On the Level of Traffic Stress for Pedestrians

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SHORT SUMMARY

Walking is the most basic and sustainable mode of transportation. Nevertheless, fifty percent of pedestrians in Germany feel unsafe in road traffic. Since feelings of low safety are associated with higher stress, fewer people are likely to walk in less comfortable environments. This paper introduces a new rating scheme called "Level of Stress for Pedestrians". This rating scheme defines five different pedestrian stress levels and links them to attributes of road segments such as the sidewalk width or the number of crossing facilities. The rating scheme is not bound to specific locations due to its static nature and can therefore be applied to different cities. With the aid of the pedestrian level of stress, static weak points in the pedestrian network can be identified and eliminated.

Keywords: Pedestrian Traffic, Level of Stress, Walkability, Pedestrian Safety.

1. INTRODUCTION

Lack of exercise is one of the main causes of various common diseases. Walking is the most basic mode of transport and a simple and effective way to keep fit and healthy (WHO, 2017). Walking is a good way to prevent disease, reduce obesity and relieve stress (Mammen & Faulkner, 2013), (Marselle, Irvine, & Warber, 2014). In addition, walking is environmentally friendly, inexpensive and does not require any additional equipment (Gerike et al., 2021), (Litman, 2003). According to a German study, pedestrians covered 22 percent of all journeys in 2017 (BMDV, 2017). However, according to a survey conducted in Germany, only 50 percent of the pedestrians surveyed to feel safe in road traffic (Thielitz, 2021). Often, the feeling of low safety is associated with higher stress (Gilbert et al., 2008).

As a result, in less comfortable environments with higher levels of stress, fewer people are likely to walk (Montgomery Planning, 2020). For this purpose, the Montgomery County Planning Department has designed a "Pedestrian Level of Traffic Stress" rating scheme (Montgomery Planning, 2020). This involves capturing the existing sidewalk infrastructure and rating it based on pedestrian friendliness criteria. It classifies street segments according to the level of stress for pedestrians and other sidewalk users without requiring a large amount of data. It was designed to complement the Bicycle Level of Traffic Stress (Mekuria, Furth, & Nixon, 2021). These two methods are typically used in the preparation of regional transportation (system) plans or screenings.

In (Pareek & Parbhakar, 2018), the focus is on designing a survey that was used to obtain information on the strengths and weaknesses of bicycle routes in Jaipur, India. Applying GNSS detection on two bicycle routes, suggestions for improvements were formulated based on the information obtained on safety, directness, and comfort. The aim of the study by (LaJeunesse et al., 2021) was to determine a pedestrian quality of service level based on physiological measurements. 15 pedestrians were equipped with a smart wristband and a GNSS tracker for one week. The recordings obtained were to identify stress levels of pedestrians during normal walking activities in different traffic situations. A correlation of stress with road conditions was found.

Both the findings of the above studies and the Montgomery County Planning Department's methodology are not directly transferable to foreign cities due to different morphologies of the cities. Therefore, in the following, five different stress levels are defined by means of road attributes adapted to the needs of the morphology of European cities and their pedestrians, based on the evaluation schemes of the Montgomery County Planning Department (Pedestrian Level of Comfort (Montgomery Planning, 2020)) and the Level of Traffic Stress for Bikes (Furth, Mekuria, & Nixon, 2016), (Mekuria et al., 2021).

2. METHODOLOGY

The authors of (Furth et al., 2016) presented a new method to classify road sections and crossings into different levels of traffic stress for cyclists. The basis for their classification comprises two aspects: (i) Geller's classification of the bicycling population where transportation cyclists from Portland were classified into one of four groups based on their responses when bicycling in different traffic environments (Geller, 2006), and (ii) Dutch Design Standards, which are known to receive great acceptance from the general population (Furth et al., 2016). These stress levels were assigned to the manifestations of roadway attributes such as number of lanes, reach from curb, speed limit, bike lane blockage, crossings, and side parking. From this, a guideline scale was obtained and applied as a case study to the San Jose street network. The result was a street map with differently colored street segments indicating the stress level of each link for bicyclists.

Such a rating scheme is not directly transferable from cyclists to pedestrian needs and stress levels. Thus, the Montgomery County Planning Department designed an analogous evaluation scheme for pedestrians' traffic stress level in 2020 (Montgomery Planning, 2020). This method similarly groups attributes of roadway segments into four different stress levels. In addition to the condition and size of the sidewalk, parking and lighting are used as data for the Level of Stress. Additionally, other attributes of road segments are among the key influencing factors for level of traffic stress for pedestrians.

