



Comparison of the stair safety awareness in different target groups by applying the VASMA-C methodology

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Abstract

There are many cases in the construction industry when decision making related to the specific elements of the single-family houses is left to the property owners. The choice of the internal stairs design is one of them. While stair-related injuries are among the most common reasons for children's accidents at home, stair safety awareness in different target groups becomes an important matter to prevent kid injuries in domestic environments. Eleven staircase parameters affecting children's safety in single-family houses were determined in this study. The online survey dedicated to collecting and assessing the importance of these parameters was constructed and spread in Lithuania. The new modification of the VASMA (Visual Analogue Scale Matrix for Criteria Weighting) methodology called VASMA-C was proposed to analyse collected data and to expose opinions differences in three target groups: experts in the field, apartment residents and house residents living with children. The comparative study disclosed that staircase landing is the parameter whose importance among the expert and non-expert evaluators differs the most. It was also revealed that apartment residents have the most divergent understanding of staircase safety compared with the rest of the target groups. These findings indicate that different customers need diverse information about the staircase parameters affecting children's health and the stair vendors should be aware of these demands.

Keywords Stairs · Safety · Children · Criteria weighting · VASMA · Entropy

1 Introduction

For the past decade, there has been a growing interest in improving residential quality. Children's safety at home is one of the most important requirements when thinking about the construction of the house and its separate elements [1]. Many pediatric injuries occur in domestic environments: home fire, scalds, medication poisoning, electrical burn, and falls are the most frequently noticed hazards causing

kid illnesses, disabilities, or even deaths [2]. Stair-related injuries are one the most common reasons for young children visiting the emergency departments [3]. However, accidents on stairs (falls, slips, and trips) are rarely caused by a single reason but rather by a combination of factors like staircase design, maintenance, lightning, and the individualities of the staircase users. Since children have a limited ability to recognize stair-related hazards, it is the shared responsibility of parents, caregivers, the community, and the government to ensure children's safety in domestic environments [4].

Berry et al. [5] explored the connection between household safety, housing tenure, and dwelling type. They determined that families living in privately owned rental houses establish the most hazardous living environment for toddlers compared with families living in privately owned and government-owned rental housing. The relationship between the dwelling type and domestic safety was also analysed by Pauls [6], who discovered the significant increase of stair-related injuries in single-family houses and the gradual decrease of traumas among the population residing in apartments. Differences in the regulations for public and private

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buildings were identified as the possible reason for this situation. While public buildings and their inside elements are built in strict compliance with the security requirements, there is much freedom for the stair customers to choose a desirable staircase design. For instance, staircase shape is normally provided in the house project, but the final decisions on the specific parameters like riser height, tread width, step coating, handrail construction, stair lighting and other features are left to the property owners.

House owner requirements for the inside staircase design are typically determined based on their knowledge, experience, and recommendations from stair sellers, designers, and friends. It is already known that there might be an asymmetry between expert-based and non-expert-based opinions [7, 8]. However, the authors of this article consider that stair safety awareness might also be different among the non-experts currently living in private houses and the apartment residents. In this study, the private house notion encompasses detached, semi-detached and attached single-family houses, while the apartment concept describes private and rented flats located in multi-story apartment buildings.

The main aim of this study is to reveal how staircase safety awareness differs in three target groups: experts of the domain, apartment residents (AR), and private house residents living with children (HRWC). These target groups were chosen since it is a common case when families living in apartments and planning to have children decide to buy or rent a larger dwelling with the inside stairs, but their knowledge of the staircase safety might be insufficient to ensure a hazard-free domestic environment for the children. The proper knowledge of the stair customer differences enables stair sellers to choose the best strategies for explaining why staircase design solutions that look attractive do not necessarily meet safety requirements. To the best of our knowledge, there are no currently other studies dedicated to these purposes.

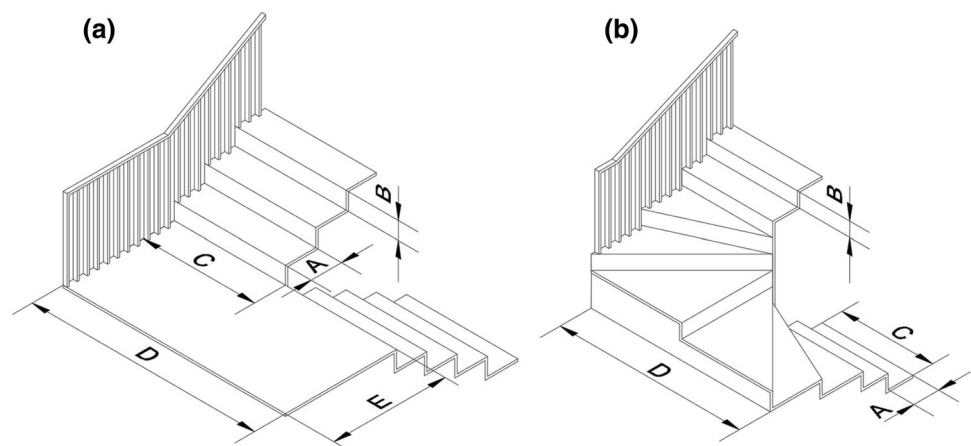
2 Analysis of the parameters influencing inside stairs safety

