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Assessment of the Quality of Urban Spaces in the Context of Child-friendly Mobility

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1 ABSTRACT

Child-friendly urban spaces promote safe, independent and active mobility of children. This paper explores which indicators can be used to assess the quality of urban spaces in the context of child-friendly mobility. For this purpose, indicators from literature, guidelines etc. are collected. In total, 77 indicators are identified, described in terms of their relevance for child-friendly mobility and divided into four categories: (i) traffic situation and traffic conditions, (ii) urban space - infrastructure, (iii) urban space - amenities and other conditions, and (iv) other. For each indicator, very good (grade 1) and very poor conditions (grade 5) with regard to the quality of urban spaces in the context of child-friendly mobility are defined. A weighting is applied to evaluate the indicators according to their relevance for child-friendly urban spaces. In addition, a (more user-friendly) reduced set of 30 indicators is developed. The full catalogue of indicators, the subset and the associated evaluation scheme were used for an on-site inspection of a road section in the city of Vienna. The road section is also inventoried "digitally" based on geodata to analyze to what extent freely available geodata can be used to conduct the assessment without being on-site. By comparing the results (full set versus sub-set as well as manual versus digital assessment), the user-friendliness of the catalogue(s), the possibilities and limitations of a digital assessment of urban spaces in the context of child-friendly mobility are shown. The results show that processed indicator sets are suitable for the evaluation of the quality of urban spaces. In general, it can be stated that the results of the manual assessment agree very well with the entire catalog of indicators and with the shortened indicator set. The digital evaluation with indicator set also leads to comparable results, although outliers can also be identified for many "non-assessable" indicators. Due to a lack of data availability or quality, a (partially) automated digital evaluation is technically feasible, but many indicators have to be analysed or interpreted in-depth, which contradicts an automated evaluation. In the future, an automated evaluation of the quality of urban spaces in the context of child-friendly mobility could be possible and therefore offer a need for further research.

2 INTRODUCTION

2.1 Starting point

The *Federal Constitutional Law on the Rights of Children* states, among other things, "Every child has the right to appropriate participation and consideration of his or her opinion in all matters concerning the child, in a manner appropriate to his or her age and development" (BVG Children's Rights, 2011). "Matters concerning the child" also include all those related to children's homes and living spaces. However, in urban or transport planning and related political decisions, children's opinion and specific requirements are usually secondary. Although comparably vulnerable road users, such as pedestrians and cyclists, are becoming increasingly important in cities' strategies (e.g. MA 18 - Stadtentwicklung Wien, 2015), existing spaces have been and continue to be used primarily for cars respectively car users. This contradicts the requirement that children as a particularly vulnerable group must be able to use public space safely and need to access their destinations to play and stay without barriers.

In addition to these ethical aspects, some *worrying trends* can be observed with regard to young age groups. In fact, one of that is the decline in physical activity: In Austria, only 17.4% of 11 to 17 year olds meet physical activity recommendations of the World Health Organization (WHO) (Maier et al., 2017). These low rates of physical activity are also reflected in the development of everyday mobility of children: Accordingly, results of the Austrian national household survey show that walking decreases by 15 percentage points between 1995 and 2013/14 for the age group of 6 to 14 years old children (Tomschy et al., 2016; Tomschy et al., 2017). At the same time, car-passenger trips increased by 12 percentage points. 36%

of education trips as car passenger are shorter than 2.5 km. Furthermore, studies in different European countries indicate that children's independent mobility is on the decline (Shaw et al., 2013, Shaw et al., 2015). These developments clearly show that urban spaces need to be designed in a way that active and independent mobility is promoted.

2.2 Child-friendly mobility

The quality of urban spaces in the context of child-friendly mobility cannot be considered one-dimensionally. Many factors simultaneously influence whether children can move, play and stay in urban spaces on foot, by bicycle, scooter, inline skates, or skateboard. This refers, for example to spatial / structural, social, and economic factors.

Spatial characteristics refer to the traffic situation in the vicinity (e.g., speed limits), presence of parked vehicles, existence of barriers such as roads heavily used by motorized traffic within walking distance, or noise pollution, to name a few (Blinkert et al., 2015). They include private areas (e.g. type of house, presence of a garden/(front) yard) as well as public areas (e.g. distance of the front door to the street, existence of green areas, playgrounds). When collecting indicators in this field one can make use of studies on walkability which have recently been published around the globe (e.g., Zuniga-Teran et al., 2017; Kostovasilis, 2013; Wey & Chiu, 2013; Khder et al., 2016; Leslie et al., 2006). However, one must take into account that children and adolescents have different demands on their (built) environment than adults. Exemplarily, while walking trips for adults are primarily relevant for errands and recreation (Leslie, et al., 2006), for children it is playing and meeting friends (Blinkert et al., 2015). This results in different requirements for the design and equipment of public spaces. In addition, child-relevant factors for other travel modes such as bicycle, scooter, etc. must be identified. Several Austrian guidelines are an important basis for the collection of indicators on child-friendly mobility in this study. Those guidelines contain recommendations, mainly in the spatial context; they are, however, not exhaustive. The guidelines "RVS 03.04.13 - Child-friendly mobility" (FSV, 2015) and "RVS 03.04.14 - Design of the school environment" (FSV, 2016). Another guideline on child-friendly transport planning and design, was published by the former Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW, 2014). Another important basis is also a study of Blinkert et al. (2015) which has investigated how areas can be described and evaluated in terms of their qualities for children and what influence the residential environment has on children's play and everyday life.

Besides spatial characteristics, *social and economic aspects* influence the amount of free time spent outside by children, most of them indirectly via selection/distribution to favorable or unfavorable residential areas. These include f.e. the parents' level of education and the social climate in the neighborhood. In addition, the economic resources of the family, the family status of the parents (single parent or both parents), the employment of the parents, and an existing migration background all influence the unsupervised time spent outside the home.

It can be summarized that there are many factors which are difficult to capture in their entirety. In this work, only spatial and structural characteristics are considered.

2.3 On-site inventories

Spatial characteristics to assess child friendly mobility can be collected by on-site inspections / inventories conducted by observers (see for example Blinkert et al., 2015). Maps and photos can also be used to support the data collection. However, walk-throughs are time-consuming. Therefore the question arises, to what extent it is also possible to obtain information on the basis of existing geodata on a small scale. It could also be helpful to make assessments by combining objective data (GIS, open data) with data from on-site inventories. The development of automated evaluation tools would help cities to address the challenge of assessing socio-ecological qualities of urban spaces and to promote livability.

2.4 Objectives

Based on the starting point and challenges described, this paper deals with an evaluation of urban spaces in the context of child-friendly mobility. The main objective is to investigate which indicators can be used to assess the quality of urban spaces in the context of child-friendly mobility. A user-friendly set and evaluation scheme should be developed. Bases on on-site inspections in the city of Vienna the applicability is to be

tested. In addition, it is analyzed to what extent freely available geodata can be used to conduct the assessment without being on-site. By comparing the results (full set versus sub-set as well as manual versus digital assessment), the user-friendliness of the catalogue(s), the possibilities and limitations of a digital assessment of urban spaces in the context of child-friendly mobility are shown. The paper is structured as follows: In section 3 the approach is described. In section 4 the full catalogue of indicators is presented, the weighting procedure and the limitations. Based on that, the sub-set of indicators and the digital evaluation are presented. Section 5 presents the results of the application of the evaluation procedure. In section 6 conclusions are derived.

3 APPROACH

A multiple step approach is used to address this complex topic:

In a first step, relevant factors are researched based on guidelines and other literature. This results in a compiled list of indicators for assessing urban spaces in terms of child-friendly mobility. These factors can have an impact both directly and indirectly by influencing each other. The majority of the indicators have an effect through the reduction of motorized traffic, the reduction of motor vehicle speed and the creation of good visibility conditions in urban areas. In addition to road safety, some indicators also have an impact on subjective perceived social safety, but also on other aspects such as aesthetics of urban spaces. This, in turn, affects parents' decisions to let children go outside unsupervised.

In a second step, the list is summarized and shortened to a sub-set of 30 indicators to make it possible to evaluate individual street sections quick and simple.

In a third step, this sub-set of indicators and the associated evaluation scheme are applied for three different road sections in the city of Vienna. The application is carried out both "manually", that is, by walking and assessing the conditions on site, and "digitally", that is, by means of available data and computers.

4 INDICATORS

4.1 Catalogue of indicators

Based on literature, 77 indicators were identified. Two thirds of them are mentioned in several sources and largely overlap in content. Although studies contain a description on the positive or negative effect on child-friendly mobility, in the majority of cases no detailed information can be found regarding the indicator's expression in order to lead to this effect. This leaves a lot of room for interpretation as well as for the evaluation of the indicators. Although there are indicators that belong at least partially to private space (e.g. "type of house", "presence of gardens") they are nevertheless included in the catalogue.
The collected indicators are divided into four categories: (A) traffic situation & conditions, (B) urban space - infrastructure, (C) urban space - amenities and other conditions, and (D) other. Tables A1-A4 (Appendix) contain the description of all indicators, references, and (if available) specific recommendations. Most of the recommendations found in literature are qualitative; only occasionally (additional) quantitative information can be found. In principle, the aim should be to evaluate each indicator as objectively as possible. It seems, however, sometimes unavoidable to subjectively assess the indicators. For the evaluation, a five-part rating scale was used. The scale points were defined with 1 - very good, 2 – good, 3 – average, 4 – poor, 5 - very bad. For the endpoints (very good and very bad conditions with regard to child friendly mobility) a verbal description is given (Tables A1-A4, Appendix).

