide enough storage, etc.).	(Greed, 2015; Loth, 2021; Loth et al., 2018)
	9. I find it unpleasant to use the toilets in regional trains.	(Greed, 2015; Kaygan et al., 2023; Kim, 2021; Loukaitou-Sideris, 2014)
	10. I usually find the toilets in regional trains sufficiently clean and hygienic.	(Greed, 2015; Kowalik et al., 2019; Loth, 2021; Loth and Molenbroek, 2011)
	11. I usually find the interior of regional trains neither sufficiently clean nor hygienic.	(Ahmadpour et al., 2014; Eboli and Mazzulla, 2012; Greed, 2015; Kowalik et al., 2019)
	12. I find the seats in regional trains sufficiently clean and hygienic.	(Babbar et al., 2022; Eboli and Mazzulla, 2012; Forsberg et al., 2017; Hiemstra-van Mastrigt, 2015; Loth et al., 2018; Mohammadi et al., 2020)
	13. I feel uncomfortable when the interior of regional trains is in poor condition (e.g., defaced, damaged).	(Chen et al., 2020; dell'Olivo et al., 2011; Eboli and Mazzulla, 2012; Mohammadi et al., 2020)
	14. I usually find handrails, buttons, etc., in regional trains not sufficiently clean and hygienic.	(Eboli and Mazzulla, 2012; Eriksson et al., 2022; Greed, 2015; Loth, 2021)
	15. I think there are too few trash bins in regional trains.	(dell'Olivo et al., 2011; Eboli and Mazzulla, 2012; Greed, 2015)
		(Greed, 2015)

(continued on next page)

Table A1 (continued)

Construct	Item	Source
Usability	16. Regional trains are usually too warm or too cold for me.	(Chen et al., 2020; Karjalainen, 2007; Mohammadi et al., 2020; Qiao et al., 2023)
	17. I find regional trains easy and practical to use as they are designed.	(Babbar et al., 2022; Forsberg et al., 2017; Hiemstra-van Mastrigt, 2015; Loth et al., 2018; Mohammadi et al., 2020)
	18. The way the entrance doors of regional trains are designed makes it difficult for me to get on and off.	(Alberda et al., 2015; Babbar et al., 2022; Hwangbo et al., 2015)
	19. The way the interconnecting doors of regional trains are designed makes it difficult for me to move from one carriage to another.	(Babbar et al., 2022; Forsberg et al., 2017; Hiemstra-van Mastrigt, 2015; Loth et al., 2018; Mohammadi et al., 2020)
	20. I know how to use the facilities in regional trains that I want to access (e.g., Wi-Fi, toilet doors).	(Babbar et al., 2022; Forsberg et al., 2017; Hiemstra-van Mastrigt, 2015; Loth et al., 2018; Mohammadi et al., 2020)
	21. I can easily stow my luggage or belongings (e.g., jacket, bouquet of flowers) in overhead compartments in regional trains.	(Babbar et al., 2022; Forsberg et al., 2017; Hiemstra-van Mastrigt, 2015; Loth et al., 2018; Mohammadi et al., 2020)
	22. When I'm not seated, I can hold on to the handrails in regional trains in a way that keeps me safe and stable.	(Ahmadpour et al., 2014; Alberda et al., 2015; Leyk et al., 2007; Linder and Svensson, 2019)
	23. I find many handrails in regional trains neither easy nor good to reach.	(Babbar et al., 2022; Hwangbo et al., 2015; Mohammadi et al., 2020)
	24. I cannot find the information I need and look for in regional trains easily or quickly.	(Babbar et al., 2022; dell'Olio et al., 2011; Eboli and Mazzulla, 2012; Mohammadi et al., 2020)
	25. I can do everything I want or need to do during the journey (e.g., taking care of children, working, reading, studying) in regional trains as they are designed.	(Ahmadpour et al., 2014; Hwangbo et al., 2015; Mohammadi et al., 2020)
	26. There is usually insufficient space to store luggage or belongings in regional trains.	(Ahmadpour et al., 2014; Alberda et al., 2015; Loth et al., 2018)
	27. Regional trains are sufficiently barrier-free for my needs (e.g., I can board and alight without problems, etc.).	(Alberda et al., 2015; Babbar et al., 2022; Hwangbo et al., 2015)
	28. I am usually not provided with enough information about my journey in regional trains, so I miss important details.	(Babbar et al., 2022; dell'Olio et al., 2011; Eboli and Mazzulla, 2012; Mohammadi et al., 2020)
	29. When I need help, there are enough responsible staff members on regional trains for me to ask for assistance.	(Ahmadpour et al., 2014; dell'Olio et al., 2011; Mohammadi et al., 2020)
Comfort	30. I find regional trains comfortable as they are designed.	(Ahmadpour et al., 2014; Jordan, 2000; Mohammadi et al., 2020)
	31. I usually have enough space in regional trains.	(Ahmadpour et al., 2014; Alberda et al., 2015; Babbar et al., 2022; Forsberg et al., 2017; Hwangbo et al., 2015)
	32. Regional trains are usually too crowded for me.	(Ahmadpour et al., 2014; dell'Olio et al., 2011; Evans and Wener, 2007; Mohammadi et al., 2020)
	33. I feel uncomfortable when I have to sit next to or opposite strangers in regional trains.	(Bose et al., 2011; Carlsson et al., 2021; Cullen et al., 2021; Evans and Wener, 2007; Forsberg et al., 2017; Linder and Svedberg, 2019)
	34. I usually have enough personal space and privacy in regional trains.	(Acar and Weekes, 2006; Evans and Wener, 2007; Hiemstra-van Mastrigt, 2015; Loth et al., 2018)
	35. The distance to other passengers while seated or standing is sufficient for my comfort.	(Ahmadpour et al., 2014; Babbar et al., 2022; Evans and Wener, 2007; Forsberg et al., 2017; Loth et al., 2018; Mohammadi et al., 2020)
	36. I find the seats in regional trains uncomfortable.	(Acar and Weekes, 2006; Ahmadpour et al., 2014; Da Gameiro Silva, 2002; Hiemstra-van Mastrigt, 2015; Mohammadi et al., 2020)

Table A2

Descriptive statistics of the MDGG-Q with a five-factor solution.