The research presented by Ban and Chen [1] exposed that there are three groups of factors affecting domestic safety awareness: specifics of the house residents, their competency to assess the safety status, and the asymmetry of the information related to the safety hazards, house management policies, and the structure of the constructional objects. For instance, children's safety on stairs is affected by the individualities of the staircase user (age, fitness, mobility, impairments, behavioral peculiarities), stair maintenance level and the staircase design features like stair structure, stair gates, step coating, or staircase lighting [9]. Thus, the analysis of the staircase parameters affecting kids' safety in two-story private houses will be done in this section.

Many studies highlight the connection between staircase safety and geometric parameters. Kendrick et al. [10] presented an extensive case-control study where risk and protective factors for falls on stairs of the young children (aged 0–4 years) were analysed. In this study, the existence of the safety gates, intermediate landings, the proper handrail and railing design, non-slippery covering of stairs, and appropriate lightning were determined as the most important safety factors. In contrast, spiral and winding stairs, wide gaps between railings, poor lighting, and too steep and narrow steps were recognised as the most hazardous staircase features. Francksen et al. [11] added that step geometry should be uniform in shape and dimension. Berger et al. [12] stated that safer staircase designs include lower risers and wider treads ever since these features aggravate children crawling and climbing capabilities.

The choice of the staircase type (straight, divided in runs, divided in runs with a turn, with winders, spiral) is also an important safety factor since intermediate landings serve as a compensating factor in case of a fall (Fig. 1). Kendrick et al. [10] indicated that non-installation of

Fig. 1 **a** stairs with the intermediate landing, **b** winding staircase. A—tread width (step width), B—riser height (step height), C—flight width, D—staircase width, E—intermediate landing width



landings part-way up the stairs is commonly noticed in the living environments where severe children injuries caused by falling from stairs were confirmed. While the non-existence of the intermediate landings increases the falling time, it is one of the parameters strongly affecting children's safety on stairs [13].

Slip from the staircase is another common hazard for the residents of the single-family house. Slips due to overstepping treads in one of the most frequent types of stairway falls. A non-slippery surface on the whole steps or at least on the leading edges is crucial to eliminate this threat. Carpets or step covering with slip-resistant paints may be used for this purpose [9].

Staircase lighting also plays an important role in ensuring visibility of the stairs nosing and reducing slippery hazards. Since staircases of private houses are commonly installed in places where natural lighting is not reachable, visual contrast indication created by installing artificial lights along the nosing of the tread is extremely important [14]. Natural lighting (windows and doors with glasses) produces better visibility of stairs in the daytime and is very important for the emergencies like fire or a power outage, while artificial lighting increases a person's courage to climb the stairs both during the daytime and the night-time.

The appropriate handrail and railings design also work as a risk prevention tool [15]. A handrail is the part of stairs that people hold on to when climbing the stairs, and the railing is the barrier that prevents people from falling off the staircase side. The handrails (also called a bannister) act as a support, stabilisation and guidance tool. They are typically attached to a wall or placed on top of the balusters that fill the railings. Handrails should be available at all points throughout the flight and placed at a height within the user's reach. Therefore, it is recommended to install secondary handrails at a lower level of the stairs in private houses where children are raised. However, since there is a high risk that a distracted child might fall from stairs through the wide gaps between balusters, railings design should have intermediate rails or ornamental pattern, which does not have a bigger than 100 mm diameter sphere to pass through them. Railings also should not offer easy or obvious methods to climb them.

Based on the performed analysis, the final list of staircase parameters affecting children's safety in private houses was determined. This list consists of 11 items: (1) Staircase strength and durability, (2) Handrail construction, (3) Handrail material, (4) Intermediate landing, (5) Staircase width, (6) Riser height, (7) Thread width, (8) Step coating, (9) Safety gates, (10) Natural lighting, (11) Artificial lighting. The safety awareness of these parameters in different target groups was analysed in the study case presented in this paper.