4.1.1 Category A: Traffic situation and traffic conditions

Current traffic conditions are summarized under this category; this concerns information on cross-section design (e.g. dimensioning of cross-section elements), traffic organization (such as legal regulations like the speed limit) and the prevailing traffic situation (e.g. compliance with the speed limit, traffic volumes, share of trucks). The indicators of this category can be considered together as "k.o. "-criteria for child-friendly mobility - conditions that must be met in order to achieve desired goals. This means that a majority negative rating in category A, cannot be outweighed by indicators of other categories. In total, 19 indicators are assigned to this category (Table A1, Appendix).

4.1.2 Category B: Urban space - infrastructure

This category contains 26 indicators regarding the infrastructural design which can promote safe, independent and active mobility of children (Table A2, Appendix). In contrast to category A, indicators of category B have a supporting but not decisive effect on child-friendly mobility. Examples include selective elements such as crossing aids, traffic light signal systems with green times adapted to the walking speed of children, floor markings, pictograms, or the combination of structural measures for traffic calming. Many indicators identified in literature differ only slightly. For example, four different indicators for the implementation of crossing aids can be found.

4.1.3 Category C: Urban space - equipment and other conditions

Indicators of category C allow to evaluate the local conditions that are not directly related to traffic. A total of 27 indicators are assigned to this category (Table A3, Appendix). The equipment of the urban space can especially contribute to child-friendly mobility, if indicators of categories A and B are evaluated positively. For example, private spaces such as the type of house (e.g., single-family home), or the presence of a yard may have a positive effect on children's unsupervised time spent outdoors (Blinkert et al., 2015), and thus particularly on active and independent mobility. In addition, low air pollution, low noise pollution, and seats in public space may promote active, independent mobility. However, if traffic conditions or infrastructure (A, B) are otherwise poor, these criteria have little influence on children's freedom of movement.

4.1.4 Category D: Other

This category includes 5 criteria that cannot be assigned to any other category, but find mention in literature several times (Table A4, Appendix). They include many different effects at the same time - for example, opportunities for interaction with peers, or the connectivity of the urban space. Strictly speaking, the expression of these indicators results from the effect of other indicators.

4.2 Weighting

A weighting procedure was applied to be able to evaluate the indicators according to their relevance for child-friendly urban spaces. We propose (i) an intra-category rating of the indicators and (ii) a category weighting. For the intra-category weighting, each indicator is assigned a weighting factor of 1 to 10, with 10 representing the strongest weighting based on the findings collected in the literature and a subjective assessment of Neuhauser (2020). These weighting factors are used to determine the percentage by which the respective indicator is included in the overall category result. The indicator "traffic volume (motorized)" receives the highest weighting with a prioritization of 14% in category A. In category D, all five indicators are considered equally important and are therefore all assigned a weighting factor of 1 (corresponds to 20% each). The weighting factors are included in Tables A1 to A4 (Appendix). A category weighting is additionally introduced. According to Neuhauser (2020), the findings of the literature review underline that the traffic situation and traffic conditions have the greatest influence on the child-friendliness of urban spaces. Urban space infrastructure is less significant, but still has a stronger impact on child-friendly mobility than urban space amenities. Other indicators only have a minor impact on the overall result. Thus, the proposed weighting clearly prioritizes category A (Traffic situation and conditions) with 55%, followed by category B (Urban space infrastructure) with 25%, category C (Urban space amenities and other conditions) with 15%, and category D (Other) with 5% (Neuhauser, 2020).

4.3 Limitations of the catalogue

4.3.1 Number of indicators

An attempt was made to include all indicators evident from the literature in the catalog. This leads to a complex list of 77 indicators. This contradicts the demand for a tool for "quick" and "easy" assessment of urban spaces.

4.3.2 Similarity

Since all indicators based on literature are included in the catalog, some of them differ only slightly. As an example, "curb extensions as crossing aids" and "roadway narrowing" are mentioned. Both serve mainly to improve the visibility of other road users, although narrowing the carriageway can also lead to a reduction in

speed. By grouping similar indicators together, multiple mentions in the list can be countered, although care must be taken not to lose any relevant information.

4.3.3 Qualitative information

It is striking that there are much more indicators in category B and C than in A, although the traffic conditions are much more important in the assessment of the child-friendliness of urban spaces. It is equally striking that there are only qualitative recommendations and descriptions for most of the indicators. Only for six indicators specific recommendations for measures are discovered. This is logical in that urban areas differ greatly from one another. There are only a few recommendations for traffic regulation and infrastructural design and equipment that are valid for different urban areas. For example, it can be stated as a general rule that a speed limit of 30 km/h is better than a speed limit of 50 km/h in terms of child-friendly mobility. The situation is different, for example, with the indicator "presence of planting (e.g. trees, hedges)". Thus, it makes no sense to assume that a tree every 20 meters is "better" than a tree every 50 meters. Many indicators interact with each other and can only be evaluated in their entirety. It follows that the assessment of many indicators must be made subjectively and the urban space must be considered as a whole. However, this makes it difficult to derive specific recommendations or to assign the indicators to individual user groups such as pedestrians or cyclists.

4.3.4 Impact assessment

It is difficult to distinguish whether indicators affect children's safe, independent and/or active mobility. It is assumend, that if an indicator has a positive effect on safe mobility, children move more independently because they are allowed to. If children move independently, this inevitably leads to higher level of active mobility. It is not examined if children in better rated urban spaces have higher rates of active mobiliy. It is only evaluated based on literature whether the expression of the respective indicator has a theoretically positive/negative effect on child-friendly mobility.

4.3.5 Loss of information through "digital" evaluation

Additional information may be lost through the digital assessment. For example, if the presence of a pavement is determined via a digital data, no statement can be made about its quality. It is possible that the pavement is not sufficiently dimensioned so that vehicles can drive over it and it does not lead to more child-friendly conditions. This circumstance can only be taken into account by on-site inspections.

4.3.6 Incompatible combinations

Some of the indicators are interdependent (e.g. "presence of playgrounds" and "playground equipment"), but not all of them can be combined with each other (e.g. "presence of median islands as structural crossing aid" and "pedestrian zone"). In this case, the respective indicator must be removed from the evaluation. By creating different lists for different frameworks, incompatible combinations of indicators could be avoided. For example, separate lists could be created for pedestrian zones, one-way streets, the school environment, or possibly also for different user groups such as pedestrians, cyclists, or scooter riders, which are equipped with different indicators and weightings.

4.3.7 Indicators not assessable

With each indicator that drops out of the evaluation as "not assessable", the weights of the remaining indicators change. A direct comparison of two urban areas / road sections is only possible based on indicators that form the "lowest common denominator". How many indicators must remain as the lowest common denominator is not investigated. It should be noted, that the omission of too many indicators can lead to a distortion of the results.

4.3.8 Transferability

In their present form, the indicators can only be used for the city of Vienna. The definitions of the indicators take into account the specific cityscape, the infrastructure and the legal framework. For the use of evaluations in other cities, countries or in the rural area, the indicators must be modified accordingly and adapted to possibly different circumstances. It must be checked, to what extent data are available for a digital assessment outside Vienna.

4.4 Subset of indicators

Based on some of the limitations mentioned above, the full catalogue is shortend to create a more suitable set of indicators for faster application. The most relevant indicators for child-friendly mobility will be retained; rather unimportant indicators are omitted. If possible, similar indicators are combined. This favors having fewer very similar or incompatible indicators in the list. However, the problem that mainly qualitative information is available and no statements can be made about the actual impact of indicators cannot be counteracted by creating the shortened indicator set. Likewise, the loss of information due to the "digital" evaluation and the problem of non-assessable indicators remains. The subset of indicators contains 30 indicators (Tables 1 to 4).

Full catalogue	Indicator	Subset
A1+A2	Restricted motorized traffic	A1*
A3	Existence of one-way streets	A2*
A4	Existence of through roads	A3*
A5	Existence of speed limits	A4*
A6	Compliance with the speed limit	A5*
A7	Traffic volume (motorized)	A6*
A9	Existence of adjacent busy roads	A7*
A13+A14	Bicycle path/lane	A8*
A18+A19	Sidewalk/walkway	A9*
omitted	A8, A10, A11, A12, A15, A16, A17	

Table 1: Subset of indicators in category A: Traffic situation and traffic conditions.

