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Original Research Paper

Methodology and evidence from a case study in Rome to increase pedestrian safety along home-to-school routes

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HIGHLIGHTS

- Interactions between built environment, road safety and maintenance for home-to-school routes have not been much studied.
- An array of criteria including wellbeing, usage, appearance is considered to make home-to-school routes safer.
- An easy-to-adopt methodology is described based on surveys and flexible checklists implementable by experts and users.
- Effective solutions rely on the simultaneous implementation of regulatory measures, maintenance plans and funding.

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ABSTRACT

Home-to-school routes are very sensitive areas: they represent, for children, a learning tool for their everyday activities, but if poorly designed, maintained and equipped they can expose them to traffic risks. Sidewalks' inappropriate level of service and poor maintenance, especially, are main factors contributing to walking unsuitability, thus to poor comfort and safety levels for young pedestrians, and more in general for all the vulnerable non-motorized road users. This paper deals with a methodology specifically developed to highlight the quality of the urban environment where the home-to-school routes are located, according to four main criteria: wellbeing, usage, appearance, and safety and security. Each criterion is associated with a checklist including the most relevant features to assess, with a focus on maintenance as a key parameter to create safe and comfortable routes to school. An application, a case study in Rome, where the lack of regular maintenance results into a network of unsafe sidewalks, is also presented, analyzing three different areas where a number of schools are located. Detours when approaching school premises were surveyed, due to the levels of distresses and linked to the poor comfort and safety levels. As the mutual influence of built environment over road safety and maintenance requirements for home-to-school paths is not largely investigated thus far, the paper's goal is to provide advanced knowledge for studies and applications further afield.

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1. Introduction

The importance of the built environment as a learning tool in any children developmental stage is long-acknowledged in the field of behavioral and educational studies (Francis, 1998; Gaster, 1991; Pennartz and Elsinga, 1990). The reiterated attention on road safety in planning and designing practice did contribute to shed a light on children's needs, but statistics on vulnerable road users (not only children) are a constant reminder that much has still to be done (Cantisani et al., 2019a; Lin et al., 2019).

In 2008, the World Health Organization clearly stressed that road traffic injuries "are the leading cause of death among 15–19-year-olds and the second leading cause among 10–14-year-olds" (Peden et al., 2008). It is also stated that the phenomenon was clearly related to poverty, being the groups "that stand out most clearly with respect to their higher injury rates are indigenous populations, who also tend to experience greater relative poverty than their compatriots" (Peden et al., 2008), with corroborating figures from developed countries such as the U.S. or Australia.

If comparing the overall pedestrian fatality trends in the most motorized areas in the world (Martin and Pfeiffer, 2017) contrasts lead to draw one conclusion: continuous, mutual political efforts from supranational to national levels to raise awareness on the road safety risks, enforce stricter regulations, orient the demand towards less motorized and more sustainable lifestyles are all drivers to reduce fatalities. Moreover, the interpretation of road safety data in synergy with those from the relationships between public health and urban planning (D'Alessandro et al., 2017) contributes to a better understanding of the phenomenon, and to develop more effective countermeasures.

High motorization rates favored by a number of factors (low gas prices and transit poor quality, among these), unhealthy lifestyles (with walking as just an ancillary mode to the motorized ones), old and new habits (like vehicles' high speed, driving under influence, distract driving and walking, poor use of safety devices like helmets and seat belts), all contribute to thwart even the most ambitious road safety plans, as evidenced by several studies (Cantisani et al., 2019b).

The reiterated need to intensify efforts on road safety especially for the vulnerable road users, among these children, is clearly stated in the United Nations' Sustainable Development Goal (SDG) 3.2 which aims "to reduce global road traffic deaths and injuries by 50% by the year 2020, compared to their 2010 levels" (International Transport Forum, 2017).

In Europe, although during the 2006–2013 period the amount of the pedestrian fatalities slowly decreased, in the following years (2014–2015) the trend seemed to reverse and the fact that "children have, on average, about a sixth of the risk of dying in a road accident compared to the other age groups" (ERSO, 2017) is still not least acceptable. Few facts and figures to stress the problem.

- The percentage of road fatalities involving children fell steadily from 2006 until 2015, except for 2014, accounting about of 2.5% of all the road fatalities in the European Union member states.
- More children were killed in the 10–14 age group than in either the 0–4 or the 5–9 age groups, evidencing that road safety educational programs are most needed, especially for children who might start experiencing unaccompanied travels regularly.
- 43% of fatalities involves children as pedestrians or as cyclists (vs 48% of those travelling by car).
- The relevance of bicycles and mopeds in the phenomenon becomes not negligible from the age of 5 years on, clearly consistent with the evolving travel choices of children as they grow older.
- 20% of injured children attending a hospital were admitted with an average stay of six days (ERSO, 2017).

Italy is no exception (although slightly above the European average), and just focusing on 2017 (Table 1), the amount of killed children accounts for more than the 3% of the national fatality toll, whereas the injured for about the 8.5% of the total casualties. Within the data reported in Table 1, for the killed, only 21 children were pedestrians, and 2812 among the injured, i.e., 19% and 13.5%, respectively (ISTAT, 2017).

Figure of Table 1 might seem modest, but if analyzed in terms of systematic trips they highlight how children are exposed to traffic risks during their everyday activities. For example, walking is certainly the main mode to reach school, at least for young students up to 14 years old (Fig. 1), taking no more than 15 min for the majority of them (ISTAT, 2012).

1.1. *Studies on home-to-school paths: the different approaches*

Home-to-school paths (or routes) seem, therefore, a very sensitive area to investigate to improve safety conditions for children and most of the related the studies have focused on the analysis of children behaviors and accidents (Bijur et al., 1986; Jones et al., 2005; Sandels, 1975) as a starting point to make recommendations for improving practice to redesign roads near school areas. These studies therefore focus on the items below.

