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Perceived noises in your residence: which one annoys the most?

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ABSTRACT

The Brazilian standard NBR 15575 establishes performance criteria for residential buildings, including acoustic performance requirements for airborne sound insulation of internal walls, facades and floors, as well as for impact sound level of floors. The standard also specifies non-mandatory sound pressure levels in the dwelling from service equipment for informative purposes. This study aims to investigate which type of noise source is the most uncomfortable for Brazilian dwellings occupants. In order to reach the proposed objective, a preliminary questionnaire for collecting sound source descriptors was carried out. This step aims to gather free-form descriptive words of the sound sources from subjects that are not familiarized with acoustic terms. After the annotation analysis, a questionnaire was applied using a ranking scale. The selected descriptive words were also correlated to the noise sources mentioned in the standard. It is expected that this work may give input to the ABNT NBR 15575 systematic revision, that kicked off in 2019.

Keywords: Residence, Residence noises, Brazilian standard, Building acoustics

1. INTRODUCTION

Several countries around the world have set performance requirements for residential buildings. In Brazil there is a specific standard ABNT NBR 15575:2013 that establishes performance criteria for residential buildings for diverse criteria such as structural, thermal, lighting and acoustic, and according to its part 1, a building must meet the necessary requirements to be considered inhabitable. Acoustic performance requirements (1) are presented in four of its five parts, as highlighted in bold Table 1.

Table 1 – Parts of ABNT NBR 15575

Part	Requirements for
1	**General**
2	Structural systems
3	**Floor systems**
4	**Internal and External vertical walls systems**
5	**Rooftop systems**
6	**Sanitary installations**

Part 1 enforces the use of the following parts and contains non-mandatory criteria for building service equipment (2) that is also described in part 6. Part 3 contains impact and airborne sound insulation (3) requirements for floor systems . Part 4 contains airborne sound insulation requirements for internal walls and facades (4). Finally, part 5 presents impact and airborne sound insulation requirements for rooftops (5).

In 2018 the first review process of the standard started has unleashed hard discussions about the values of the acoustics requirements. Being the first standard that includes acoustic criteria of residential buildings, most of the required performance values were established by adapting international criteria to the Brazilian construction system reality. Up to now, it has not been performed a comprehensive research to inquiry both quantitative and qualitative aspects on residents' expectations about acoustic performance of dwellings.

To give input to the discussion, this study aims to look into which type of noises are considered most annoying in dwellings, as a first approach on searching acoustic criteria that can guarantee satisfactory conditions for the occupants. Similar works can be found in (6), (7), (8), (9) and (10).

2. METHODS AND RESULTS

To investigate what type of sound sources in dwellings is the most annoying, the research was carried out in two stages. In the first one, a preliminary questionnaire was circulated to collect perceived sound sources in dwellings by its occupants. The results of this stage were then analysed and interpreted to compose the second part of the study. The second stage consisted on circulating an improved questionnaire that asked the subject to relate the sound sources and its level of annoyance. Furthermore, the second questionnaire included a ranking scale of the different types of sound sources, according to its origin.

In the next sections, each stage is described in detail as well as their respective results.

2.1 Stage 1: Preliminary questionnaire

According to the ABNT NBR 15575, the building acoustic performance must be met to mitigate airborne sound transmitted by walls, floors, rooftops or façades, impact noise transmitted by floors, and noise from service equipment premises. The first challenge in faced in the development of this study was that subjects in general are not familiar with this terminology. To facilitate the comprehension, a preliminary questionnaire was prepared with an alternative vocabulary. Subjects were requested to fill open questions that asked about which noises annoy them the most in their dwellings, considering different origins. The adapted questions[1] are shown in Table 2.

Table 2 – Preliminary questionnaire questions

	Question
1	In which State do you live? If you don't live in Brazil, please inform in which country do you live.
2	What are the sounds coming from the attached dwellings that annoy you the most?
3	What are the sounds coming from the upstairs dwelling that annoy you the most?
4	What are the sounds coming from the downstairs dwelling that annoy you the most?
5	What are the external sounds that annoy you the most?
6	What are the sound from the circulation areas (corridors and stairs) that annoy you the most?