Full catalogue	Indicator	Subset
B4	Consideration of children's point of view	B1*
B7+B8+B9+B10	Structural crossing aids	B2*
B19	Existence of crosswalks	B3*
B11+B12+B13+B14	Structural traffic calming	B4*
B16	Existence of traffic light systems	B5*
B17	Traffic light system - green phases for pedestrians	B6*
B18	Traffic light system - turning traffic and pedestrian traffic separated	B7*
omitted	B1- B3, B5, B6, B15, B20, B21- B26	

Table 2: Subset of indicators in category B: Urban space – infrastructure.

Full catalogue	Indicator	Subset
C5+C6	Playgrounds	C1*
C7+C8+C9	Open spaces	C2*
C10+C11	Retreats	C3*
C12	Lighting	C4*
C16+C17	Water	C5*
C19	Existence of planting (e.g. trees, hedges)	C6*
C20	Existence of larger green areas (e.g. meadow, forest, park)	C7*
C26	Air pollution	C8*
C27	Noise pollution	C9*
omitted	C1-C4, C13-C15, C18, C21-C25	

Table 3: Subset of indicators in category C: Urban space – equipment and other conditions.

Full catalogue	Indicator	Subset
D1	Harmlessness	D1*

D2	Reachability/accessibility	D2*
D3	Opportunities for interaction	D3*
D4	Diversity/designability	D4*
D5	Connectivity	D5*
omitted	-	

Table 4: Subset of indicators in category D: Other.

4.5 Digital evaluation

For the "digital evaluation" based on the indicator subset, different sources for free available geodata are used. Almost all indicators are assessed digitally via ViennaGIS. Only the indicators "sidewalk/walkway" and "noise pollution" are partially assessed using information from other data sources (data.gv.at; maps.learminfo.at). In addition, for each indicator, the quality of the data is reported. This includes whether the data can be assessed automatically and whether all information necessary for the assessment is included. The better the quality of the data, the faster and more accurate the assessment can be performed. Based on the quality of the data, indicators can be evaluated directly, after further analysis, or not digitally at all. Three quality levels are described:

- Level 1 data can be displayed automatically, i.e. "at the click of a mouse": The data contain all information and details. An example is the indicator "presence of speed limits"; speed limits can be displayed clearly and directly for the entire urban area.
- Level 2 data are available, but need to be interpreted in more detail to allow an assessment. The data contain only partial information and/or need to be further processed or analyzed in more detail for the evaluation. This applies exemplarily to the indicator "structural crossing aids". For example, sidewalk extensions or median islands are visible via ViennaGIS. However, these are not automatically displayed, but have to be identified piece by piece on the map. It may be necessary to review level 2 data again by performing a "virtual walk-through" (e.g. Instantstreetview.com) in order to be able to give a valid assessment. Another example is the indicator "playground" which includes not only the presence, but also the equipment of playgrounds. However, via the available data, it is only possible to determine where playgrounds are present, but not how they are designed.
- Level 3 data is not available or cannot be evaluated on a digital basis. For example, no data can be found on the lighting.

5 ASSESSMENT

5.1 Case study

The evaluation scheme is applied for three inherently homogeneous road sections in the city of Vienna by using the full catalogue as well as the subset on-site (Neuhauser, 2020). In this paper, only one example is presented. In a second step, the assessment is also conducted "digitally". The use case described in this paper is "Köstlergasse" - a one-way street about 200 meters long. It is located in the 6th district of Vienna and connects "Gumpendorfer Straße" with "Linke Wienzeile". The on-site inspection took place in January 2020 and lasted about 120 minutes.

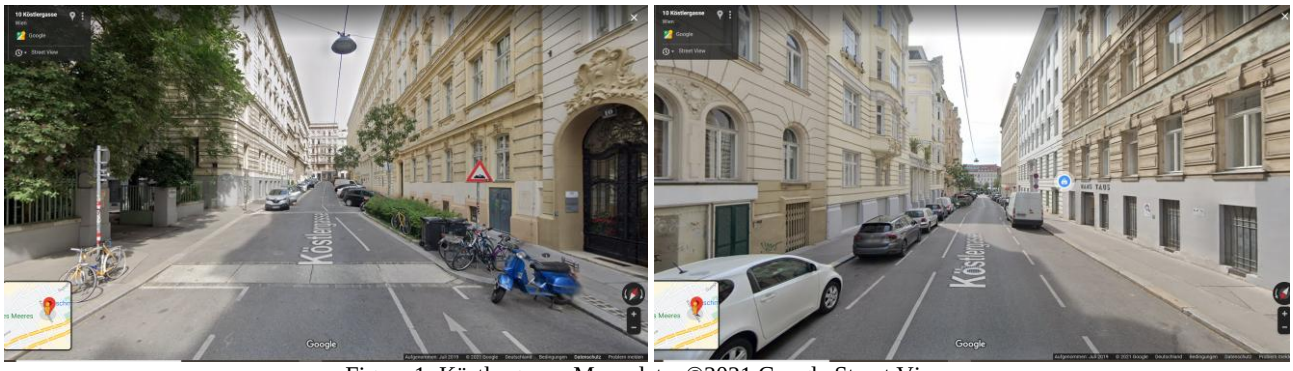

Figure 1: Köstlergasse, Maps data: ©2021 Google Street View

5.2 Results

Table 5 includes the average values of the assessment of the indicators per category (with intra-category weighting and unweighted) as well as the number of assessable indicators. The results are distinguished

between on-site assessment (full catalogue, subset) and digital assessment (subset). For the digital assessment also the data quality is displayed. It should be noted that, strictly speaking, averaging across the indicators in the categories is not permissible. However, the median represents a strong coarsening, so that the mean is used as a good approximation.

Indicator category		On-Site Assessment		Digital Assessment	
		Full catalogue	Subset	Subset	Data quality**
A	unweighted	2.65	2.89	2.71	L1: A1-2*, A4* L2: A3*, A7-9* L3: A5-6*
	weighted	2.95	3.08	3.06	
	nr of indicators	17/19	9/9	7/9	
B	unweighted	2.74	2.43	1.50	L1: B5* L2: B2-4* L3: B1*, B6-7*
	weighted	2.67	2.65	1.50	
	nr of indicators	23/26	7/7	4/7	
C	unweighted	3.83	3.67	3.57	L1: C7-9* L2: C1-2*, C5-6*, C8* L3: C3-4*
	weighted	3.58	3.29	3.56	
	nr of indicators	23/27	9/9	7/9	
D	unweighted	2.40	2.40	1.67	L1: - L2: D1-2*, D5* L3: D3-4*
	weighted	2.40	2.40	1.67	
	nr of indicators	5/5	5/5	3/5	
Total	Average unweighted	2.90	2.85	2.36	-
	Average weighted (incl. category weighting)	2.90 (2.95)	2.86 (2.97)	2.45 (2.68)	
	nr of indicators	68/77	30/30	21/30	

Table 5: Average scores of child-friendly mobility, 1 (very good)-5 (very bad). **Quality level of data level 1 to 3, see chapter "digital evaluation"

The results show, that based on the on-site assessment, 88% of the full catalogue indicators and all of the indicators in the subset can be evaluated. The digital assessment is based on 21 out of 30 indicators. Overall, the selected road section is rated "good" to "average" regarding child-friendly mobility. The worst conditions are achieved in category C (Urban space – equipment and other conditions). Due to the tight space conditions and the inner-city location, Köstlergasse lacks open spaces, green zones, seating areas, retreats and the like. The results appear plausible, especially when compared to the results from applying the evaluation procedure to other road segments, e.g. a pedestrian zone (Neuhauser, 2020). Comparing the total scores, the results of the on-site assessments agree well. With the full catalogue of indicators, values of 2.90 to 2.95 are determined; with the shortened set of indicators, values of 2.85 to 2.97. The overall results of the digital evaluation based on the sub-set are 2.35 to 2.68 and therefore differ by about 7% from the "on-site" result. This can be attributed to the higher scores in category B and D with rather low numbers of assessable indicators. The results in category A differ only slightly from each other; this category has the greatest influence on the overall result with 55% if the category weighting is applied. In fact, the data for the digital evaluation is only available to a limited extent (70% of indicators). In addition, some indicators could only be assessed inaccurately digitally. In total, level 1 data (highest quality) can be found for six indicators, level 2 data is available for 15 indicators. No usable data (level 3) can be found for nine indicators. Due to the poor availability and quality of the data, there is a large margin for interpretation. However, it should also be noted, that the digital assessment could be completed in about 30 minutes. Thus, the "digital approach" is 75% faster than the walk-through (120 minutes; arrival and departure not included). However, it has to be considered that the street section had already been walked before from the same observer and therefore the digital assessment could possibly be more time consuming for an unknown urban space. The walk-through is therefore significantly more time-consuming, although more precise results can be determined as a result.