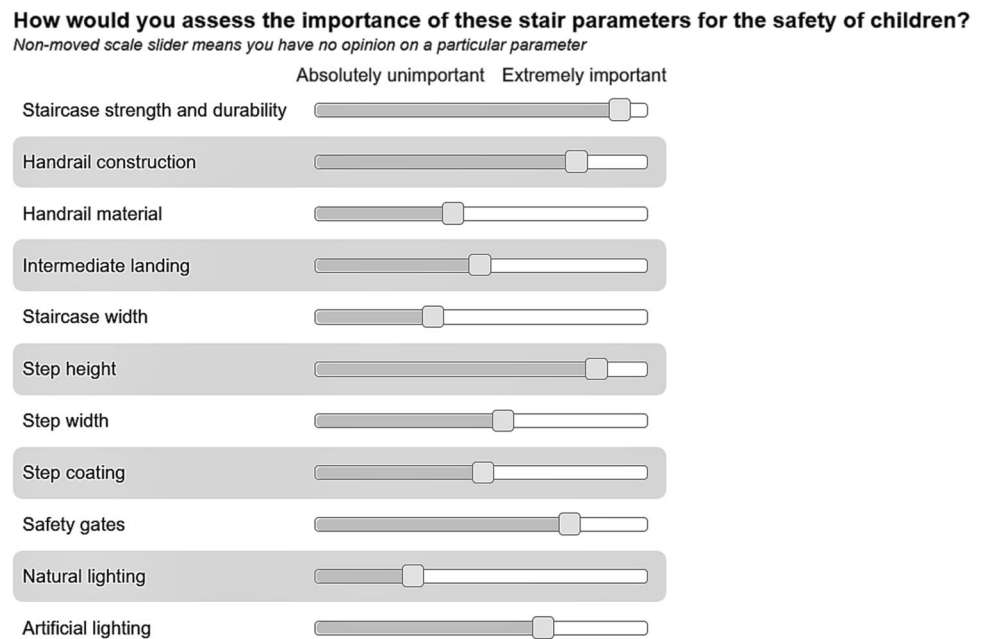
3 Safety awareness on the stair safety parameters: the study case

Recently, there has been an increased interest in the private house market in Lithuania. Every newcomer strives to buy the house of their dreams and to produce a safe and comfortable environment for their residents. Owners of two-story private houses have the responsibility to think not only about the appropriate interior solutions but also about the safety of the inside stairs. The main goal of this study case is to distinguish differences in stair safety awareness in three target groups: the experts, the apartment residents, and the residents of single-family houses who already raise children. The authors of this paper expect to understand what information about stair safety parameters should be given to people who currently live in apartments but are planning to move into a single-family house. Assessment of the importance of the predetermined stair safety parameters will be the core of this study case.

3.1 Survey construction

The six-question online survey was constructed to identify the discrepancies in the respondents' awareness of the stair-related parameters affecting children's safety at home. The first three survey questions were dedicated to collecting sociodemographic information about the participants (gender, age, city), and the other couple of questions were devoted to identifying if the respondents nurture children up to 6 years old and if they are currently living in the apartment or the multi-storey private house. The final survey question was dedicated to collecting data on how the respondents understood the importance of all the 11 stair safety parameters. The single matrix question consisting of eleven Visual Analogue Scales (VAS) (each representing one of the earlier predetermined parameters) was used as the data collection tool. The visual appearance of the matrix question presented to the survey participants is presented in Fig. 2. In this survey, the parameters "riser height" and "thread width" were named as "step height" and "step width" to be understandable for both the expert and non-expert respondents. To reduce the uncertainties raised in the criteria assessment process, all the survey participants were informed that the non-moved slider represents a situation when the respondent does not have a specific opinion about the presented parameter. It means that all the respondents were given the choice not to assess all the eleven criteria. This freedom is possible since Visual Analogue Scale Matrix for Criteria Weighting (VASMA) methodology [16] (which is the base of the VASMA-C approach proposed in this paper) analyse data

Fig. 2 The screenshot of the matrix question which consists of 11 VAS scales representing the analysed criteria set



entropy and psychometric features of the VAS scales to reduce the uncertainties of the collected data.

3.2 Survey participants

One hundred and two individuals fully completed the online survey: 10 experts and 92 non-experts living in Lithuania. The expert group consisted of architects (40%), constructors (30%), and scientists in the field (30%). Non-expert participants represented House Residents living with Children (HRWC) and people currently living in the apartment buildings (AR). The demographic profile of all the respondents is presented in Table 1.

All the experts were invited to participate in the experiment personally by sending them e-mails with the survey link. Respondents belonging to the HRWC (46 people) and AR groups (46 people) were volunteers, reached through the organic survey spread in the social networks. Descriptive statistics of all the collected data are presented in Table 2.