The questionnaire was completed by 123 subjects, being 97% residents in Brazil , one person from Denmark, one from Portugal, one from Italy and another one from UK. Information of 9 out of 23 States were collected in this study. Among Brazilian residents, 84 are from São Paulo, 20 are from Rio Grande do Sul and the last 15 from other Brazilian States (Minas Gerais, Santa Catarina, Rio de Janeiro, Paraíba, Paraná, Ceará and Bahia).

From the results it was observed that for 55% of the subjects "traffic noise" was considered as the most annoying external sound, corroborating international findings (11) and remarking that façade sound insulation performance is an important criteria for this population sampling. When asked about sounds coming from the upstairs dwelling, 44% of the subjects related walking noise as the most annoying. It is worth to remark that from all the sound sources collected in question 3, 76% were impact sounds such as walking, furniture dragging, and drop of objects. It is noticeable that all these sound sources have the same type of transmission, indicating that impact sound insulation has a great concern on the annoyance pointed out by subjects.

Concerning noises coming from attached dwellings and from circulation areas, they seem to represent a less critical complain, due to the 37% and 47% respectively "not applicable (NA)" answers given[2]. The results are presented in in Figures 1 and 2.

[1] Free translation from the authors. The questionnaire was circulated in portuguese and the questions might present little semantic differences.

[2] Subjects were given instructions to select "not applicable" when they have no clear decision about their annoyance or when the mentioned spatial configuration do not apply to their dwellings.

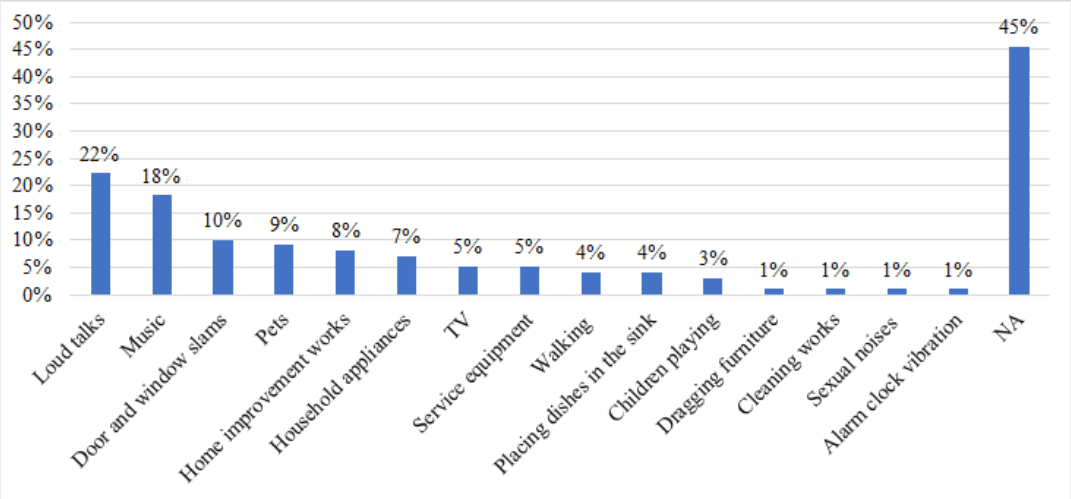

Figure 1 – Collected sound sources from attached dwellings

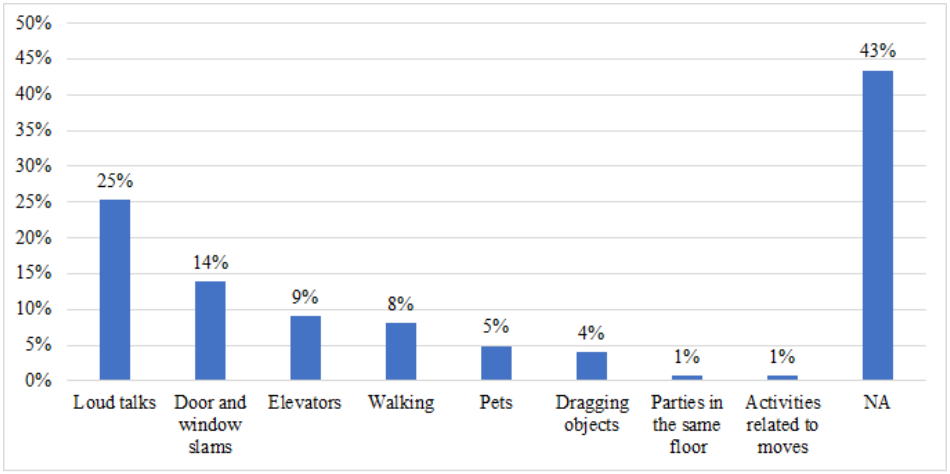

Figure 2 – Collected sound sources from circulation areas

The results of the question concerning sounds that are most annoying from the downstairs dwelling are inconclusive, because up to 70% of the people answered that is “not applicable (NA)”.