6 CONCLUSION

The current study reflects the complexity of the assessment of the quality of urban spaces in the context of child-friendly mobility. Lots of indicators and criteria have been gathered from literature; some of them could be added in the Austrian RVS guidelines. As a result, a catalogue describes 77 indicators which are

relevant for child-friendly mobility. However, the application of the full indicator catalogue is associated with limitations. By defining a subset (30 indicators), some limitations can be counteracted, but some remain. Comparable results are achieved, however, it should be taken into account, that this reduction of the catalogue is made subjectively. In addition, only the small-scale theoretical effects of indicators are evaluated. Effects outside the selected road section are not taken into account. More research is needed to test the assessment method for different road sections. This can help to verify the results stated above. As the weighting can have a significant influence on the results of the evaluation, experts could be involved to refine the weighting process. Furthermore, before-and-after evaluations (e.g. change of use of travel modes, of the share of independent mobility of children, of attitudes) in the course of the implementation of road redesign measures could help to assess the direction of action respecitvely the effectiveness of measures. Future research could also lead to more specific (quantitative) recommendations for the dimensioning and design of elements in the urban area.

The current study also shows that it is possible to evaluate urban spaces in the city of Vienna by indicators both manually by means of inventory and based on digital data. According to the subjective assessment of the observer, the results of the manual evaluation reflect very well the conditions found on site with regard to child-friendly mobility (Neuhauser, 2020). Although the evaluation based on geodata lead to comparable results, it seems, however, necessary to critically review the results determined in this way. In particular, the availability and quality of data is a challenge as most of the data belong to quality level 2 or 3 and cannot be used without further ado. Decisive influencing variables can possibly be considered only insufficiently or not at all. Therefore, it should be kept in mind that a digital assessment brings not only opportunities but also risks.

Given sufficient availability of data, in the public sector, "child-friendliness" could be taken into account in the future, for example, in urban and transport planning with a similar collection of indicators or used to prioritize investments. By visualizing the quality of urban spaces in the context of child-friendly mobility in the entire urban area, it may be possible in the future to bring this to the attention of decision-makers. But also for the private sector, additional data may be available in the future and processed accordingly. Subsequently, it would be conceivable to weight the indicators online according to one's own preferences and to display the results for the entire urban area. In this way, parents and children could use smartphones to find out about child-friendly areas in their neighborhoods. Possibly, these results could also be linked to traffic models and real-time data. For parents, this could be decisive for choosing the location of their residence and thus subsequently also influence rents and real estate prices.

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8 APPENDIX

Indicator/criterion	Relevance with regard to child-friendly mobility, literature source, recommendation, and evaluation
A1 - Existence of residential or play street / encounter zone (traffic calming)	Traffic calming leads to increased safety for all road users and can be prescribed by law or achieved through construction measures. The existence of a residential or play street or an encounter zone allows traffic areas to be shared by pedestrians, cyclists, and motorized traffic. The maximum speed allowed and the behavior for the shared use of the traffic areas (e.g. playing on the roadway is allowed) are regulated by law. This protects children who, for example, have difficulty assessing speeds. Traffic calming promotes child-friendly mobility. Weighting factor: 6
Source(s)*	a, b, c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Traffic calming through the residential or play street / encounter zone in the entire street section
Grade 5 (very bad)	No traffic calming due to the lack of a residential or play street / encounter zone in the entire street section
A2 - Existence of pedestrian zone / car-free zone or driving bans	Pedestrian zones or car-free zones offer particulary high safety for children due to the absence of motorized traffic. Temporary car-free zones or driving bans are also possible. Weighting factor: 6
Source(s)*	a, b, c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Traffic calming through permanent pedestrian zone / car-free zone or permanent driving bans for motorized traffic in the entire street section
Grade 5 (very bad)	No traffic calming due to the absence of a pedestrian zone / car-free zone, respectively no driving bans for motorized traffic in the entire street section
A3 - Existence of one-way streets	Exceptions to the one-way rule (e.g. bicycle riding in the opposite direction of traffic) offer children the opportunity to ride their bicycle over short distances in the opposite direction of the one-way street with low traffic. Weighting factor: 3
Source(s)*	e
Specific recommendation(s)**	-
Grade 1 (very good)	Motorized traffic in the entire street section only possible in one direction (one-way street available)
Grade 5 (very bad)	Motorized traffic in the entire street section possible in both directions (no one-way street available)
A4 - Existence of through roads	Through roads lead to increased traffic volumes and are driven at higher speeds by motor vehicles. This also leads to increased air and noise pollution and has a negative impact on child-friendly mobility. Weighting factor: 4
Source(s)*	a
Specific recommendation(s)**	-

Grade 1 (very good)	No through roads available: No motorized through traffic possible in the entire street section (structurally, e.g. deadlock) or permitted (legally, e.g. "residents' traffic only")
Grade 5 (very bad)	Through roads available: Motorized through traffic possible in the entire road section
A5 - Existence of speed limits	The lower the speed of motorized traffic, the lower the risk of severity of accidents. According to RVS 03.04.14**, a speed of 20 km/h is suggested for encounter zones. Driving at walking speed can be considered particulary safe for children. Speed limits can be permanent, or only temporary (e.g. in front of schools). Weighting factor: 8
Source(s)*	a, b, c, d, e
Specific recommendation(s)**	[d)]Walking speed in residential street, [c)d)]20 km/h in encounter zones, [b)c)d)e)]30 km/h in local area and around schools
Grade 1 (very good)	Permanent speed limits to driving at walking speed; Speed ≤ 5 km/h in the entire street section
Grade 5 (very bad)	No speed limits; Speed ≥ 50 km/h in the entire street section
A6 - Compliance with the speed limit	The legal speed limit alone does not mean that it will be adhered to. Therefore, compliance with the speed limit is another indicator that is relevant for child-friendly mobility. Without additional structural measures, speed limits are often not observed. This has a negative impact on child-friendly mobility. Weighting factor: 6
Source(s)*	a, b, d
Specific recommendation(s)**	-
Grade 1 (very good)	Maximum allowed speed is observed by all road users in the entire road section
Grade 5 (very bad)	Maximum allowed speed is exceeded by all road users in the entire road section
A7 - Traffic volume (motorized)	The less motorized traffic, the fewer dangers and the better the opportunities for children to move around independently (according to RVS 03.04.14** "subjectively busy roads", no numerical definition). The greatest dangers for children come from motorized traffic. Weighting factor: 10
Source(s)*	c, d
Specific recommendation(s)**	-
Grade 1 (very good)	Entire street section is not used by motorized traffic at all (or only sporadically)
Grade 5 (very bad)	Entire street section is consistently used by large volumes of motorized traffic
A8 - Truck traffic	The severity of accidents for pedestrians, cyclists, and the like is particularly high in accidents involving truck traffic. There are larger areas around the vehicle that are not visible to drivers than in the case of passenger cars. Children are not aware of this danger. A high share of truck traffic has a negative impact on the safety of children, the fears of parents and the resulting restrictions on child-friendly mobility. Without exception, every truck has a negative impact on child-friendly mobility. Weighting factor: 3
Source(s)*	c
Specific recommendation(s)**	-

Grade 1 (very good)	No truck traffic allowed or present in the entire road section
Grade 5 (very bad)	Large volume of truck traffic in the entire street section
A9 - Existence of adjacent busy roads	(An) adjacent busy road(s) represent the end of children's action space as an impassable barrier. The amount of traffic in the considered street section itself can be significantly lower at the same time. However, due to adjacent busy roads, children cannot move safely or independently beyond them. This has a negative impact on children's mobility. Weighting factor: 5
Source(s)*	b, c
Specific recommendation(s)**	-
Grade 1 (very good)	No adjacent busy roads (Speed ≤ 30 km/h, low traffic volume) at all ends or junctions of the same street section
Grade 5 (very bad)	Adjacent busy roads (Speed > 30 km/h, high traffic volume) as a barrier at all ends or junctions of the street
A10 - Existence of parked vehicles	Children cannot be seen between or behind parked vehicles due to their short stature. They are also more difficult to be seen through parked vehicles. The intersection area in particular is a danger zone and should be kept clear of parked cars. Sufficient visibility should also be possible along the road. It should be noted that depending on the parking regulations (diagonal; longitudinal; transverse), visibility restrictions, duration of parking maneuvers and thus effects on flowing traffic may vary. Weighting factor: 4
Source(s)*	a, b, c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Along the entire street section there is no parked car
Grade 5 (very bad)	Along the entire street section there are parked cars on both sides of the road
A11 - Existence of public transport	Public transportation can be used unsupervised from the age of about 8-10 years. An expansion of children's activity space can be promoted by child-friendly bus and train services as well as sufficiently large child-friendly public transport stops. Weighting factor: 1
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Public transportation is available and accessible to and usable by all children in the street section, regardless of age
Grade 5 (very bad)	Public transport is not available or not usable for children (e.g. large train station: difficult to understand, complicated)
A12 - Existence of commercial and service establishments	Commercial and service establishments lead to conditions unfriendly to children due to increased traffic volume, increased heavy traffic and increased noise pollution. Weighting factor: 1
Source(s)*	a, b
Specific recommendation(s)**	-
Grade 1 (very good)	No commercial or service establishments in the entire street section, purely residential area
Grade 5 (very bad)	Commercial and/or service business at every house number on the entire street section (lots of additional traffic)