While a high rate of missing data might be observed in this type of data collection, the internal reliability of the 11 items presented in a single matrix question had to be checked. The total Cronbach's Alpha coefficient was calculated and showed that the overall internal reliability of the collected data is very high (0.9771). The Cronbach's Alpha calculated separately for each of the criteria also showed high reliability (0.8857 to 0.9182); thus, it was decided that the collected data are suitable for the further data processing steps.

3.3 VASMA-C methodology for the criteria importance comparison in the distinct target groups

It is well known that the chosen data processing technique can highly influence survey results; therefore, it is important to choose the appropriate tools for the survey data analysis [17]. Recently, the comparison of the importance of the specific parameters set was proposed to be solved as the

Table 1 Demographic profile of the respondents

Variable	Experts		House residents with children (HRWC)		Apartment residents (AR)	
	Category	(%)	Category	(%)	Category	(%)
Gender	Female	50.0	Female	50.0	Female	50.0
	Male	50.0	Male	50.0	Male	50.0
Age	18–29	0.0	18–29	8.0	18–29	16.0
	30–39	30.0	30–39	61.0	30–39	54.0
	40–49	20.0	40–49	16.0	40–49	12.0
	50–older	50.0	50–older	15.0	50–older	18.0

Table 2 Descriptive statistics of the criteria weighting performed by the VAS Matrix

No.	Criteria descriptions	Count of assessments	Mean	SD	Median	Cronbach's Alfa
C1	Staircase strength and durability	99	89.05	10.25	92.00	0.9123
C2	Handrail construction	101	82.10	20.62	89.00	0.9182
C3	Handrail material	83	56.35	30.37	61.00	0.9074
C4	Intermediate landing	74	57.43	35.17	69.00	0.9059
C5	Staircase width	70	73.87	22.42	76.00	0.8871
C6	Step height	85	79.55	23.81	89.00	0.8989
C7	Step width	89	84.13	16.21	90.00	0.8887
C8	Step coating	87	79.40	22.19	84.00	0.8857
C9	Safety gates	83	72.55	29.92	85.00	0.9159
C10	Natural lighting	78	71.24	20.35	74.50	0.8983
C11	Artificial lighting	76	78.22	21.85	87.00	0.9034

criteria weighting task. Both the direct weighting (DW) and indirect weighting (IW) approaches can be applied for these purposes. The DW techniques are usually applied to analyse data collected from the non-expert evaluators [18, 19], while the IW methods are chosen when expert-based decisions making are required [20]. Direct Rating [21] or Point Allocation [21] approaches are commonly applied to analysing non-expert appraisals; however, both of them have two important disadvantages—high biases of the collected data and low variation of the criteria weights [16]. Therefore, other criteria weighting techniques like AHP [22] or SWARA [23, 24] are also chosen to analyse the importance of the criteria set. For instance, Morkunaite et al. [25] applied AHP to analyse quantitative and qualitative criteria setting for selecting heritage contractors. Soh et al. [26] performed a questionnaire survey on determining the differences in understanding the importance of design for safety strategies in building projects and applied the Fuzzy AHP to determine dissimilarities between the clients, and designers. Durdyyev et al. [27] hired experts as the survey participants and employed the cybernetic fuzzy AHP to prioritise factors affecting the green building purchase intention among Malaysian homebuyers.

Although the AHP and SWARA are widely used criteria weighting approaches, both of them are pairwise approaches, which means that each of the criteria must be mandatorily assessed regardless of whether the respondent knows the specific parameter or not. Researchers are making great efforts to reduce the non-response rate of survey data. Nonetheless, it is very difficult to persuade less motivated respondents to complete the survey completely. Moreover, the results collected in such a coercive way may not reflect the true views of the survey respondents. Although the presence of missing data involves more uncertainty in the decision-making processes, management of the data “missing-by-design” is a task that can be addressed by specific data analysis methods. For instance,

VASMA (VAS Matrix for criteria weighting) is constructed as the survey-based criteria weighting technique that employs a single matrix question constructed from the Visual Analogue Scale (VAS) to collect data and does not require a respondent to assess all the criteria [16]. It is possible since VASMA weighting respects the psychometric features of the VAS scales and analyses the uncertainties caused by the survey-based preference elicitation. The VASMA methodology applies a combination of subjective and objective weights to exploit the uncertainties occurring in the survey-based preference elicitation. The information entropy theory is employed to determine the objective weights, and the WASPAS-SVNS (Weighted Aggregated Sum Product Assessment method under Single Value Neutrosophic Sets) approach is employed to calculate the subjective weights [28].