In addition, active transport is much more widespread in Europe than in the United

States. For example, the amount of pedestrians in Germany is almost 2.5 times higher than in the U.S., for cyclists, the amount is almost 8 times higher (Buehler et al., 2011). As a result, the perception of danger, stress and distance in the U.S. is quite different in active transport. A concept on pedestrian stress levels for European cities has to be newly developed and elaborated.

Therefore, a novel rating scheme for the level of traffic stress for pedestrians is introduced. This rating scheme is based on the findings from (Furth et al., 2016), (Montgomery Planning, 2020) as well as the (FGSV, 2006) and (FGSV, 2002) regulations.

Key Influencing Factors for Level of Traffic Stress for Pedestrians

From (Furth et al., 2016), (Montgomery Planning, 2020) as well as the (FGSV, 2006), (FGSV, 2002) and (Thielitz, 2021), primarily five key influencing factors could be identified, where the fifth factor speed limit is assumed to be implicit and will not be explained in detail in the following. The key influencing factors mentioned below form the basis for an initial concept of a level of traffic stress definition for pedestrians.

Sidewalk width

Sidewalk width is one of the most used geometrical factors when measuring the quality of pedestrian movement (Raad & Burke, 2018). The main cause of this is the limitation of the safe operating space for pedestrians. According to (Kang, 2015) and (Kim, Park, & Jang, 2019), a wide sidewalk has a significant positive impact on walking. It is therefore essential for the comfort of pedestrians (Dragovic et al., 2021).

In Germany, the minimum required width for sidewalks is set to 2.50m (FGSV, 2006). This guideline value is obtained by assuming that two persons can conveniently pass each other. For each of these persons a space of 0.8m is assumed. In addition, there is a security clearance between the persons (0.2m), for adjacent buildings (0.2m) and adjacent streets (0.5m). In reality, however, the sidewalk widths usually differ from case to case (Dragovic et al., 2021). The reasons in most cases are urban morphology and the priority of motorized vehicles. According to (Fachverband Fußverkehr Deutschland, n.d.), for decades sidewalk widths have resulted only from residual areas in street layouts. Furthermore, deviating values for people with movement restrictions are not taken into account. According to a survey (Thielitz, 2021), 60 percent of all motion-impaired participants found the sidewalks not wide enough and even 40 percent of all participants without any motion-disability found the sidewalk width too small. This causes stress and makes people reluctant to walk (Montgomery Planning, 2020).

Number of Crossing Facilities

(Cervero et al., 2009) states that highly connected street networks in neighborhoods have a beneficial effect on the active transport of residents. Therefore, the number of street crossings and the associated connectivity of the street network correlate positively with the probability of walking (Hooper et al., 2015). The authors of (Ewing & Cervero, 2010) and (Kaplan, Nielsen, & Prato, 2016) found out that the shorter the distances between intersections, the higher the share of pedestrians in the local modal split. In addition, high connectivity enables many route options (Gerike et al., 2021).

So far, there is a lack of information in current regulations regarding the density of crossing facilities for pedestrians. However, pedestrians are most sensitive to detours (Gerike et al., 2021). An earlier version of a German guideline recommended that crossing facilities should be spaced no more than 100 - 150m apart from each other (FGSV, 1995). However, this recommendation was discarded with an updated version in 2006 (FGSV, 2006).

The value of 150m between crossings is adopted and considered as a first guide value for spacing of crossing facilities. Using it, a new threshold for pedestrian crossing options is defined. Accordingly, a first guide value for crossings per kilometer of street is

$$\frac{1}{0.150} = 6.67 \left[\frac{\text{crossings}}{km}\right]. \tag{1}$$

Type of Crossing

The crossing type is classified into signalized and unsignalized. As described in (Furth et al., 2016), it is assumed that signalized crossings do not cause additional traffic stress, in contrast to unsignalized crossings, which can represent an obstacle. Thus, the more lanes have to be crossed and the higher the speed limit of the traffic on the street is, the higher is the perceived level of traffic stress.

Collectively Used Infrastructure with Cyclists

Pedestrians and bicyclists compete for limited space on the road (Gerike et al., 2021). In addition, nearly half of all pedestrians feel disturbed by shared pedestrian and bicycle paths (Thielitz, 2021). Late ringing or overtaking with too little distance are particular stressors (Thielitz, 2021). A distinction is made between four different designs of sidewalk and bike lane divisions. Examples can be seen in Figure 1.

Definition: Level of Traffic Stress for Pedestrians

The general definition of stress levels uses the following descriptions of pedestrians' perspectives. Table 1 explains these five new levels of pedestrian traffic stress that are developed from the previously identified key influencing factors.

Linking the Attributes of the Main Influencing Factors to the Levels of Stress for Pedestrians

Table 2 presents the traffic stress criteria for different pedestrian areas. This way, road sections can be categorized into levels of traffic stress for pedestrians. The principle of the most uncomfortable attribute is applied. Thus, when aggregating the stress levels of different attributes of a road segment, the highest stress level is always considered as decisive for each road segment.