- Infrastructural interventions: they are aimed at increasing the drivers' attention when approaching a school area and reduce speed between 30 and 10 km/h. Traffic calming techniques are among the most used, and are all the more

Table 1 – Killed and injured pedestrian children in Italy, 2014–2017 (ACI, 2018; ISTAT, 2017).

Age group	Amount of Children							
	2014		2015		2016		2017	
	a	b	a	b	a	b	a	b
0–5	7	551	5	524	3	469	2	497
6–9	4	499	1	459	2	468	3	459
10–14	9	1077	3	1042	7	1006	5	1009
15–17	6	867	9	812	9	823	11	847
Total	26	2994	18	2837	21	2766	21	2812

Note: a means killed; b means injured.

effective when they are regularly implemented around school areas (Loprencipe et al., 2019; Greze, 1994; Preston, 1994).

- Regulatory interventions: the use of speed reduction and direct control on motorized traffic is an established practice, within general regulatory programs (Rauh et al., 2001; De Barba et al., 2002).
- Education: in past times, for school children the need to be aware of the traffic risks in the everyday trips was usually part of civics lessons. Although useful, this approach missed the main objective, namely the awareness of danger. Nowadays, in the current educational practice, more tools are available: simple questionnaires on home-to-school paths, mental maps, walkability lists, etc. Such information often also constitutes the knowledge base for supporting regulatory and planning decisions, studies and programs, at local level (Molina-García and Queralt, 2017; Ross et al., 2018; Sisiopiku and Cruzado, 2002).

However, an appropriate design approach should include all of the above, balancing quantity with quality. The use of the quantitative design criteria originates from the need to have functional directions, standards and regulations necessary to define the technical aspects of the project. But they can be really effective only if combined with the knowledge of users' needs. It is, therefore, necessary to define additional criteria that focus on the complexity, variability and specificity of urban life, so to define a "multiple" quality (Demasi et al., 2018). The design problem, then, is to recompose the quantitative approach for the definition of minimum standard thresholds to meet the users' requests, with the qualitative interpretation of the urban complexity.

2. The adopted methodology: towards a performance-driven approach for assessing walkability

Road safety design interventions based merely on quantitative facts are appropriate as long as they can validate whether users' basic needs are met, thus pursuing a "not explicit" or unexpressed quality. However, this is not enough if the objective is to pursue an "appealing quality", linked instead to the full satisfaction of the users' needs (Papa et al., 1993). The "appealing quality" must also be preserved over time: spaces for pedestrians must be designed, monitored and maintained before reaching subpar conditions (far below "implicit quality" thresholds). Criteria able to contribute to the process of achieving appealing quality and to evaluate it are many. Among these, the followings are essential.

- Usage: as the set of conditions relating to the suitability of the home-to-school path to be freely walked by pedestrians. As such, home-to-school paths shall be: a) accessible, to be equally useable by all users; b) easy to maintain, to ensure high-level performance during its whole life cycle; c) flexible, to be adaptable to different functions within the diverse urban environments.
- Safety and security: as the set of conditions relating to the safety of users, as well as the safeguard and prevention of damages due to accidental factors. Home-to-school paths must therefore ensure the safety of users while performing their usual activities (walking, resting, waiting, etc.) and the preservation of facilities and surrounding areas where such activities take place, avoiding: a) as regards to safety, any conditions that could lead to hazards from falls, slides, shocks, etc., but also prevent from dangers due to motorized traffic; b) as regards to security, avoidance of petty crimes (theft, burglary, vandalism).
- Appearance: as the formal conditions which can attract pedestrians. As such, appearance shall include: a) variety, i.e., multiplicity of characteristics of the built environment that can turn the home to school trip into an experience to daily enjoy; b) reliability, as the built environment capability to preserve its quality; c) perception ease: users' undemanding capability to understand the function of the elements (signs) and information (signals) that shape the urban space (they can be visual, tactile, auditory, etc.).
- Wellbeing: as a set of conditions that relate to the meeting of requirements associated with psycho-physical comfort and ease of use. For the former, wellbeing while planning a home-to-school path can be considered as a kind of prerequisite, and a multi-scope criterion as it encompasses the following requirement areas.

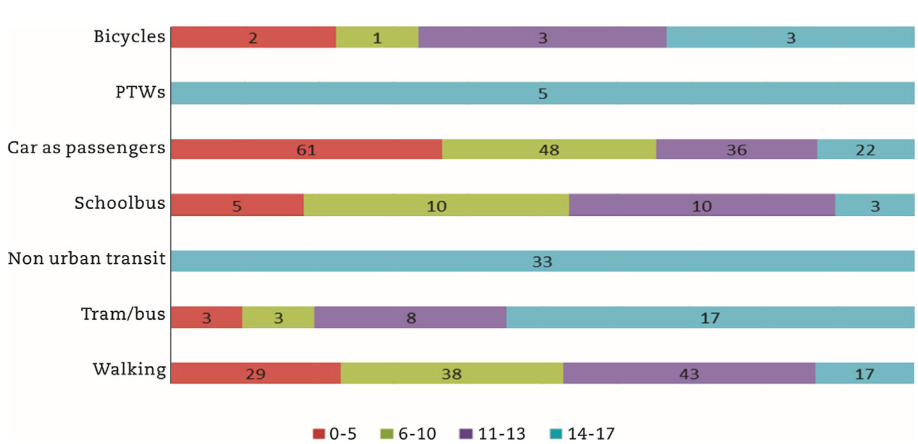

Fig. 1 – Home-to-school trips per mode and age group in Italy (2014) (ISTAT, 2017).

Table 2 – Wellbeing checklist.