Item	Descriptive Statistics			Factors						
	Mean	Skewness	Kurtosis	Space and Privacy	Sanitary facilities and hygiene	Usability	Grab handles	Comfort	H2	
31	3.56	-0.37	0.16	0.71	0.06	0.15	-0.01	0.01	0.61	
35	3.27	-0.03	0.21	0.64	0.12	-0.14	0.12	0.01	0.56	
34	2.96	0.13	-0.20	0.57	0.27	-0.03	-0.03	0.01	0.53	
21	3.38	-0.14	-0.05	0.45	-0.03	0.14	-0.04	0.03	0.22	
4	3.55	-0.06	-0.63	0.38	-0.05	-0.15	0.26	0.36	0.44	
27	3.12	0.30	-0.07	0.33	-0.07	0.06	0.16	0.13	0.25	
11	2.48	0.52	-0.10	0.05	0.77	-0.05	-0.02	-0.10	0.60	
9	3.32	-0.29	-0.45	0.12	0.56	0.21	-0.05	0.00	0.42	
10	2.48	1.25	0.83	-0.01	0.45	-0.08	0.10	0.15	0.29	
12	3.16	0.8	-0.39	-0.03	0.43	0.04	0.13	0.25	0.47	
13	3.32	-0.26	-0.23	0.34	0.38	0.02	0.00	0.11	0.51	
27	4.35	-0.82	0.41	0.10	-0.01	0.73	-0.02	-0.14	0.57	
18	4.36	-0.69	-0.03	-0.09	-0.01	0.66	0.13	0.19	0.57	
19	4.03	-0.34	-0.19	-0.08	0.04	0.41	0.26	0.20	0.44	
1	3.74	-0.45	0.42	0.22	0.20	0.34	0.07	-0.11	0.37	
5	3.58	0.06	-0.40	0.02	-0.01	0.07	0.59	0.03	0.43	
23	3.72	-0.21	-0.33	-0.06	0.02	0.18	0.52	0.08	0.41	
22	3.62	-0.12	0.03	0.36	-0.03	0.18	0.49	-0.31	0.59	
14	3.09	0.23	-0.23	-0.06	0.34	-0.10	0.44	0.12	0.48	
7	4.06	-0.43	0.11	0.03	0.05	0.37	0.11	0.40	0.43	
36	3.68	-0.24	-0.29	0.35	0.01	0.13	-0.03	0.39	0.46	
15	3.14	0.20	-0.36	0.18	0.03	0.16	0.09	0.31	0.26	
16	3.77	-0.18	0.12	0.19	-0.08	0.02	0.24	0.31	0.28	

Table A3

The final MDGG questionnaire for regional trains.

1. Space and privacy	
1.1.	I usually have enough space in regional trains.
1.2.	The distance to other passengers while seated or standing is sufficient for my comfort.
1.3.	I usually have enough personal space and privacy in regional trains.
1.4.	I can easily stow my luggage or belongings (e.g., jacket, bouquet of flowers) in overhead compartments in regional trains.
1.5.	I feel uncomfortable when I have to sit next to or opposite strangers in regional trains.
1.6.	There is usually insufficient space to store luggage or belongings in regional trains.
2. Sanitary facilities and hygiene	
2.1.	I usually find the toilets in regional trains sufficiently clean and hygienic.
2.2.	The way the toilets in regional trains are designed meets my needs (e.g., they are spacious, provide enough storage, etc.).
2.3.	I find it unpleasant to use the toilets in regional trains.
2.4.	I usually find the interior of regional trains neither sufficiently clean nor hygienic.
2.5.	I find the seats in regional trains sufficiently clean and hygienic.
3. Usability	
3.1.	The way the entrance doors of regional trains are designed makes it difficult for me to get on and off.
3.2.	The way the interconnecting doors of regional trains are designed makes it difficult for me to move from one carriage to another.
3.3.	Regional trains are sufficiently barrier-free for my needs (e.g., I can board and alight without problems, etc.).
3.4.	I feel sufficiently protected from potential dangers (e.g., accidents, falls) in regional trains as they are designed.
4. Grab handles	
4.1.	There are not enough handrails in regional trains for me to hold on to at all times.
4.2.	I find many handrails in regional trains neither easy nor good to reach.
4.3.	When I'm not seated, I can hold on to the handrails in regional trains in a way that keeps me safe and stable.
4.4.	I usually find handrails, buttons, etc., in regional trains not sufficiently clean and hygienic.
5. Comfort	
5.1.	In regional trains, I often find the floor either too slippery, uneven, or wobbly.
5.2.	I find the seats in regional trains uncomfortable.
5.3.	I think there are too few trash bins in regional trains.
5.4.	Regional trains are usually too warm or too cold for me.

Data availability

The data that has been used is confidential as they are part of a larger research project and includes sensitive data.

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