Despite the differences in construction systems depending on the geographic region, in general, the analysis has not shown any dependence to the subject location.

This preliminary study shows that the impact and façade sound insulation represent the main issues to be taken into account in Brazilian residential buildings acoustic performance. This will be more discussed in section 2.2. The results of this stage enabled the selection of which terms are more suitable to create a relationship between subjective annoyance and different types of noise sources to elaborate the final questionnaire.

Table 3 shows the 5 most cited noise sources for each correspondent question presented in Table 2. For the next stage, questions 4 was excluded, as its results were not conclusive. The 5 most cited sound sources are presented in decrescent order of citation.

Table 3 – Main answers for each question of the preliminary questionnaire

Question	Words (most cited to less cited)
2	Loud talks, Music, Door and window slams, Pets and Home improvements
3	Walking, Dragging objects, Drop of objects,Service equipment and Loud talks
5	Traffic, Sound systems, Loud talks, Constructions and Recreative public spaces
6	Doors and window slams, Loud talks, Service equipment, Walking and Pets

2.2 Stage 2: Final questionnaire

The results from Stage 1 presented in section 2.1 consisted on the fundamental input to elaborate the questionnaire to access the main purpose of this work. The final questionnaire have 5 questions. In the first four, subjects were asked to inform their annoyance level considering each sound source from Table 3 related to its correspondent origin: 1-noise from attached dwelling, 2-noise from upstairs dwelling, 3-noise from circulation areas and 4-noise from external area.

The answers were collected in a 5 point scale going from 1 (less annoying) to 5 (most annoying). It was included an option 0, "not applicable (NA)". The noise source terms were presented in a random order to reduce the bias introduced by the order of appearance. Subjects were also allowed to select the same annoyance level for more than one sound source.

Finally, the last question is more direct, as the subjects are already familiarized with the types of sound sources: "Now, ranking the groups according to its annoyance level, considering 1 for the less annoyance and 4 for the most annoyance." Subjects were asked to rank four sound sources in order of annoyance for four groups. Group 1: Noises coming from side dwelling, Group 2: Noises coming from top dwelling, Group 3: Noises coming from circulation areas and Group 4: Noises coming from external areas.

To compare the answers, a normalized index was implemented for the results of annoyance level for each sound source. Being five the maximum annoyance level in the questionnaire scale and 90 the number of responses, the normalization factor was given by 5 x 90, resulting in 450 the maximum punctuation each variable can reach. The annoyance levels collected for each sound source were then stacked to be summed up, and the total score was divided by the normalization factor. After the normalization, a sound source annoyance index was obtained in a scale from 0 to 1. Furthermore, the mode and mode percentage were determined for each sound source and each annoyance level.

The final questionnaire was completed by 90 subjects and the results are presented hereinafter.

Firstly, the analysis is presented for each question and afterwards the general results are discussed . For each question is presented a table with the resulting annoyance index, mode and percentage of the mode for each sound followed by a graph indicating the annoyance level percentage for each sound source.

Table 4 and Figure 3 show the results for Question 1, concerning annoyance due to sound sources coming from attached dwellings of the same floor. From the results of Table 4 is possible to observe that the highest annoyance index was obtained for home improvements works. When the mode is evaluated, door and window slams and home improvements works achieved 5, the maximum annoyance level in the questionnaire. An interesting observation is that those two sound sources might be associated as more slams occur when home improvements are being carried out. Despite the equal mode result, the mode frequency of Home improvements is higher, indicating that is the sound source from attached dwellings with the highest annoyance level.

From the mode analysis it is notable that subjects adopted an extremist assessment, as the results were only very annoying (5) or less annoying (1). The NA results (0) were discarded in this analysis it was selected when the sound source was nonexistent or if the subjects were not annoyed at all.