A13 - Existence of bicycle path/lane	Bicycle paths of any kind are facilities intended for bicycle traffic and enable children to participate in traffic by bicycle. This can have a positive effect on children's mobility. The presence of a bike path or bike lane draws more attention to the cyclists. Weighting factor: 3
Source(s)*	b, c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Bicycle path/lane, either structurally seperated, or on the roadway, throughout the entire street section
Grade 5 (very bad)	No bicycle path/lane, neither structurally seperated nor on the roadway, in the entire street section
A14 - Bicycle path/lane dimensioning	Children need more space for riding a bicycle than adults. Bicycle paths/lanes should be wide enough to allow two cyclists to ride side by side in the same direction. Weighting factor: 2
Source(s)*	c, e
Specific recommendation(s)**	Specific recommendation: [e)]Bicycle path/lane with a width of 1.5 m per driving direction
Grade 1 (very good)	Bicycle lanes/paths provide sufficient space for two children riding a bicycle side by side throughout the street section; bicycle lanes/paths throughout the street section are at least 1.5 m wide per direction of travel
Grade 5 (very bad)	Bicycle lanes/paths do not provide sufficient space for two children riding a bicycle side by side throughout the road section; bicycle paths/lanes throughout the street section are less then 1.5 m wide per direction of travel
A15 - Bicycle path structurally separated from motorized traffic	Bicycle paths that are structurally seperated from motor vehicle traffic reduce the risk of motorists overtaking or "cutting" cyclists. Children only have to watch out for other cyclists and are better protected. Structural separation from individual motorized traffic reduces the risk of traffic accidents. Sufficient distance to parked cars should be ensured to provide protection from opening doors or protruding vehicle parts and sufficient visibility to the cyclists. Weighting factor: 2
Source(s)*	e
Specific recommendation(s)**	-
Grade 1 (very good)	Bicycle path structurally seperated from motor vehicle traffic in the entire street section
Grade 5 (very bad)	No bicycle path structurally seperated from motor vehicle traffic in the entire road section
A16 - Bicycle riding in the opposite direction of a one-way street	Bicycle riding in the opposite direction of traffic in a one-way street with low volumes of motorized traffic and short distances is safe for children. With larger volumes of traffic or longer distances, complex traffic patterns arise along the route and especially at intersections, in which children with their increased space requirements and not fully developed traffic skills cannot safely participate. Weighting factor: 2
Source(s)*	c
Specific recommendation(s)**	-
Grade 1 (very good)	Bicycle riding in the opposite direction of traffic in a one-way street is allowed throughout the entire street section and is safe for children due to low traffic loads
Grade 5 (very bad)	Bicycle riding in the opposite direction of traffic in a one-way street is not allowed in the entire street section or is not safe for children due to high traffic loads

A17 - Roadway dimensioning	Wide roadways provide space for many vehicles and encourage increased speeds of motorized traffic, which has a negative impact on the safety of children and thus on their independent mobility. Weighting factor: 1
Source(s)*	a, b, d, f
Specific recommendation(s)**	[b)]Roadway < 6 m wide
Grade 1 (very good)	One lane (per direction) in the entire street section, small lane width for motorized traffic, but sufficient space not to endanger other road users
Grade 5 (very bad)	Throughout the street section, wide roadways with multiple lanes (per direction of travel); roadway > 6 m wide throughout the street section
A18 - Existence of sidewalks/walkways	Sidewalks/walkways are facilities intended for pedestrian traffic and enable children to participate in traffic as pedestrians. Sidewalks are a part of the street separated from the roadway. Walkways are independently guided. Weighting factor: 3
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Sidewalks/walkways in the entire street section
Grade 5 (very bad)	No sidewalk/walkway in the entire street section
A19 - Sidewalk/walkway dimensioning	Children not only walk on the sidewalk, they also play. In addition, they do not move in straight line, but crisscross, depending on what they are paying attention to. To ensure sufficient space for two children including school bags next to each other, a sidewalk width of 3.0 m is recommended in school environment ("minimum width of 2.5 m" RVS 03.04.13). Weighting factor: 3
Source(s)*	c, d, e, f
Specific recommendation(s)**	[d)]Sidewalk width 2-3 m
Grade 1 (very good)	Sidewalks/walkways provide sufficient space for two children with school bags side by side in the entire street section; sidewalks/walkways are in the entire street section at least 3.0 m wide
Grade 5 (very bad)	Sidewalks/walkways in the entire street section do not provide enough space for two children with school bags side by side; sidewalks/walkways in the entire street section are less than 2.0 m wide

Table A1: Category A: Traffic situation and traffic conditions. *Sources: a - Blinkert et al., 2015; b - Blinkert, 1996; c- FSV, 2015; d - FSV, 2016; e - BMLFUW, 2014; f - Kostovasilis, 2013, **Specific recommendations are defined to be clear specification found in literature e.g. "speed limit of 30 km/h in local areas", but not "reduction in traffic volume".

Indicator/criterion	Relevance with regard to child-friendly mobility, literature source, recommendation, and evaluation
B1 - Existence of transitional areas; distance front door to street	Transition areas / forecourts provide space for play, loitering and protection in the form of distance from moving motorized traffic. Weighting factor: 4
Source(s)*	a, d
Specific recommendation(s)**	-
Grade 1 (very good)	All entrances throughout the street section are equipped with forecourts / transition areas
Grade 5 (very bad)	There is no forecourt / transition area in front of the entrances in the entire street section
B2 - Networking of play and staging areas (pedestrian connections)	Children not just want to play in one place, they have multiple play and staging areas and want to be able to move between them safely and independently on foot. Safe pedestrian connections allow children to move independently between play and staging areas. Weighting factor: 3
Source(s)*	c
Specific recommendation(s)**	-
Grade 1 (very good)	All play areas / playgrounds throughout the street section are connected by safe pedestrian connections
Grade 5 (very bad)	All play areas / playgrounds in the entire street section are not connected by a single safe pedestrian connection
B3 - Networking of play and staging areas (bicycle connections)	Children not just want to play in one place, they have multiple play and staging areas and want to be able to move between them safely and independently by bike. Safe cycling connections enable children to independently move between play and recreation areas. Weighting factor: 3
Source(s)*	c
Specific recommendation(s)**	-
Grade 1 (very good)	All play areas / playgrounds throughout the street section are connected by safe cycling connection
Grade 5 (very bad)	All play areas / playgrounds throughout the street section are not connected by a single safe cycling connection
B4 - Consideration of children's point of view	Children cannot be seen between or behind parked vehicles, trash cans, traffic signs, telephone booths, etc. due to their smaller body size. The point of view should be clear from an eye level of 0.8 m to allow safe mobility to children. Any visual obstructions in the urban space should therefore not be higher than 0.6 m. Weighting factor: 10
Source(s)*	c, d
Specific recommendation(s)**	c)Clear view from 0.8 m height
Grade 1 (very good)	There are no visual obstructions along the roadway, at the sidewalk and at intersections in the entire street section; clear view from 0.8 m eye level in the entire street section

Grade 5 (very bad)	There are visual obstructions along the roadway, at the sidewalk and at intersections in the entire street section; no clear view from 0.8 m eye level in the entire street section
B5 - Existence of pictograms, traffic signs, information boards	Pictograms, traffic signs or information boards can draw attention to children (e.g. StVO §50/12 "Children"), schools (e.g. "way to school"), playing and moving on the road (e.g. "Children at play"), etc. Especially in the vicinity of e.g. schools, playgrounds, or parks, this can draw more attention to children. The additional signage can have a positive effect on the consideration and thus the safe and independent movement of children in road traffic. Weighting factor: 1
Source(s)*	d
Specific recommendation(s)**	-
Grade 1 (very good)	Throughout the street section there are several pictograms, traffic signs, or information boards that draw special attention to children. These are placed visibly and thus do not cause any obstructions to visibility
Grade 5 (very bad)	In the entire street section there are no pictograms, traffic signs, or information boards that specifically draw attention to children OR they are not visibly placed OR they themselves cause visual obstructions
B6 - Existence of road markings	Road markings, like pictograms, can indicate children, crossing points, speed limits or hazards and increase the attention of road users. They should not influence the view of road users for an unnecessarily long time, should not distract from the traffic situation, and should be placed at a sufficient distance from danger points (e.g. crossings). This has a positive effect on child-friendly mobility. Weighting factor: 1
Source(s)*	d
Specific recommendation(s)**	-
Grade 1 (very good)	Throughout the entire street section, road markings are clearly visible and properly positioned
Grade 5 (very bad)	Throughout the entire street section, there are no road markings OR road markings are poorly visible OR road markings direct road users‘ attention away from hazards
B7 - Existence of crossing aids	Crossing aids draw the attention of other road users to pedestrians, bicyclists, etc. Crossing aids should be provided at short distances and allow crossing in the street in the shortest possible way. At the same time, crossing aids should not have a negative impact on the fluidity of traffic. Weighting factor: 6
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	There are several crossing aids at short distances throughout the street section.
Grade 5 (very bad)	There is no crossing aid in the entire street section.
B8 - Roadway elevations (paving) as a structural crossing aid (or in the entire intersection area)	Roadway elevations (raised pavement) reduces speed and draws the attention of road users to pedestrians and cyclists. The elevation signals to all road users that pedestrians or cyclists crossing the road are to be expected. This also increases the attention to non-crossing road users and reduces speed. This increases safety for all road users. Weighting factor: 4
Source(s)*	c, d, e