Recently, the original VASMA weighting methodology was applied to determine the importance of the parameters affecting the choice of the kindergartens' institutions [16] and to assess the successful drivers of crowdfunding projects [29]. However, in both of these studies, the VASMA was employed to calculate criteria weights from the assessors belonging to the single target group which have a similar knowledge and experience on the analysed topic. The deeper analysis of the study case presented in this paper revealed that the response rate of the same item (parameter) noticeably varies in the distinct target groups. For instance, all experts participating in the study assessed all the criteria analyzed in the study case, while HRWC and AR respondents behave differently. Since it was clearly stated in the survey that non-movement of the specific slider represents a situation when the respondent does not has an opinion on the specific parameter (Fig. 2), the diverging item level non-response rate for the same criteria assessed in different target groups is not an accidental result. This kind of uncertainty might have an impact on the preference elicitation results. Thus the modification of the original VASMA methodology

called VASMA-C is proposed in this paper to include the item response rate d in the calculations.

The VASMA-C methodology proposed in this paper consists of the following steps:

Step 1. Employ the VAS matrix for the data collection, save the criteria assessments as the discrete values ranging from 1 to 100 and create the initial decision matrix R^0 . In this matrix, entries equal to 0 represent cases of the non-moved VAS scales (respondents did not have an opinion on the specific parameter). *Note:* The same VAS matrix must be used to collect data from all the respondent groups.

Step 2. Perform the data cleaning and update the decision matrix R^0 . Entries from the respondents where neither of the criteria or a single criterion has been evaluated should be deleted to ensure that only the trustful data will be processed later.

Step 3. Check the internal reliability of the final data. If the internal reliability is sufficient, data recorded in the decision matrix R^0 can be split into the separate matrices $R^1, R^2, \dots, R^N$, where each of them represents appraisals collected from the different target group n .

Step 4. Calculation of the objective weights. For the calculation of the objective weights, information entropy theory is applied. The decision matrix P^n is constructed from the data matrix R^n . In this decision matrix, columns denote the set of criteria, and rows denote the possible values p_{kl} that represents the proportion of response k for the analysed criterion l for each of the possible values of the VAS scales ($k = 1 \dots 100$). All the p_{kl} values must follow the following rules: $0 \leq p_{kl} \leq 1$ and $\sum_{k=1}^{100} p_{kl} = 1$ and $p_{kl} \log_2(p_{kl}) = 0$ when $p_{kl} = 0$. Normalised information entropy $\tilde{E}_l(p)$ for each of the criteria l is calculated by the following formula:

$$\tilde{E}_l(p) = \frac{\sum_{k=1}^{100} p_{kl} \log_2(p_{kl})}{\log_2\left(\frac{1}{100}\right)}; l = 1, 2, \dots, L, \quad 0 \leq \tilde{E}_l(p) \leq 1. \quad (1)$$

The final entropy weights are calculated by the equation:

$$W_l = 1 - \tilde{E}_l(p); \quad l = 1, 2, \dots, L, \quad 0 \leq W_l \leq 1. \quad (2)$$

Step 5. Calculation of the subjective weights. The subjective part of the VASMA weights is calculated employing the WASPAS-SVNS approach, initially presented by Zavadskas et al. [28]. Another decision matrix X^n must be constructed from the decision matrix R^n to calculate subjective weights. The construction of the decision matrix X^n and the mathematics of the WASPAS-SVNS methodology is explicitly described in Lescauskiene et al. [16].

Step 6. Calculation of the VASMA-C weights. VASMA-C weight M_l for each of the parameter l is calculated from the entropy weights W_l , the subjective weights S_l and response rate d_l applying the formula:

$$M_l = \frac{S_l W_l d_l}{\sum_{l=1}^L S_l W_l d_l}, l = 1, 2, \dots, L. \quad (3)$$

Here, L is the total count of the analysed parameters, d_l ($0 \leq d_l \leq 1$) is the item response rate in the analysed target group.

Step 7. The final three steps (steps 4, 5 and 6) must be repeated for each of the matrices $R^1, R^2, \dots, R^N$ until all the M_l^n values are calculated. Here, l is the index of the analysed criterion and n is the index representing the specific target group.

Step 8. Finally, the variation of the importance of the same parameter l among the specific user groups n can be done by visually and numerically comparing the calculated M_l^n values.