Table 4 – Annoyance Index, mode and percentage of mode for each sound source from attached dwellings

Sound source	Index	Mode	% of mode
Loud talks	0,40	1	22
Music	0,41	1	29
Door and window slams	0,55	5	28
Pets	0,38	0	33
Home improvements	0,67	5	47

In Figure 2 it is plotted how answers are distributed. It is observed that Home improvements have few responses 1, 2 or 3. Considering the five selected sound sources, music has presented the lowest annoyance level, followed very closely by loud talks.

These partial conclusions are useful to be incorporated to the future ABNT NBR 15575 revision process, as the sound sources that presented the highest annoyance levels are impact sounds and beyond airborne sound insulation, there is no criteria for horizontal impact level between dwellings in the present standard.

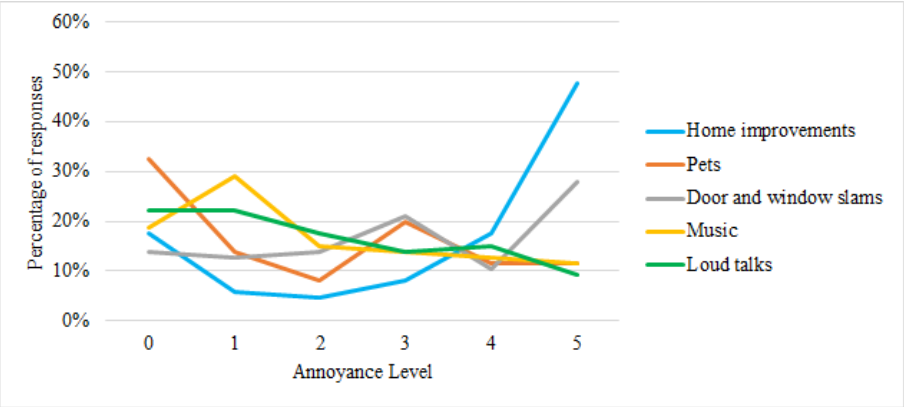

Figure 3 – Distribution of responses for the question about annoyance level related to sound sources from attached dwellings

The results of the question about sound sources coming from the upstairs dwelling are presented in Table 5 and Figure 4. From these results it is possible to conclude that the sound source with the highest annoyance level is drop of objects and walking is the lowest one, not considering the sound sources with mode 0. Here is important to observe that, part of the results converge with those obtained in Stage 1. At the first questionnaire, dragging objects was more mentioned that drop of objects. The unexpected results was obtained for walking, which was the most cited sound source in the preliminary questionnaire.

Table 5 – Annoyance Index, mode and percentage of mode for each sound source from the upstairs dwelling.

Sound source	Index	Mode	% of mode
Walking	0,48	1	29
Dragging objects	0,61	5	29
Drop of objects	0,51	2	19
Service equipment	0,38	0	25
Loud talks	0,36	0	28

From the analysis of Figure 4, it is possible to observe that walking have a mode 1, but its second mode is 5. This might have occurred due to bias introduced by the number of respondents. Despite this unexpected event, walking is also impact noise, together with dragging objects which reiterates that impact noise is the most important sound source to be considered from upstairs dwellings. Airborne sound sources were represented by loud talks and service equipment but have not reflected an issue for the subjects.

Considering the results obtained in this research, impact sound insulation requirements should be a topic of discussion on the brazilian standard future revision as well as service equipment criteria, which is not mandatory for the moment.

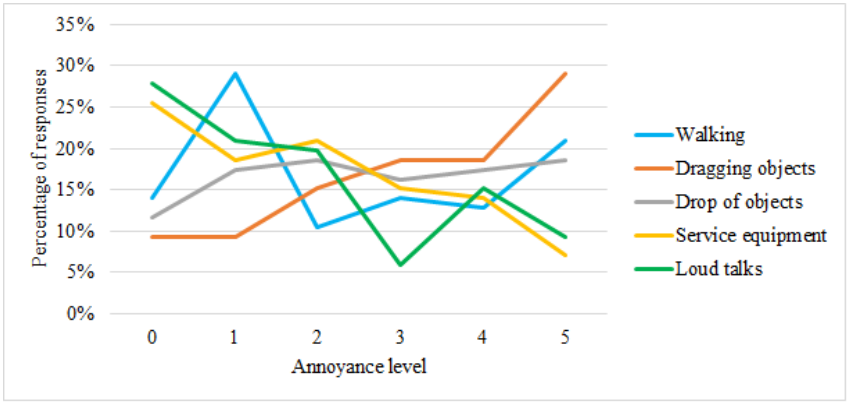

Figure 4 – Distribution of responses for the question about annoyance level related to sound sources from upstairs dwelling

In the Table 6 and Figure 5 the results for circulation areas are presented and service equipments represent the most annoying sound source. In general, it is observed a lower annoyance for these sound sources due

to the use of most 1 and 2 levels by the users. Diverging from the extremist evaluation observed for the previous sound sources.