Requirement met along the path	Score (%) >75	50–75	<50
Sunshine exposure			
Winter exposure (>8 h)	2	1	0
Summer exposure (<10 h)	2	1	0
Ventilation			
Canyon effect (building rise <5 stories)	2	1	0
Canyon effect (building-to-building street width >10 m)	2	1	0
Temperature			
Vegetation, tree-lined link	2	1	0
Brick surface	1	0	0
Impervious surface for road and sidewalk	1	0	0
HVAC unit along the street	1	0	0
Relative humidity			
Availability of natural surface (vegetation, bodies of water, etc.)	2	1	0
Noise			
Traffic noise	0	0	1
Noise from working activities	0	1	2
Public lighting			
Light poles only	1	0	0
Neon sign and other illuminated sign	2	1	0
Glare			
Reflecting surface	2	1	0
Level of service and ergonomics			
Suitability of level of service (LoS) for sidewalks	2	1	0
Suitability of urban furniture	2	1	0
Sidewalk evenness	2	1	0
Design for all			
Availability of universal design furniture	2	1	0
Total	29	13	3

a) Hygienic-environmental, to have walking environments adequately exposed to sunlight, properly ventilated and free from chemical and microbiological pollution.
b) Hygrometric, to ensure adequate levels of temperature and relative humidity along the walking path.
c) Acoustic, to avoid noise nuisance while walking, and possibly enjoy natural sounds.
d) Visual, to avoid visual nuisance and ensure brightness according to the characteristics of the eye (visual acuity, contrast, speed of perception). This is achieved through the integration of natural and artificial lighting, avoiding glare conditions.

For the latter, comfort of use implies that walking environments and paths are designed and shaped to meet appropriate the anthropometric and ergonomic requirements of all. Since such requirements are many and the urban environments may be markedly different, suitability of interventions can be controlled only through index-based performance-driven checklists, as most exhaustive as possible.

2.1. *Approach and procedure*

Specific checklists, each designed to address a given performance area among those described (wellbeing, safety and security, usage, and appearance), was developed and reported in Tables 2–5.

Requirements itemized in such tables are selected after a study process based on three steps: a) an initial analysis of requirements reported in the scientific literature review; b) local surveys to highlight elements of differentiations and commonalities in the local network dictated by the application on the case study areas (described in Section 3) and c) eventually the final selection among all the items collected of only those which are easily detectable by a walking survey and appropriate to the context in hand. Focusing on the case study presented in Section 3, such final selection enabled to exclude not affecting elements in the study areas, for example: intersection design (more or less the same over the network); vehicle traffic volume (low and competing per magnitude with the pedestrian flows); enforcement (poor), or elementsnot detectable via surveys, e.g., traffic safety education.

According to all of the above, the suitability of the local home-to-school routes can be assessed according to a two-step approach. The first one takes into account requirements in Tables 2–5, while the second one is specifically dedicated to highlight the technical problems related to the sidewalks performance (evenness and maintenance) which, if poor, can affect safety, comfort and wellbeing. More specifically they concern.

(1) The evaluation of the levels of safety, security, usage, appearance and wellbeing, via the checklists (Tables 2–5). Major paths (composed by several legs between each origin and destination) areevaluated considering every item in the checklists. In order to attribute the scores to each requirement, the authors interviewed experts in the fields of environment, human health and transportation (twenty-four technicians have participated in the study: six environmental engineers, six

Table 3 – Safety and security checklist.

Requirement met along the path	Score (%) >75	50–75	<50
Conflict with motorized users			
Sidewalk on one side of the street	1	0	0
Sidewalk on both sides of the street	2	1	0
No-slippery surface	2	1	0
Signaled crossing	2	1	0
Unsignaled crossing	1	0	0
Obstacle			
Dumpster	2	1	0
Ads marker	2	1	0
Surface evenness			
Avoidance of chinks and potholes	2	1	0
Avoidance of distresses	2	1	0
Slippery factor			
Leaf	2	1	0
Water	2	1	0
Ice	2	1	0
Safeguard from crime			
Continuous lighting	2	1	0
Emergency call equipment	2	1	0
Total	26	12	0

Table 4 – Usage checklist.

Requirement met along the path	Score (%)		
	>75	50–75	<50
Architectural barriers removal			
No grade to access building	2	1	0
Crossing equipped with ramp and grade	2	1	0
Rest facility/equipment on hilly link	2	1	0
No grade between driveways and sidewalks	2	1	0
Accessible bus stop	2	1	0
Tactile-plantar route for visually impaired users	2	1	0
Natural directions for visually impaired users	2	1	0
Rumble strip	2	1	0
Equipment for hearing impaired	2	1	0
Maintenance			
Distress density <50% of the surface	2	1	0
Cleanness and sanitation			
Availability of dumpster	2	1	0
Availability of bins	2	1	0
Road cleaning	2	1	0
Graffiti removal	2	1	0
Gutter	2	1	0
Availability of other sanitation disposal	2	1	0
Adaptability to events			
Availability of route for emergency rescue	2	1	0
Possibility to enforce car free areas	2	1	0
Possibility to remove urban furniture	2	1	0
Total	36	18	0

Table 5 – Appearance checklist.

Requirement met along the path	Score (%)		
	>75	50–75	<50
Chromatic variety			
Chromatic variety in horizontal surface	2	1	0
Chromatic variety in vertical surface	2	1	0
Signal			
Easiness to understands signals and information	1	0	0
Texture variety			
Texture variety in horizontal surface	2	1	0
Texture variety in vertical surface	2	1	0
Vegetation variety			
Simultaneous availability of tall and low vegetation	2	1	0
Simultaneous availability of seasonal and evergreen vegetation	2	1	0
Lighting variety			
Availability of public lighting	2	1	0
Possibility to remove urban furniture	2	1	0
Reliability of equipment			
Availability of infopoint	2	1	0
Usability of urban furniture	2	1	0
Signal			
Recurring feature of urban furniture	2	1	0
Easiness to understands sign of public facilities	1	0	0
Total	24	11	0

practitioners, six occupational physicians, and six transportation engineers). The scores are associated with quantity via visual inspection: if a given requirement is met for the majority of the path (i.e., for more than its 75%), then the path quality is considered acceptable; if it is met along the path between 75% and 50% of its length, then the path is acceptable but in need of adjustments associated with the rows with the lowest scores; finally, if a requirement is met for less than 50%, then the path is unsuitable and in need of urgent redesign. The geometric mean has been used to aggregate individual judgements and obtain the scores (Moretti et al., 2017);