Table 3 Criteria assessments converted from the VAS matrix to the decision matrix R^0

ID	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1	84	57	35	88	75	79	86	97	60	72	92
2	67	67	97	44	97	98	65	62	76	87	60
3	100	50	100	78	77	76	100	100	100	50	100
4	100	50	100	100	100	100	50	50	72	50	100
5	100	98	53	81	89	90	78	0	0	0	99
...	...	...	...	...	...	...	...	...	...	...	...
98	80	78	72	73	0	71	73	72	73	54	77
99	100	72	0	0	65	96	96	100	0	74	74
100	69	66	0	0	76	78	76	88	0	84	54
101	72	35	12	50	66	91	92	93	50	29	29
102	100	77	85	92	88	76	90	65	70	85	65

Table 4 Entropy weights W_i calculated from the survey data

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Experts	0.6747	0.6204	0.5716	0.5602	0.5301	0.6017	0.5301	0.5602	0.5602	0.5000	0.6017
AR	0.3759	0.3148	0.3560	0.2980	0.3355	0.3077	0.3212	0.3533	0.3119	0.3450	0.2999
HRWC	0.3904	0.3792	0.2517	0.2996	0.3320	0.3672	0.3655	0.3112	0.3204	0.2874	0.3279

Table 5 Subjective weights S_i calculated from the survey data

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Experts	0.7818	0.7130	0.6737	0.7537	0.7153	0.7767	0.7767	0.7513	0.7451	0.6258	0.7082
AR	0.9990	0.9989	0.6790	0.5161	0.9987	0.6646	0.9196	0.5735	0.7126	0.8919	0.9073
HRWC	0.9992	0.8189	0.5536	0.4206	0.7274	0.9237	0.9991	0.9010	0.7223	0.7935	0.8763

Table 6 VASMA-C weights M_i calculated from the survey data

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Experts	0.1138	0.0955	0.0831	0.0911	0.0818	0.1008	0.0888	0.0908	0.0949	0.0675	0.0919
AR	0.1554	0.1330	0.0773	0.0463	0.0945	0.0750	0.1139	0.0762	0.0731	0.0810	0.0742
HRWC	0.1466	0.1194	0.0487	0.0375	0.0654	0.1067	0.1213	0.0931	0.0809	0.0798	0.1005

3.4 VASMA-C weights determination for the eleven stairs safety parameters assessed in three target groups

Data collected with the VAS matrix have been automatically converted to discrete values ranging from 1 to 100 and saved into the initial decision matrix R^0 where columns denote stair safety parameters and rows denote the respondent's ID. Decision matrix R^0 for all the 102 respondents who completed the survey is presented in Table 3.

Since the internal reliability of the collected data was high, the decision matrix R^0 was later split into three smaller matrices R_1 , R_2 , and R_3 , each corresponding to the survey data collected from the participants belonging to one of the target groups. Finally, the objective, subjective and VASMA-C weights were calculated separately for each of the decision matrices R^1 , R^2 , and R^3 . Objective weights W_i calculated from matrices R^1 , R^2 , and R^3 are presented in Table 4. Subjective weights S_i calculated for the three target groups are presented in Table 5 and the final VASMA-C weights representing the importance of the analysed stair safety parameters are presented in Table 6.

Visual comparisons of VASMA-C weights calculated for the experts, house residents with children (HRWC), and apartment residents (AR) are presented in the left part of Fig. 3. On the right side of this figure, the Direct Rating weights calculated for the same target groups are shown. The same data sets R^0 , R^1 , R^2 and R^3 were employed for the calculation of the DR and VASMA-C weights. Direct Rating (DR) is one of the most popular preference elicitation methods where criteria weights are determined by simply calculating the normalised averages of the criteria appraisals [21].

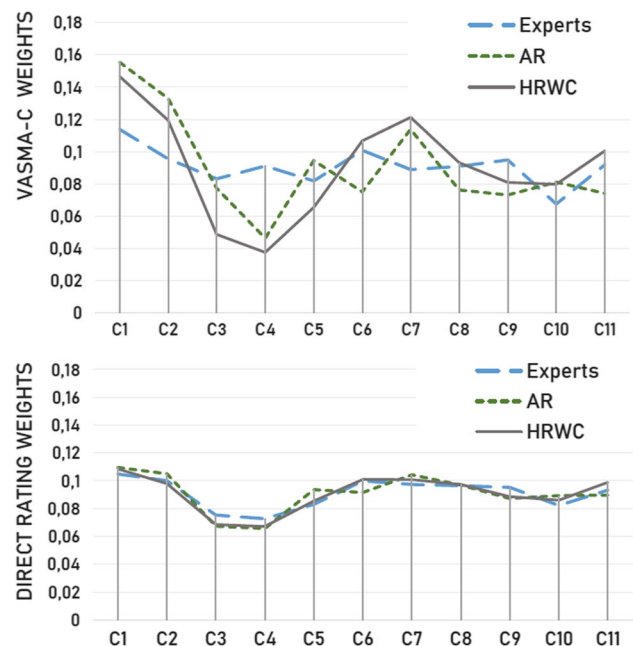


Fig. 3 Visual comparison of VASMA-C weights (top) and Direct Rating weights (bottom) calculated for the experts, house residents with children (HRWC) and apartment residents (AR). The same initial data set was used for the calculations

