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Investigation of pedestrian and vehicle level of service regulation for Hacettepe Sıhhiye campus

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Highlights

- Investigation sidewalks of Hacettepe Campus Children's Emergency Entrance
- Determination of LOS and PLOS Levels
- Different methods were compared
- Improvement of roads

Abstract

Roads and sidewalks of Hacettepe Campus Children's Emergency were investigated in order to determine the congestion in the "emergency zone" in this area and improvement effects to different road quality methods were discussed. Both level of service of roads (LOS) and sidewalks (PLOS) were studied by using different methods as Highway Capacity Manual (HCM), Landis and Australian methods. As the result of study, since the terrain in the region is not suitable for vehicles, the pedestrian path was narrowed to reduce the traffic on the vehicle road and significantly reduce the problem. In addition, the methods used in the PLOS calculation were found to be deficient in terms of applicability. When comparing the different methods AUSTRALIAN method more realistic results as it has more generalizable perspective than others in this study.

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1. Introduction

As can be known, the problems of human and vehicle traffic are increasing with the growing population day by day. Therefore, many studies and methods have been developed to solve the problems. Near of the vehicle transportation on roads walking on sidewalks, which is one of the modes of transportation, can have critical impacts on human life and traffic management [1]. Thus, sidewalks are of great importance to mitigate this situation and they separate vehicular and pedestrian traffic. As can be known, the term of level of service (LOS) is a qualitative measure used to assess the quality of service provided by road transport. In addition, the pedestrian level of service (PLOS) is a sophisticated metric designed to quantify the comfort and safety levels of existing and planned pavements. It provides an objective and robust assessment of how pedestrians perceive and respond to the road environment.

To avoid the problems, they should be determined based on important criteria such as the quality of sidewalks, their length and the distances between them, the roadway, etc. [2]. There are some studies in the literature about quality of level of service as can be seen in Table 1.

In this study, LOS and PLOS behaviors for roads and sidewalks were investigated with the traffic generated in the hospital area. Highway Capacity Manual (HCM) [3] used for LOS method and for sidewalks HCM, Australian and Landis methods were used. However, almost all of the methods do not address exactly the same points and their values need to be changed to adjust the evaluation criteria. Another aim of this study is improving road service capacity by reducing vehicle traffic and controlled the changing ranges of result by using various methods

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[4]. Provisions have been made on both the pedestrian and vehicular pathways to achieve the best possible result. This region is critical because of the school campus and the hospital region. There is no information that such a place has been studied in the literature. Thus, in order to obtain the data, 15-minute measurements were taken for one week. These measurements were used to determine the critical hours with high traffic volumes. The critical hours identified for more accurate and reliable results were measured again the next week. Using these methods, the LOS and PLOS values of the roads were determined. The fact that the roads in the region was single lane is one of the main reasons for this situation. The area has an "emergency entrance" and it is crucial for human life. Since our area is used as a campus and hospital entrance, there is increased traffic at the specified times. Additionally, in this article, a literature review was conducted and an attempt was made to find methods to analyze data in the region in the most appropriate way.

Table 1. Some literature studies

Number	Reference	Content
1	Mcleod et al. [5]	Methodology to Assess Level of Service on US-1 in the Florida Keys, Transportation Research Record 1398
2	Roess and Prassas [6]	Simplify communication of quantitative performance measures related to measures of central tendency such as LOS, average intensity
3	Margiotta et al. [7]	Simplified Highway Capacity Calculation Method for the Highway Performance Monitoring System
4	Mindell [8]	While macro problems are more considered in PLOS methods, micro problems are not considered. In this study, it draws attention to micro methods, and the study was driven by surveying the population through questionnaires.
5	Karatas et al. [9]	Examines changes in PLOS adjustments. Considers deficiencies using all 3 different methods
6	Bivina et al. [10]	A new method was established by noting the lack of classic
7	Zegeer & Zegeer [11]	Assess roadway performance including travel time, congestion, delay, etc.

2. Region Properties

This study was conducted in the hospital area of the Sıhhiye campus of Hacettepe University, which is a critical area in terms of pedestrian and vehicular traffic. The vehicular roads consist of two roads. 'A1' is the vehicle entrance road and 'A2' is the vehicle exit road (Figure 1). These roads have same width as 3 meters as can be seen in Figure 2.

There are two sidewalks, shown as "B1" and "B2" and "B1" sidewalk was measured as 8 meters. "B2" sidewalk was measured as 5.9 meters. The sidewalk 'B2' is narrower in one section because of the car parking.

Figure 1. Studied region by Google Map

Figure 2. Road and Pedestrian Paths

3. Methodology

In the study, pedestrians and vehicles were counted at 15-minute intervals for both sides between November and December 2021. LOS calculates the speed and quality of vehicle roads. In this case, a specific labelling is made by taking into account factors such as thickness, density, quality of the road and obstacles in the environment. In PLOS, the same elements apply on average. Factors such as the length of the pedestrian path, obstacles and distance from the roadway are effective. They are described as A, B, C, D, E, F. While "A" indicates the best and desired road grade, F corresponds to the worst and undesirable road grade. These ratings are based on the Highway Capacity Manual (HCM) [3] and the AASHTO Geometric Design of Highways and Streets. Table 2 shows the range of LOS grades.