(2) The further specific evaluation of sidewalks' evenness and maintenance status (according to the related indicators in Tables 3 and 4, respectively), as priorities to restore comfort, wellbeing and safety conditions for pedestrians. More specifically, this step can be considered "a focus within the focus" as these two indicators have been further processed and used to develop a specific indicator, the sidewalk condition index (SCI), derived from the pavement condition index (PCI) (Shahin, 2005), defined to assess distressed road and airport areas, and adapted in this case to non-motorized surfaces. The SCI has been already successfully applied in the II District and the procedure is extensively described elsewhere (Corazza et al., 2016a, 2018), with its algorithm synthesized in Fig. 2. Each path is subdivided in more branches (or legs) and sections. The first ones are identifiable parts of the network (e.g., a given link with its own street name or links with the same street name). Thebranches are separated into smaller components called "sections",that is pavement areas with uniform features such as construction, maintenance, usage history, and conditions.

As said, the proposed method has been used in the case study described in the next section, and results are further commented: each link was surveyed and assessed in order to fill in each row (i.e., to evaluate each requirement) in the four checklists and provide a mark (or score) according to the observed status (best possibly-met requirement = 2, unmet = 0). In some case, typically for elements expected to be found in quantity or variety (dumpsters, trees, public lighting, etc.) marks enable to assess their variability using the whole scale (2, 1 or 0); for those which existed or not, or could be simply assessed by a "yes or no" (e.g., easiness to understand signs of public facilities, or signal and information), the mark enables an assessment based on a 0–1 scale.

Considering that any area includes more paths, the calculation for each area is a two-step procedure described as follows.

The first step is to sum up the marks for each path in a given area as in Eq. (1).

$$\sum_{i=1}^{n_w} m_{wi} + \sum_{i=1}^{n_s} m_{si} + \sum_{i=1}^{n_u} m_{ui} + \sum_{i=1}^{n_a} m_{ai} = P_k \quad (1)$$

where m_{wi} is the mark given to any i item in the wellbeing check list, n_w is the number of items in the wellbeing check list, m_{si} is the mark given to any i item in the safety and security check list, n_s is the number of items in the safety and security check list, m_{ui} is the mark given to any i item in the

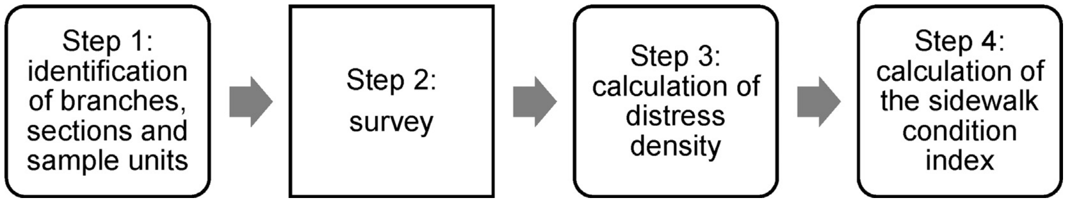

Fig. 2 – The algorithm for the SCI development.

usage check list, n_u is the number of items in the usage check list, m_{ai} is the mark given to any i item in the appearance check list, n_a is the number of items in the appearance check list, P_k is the total score for the k path in the given area.

The second step is to calculate Eq. (1) for the paths in the area, so to have the average score of the considered area as in Eq. (2).

$$\frac{\sum_{k=1}^{t} P_k}{t} = a_s \quad (2)$$

where t is the total number of paths in the given area, a_s is the average score for all the paths in the given area.

2.2. Advances in the proposed approach

As introduced in the previous section, requirements itemized in the checklists in Tables 2–5 are appropriate to analyze the home-to-school paths in the study area, since selected after a process involving expert assessment, desk research and local surveys. The former two enables to create checklists as much accurate as possible, whereas surveys "customize" the selection to the case in hand. This creates an innovative tool, which may overcome recurring limits in the current walkability surveys.

- Too general. Usually, conventional walkability surveys are based on general questions for given routes asked directly to pedestrians (typically "was it easy to cross streets?" or "was your walk pleasant/safe?", etc.). Although useful to assess how the walking environment is perceived by pedestrians, they do not provide directions to locate detected problems and prioritize interventions accordingly. For example, if the walk is perceived as unsafe or unpleasant, no information is available about where safety or pleasantness requirements are (mostly) unmet. On the contrary, the checklists proposed highlight whether any given requirement is met for the whole route (>75%), or less (50%–75%; <50%). Moreover, by linking the itemized requirements to branches and sections of the network for the analysis on sidewalk evenness and quality of maintenance, it is also possible to highlight whether such problems are due to poor maintenance. Scores also help designers to assess priorities and thus direct interventions where they are most needed.
- Pedestrians-assessed, only. The previous limit also introduces the fact that conventional walk ability surveys are designed to gather information under the pedestrians' point of view. Again, pedestrians' perception on the walking environment is paramount, but might provide no directions on how to solve problems. For example, if the walk is perceived as unpleasant because "not well lit", this could be for a number of reasons: because public lighting relies on light poles only and there are no neon signs providing additional light; the path is shadowy in winter times, etc. The checklists, in this case, by providing a set of factors to survey, facilitate the translation of the pedestrians' perception into objective performance to control. Moreover, once the scores are available, they complement and provide more accurate interpretations of the surveys on pedestrians' habits and perceptions, as further reported.
- Specifically-designed, not transferable. Most of the walk ability lists and surveys are "local", i.e., specifically designed for specific walk able environment. This means that the items included in the checklists "stem" from local analysis and unless to turn them into general statements (and then becoming "too general"), they cannot be applied elsewhere. The checklists here proposed, on the contrary, can be applied everywhere as they include objective requirements, associated with universal evaluation categories addressing safety, security, appearance, usage and wellbeing. Moreover, the checklists are open, easy to fill in and adaptable: more items can be added, whenever the local environment calls for specific issues, and templates can be easily filled in by surveyors, with no specific training. This ensures the full transferability of this methodology to different target contexts.
- Monofocused. Oftentimes walk ability lists, although addressing a series of very different components and performance levels of the urban environments (from vegetation to traffic patterns, to LoS, etc.), are designed to highlight road safety or local security problems, by introducing specific weights associated with the different evaluation categories. Use of weights to prioritize or focus on specific issues is appropriate and largely applied in walkability assessment (Appolloni et al., 2019; D'Alessandro et al., 2015). An unsafe or poorly secure environment is hardly walkable and safety and security are certainly top priorities, but if the urban context is complex, then all the requirements categories might have the same weight. Considering again the previous example when a walk is perceived as unpleasant because "not well lit", if the focus is primarily on road safety, solutions will be certainly targeted to improve the quality of public lighting for drivers and pedestrians and the design of crossing areas to mitigate conflicts, probably within the enforcement of a traffic calming plan. But, again, if the path is shadowy because of the local vegetation or the height of the building stock or the monofunctional land use, the major weight associated with safety will hardly lead to streetscape interventions which may have equal relevance in the overall