Specific recommendation(s)**	-
Grade 1 (very good)	Roadway elevations (paving) at all pedestrian/bicyclist crossings and also without crossings at short distances throughout the street section
Grade 5 (very bad)	No roadway elevation (paving) in the entire street section
B9 - Existence of curb extensions as structural crossing aids	Curb extensions in intersections increase the visibility of pedestrians and shorten the distance to cross the roadway. This has a positive effect on child-friendly mobility. Weighting factor: 4
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Curb extensions at all pedestrian crossings and all intersections of pedestrians and other road users
Grade 5 (very bad)	No curb extension in the entire street section
B10 - Existence of center islands as structural crossing aids	A center island leads to more child-friendly conditions by dividing the roadway. This means that pedestrians only have to concentrate on one direction of travel when crossing and can cross the roadway in two stages. Weighting factor: 2
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Center islands at all crossing points of pedestrians and other road users
Grade 5 (very bad)	No center island at intersections of pedestrians and other road users
B11 - Offset of the roadway to reduce speed	A lane offset can lead to reduction in driving speed and thus to traffic calming. Traffic calming has a positive effect on child-friendly mobility. Weighting factor: 4
Source(s)*	d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Lane offset leads to speed reduction in the entire street section
Grade 5 (very bad)	No lane offset OR it does not lead to speed reduction in the entire street section
B12 - Offset of the roadway to create staging areas	With lane offset, additional staging areas can be created. Additional staging areas have a positive effect on child-friendly mobility. Weighting factor: 4
Source(s)*	d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Lane offset leads to creation of staging areas in the entire street section
Grade 5 (very bad)	No lane offset OR it does not lead to creation of staging areas in the entire street section

B13 - Combination of structural measures for traffic calming	Traffic calming leads to increased safety for all road users and can be prescribed by law or achieved through construction measures. By combing several structural measures for traffic calming (roadway offset, paving, center island), the speed of motor vehicle traffic can be reduced. Weighting factor: 4
Source(s)*	d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Urban space is designed to calm traffic through a combination of structural measures
Grade 5 (very bad)	No measures have been taken for traffic calming of the urban space
B14 - Existence of lane narrowings	Lane Narrowing can keep the visibility area lear (no parked vehicles) and thus create better visibility conditions. In addition, lane narrowing can lead to a reduction in driving speeds, which is positive in the context of child-friendly mobility. Weighting factor: 2
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Lane narrowing along the street and in all intersections throughout the street section
Grade 5 (very bad)	No lane narrowing; parked cars continuously along the street and in all intersection areas throughout the street section
B15 - Existence of intersections with priority to the right	On unregulated intersections, the priority to the right applies. It increases the attention of road users and reduces driving speed. This has a positive effect on child-friendly mobility. However, it can be difficult for children to correctly assess the behavior of other road users. A traffic light system-regulated intersection is therefor not necessarily to be evaluated worse. Weighting factor: 1
Source(s)*	e
Specific recommendation(s)**	-
Grade 1 (very good)	Instead of traffic light systems, intersections are regulated with priority to the right in the entire street section
Grade 5 (very bad)	Instead of traffic light systems, intersections are regulated with "priority road","give way" or "stop" in the entire street section
B16 - Existence of traffic light systems	Traffic light systems force vehicles to stop and enable children to cross the road safely. Children must focus primarily on the traffic light system to cross the street, although traffic must also be observed. Weighting factor: 8
Source(s)*	c, d
Specific recommendation(s)**	-
Grade 1 (very good)	All intersections are equipped with a traffic light system
Grade 5 (very bad)	No intersection is equipped with a traffic light system
B17 - Traffic light system - green phases for pedestrians	Children aged 6-10 move about 1.1 m/s walking speed; people walking with younger children move at about 0.6 m/s (according to RVS 03.04.13, pedestrians walk at 0.6-2.0 m/s; according to Klimaaktiv, children walk at 0.8 m/s)**. Green phases adapted to walking speed of

	children enable safe crossing of the street. Weighting factor: 6
Source(s)*	c
Specific recommendation(s)**	*c) Green phases for walking speed ≤ 0.6 m/s*
Grade 1 (very good)	The green phase of a traffic light system is adapted to the walking speed of children; green phases for walking speed ≤ 0.6 m/s
Grade 5 (very bad)	The green phase of a traffic light system is not adopted to the walking speed of children; green phases for walking speed ≥ 2.0 m/s
B18 - Traffic light system - turning traffic and pedestrian traffic separated	Due to their short height, children are difficult to see during complex maneuvers such as turning or can be easily hidden and overlooked by e.g. signs, trash cans, or their own vehicle. Therefore, separating turning traffic from pedestrian traffic has a positive effect on child-friendly mobility. Weighting factor: 6
Source(s)*	c, e
Specific recommendation(s)**	*c) Geen phases for walking speed ≤ 0.6 m/s*
Grade 1 (very good)	At all traffic light systems, turning traffic and pedestrian traffic are switched green separately
Grade 5 (very bad)	At all traffic light systems, turning traffic and pedestrian traffic are guided together or pedestrian traffic is not controlled by a traffic light system at all
B19 - Existence of crosswalks	Crosswalks increase the attention of other road users to pedestrians (see crossing facilities). A crosswalk signals to all road users that crossing pedestrians are to be expected. This also increases the attention to non-crossing pedestrians in the area of the crosswalk and reduces speed. Crosswalks work particulary well in combination with other measures (e.g. raised roadway, lighting, center island). Note: Crosswalks are only effective at certain minimum frequencies of pedestrian and motorized traffic. These minimum frequencies are not considered in the evaluation but may need to be reviewed in retrospect. Weighting factor: 6
Source(s)*	c, d
Specific recommendation(s)**	-
Grade 1 (very good)	All intersections of motorized traffic and pedestrian traffic are equipped with crosswalks
Grade 5 (very bad)	No intersection of motorized traffic and pedestrian traffic is equipped with crosswalks (Note: Check minimum frequencies for pedestrian and motorized traffic if necessary)
B20 - Existence of bollards/barriers	Bollards/barriers in the form of a blockade/lock allow only partial access to the street section under consideration (e.g. residents, public traffic, cyclists). Flowing traffic is kept away from the street section. This has a positive influence on child-friendly mobility. Such barriers can also be temporary (e.g. start and end of classes in front of educational institutions). In addition, bollards can be present, e.g. on sidewalks and bike paths, as protection from motorized traffic. Weighting factor: 2
Source(s)*	d
Specific recommendation(s)**	-
Grade 1 (very good)	Bollards/barriers as a permanent blockade/lock or to protect pedestrian and bicycle traffic throughout the street section

Grade 5 (very bad)	No bollards/barriers in the entire street section
B21 - Public transport stops	Children do not just stand while waiting at the bus stop, they playfully pass the time and forget about the dangers in the surrounding area. For this reason, bus stops must be sufficiently large to provide space for moving children and lead to child-friendly conditions. In addition, fences, for example, can provide a barrier to dangerous areas. Weighting factor: 2
Source(s)*	c, d
Specific recommendation(s)**	-
Grade 1 (very good)	Public transport stop is present and stop area is sufficiently sized and provides adequate space for multiple waiting children
Grade 5 (very bad)	No public transport stop OR Stop area is not of sufficient size and does not provide adequate space for multiple waiting children
B22 - Safe walking to and from public transport stops	Safe walking to and from public transport stops should always be possible. Especially under time pressure (e.g., when the bus is already at the stop), crossing the road quickly can lead to dangerous situations. Walking to and from bus stops should therefore be possible without crossing the road in order to have a positive effect on child-friendly mobility. Weighting factor: 2
Source(s)*	d
Specific recommendation(s)**	-
Grade 1 (very good)	Public transport stop is available and safe walking to and from the stop is possible
Grade 5 (very bad)	No safe walking to and from public transport stops possible
B23 - Danger from public transport vehicles / public transport lanes	Heavy vehicles such as buses or streetcars can increase the risk of accidents in the street section under consideration. The vehicles are higher and longer, and the driving behavior differs from that of a passenger car. Accidents involving these vehicles are likely to have particulary severe consequences. This has a negative impact on child-friendly mobility. Weighting factor: 1
Source(s)*	d
Specific recommendation(s)**	-
Grade 1 (very good)	No hazards from public transport vehicles and lanes in the entire street section
Grade 5 (very bad)	Dangers from public transport vehicles and lanes in the entire street section
B24 - Entrances and exits at sidewalk level	For entrances and exits to e.g. garages or courtyards, either the sidewalk can be interrupted and lowered to street level, or the sidewalk can be pulled through and the street raised to sidewalk level. The continuous sidewalk and the formation of ramps for vehicular traffic are to be evaluated positively. This signals to drivers that the road ends here, that pedestrians are moving on this area and that they should be watched out for. Weighting factor: 1
Source(s)*	d
Specific recommendation(s)**	-
Grade 1 (very good)	No entrances and exits in the entire street section OR the sidewalk is pulled through at all entrances and exits or the street is raised to the sidewalk level