Table 6 – Annoyance Index, mode and percentage of mode for each sound source from circulation areas

Sound source	Index	Mode	% of mode
Door and window slams	0,48	2	22
Loud talks	0,48	1	24
Service equipments	0,40	2	24
Walking	0,33	1	29
Pets	0,33	0	30

The graph in Figure 5, shows this accumulation in 1 and 2 levels of annoyance. Due to these results we conclude that the performance of circulation areas have not take as a priority in standard revision because does not represent a great problem to solve.

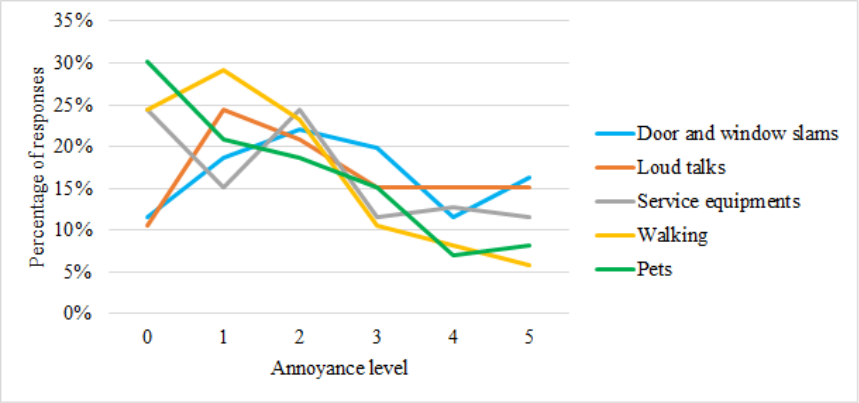

Figure 5 – Distribution of responses for the question about annoyance level related to sound sources from circulation areas

The results for external sound sources are presented in Table 7 and Figure 6. Unlike happens for circulation, the mode here is more elevated. Three sound sources achieved mode 5: Traffic, Sound systems and Constructions. Among them, constructions represent the most annoying sound source. Construction can be connected to traffic noise too, due to the traffic of construction trucks, for example. This mode results indicate that the façade sound insulation performance is a very important criteria to be considered in the ABNT 15575 revision.

Table 7 – Annoyance Index, mode and percentage of mode for each sound source from external areas

Sound source	Index	Mode	% of mode
Traffic	0,61	5	29
Sound systems	0,65	5	32
Loud talks	0,53	3	33
Constructions	0,65	5	38
Recreative public spaces	0,49	0	23

From the graph of Figure 6 it is observed that the mode of recreative spaces is 0, but this level could be selected if it was not applicable or if the subject was not annoyed at all. If 0 results are was excluded, the second mode is 5. It indicates that recreative public spaces are very annoying when placed close to residential buildings, even if compared with the other sound sources (traffic, sound systems and construction).

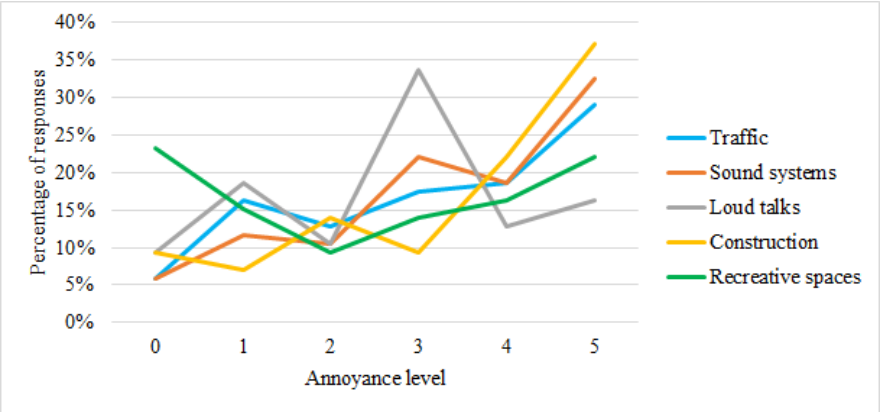

Figure 6 – Distribution of responses for the question about annoyance level related to sound sources from external areas