(a) (b)

Fig. 3 – Squares in the case study. (a) Piazza Mincio. (b) Piazza Caprera.

improvement of the quality of lighting in a street. Therefore, the proposed checklists not only include objective requirements, but likewise provide objective assessment, being all the evaluation category equally relevant.

The last points introduce the issue of the design of the checklists which must be objective, but also flexible and adaptable to the context in hand and the tools available.

For example, in Table 3 (safety and security), when analyzing the conflicts with motorized users, additional important features should be itemized, e.g., width of sidewalks (clearance at least 1.5 m) and carriageways, and parking patterns (extremely important as they would tell a lot on the children's perception of incoming cars). For the case study described in the next section, these requirements were not considered due to two specific area features: a) on-street parking allowed along both sides of the roads across the whole area (thus, this would not create significant scores); b) a consolidated urban fabric which dictated, since the beginning of the last century, width of sidewalks and carriageways. The resulting narrow sidewalks are certainly a problem, but also part of the local streetscape, hardly modifiable, for the case in hand.

The presented checklists were designed to be filled in by visual inspection, but in case of availability of GIS-referenced data, more quantitative items can be added, typically: distances between buildings (which affect noise and light levels as well as the climate on a given street), surface of shadowy areas, size of impervious surfaces, land use features, etc. All of the above can be easily itemized in the checklists and scored in the same way.

3. The case study areas

The two areas first considered in this case study are in the II District, a central neighborhood in the Municipality of Rome. A square (respectively Piazza Mincio in Fig. 3(a) and Piazza Caprera in Fig. 3(b)) and several school premises around (high schools, a junior school and more nearby private educational establishments) are the common trait of both, which turn these areas into vibrant cores of the district everyday life.

It should be noticed that these areas of the II District can be considered a premium-value environment, with plenty of vegetation, low-rise buildings, landmarks and mixed land use, which could make them the epitome of the 3Ds concept (Cervero and Kockelman, 1997). Unfortunately, the II District also concentrates among the highest rates of accidents and black spots involving vulnerable road users including riders in the city (Ragnoli et al., 2018), and is characterized by a deteriorated sidewalk network, due to long-lamented poor maintenance. The links across the area connecting the schools (among these those ending at Piazza Mincio and Piazza Caprera) are reported in Fig. 4. Here, observed paths are divided into major (where pedestrian flows are generated between the school areas and the local bus stops as major attractors/generators) and others (where additional facilities contribute to generate pedestrian flows, typically shops).

The case study also included an additional test field in the nearby area of San Lorenzo, still in the II District (Fig. 5).

Although different in terms of social status (San Lorenzo is undergoing an unusual mix of gentrification process and nightlife activities development) and quality of the built environment (Fig. 6), the availability of schools as catalysts for walking is alike in the three areas. One more reason to include San Lorenzo is that there are no squares close to the local

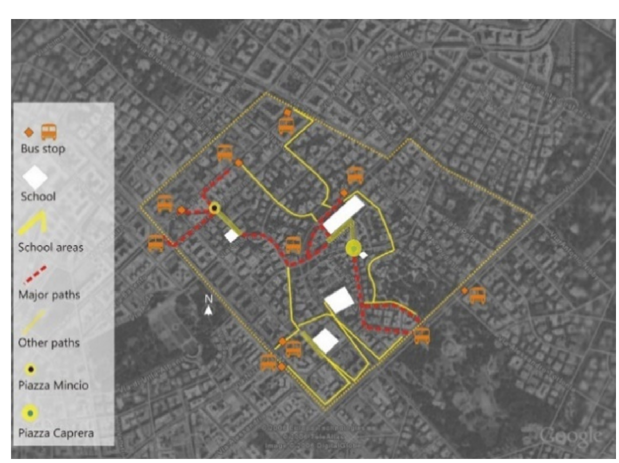

Fig. 4 – The Piazza Mincio-Piazza Caprera case study area.

junior school (in white in Fig. 5), but large outdoors areas in front. This enables to compare similar but not equal areas, consistently with the different types of urban fabric and land use mix, typical of many European cities.

In spite of this element of attractiveness, the three areas can be considered an important test bench for Rome also because representative of long lamented problems of the city: they are serviced by a public transport system not able to meet Roman citizens' demand in a satisfactory way. As such, local transit cannot compete with the personal convenience of the private cars, which also explains why the city motorization rate has very modestly decreased since the beginning of the 2000s. This rate, including that of two-wheelers, passed from 830[(number of vehicles/number of inhabitants, including infant and senior population) × 1000] in 2002 to around 750 in 2018 (Musso and Corazza, 2006). Needless to say, this also contributes to the high accident rates in the whole urban area with reported higher risks for pedestrians, especially in the neighborhoods closer to the center of the city, like the II District (D'Alessandro et al., 2010).