Grade 5 (very bad)	Sidewalk is lowered to street level at all entrances and exits
B25 - traffic violations	Traffic violations and other hazards posed by road traffic that have not yet been defined, such as frequent red light runnings; sidewalk crossings in tractrix curves; motor vehicles parked on the sidewalk; etc., have a negative impact on child-friendly mobility. Weighting factor: 1
Source(s)*	a, b, c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	No other traffic-related hazards can be identified throughout the street section
Grade 5 (very bad)	Other traffic hazards can be identified throughout the street section
B26 - Clarity	Traffic signs, signals, information, etc. are visible, understandable, and clear for children and other road users and lead to child-friendly conditions. Weighting factor: 2
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Entire street section is clear and understandable for children and other road users
Grade 5 (very bad)	Entire street section is unclear and not understandable for children and other road users

Table A2: Category B: Urban space – infrastructure. *Sources: a - Blinkert et al., 2015; b - Blinkert, 1996; c- FSV, 2015; d - FSV, 2016; e - BMLFUW, 2014; f - Kostovasilis, 2013, **Specific recommendations are defined to be clear specification found in literature e.g. "speed limit of 30 km/h in local areas", but not "reduction in traffic volume".

Indicator/criterion	Relevance with regard to child-friendly mobility, literature source, recommendation, and evaluation
C1 - Type of house	Children are more likely to be allowed to play outside unsupervised the closer they live to street level (presumably because of proximity to their own homes). The highest levels of playtime are found for children living in detached houses or on the ground floor and first floor. Therefore, the house type can have either a positive or negative impact on child-friendly mobility. Weighting factor: 2
Source(s)*	a
Specific recommendation(s)**	-
Grade 1 (very good)	In the entire street section, there are only detached houses or residential buildings with a maximum of one upper floor
Grade 5 (very bad)	In the entire street section, there are only residential houses with more than one upper floor
C2 - Existense of gardens	In their own garden, children can play away from the dangers of road traffic. This is to be evaluated positively. Weighting factor: 2
Source(s)*	a
Specific recommendation(s)**	-
Grade 1 (very good)	In the whole street section children have their own garden at their disposal
Grade 5 (very bad)	In the entire street section, children do not have their own garden at their disposal
C3 - Existence of courtyards	In their own courtyard, children can play away from the dangers of road traffic. This is to be evaluated positively. Weighting factor: 2
Source(s)*	a
Specific recommendation(s)**	-
Grade 1 (very good)	In the entire street section, children in multi-apartment buildings have their own courtyard at their disposal
Grade 5 (very bad)	In the entire street section, children in multi-apartment buildings do not have their own courtyard at their disposal
C4 - Existence of front yards	In their own front yard, children can play close to their homes within sight of their parents. Like a forecourt, the front yard serves as a transitional space from the living area to the traffic area and has a positive effect on child-friendly mobility. Weighting factor: 2
Source(s)*	a
Specific recommendation(s)**	-
Grade 1 (very good)	In the entire street section, children have thier own front yard at their disposal
Grade 5 (very bad)	In the entire street section, children do not have their own front yard at their disposal
C5 - Existence of playgrounds	The mere existence of a playground in the immediate vicinity has no influence on the amount of time spent outside by children unsupervised. Nevertheless, it is assumed that a playground in the neighborhood has a positive influence on child-friendly mobility, at least on a small scale. Weighting factor: 6

Source(s)*	a
Specific recommendation(s)**	-
Grade 1 (very good)	There are several playgrounds in the considered street section
Grade 5 (very bad)	There are no playgrounds in the considered street section
C6 - Playground equipment	A playground will only be used as such and have a positive effect on children's mobility if it is varied (multifunctional) and natural in design, offers sufficient opportunities for development, and is considered clean and socially safe (e.g., not sleeping place for homeless people). Weighting factor: 6
Source(s)*	a, e
Specific recommendation(s)**	-
Grade 1 (very good)	Playgrounds are clean and used by children of all ages; equipped with variable play equipment; hills; grassy areas; shrubs; water (multifunctional, natural, clean, socially safe)
Grade 5 (very bad)	Playgrounds are misused by others (e.g., meeting point for smokers) or not equipped with variable play equipment; hills; grassy areas; shrubs; water
C7 - Existence of play areas	Generous and attractive play areas allow for exuberant play and romping. "Generous" and "attractive" (RVS 03.04.13**) are subjective; there should be more than enough space for several independent groups of children at the same time, and the space should provide enough open space to stimulate children's creativity and allow for a wide variety of play styles. This has a positive effect on child-friendly mobility. Weighting factor: 6
Source(s)*	a, c, d
Specific recommendation(s)**	-
Grade 1 (very good)	There are sufficient generous and attractive play areas in the entire street section
Grade 5 (very bad)	There are no play areas in the entire street section
C8 - Existence of parks/public places	Parks/public places can be animating for children due to the existing space, greenery and equipment with fountains or statues. Perhaps for this very reason, because they are not built for children to play in, they offer different opportunities than traditional playgrounds and should be viewed positively. Weighting factor: 6
Source(s)*	c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Several parks/public spaces can be used by children to play and rest
Grade 5 (very bad)	No park/public space in the entire street section
C9 - Existence of open spaces (e.g., staging areas along the sidewalk)	Open spaces (staging areas) allow children to play, linger, explore, entertain, etc. without impending other pedestrian traffic. They also act as a buffer zone when children come out of houses, for example, and need time to adjust to weather/traffic/environment. This has a positive effect on child-friendly-mobility. Weighting factor: 3

Source(s)*	d
Specific recommendation(s)**	-
Grade 1 (very good)	Open spaces (staging areas) are provided at regular distances throughout the street section
Grade 5 (very bad)	No open spaces (staging areas) in the entire street section
C10 - Existence of retreats, resting places	Retreats give children the opportunity to rest and talk and play "privately" with their peers. Retreats are used more by girls than by boys. Retreat spaces should not be out of the way but should provide a good view of what is happening on the street or in the square. This leads to child-friendly conditions. Weighting factor: 3
Source(s)*	e
Specific recommendation(s)**	-
Grade 1 (very good)	Multiple retreat spaces in the form of alcoves, benches, climbing frames with indoor space, shrubs, etc. throughout the street section
Grade 5 (very bad)	No retreat spaces in the entire street section
C11 - Existence of seating	Seating has a positive impact on child-friendly mobility by providing the opportunity to rest and retreat. Weighting factor: 3
Source(s)*	d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Sufficient seating for multiple groups of children throughout street section
Grade 5 (very bad)	No seating throughout the street section
C12 - Lighting	Sufficient lighting leads to the mitigation of danger points. Children will not use overpasses or underpasses that are difficult to see if the lighting is poor. The route to and from public transport stops should also be sufficiently illuminated to have a positive effect on child-friendly mobility. Weighting factor: 10
Source(s)*	c, d, e, f
Specific recommendation(s)**	-
Grade 1 (very good)	Good lighting throughout the street section
Grade 5 (very bad)	No or insufficient lighting throughout the street section
C13 - Open design of the urban space ("open space")	If the urban space is open, children can move safely and freely. If there are no restrictions to movement (e.g. wide sidewalks, generous staging areas and play areas, multiple opportunities to change sides of the street and to get to other areas of the street section), this leads to child-friendly conditions. Weighting factor: 3
Source(s)*	f
Specific recommendation(s)**	-

Grade 1 (very good)	The street section under consideration is open in its entirety (wide sidewalks, staging areas, play areas)
Grade 5 (very bad)	The street section under consideration is not open in its entirety (narrow sidewalks, no staging areas, no play areas)
C14 - Child-friendly design of urban spaces	If the urban space is designed in a child-friendly way (safety measures, space conditions, play opportunities, etc.), this has a positive effect on child-friendly mobility. Weighting factor: 3
Source(s)*	c, e
Specific recommendation(s)**	-
Grade 1 (very good)	The considered street section as a whole is designed child-friendly
Grade 5 (very bad)	The considered street section as a whole is not designed child-friendly
C15 - Child-friendly guidance systems	Guidance systems can show the way, warn of dangers, point out other road users, etc. This information must also be available for children, i.e. placed at an appropriate height to be visible, presented in an understandable way (not all children can read), etc., to have a positive effect on child-friendly mobility. Weighting factor: 2
Source(s)*	c, e
Specific recommendation(s)**	-
Grade 1 (very good)	Guidance systems throughout the street section are adapted to the way children see and think
Grade 5 (very bad)	There are no guidance systems specially adapted for children
C16 - Existence of drinking fountains	A drinking fountain can add value to a public space. The splashing of the water may lead to new ideas for play. In addition, children can cool off on hot days, or the presence of a fountain leads to cooling in itself (spray mist) and it is also possible to drink from a drinking fountain. Weighting factor: 3
Source(s)*	e
Specific recommendation(s)**	-
Grade 1 (very good)	A drinking fountain is well visible and easily accessible.
Grade 5 (very bad)	No drinking fountain in the entire street section
C17 - Existence of water points	Water as a designable element exerts a special attraction on children in any form and has a positive effect on child-friendly mobility. Weighting factor: 3
Source(s)*	a, b, e
Specific recommendation(s)**	-
Grade 1 (very good)	Water point usable/playable by all children
Grade 5 (very bad)	No water point in the entire street section