The results presented in Fig. 3 demonstrate noteworthy differences in the criteria weights calculated by the VASMA-C and the Direct Rating methodologies. For instance, the DR weights of the parameter C4 (Staircase landings) are similarly important among the experts, HRWC and AR respondents, while the different situations might be observed when

VASMA-C methodology is applied in the data processing step. These results highlight that VASMA-C as well as the original VASMA weighting approach better exposes knowledge differences in different target groups compared with the DR weights. It is possible since VASMA and its modification VASMA-C are devoted to analysing psychometric features of the VAS scales employing entropy logic and WASPAS-SVNS multicriteria decision-making technique to analyse uncertainties of the collected data.

4 Results and discussion

This discussion is presented to better understand stair-safety awareness in different target groups and suggest recommendations on how the results of this study case benefit the children's safety management strategies.

4.1 Comparison of the expert and the non-expert knowledge on stair safety affecting parameters

Data collected from the experts' show that a high entropy weights might be observed among their valuations. It means that all the experts had quite a similar knowledge about the parameters affecting children's safety in single-family houses. The VASMA-C weights calculated from the expert-based assessments revealed that parameters C1 (*Staircase strength and durability*), C6 (*Step height*), and C2 (*Handrail construction*) were identified as the most important factors affecting stair safety on stairs, while C3 (*Handrail material*), C5 (*Staircase width*), and C10 (*Natural lighting*) were determined as the least important ones.

The ranks of the VASMA-C weights were compared to understand expert and non-expert awareness of the stair safety affecting parameters. The importance of *staircase landings* (C4) had the largest knowledge discrepancies among the expert and non-expert evaluators. The existence of the staircase landings is determined as the sixth important factor among the experts ($M_i = 0.0911$) and it is the least important parameter for both the HRWC ($M_i = 0.0375$) and AR ($M_i = 0.0463$) groups. While expert valuations complement the findings of other scientific studies analyzing staircase landing importance on staircase safety [10, 13], it is important to analyse why non-expert assessments are so contradictory. It is highly believable that depreciation of the intermediate landings among the non-expert participants is affected by the public opinion that landings are designed only for stopping and resting while climbing the stairs. Their purpose of decreasing the falling time and preventing severe injuries on stairs might be less known among the non-expert evaluators. Since both HRWC and AR groups underestimate the significance of intermediate landings, a wider spread of information on how staircase landings affect children's safety

at home is necessary to reduce the number the severity of stair-related injuries.

The significance of the *safety gates* (C9) was also differently assessed among the experts and the rest of the target groups. The parameter C9 is ranked as the fourth most important parameter among the experts, seventh—among the HRWC respondents, and only tenth—among the AR respondents. While the absence of the safety gates is one of the most common reasons causing toddler injuries on stairs, it is underestimating in HRWC and AR target groups might cause serious risks for children safety at home.

4.2 Comparison of the stair safety awareness among AR and HRWC respondents

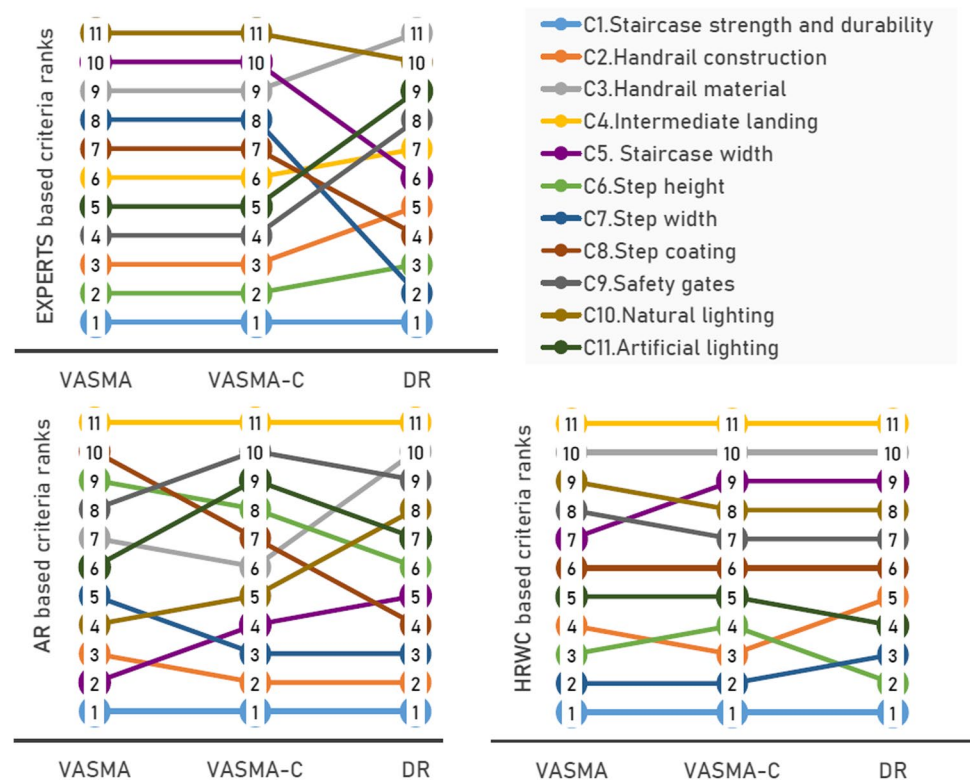
The comparison of the VASMA-C weight rankings showed that AR and HRWC respondents also have diverged understanding of the parameters affecting children's safety on stairs. The important disparities were noticed by analysing geometric parameters (C5, C6 and C7) of stairs. For instance, staircase width (C5) was determined as the fourth most important parameter among the apartment residents, though it was recognised as one of the least important parameters by both the experts and the house residents living with children (Fig. 4). The opposite situation was observed by analyzing the significance of step height (C6). Such results might be caused by different reasons including the diverse experience of living in a single-family house. Since AR respondents are probably more experienced in climbing stairs of apartment buildings, they might assume that staircases installed in single-family houses also should be wide enough to pass for two people. Respondents living in private houses oppose this opinion by commenting that there is no need for wide stairs in a single-family house. Furthermore, some of the HRWC respondents think that a narrow staircase is safer than the wider one.