4. Results: outcomes and findings from the case study areas

According to Eqs. (1) and (2), resulting average scores from the checklists are summarized in Table 6, where also preliminary results achieved in San Lorenzo are available.

For each path, the total score was calculated by summing up single scores the surveyors gave to each item in the four checklists shown in Tables 2–5 For example, in the "Piazza Caprera" area, the surveyor's scores for wellbeing resulted into an average of: 10 for those requirements met more than 75% along the path (with maximum achievable value of 29, as in the bottom row of Table 2); 2 for those requirements met between 50% and 75% along the path (with maximum achievable value of 13, as in Table 2); and in the end, 0 on a maximum of 3 (Table 2) if the requirement is met less than 50%. In conclusion, the total score is: 10/29, 2/13 and 0/3. Adding the nominators and the denominator, a ratio of 12/45 = 0.27 is obtained. This is reiterated for all the criteria,

Fig. 5 – The San Lorenzo case study area.

Fig. 6 – School front in the San Lorenzo area.

and summing up the ratios of each, the total score of the path is eventually calculated.

More considerations can be further elaborated for both the checklists application and the PCI analysis, as follows. For the latter, whenever in Table 4, the requirement on distress density (within maintenance index) was not met, the PCI index was calculated to have a more accurate assessment. In this case, a total of 52 sample units needed to be further analyzed. Fig. 7 shows how the percentage density of the deteriorated pavement ranges between 30% and 50% in 16 out of the 52 sample surveyed; in this range, the number of units in very good conditions (7 with deterioration density below 10%) exceeds that of units in very poor conditions (3 with deterioration density above 90%). Overall, 65% of the samples have a deterioration density of less than 50% and therefore the observed routes can be assigned a score of 1 for the maintenance index ("distress density") of Table 4. Recurring distresses (those occurring more than 50%) are patches, holes, visco-plastic deformations and depressions. From the density of the individual distresses on each sample unit, the scores for the "Chinks and potholes" (as general absence of holes) and "Distresses" (as general absence of evenness) indices in Table 2 were also defined. The former set was not detected only on 11% of the samples units considered and then scored 0. For the latter, the set of distresses was not detected only on 8% of the units, which explains why the index was scored 0. These results were in full accordance to what already detected in the area, when analyzing the overall pedestrian network (Corazza et al., 2016a).

Table 6 – Average scores from the checklists.

Checklist	Average score		
	Piazza Mincio	Piazza Caprera	San Lorenzo
Wellbeing	16/45 (0.35)	12/45 (0.27)	10/45 (0.22)
Safety and security	10/38 (0.26)	11/38 (0.29)	7/38 (0.18)
Usage	12/54 (0.22)	8/54 (0.15)	7/54 (0.13)
Appearance	20/35 (0.57)	7/35 (0.20)	5/35 (0.14)
Total	1.40	0.91	0.68

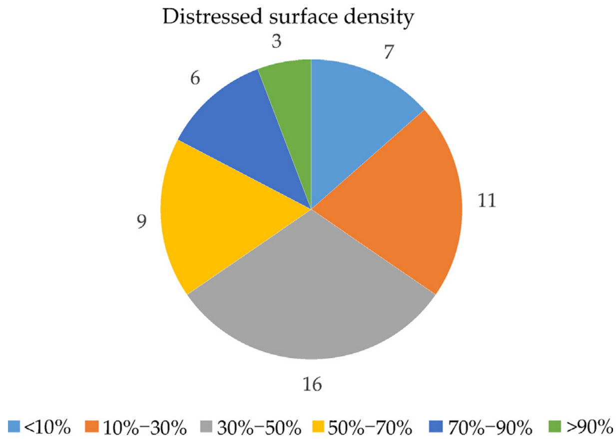

Fig. 7 – Distress density.

For what concerns the other outcomes from the checklists, results can be analyzed both in terms of differences among the three areas and the surveyed levels of met requirements.

Scores variations reported in Table 6 are clearly due to the differences among the links surveyed, but the higher scores in both Piazza Mincio and Piazza Caprera, if compared to San Lorenzo, are evidently affected by the superior quality of the local built environment of the former two.

More interesting is the analysis in terms of requirements meeting. If the path is analyzed from the wellbeing point of view, its poor performance can be associated to noise, unsuitability of LoS and the quality of public lighting, which is not specifically designed for pedestrians, but for motorized users. The lack of conflicts with other users contributes to positively assess the path in this regard, however if the very ending leg of the journey is considered, the lack of horizontal signs for crossing makes it inadequate.

The evaluation in terms of usage is low due to recurring architectural barriers, the modest availability of bins and dumpsters, but above all for its poor adaptability to events like the access or egress from school. Likewise, appearance is modest too, due to poor chromatic and texture variations, no opportunities to rest, and the difficulties in understanding signs and signals.

If the overall requirements are evaluated and reconsidered according to the walking habits of the students accessing the school areas, the assessment of the very last legs of the path (those which enable students to approach the front areas of the schools) is negative, due to dimensional unsuitability of such front areas (sidewalks too narrow, far below the required LoS to accommodate the amount of students waiting to access the schools). The observation of how students walk to approach the school areas also corroborates the assumption that such basic requirement is totally unmet.

Although the students age is different (the junior ones attending classes in the school of Fig. 9 walk or are motored by the parents, whereas those attending the high schools either walk, drive microcars or ride powered-two-wheelers), the way of approaching, clustering and hanging out in front of the schools is similar for all the surveyed educational establishments.