In the last part of the questionnaire, subjects were asked to make a ranking for each of the four groups of sound sources, being 1st the less annoying and 4th the most annoying. The results are expressed in Table 8 and Figure 7. If the Annoyance index is considered, external sound sources are the most annoying, but when focusing on the mode, both Group B and D presented mode 4 (4th) . By combining the results, it is delivered and annoyance rank where Group D is the most annoying, then Group B, Group C and Group A the less one.

Table 8 – Index, mode and percentage of mode for each group of sound sources

Sound source	Index	Mode	% of mode
Group A: attached dwellings	0,39	1	23
Group B: upstairs dwellings	0,53	4	40
Group C: circulation areas	0,40	1	30
Group D: external areas	0,64	4	55

From the graph of Figure 7 is not possible to say if Group A or C is the last on the annoyance rank, as both have a mode 1 (1st). According to the percentage of responses Group A was ranked more times as 4th and 1st than Group C. A more conclusive result can be obtained by increasing the number of subjects in the research.

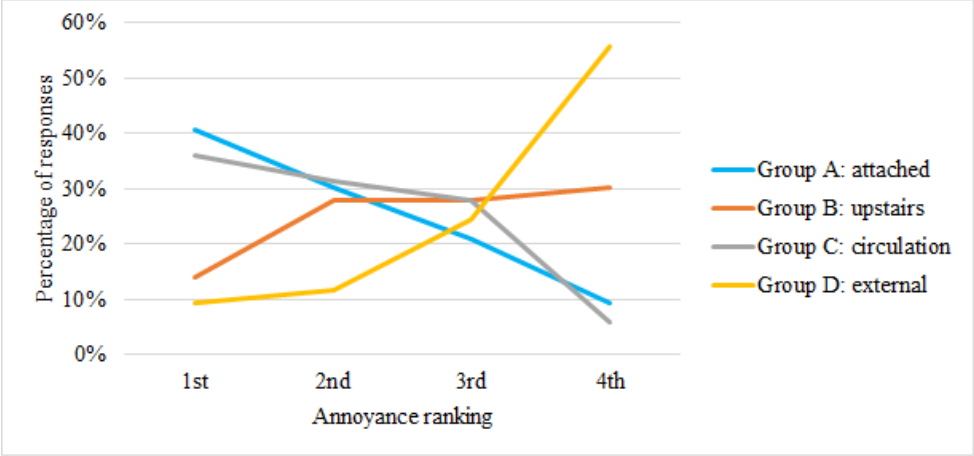

Figure 7 – Distribution of the responses for the annoyance ranking

These final results indicate that the façade sound insulation performance is the most important criteria for the respondents of the questionnaire, followed by impact sound insulation performance.

3. CONCLUSIONS

The methods adopted in this research enabled to make a first approach on the determination of which sound sources are more annoying for Brazilian users in residential buildings, correlating them with brazilian building performance standard requirements for airborne, façade, impact sound insulation and recommended limits for service equipment.

The findings of this pilot project can be relevant to support the future ABNT NBR 15575 revision. From the obtained results it can be concluded that façade sound insulation is the most relevant requirement to be taken into account. More than 55% of the subjects in the Stage 1 of the research mentioned “traffic” as the most annoying sound source perceived in their dwellings.

Impact sound insulation performance is the second more relevant. Considering the ranking results, Group 2 - sound sources from upstairs dwelling, involves airborne and impact sound sources, but when taken into account the results of Stage 1, impact sound seem to be a greater annoyance problem than airborne sounds. For each 5 noise sources mentioned by the subjects, 3 were impact sound sources.

The performance of airborne sound insulation between dwellings of the same floor or circulation areas seem to not represent a big issue. In Stage 1, more than 35% of subjects chose the “Not Applicable” option.

The obtained conclusions are valid only for the sample of subjects that participated in the study. In future works, a more comprehensive study is intended to be carried out, with a larger sample to statistically represent, at least, the Brazilian urban population.

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