(a) Pedestrians and bikes share the same way, Nuremberg.

(b) Structural separation with curb, Nuremberg.

(c) Textural separation, cyclists could swerve onto the sidewalk, Nuremberg.

(d) Pedestrian way and bike lane are separated, Munich.

Figure 1: Examples of sidewalk and bicycle path combinations

3. RESULTS AND DISCUSSION

With the rating scheme developed above, street segments can be categorized according to various stress levels for pedestrians. The concept focuses on purely static aspects of the pedestrian network and is therefore independent of time and place. This static concept is not bound to a specific location and can therefore be applied to different European cities. Using this concept, static weak points in the pedestrian network can be identified and eliminated. It offers a first step towards the possibility of reducing the stress level of pedestrians. The existing concept can be used primarily to identify locations in the pedestrian network where interaction between cyclists and pedestrians could become a problem. In addition, locations with particularly few crossing options can be studied in more detail and, based on that, more options for crossings can be provided.

In a further step, the pedestrian network can be categorized according to existing widths. This aspect becomes especially important when incorporating the needs of pedestrians with restricted mobility such as wheelchairs. For these people, even more aspects should be taken into account, for example the height of the sidewalk border or accessibility.

Table 1: Definitions of Levels of Traffic Stress for Pedestrians

Traffic Stress Level	**Keywords**	**Description**
1	**pleasant, stress-free**	Demands little attention to traffic. No interaction with motorized vehicles or bicycles. Bicycles must be pushed. Pedestrians only zone. Sidewalk width ranges over the whole street or area. (example: park, pedestrian area)
2	**acceptable, but increased attention is required**	Demands some attention to traffic. Surrounding traffic velocity is low. Bicyclists and pedestrians do not share their paths. Safe crossing of the street is often enough possible. Sidewalk is sufficiently wide.
3	**unpleasant, exhausting, but fair and confident**	Demands medium attention to traffic. Crossing the street may be stressful due to few and/or unsafe crossing options and high traffic velocities. Bicycle lanes are directly next to footpaths. Footpath is quite narrow.
4	**unpleasant, preventable, acceptable for short sections**	Demands high attention to traffic. High traffic velocities. Footpath is available but very narrow. Footpath is shared with bicycles. Crossing of the street is stressful due to a lack of or only unsafe crossing options.
5	**fear-inducing, dangerous, to be avoided, detours are preferred**	Demands very high attention to traffic. Surrounding traffic velocity is very high. No footpath available. No crossing options available.

As a first step, we developed a static concept of assigning different levels of stress. As extension of the existing definition, we will introduce dynamic aspects such as the number and density of surrounding traffic participants both on the sidewalk and on bicycle/vehicle lanes. Also, semi-dynamic influences such as speeds are taken into account. They are statically given by an upper speed limit on the street but can dynamically oscillate between low and high speeds. However, factors such as traffic volume and volumes of pedestrian crowds would provide further important insights into pedestrian stress levels.

4. CONCLUSIONS

In this paper, a first concept for the classification of road segments according to five different traffic stress levels for pedestrians is presented. Based on the characteristics of the defined key influencing factors (i) sidewalk width, (ii) number of crossing facilities, (iii) type of crossings, and (iv) collectively used infrastructure with cyclists, road segments can be assigned to the defined levels of traffic stress. So far, the concept focuses on static criteria of the infrastructure but is to be extended by

Table 2: Traffic Stress Criteria for Walkways; N/A stands for *Not Applicable*

Traffic Stress Level	Sidewalk Width	Number of Crossings	Type of Crossing	Speed Limit	Shared with Bikes
1	Whole street	N/A	N/A	Walking speed	No
2	> 2.5m	> 6.6	Signalized	Walking speed	Structural separation
3	approx. 2.5m	approx. 6.6	Not signalized	< 30km/h	Textural separation
4	< 2.5m	< 6.6	Not signalized	< 50km/h	Yes
5	None	None	Not signalized	> 50km/h	N/A

dynamic and semi-dynamic aspects.

A great focus will be placed on extending the static concept to include needs of movement restricted pedestrians. They have different requirements for stress-free mobility, some of which are not appropriately represented from the regulations used above. This developed static concept will then be applied and tested on different subareas of several German cities. Due to missing data on sidewalk widths and sidewalk conditions, a categorization of these key influencing factors into stress levels is not easily feasible. As a consequence, individual city districts are first inspected to obtain information on the missing conditions. In the following, the static criteria are extended by semi-dynamic and fully dynamic attributes. Possible attributes to be considered are, for example, traffic volume and traffic light switching.

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