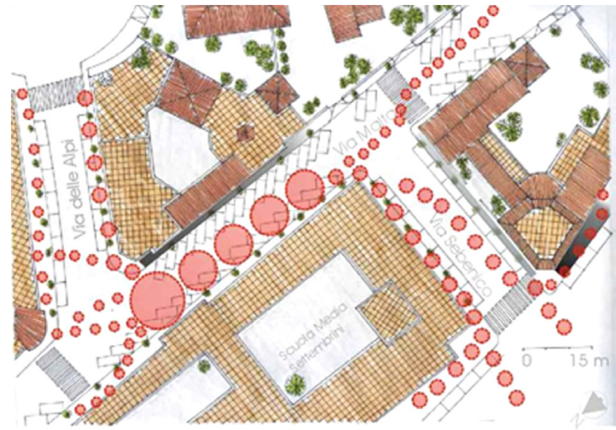

Fig. 8 – Approaching trajectories to one of the schools located in Piazza Caprera area.

When very close to the school entrance, students detour from sidewalks and invade the carriageways, thus creating a sort of "bubble", i.e., a cluster of stationary pedestrians invading the carriageway (represented by the biggest dotted circle where the trajectories merge in Fig. 8). This keeps on enlarging up until access time; in the case of the junior school, this process also includes accompanying parents who contribute to feed the "bubble" even once the students are in, and slowly deflates after. The process begins about 15 min before access time, resulting in the gradual invasion of the driveway. This implies that during this period there is a spontaneous sharing of the roadway by vehicles and pedestrians, of which the former are not alerted or fully aware. Two factors contribute to this unsafe situation: the lack of vertical and horizontal signs alerting drivers of the

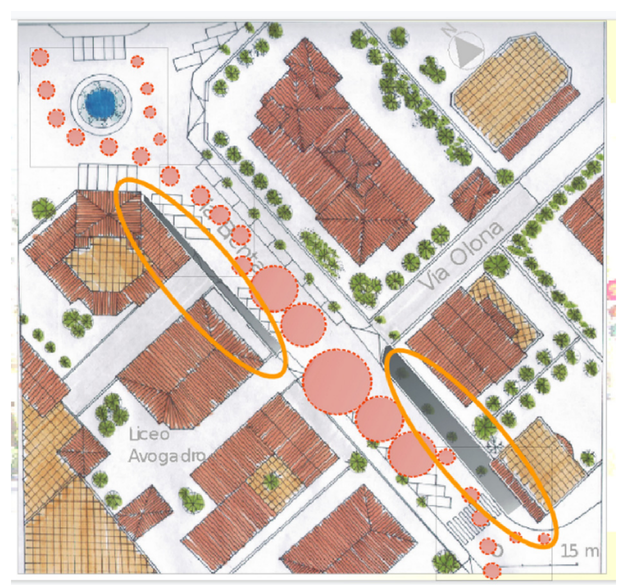

Fig. 9 – Approaching trajectories due to poorly maintained and narrow sidewalks, in the school located in Piazza Mincio area.

Fig. 10 – An example of poorly maintained sidewalks, in the home-to-school path near Piazza Mincio.

school area, and the circumstance that along with students and parents walking to schools, an additional contribution to congestion is due by more motorized users cruising for parking to reach their workplaces.

The reasons for which the "bubble" is generated can be of behavioral nature, but the dimension and the performance status of the sidewalks still play a fundamental role.

The size and LoS of the sidewalks is indeed inadequate for the level of pedestrian traffic around the schools, with situations of pedestrian congestion in peak times (access/egress times from schools).

A typical example is represented by Fig. 9, where the "bubble" is generated by the poorly maintained and narrow sidewalks (with an average width of around 1.5 m, but reduced by vegetation, lighting poles and traffic signs; highlighted in orange in the picture), which compel students to walks on the carriageway.

Fig. 10 shows a typical example of a high-severity distress along the path to the local school which compels the detours just mentioned.

It should also be noticed that, in some cases, available areas to walk are reduced also by vegetation and vehicles illegally parked on the sidewalks. Focusing on the streets reported in Figs. 8 and 11 describes how the situation is worsened by the parking requirements, massive in the area (Fig. 11(a) at Via delle Alpi). Although compliant with regulations, angle parking creates the spillover effect which decreases the actual walking clearance (Fig. 11(b) at Via Malta), and so do the parking signs (Fig. 11(c) at Via Sebenico, although here the scheme is parallel). Needless, to say this strongly affects the rating of the streets associated with the school paths in the Piazza Caprera area, and so with the negative assessment if compared to the Piazza Mincio situation.

The performance status and layouts of the sidewalks can, thus, contribute to the choice of pedestrians to detour and walk on the carriageway. In fact, in the case of the junior school, the distress density along one of the surveyed branch approaching the school is sufficiently high (44%) to justify such detour. This is also observed also for even higher values of distress density (70%) around the high schools, for one of which is also to compute a not negligible amount of potholes (20%). Needless to say, distress high density, poor LoS and dimensional unsuitability of sidewalks, lack of horizontal and vertical signs contribute to making the routes dangerous and not comfortable even for other categories of vulnerable users, particularly the elderly and the physically challenged.

5. Discussion: from problems to solutions

Problems detected in the previous section call for multiple solutions. Low performance in the field of safety could be partly solved by enforcing appropriate regulatory tools at area level, and among these the "Zone 30" (in Italy called "Environmental Islands), which if complemented by traffic calming schemes can be the most efficient. Such schemes, when properly designed and implemented, would also help reducing additional problems in the case study like parking spillover and unsuitable LoS for sidewalks. Unfortunately, The Environmental Islands in Italy are not common, nor is the implementation of traffic calming. However, the recent revision of the National Highway Codes can speed up the diffusion of both thanks to the introduction of the "School Roads" concept. According to this, roads around school premises can be either temporarily (i.e., during access and egress times) pedestrianized, car access restricted or turned into mini "Zone 30 s". Although just launched, "School Roads" seem to be a promising and efficient tool.