The AR and HRWC respondents differently assessed the importance of natural lighting (C10) and artificial lighting (C11), also. While apartment residents believe that natural lighting has greater importance on stairs safety than artificial lighting, both experts and HRWC believe in diverging. These results also imply that stair safety awareness depends not only on the respondent's expertise level but also on the factual experience of living in an individual house.

4.3 Sensitivity analysis

The sensitivity analysis was performed to study the consistency of the rankings calculated by VASMA, VASMA-C and Direct Rating techniques (Fig. 4). A comparison of criteria rankings was executed for each of the analysed target groups: experts, apartment residents and house residents living with children.

Fig. 4 Comparison of criteria ranks calculated by VASMA, VASMA-C and Direct Rating approaches presented for each of the target groups



Consideration of the item level response rate is a key difference between the VASMA and VASMA-C methods. Ever since all the experts participating in the study assessed the importance of all the eleven parameters analysed in the study, criteria weights and ranks calculated by VASMA and VASMA-C methods are identical. The different situations can be observed when data collected from non-expert evaluators are analysed. For instance, parameter C2 (*Handrail constructions*) was ranked 4th when the original VASMA methodology, and 3rd when the VASMA-C adaptation was applied to analyse data collected from the HRWC respondents. In this target group, the item response rate of parameter C2 is $d_2 = 0.9778$, and it is much lower for parameter C6 ($d_6 = 0.8000$) which was ranked 4th with the VASMA-C weighting methodology. This example demonstrates that the diverging item response rates have a meaningful impact on the parameter rankings. Thus, the inclusion of the item response rate variable into the VASMA-C methodology was a valuable addition for the stair safety affecting factors comparison in the different target groups.

5 Conclusions

Many pediatric injuries could be avoided if society were better informed about the stair-related hazards. The study case performed in Lithuania confirmed that stair safety awareness is different in the analysed target groups: Experts in the field,

apartment residents (AR), and House residents living with children (HRWC). Results of this research complement the existing studies saying that there are some important discrepancies between the expert and non-expert knowledge on the same topics. It was the most perceptible in the assessment of the significance of staircase landings, where experts enlightened the strong connection between the existence of intermediate landings and staircase safety, and non-expert assessors underestimated the importance of this parameter. It puts forward the decision that sellers should be more proactive in informing customers about the specific hazards associated with the staircase design choices.

The results of this study case were attained by applying the new modification of the VASMA methodology called VASMA-C. It is the direct weighting approach dedicated to calculating criteria weights from the survey data with many uncertainties and adapted for opinion comparison reasons in different target groups. The study case performed in Lithuania proved that the presented VASMA-C criteria weighting methodology is capable of detecting knowledge differences between in separate target groups. Thus, the authors of this paper have confidence that this methodology can be successfully applied in other survey-based studies with similar purposes. However, more research is needed to understand how the VASMA-C weights depends on the number of survey participants belonging to the same target group and how the number of the parameters presented in a single VAS matrix impact the survey results.

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Availability of data and materials All the data of this study can be provided by the authors upon request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This research was done according to ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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