C18 - Existence of bicycle and scooter parking facilities	The existence of bicycle and scooter parking facilities enables children to park their transport equipment safely in a designated place. This is a positive feature. Weighting factor: 3
Source(s)*	c, e
Specific recommendation(s)**	-
Grade 1 (very good)	Sufficient high-quality, child-friendly, theft-proof (and possibly covered) bicycle and scooter parking facilities
Grade 5 (very bad)	No bicycle and scooter parking facilities throughout the street section
C19 - Existence of planting (e.g. trees, hedges, shrubs, perennials)	Planting should in any case be free of thorns and prickles and should not exceed the maximum height of 0.6 m in the area of the road (point of view free from height of 0.8 m) to avoid visual obstruction. Plantings can provide shade for resting. The more diverse and varied the plantings in the street section, the more opportunities they can provide for children to play/rest. Planting of any form has a positive impact on child-friendly mobility. Weighting factor: 8
Source(s)*	a, b, c, d, e
Specific recommendation(s)**	-
Grade 1 (very good)	Versatile plantings throughout the street section (e.g. play elements, retreat, shade, decoration)
Grade 5 (very bad)	No planting in the entire street section
C20 - Existence of larger green areas (meadow, forest, park)	Individual trees/shrubs can be well suited for specific play situations. Larger contiguous green zones provide fresh air, sufficient open space for games of all kinds, and a comprehensive experience of nature. This should be viewed positively. Weighting factor: 3
Source(s)*	b
Specific recommendation(s)**	-
Grade 1 (very good)	Large contiguous green zones can be used by children
Grade 5 (very bad)	No larger contiguous green zone throughout the street section
C21 - Existence of hilly meadows	A hilly meadow provides enough space for various games and creativity. Particularly the hilly makes the space more interesting and promotes creativity and thus child-friendly conditions. Weighting factor: 3
Source(s)*	b
Specific recommendation(s)**	-
Grade 1 (very good)	Hilly meadows can be used by children
Grade 5 (very bad)	No hilly meadow in the entire street section
C22 - Existence of stones	Different materials can be used in urban spaces (paving, concrete, natural stone). In addition, large stone elements can also serve as seating or possibly even be played with. This offers variety and encourages creativity. Weighting factor: 2
Source(s)*	a, e

Specific recommendation(s)**	-
Grade 1 (very good)	Stones serve as a design measure or as seating/playing/decorative elements
Grade 5 (very bad)	No stones as design or play/seating elements in the entire street section
C23 - Orientation of public transport to the needs of children	For children, public transport should be easy to understand. This includes easily comprehensible route network and children's fares. Stop near child-specific destinations or timetables adapted to school times, for example, have a positive effect on child-friendly mobility. Weighting factor: 1
Source(s)*	c, e
Specific recommendation(s)**	-
Grade 1 (very good)	Child-specific destinations are connected by public transport
Grade 5 (very bad)	No public transport or not usable by children
C24 - Prohibitions by the authorities (e.g. use of areas)	Some playgrounds may only be used at certain times. Similarly, walking on meadows may be prohibited by authorities to protect green spaces/plants. This has a negative impact on child-friendly mobility. Weighting factor: 2
Source(s)*	a, b
Specific recommendation(s)**	-
Grade 1 (very good)	All green spaces, play areas, etc. can be used for play without spatial and temporal restrictions (bans by authorities)
Grade 5 (very bad)	All green spaces, play areas, etc. have spatial or temporal barriers/use prohibitions
C25 - Prohibitions of owners (e.g. use of areas)	Playing on private areas can be restricted or completely prohibited by the owner. This has a negative impact on child-friendly mobility. Weighting factor: 2
Source(s)*	a, b
Specific recommendation(s)**	-
Grade 1 (very good)	All courtyards, house driveways, etc. can be used for playing without spatial and temporal restrictions (prohibitions by owners)
Grade 5 (very bad)	All courtyards, house driveways, etc. have spatial or temporal barriers/prohibitions of use ("Ball playing in the courtyard prohibited")
C26 - Air pollution	Children react more sensitively to air pollution because their respiratory tracts have even smaller cross-sections than those of adults. On-site subjective assessment of whether the air in the street section under consideration is rather good or bad. In fact, more of an estimate of visible impacts and associated attitutes than of the air pollution itself. Data can be used to evaluate actual air pollution. Weighting factor: 3
Source(s)*	c, e
Specific recommendation(s)**	-
Grade 1 (very good)	Good air throughout the street section due to low traffic volumes, few industrial/service businesses, and sufficient green space

Grade 5 (very bad)	Poor air in the whole street section due to high traffic volume or industrial/service enterprises, no green areas
C27 - Noise pollution	Noise leads to stress and to an increased risk of diseases of the heart muscle. In this context, noise is understood to be e.g. road traffic or construction sites, but not children making noise while playing. Subjective assessment of whether there is a lot or little noise pollution ("little noise pollution", RVS 03.04.13**). Noise has a negative impact on child-friendly mobility. Weighting factor: 3
Source(s)*	a, b, c, e
Specific recommendation(s)**	-
Grade 1 (very good)	No noise pollution throughout the street section due to low traffic volume and few industrial/service businesses; possible noise abatement measure ("without being disturbed by noise", RVS Chapter 3.2)
Grade 5 (very bad)	Noise pollution in the entire street section due to high traffic volume or industrial/service enterprises or others

Table A3: Category C: Urban space - equipment and other conditions. *Sources: a - Blinkert et al., 2015; b - Blinkert, 1996; c- FSV, 2015; d - FSV, 2016; e - BMLFUW, 2014; f - Kostovasilis, 2013, **Specific recommendations are defined to be clear specification found in literature e.g. "speed limit of 30 km/h in local areas", but not "reduction in traffic volume".

Indicator/criterion	Relevance with regard to child-friendly mobility, literature source, recommendation, and evaluation
D1 - Harmlessness	Harmlessness for children must be given in relation to traffic, but also to e.g. dirty, neglected places; shady persons; dangerous playgrounds (wood spinters, thorn bushes, …); etc., in the whole urban space in order to have a positive effect on child-friendly mobility. Weighting factor: 1
Source(s)*	a, b, c, f
Specific recommendation(s)**	-
Grade 1 (very good)	The entire action space is non-hazardous and can be safely used by children for exercise and play
Grade 5 (very bad)	The entire action space is dangerous and cannot be safely used by children for movement and play
D2 - Reachability/accessibility	Social (prohibitions), traffic (busy road) and spatial (distance too grat) barriers can limit the reachability/accessibility for children's play places. This has a negative impact on child-friendly mobility. Paths should be designed so that children can reach their destinations and also use the path to get there in a variety of ways. Weighting factor: 1
Source(s)*	a, b, f
Specific recommendation(s)**	-
Grade 1 (very good)	All areas of the entire street section are accessible and reachable by children
Grade 5 (very bad)	All areas of the entire street section are inaccessible and unreachable for chilren
D3 - Opportunities for interaction	Interaction is encouraged when many children are present and sufficient space is available. Interaction opportunities with peers have a positive impact on child-friendly mobility. Weighting factor: 1
Source(s)*	a, b, c
Specific recommendation(s)**	-
Grade 1 (very good)	Children move throughout the street section: Interaction with peers is possible
Grade 5 (very bad)	No children move throughout the street section: Interation with peers is not possible
D4 - Diversity/designability	Spaces are designable for children when they are not fixed for specific purposes. Varied places and changeable materials can be used in a variety of ways and have a positive effect on child-friendly mobility. Weighting factor: 1
Source(s)*	a, b, c, e, f
Specific recommendation(s)**	-
Grade 1 (very good)	Throughout the street section, there are varied spaces and materials that provide children with design freedom
Grade 5 (very bad)	The entire street section is not designable for children
D5 - Connectivity	Connectivity depends on many factors together and can only be considered in its entirety. Connectivity of urban spaces can have a positive impact on child-friendly mobility. Weighting factor: 1

Source(s)*	e, f
Specific recommendation(s)**	-
Grade 1 (very good)	Path networks throughout the street section are safe, attractive, close-knit, conflict-free, and detour-free
Grade 5 (very bad)	Path networks in the entire street section are unsafe, unattractive, wide-meshed, not free of conflicts and long detours have to be taken

Table A4: Category D: Other. *Sources: a - Blinkert et al., 2015; b - Blinkert, 1996; c- FSV, 2015; d - FSV, 2016; e - BMLFUW, 2014; f - Kostovasilis, 2013, **Specific recommendations are defined to be clear specification found in literature e.g. "speed limit of 30 km/h in local areas", but not "reduction in traffic volume".