The reiterated presence of distresses on the sidewalk network calls for regular road maintenance programs. Maintenance interventions should be directed not just to restore

Fig. 11 – Examples of constraints due to traffic signs. (a) Via delle Alpi. (b) Via Malta. (c) Via Sebenico.

evenness on sidewalks, but also to create more comfortable and safer walking conditions by keeping horizontal markings visible, walking surfaces clean, and vegetation well-tended. The maintenance of the latter requires additional care when addressing problems due to distresses caused by exposed roots, for which the landscapers' and botanists' expertise is important.

Eventually, removal of architectural barriers and availability of quality urban furniture shift the focus on the need to ensure constant funding to plan and implement regular (re) design or rehabilitation programs. This is a "sensitive" field for many local administrations, for which all of the above might result not affordable (and Rome has recently become a showcase in this). However, the increasing diffusion of community-oriented crowdfunding options can contribute to solve this problem, and foster the citizens' sense of place.

6. Conclusions

The paper describes an innovative methodology to assess home-to-school paths. This includes a series of checklists, each associated with a specific evaluation category and a related set of requirements. Surveyors simply assess whether the requirements are met or not, and to which extent along the path, and provide scores accordingly. Major attention is attached to sidewalks dimension, quality, and maintenance thanks to the specific adaptation of the PCI, as described in Section 2.1. When these are not appropriate, children (and pedestrians in general) are compelled to detour and walk on the carriageway. The methodology is easily adaptable to different urban environments, as the set of requirements can be adapted to local situations, by simply adding or removing items. This creates an innovative synergy between exhaustive checklists and advanced indicators to assess the sidewalks performance, thanks more elements of strength, such as a) the usual approach based on simple walkability lists which, as stressed in Section 2.2., is often too general and local, is here advanced: the checklists proposed are flexible, as more or less items can be added or removed, and therefore transferable to whatever type of urban context; b) the requirements itemized are comprehensive of the main urban features, thus switching from the usual safety-based approach the majority of walkability lists are built upon, towards a multi-faceted analysis including comfort, appearance, security and wellbeing; c) visual inspection can be performed by any type of surveyor, thus enabling to collect andmerge users' (pedestrians) and experts' (maintenance managers, streetscapers, traffic planners, etc.) assessments with the same tool; d) the checklists outcomes are designed to be further processed thanks to the consequent specific expert assessment of the sidewalks quality, by very reliable specific indicators originated from the successful application of the PCI index in other fields; e) eventually, the whole procedure is intentionally simple, as designed to be resource-saving, result-driven and easy to adopt.

As a result, from all of the implementation of this procedure, the findings from the three Rome case study areas stress that poor sidewalks maintenance, unsuitable size of sidewalks are major contributors to surveyed detours. However, inappropriate location of urban furniture and public utilities, vegetation, parking spillover are additional factors. This situation can be even worsened if the local built environment is consolidated, with little possibility to alter the road layout. This calls for area-wide solutions, like the enforcement of Zone 30 s and traffic calming, which enable a moderate redesign of the road layout (and within this the recently launched "School Road" concept, which strictly focuses on areas around school premises, with low impact on the surrounding environment); regular road maintenance programs, including intervention on vegetation; more appropriate urban design programs to remove architectural barriers and unsuitable urban furniture.

Thus, the analysis of results shows an immediate two-pronged task. On the one hand, it highlights the need of urgent maintenance and in some cases total redesign of the sidewalk network, much more urgent in the areas where schools are located and on the paths connecting them. The use of the checklists and the PCI algorithm makes this task relatively easy for local administrators planning regular maintenance programs and enforcing road safety plans and regulations effectively. These might be perceived as common solutions however, often, in cities maintenance and redesign plans are originated and/or decided not according to the actual users' requirements or the surveyed infrastructure diminishing performance but different happenstances (funding availability, special events, general re-stylingor beautification programs, just to name some of the most recurring), with resulting interventions not site-specific or community-triggered. This procedure, on the contrary, provides decision-makers and maintenance planners with detailed directions on where and how to intervene to improve the walking environment, as originated by real needs and surveyed problems.

This also introduces the possibility to directly involve communities in the rehabilitation process by regularly promoting the surveys, thus increasing participation and sense of belonging and, eventually, support integration and contribute to healthier lifestyles.

On the other hand, the possibility to integrate the checklists and the PCI algorithm with other walkability tools paves the way for further scientific improvements. More specifically, it is currently under study the fine-tuning of this methodology within a specific tool to assess walkability, the walking suitability index of the territory (T-WSI), already successfully applied elsewhere in Rome (Appolloni et al., 2019) and in the town of Rieti, in central Italy (D'Alessandro et al., 2015, 2016). T-WSI innovates the way to assess walkability as it is not designed to evaluate walking-friendliness of given origin-destination paths, but that of the whole walking environment, independently from the distance to walk. In addition, the consideration that road maintenance planning is often dictated by road safety priorities and economic constraints suggests to include, within the checklists and the PCI algorithm, the safety potential (SAPO) indicator (Corazza et al., 2016b, 2017; Sgarra et al., 2014). SAPO allows drawing a priority list of road links for which it is of the utmost importance to intervene to improve safety, by assessing the expected reduction of accidents and costs to these associated, thus highlighting potential savings resulted from road safety and maintenance interventions.

To conclude, including T-WSI and SAPO also call for more prospective study areas, resulting into larger data sets. Larger data availability can certainly enable to explore more avenues, e.g., the relationships between household and walkability (Manaugh and El-Geneidy, 2011), or socio-economic impacts and walking environments (Osama and Sayed, 2017), thus improving the comprehensiveness in the analyses of home-to-school routes.

Conflict of interest

The authors do not have any conflict of interest with other entities or researchers.

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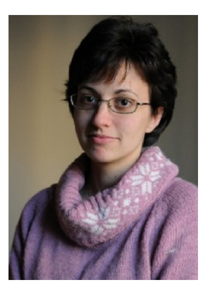

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