LOS degrees in traffic are given below:

A: Free Flow: traffic flows above the posted speed limit. Drivers have physical and mental comfort.

B: Reasonably Free Flow: LOS-A values are the same, but drivers' maneuverability is limited.

C: Stable Flow: maneuverability is limited. Driver attention is required for lane changes. Minimal traffic congestion may occur.

D: Approaching Unstable Traffic Flow: traffic volume is slightly higher and speed is slightly reduced. Driver comfort level is low. There is a high volume of traffic on certain days.

E: Unstable Flow: maneuvering in the traffic flow is almost difficult. Drivers lack physical and mental comfort. Traffic is fluid, and speeds are constantly changing.

F: Forced/Breakdown Flow: The flow is almost at a standstill. Each vehicle moves slowly with the vehicle in front of it. Travel time is unpredictable.

Table 2: Changing principles of LOS values [3]

LOS	Density Range
A	Score < 7
B	7 ≤ Score < 11
C	11 ≤ Score < 16
D	16 ≤ Score < 22
E	22 ≤ Score < 28
F	Score ≤ 28

Steps of calculation can be summarized as below:

1) Determining the width of the road: if the width of the road is less than the appropriate width, the speed of free traffic is reduced.

2) Determination of the lateral distance of the right shoulder: since the reduction of the lateral distance reduces the psychological comfort of the driver, it has a negative effect on the flow speed. (1)

3) determination of peak hour factor: it is the ratio between the hourly traffic volume and the ratio between the maximum 15-minute volume and the hourly traffic volume.

4) determination of the heavy traffic adjustment factor: heavy vehicles have a negative impact on the capacity of the road. Depending on this impact is the factor used in the calculation.

5) Determination of the flow rate: The resulting purchase value is calculated as follows.

6) Calculation of density and determination of LOS: The ratio of the calculated flow velocity to the average velocity gives the density. The appropriate LOS value is determined with the obtained density value.

PLOS calculations were made for three different methods as HCM, Landis and Australian methods. The number of pedestrians per minute is calculated. The highest value of the 15-minute measurements is taken and divided by 15 minutes. Then this value is divided by the length of the road to get a number. This numerical value is assigned a letter score using the PLOS scoring criteria as can be seen in Table 3.

HCM method for PLOS is a labelling method used to estimate the performance characteristics of the roadway used for pedestrians and transit passengers in each area [12, 13]. Together with the data obtained by applying this method on the Hacettepe Sıhhiye Campus.

Table 3: Sidewalk PLOS rating for HCM methods [14]

LOS	Density Range
A	0 < Score ≤ 5
B	5 < Score ≤ 7
C	7 <Score ≤ 10
D	10 < Score ≤ 15
E	15 < Score ≤ 23
F	Variable

The Landis method is another method of measuring the value of a sidewalk to pedestrians. This method evaluates the quality of pavement work, safety, and comfort. Factors such as on-street parking, bike lanes, the distance between the street and the sidewalk (width of the shoulder), and buffer areas are important. The greater the distance between pedestrians and the roadway, the safer the street. Equation 1 is used to calculate and Table 4 shows the levels.

$$PLOS = \left[\begin{array}{c} 1.2021 \times \ln \left[\begin{array}{c} W_{ol} + W_1 \\ +f_p \; x \; \%OSP \\ +f_b \; x \; W_b \\ +f_{sw} \; x \; W_s \end{array} \right] \\ +0.253 \times \ln \left(\frac{Vol_{15}}{\mathrm{L}} \right) \\ +0.0005 SPD^2 + 5.386 \end{array} \right] \quad (1)$$

W_{ol}=width of outside lane (ft)
W_1 = width of shoulder or bike lane (ft)
f_p = on-street parking effect coefficient
%OSP = percentage of segment with on-street parking
f_b = buffer area barrier coefficient
Wl = width of shoulder or bike lane (ft)
W_b = buffer width, which is the distance between edge of pavement and sidewalk (ft)
f_{sw} = sidewalk presence coefficient
Vol_{15} = average traffic during 15-min period
L = total number of through lanes for road or Street
SPD = average running speed of motor vehicle traffic (mph)

Another method of evaluating road use is the Australia method. In this method, the directions of the road to be improved can be determined. To determine the PLOS value, the calculation is made considering the physical factors, location and users. It is divided into eleven factors, which are assigned to three main categories. These are the factors that directly affect the quality of the road. According to the impact of the factors on the PLOS, a score is given according to the well-known rating system. Based on the score obtained, the PLOS value is defined according to the interval in which it is located. PLOS values are as follows, depending on the scores obtained as can be seen Table 5.

Table 4: Sidewalk PLOS rating for Landis methods

LOS	Density Range
A	0 < Score ≤ 1,5
B	1,5 < Score ≤ 2,5
C	2,5 < Score ≤ 3,5
D	3,5 < Score ≤ 4,5
E	4,5 < Score ≤ 5,5
F	5,5 ≤ Score

Table 5: Sidewalk PLOS rating for Australia methods

LOS	Density Range
A	132 ≤ Score
B	101 < Score ≤ 131
C	69 < Score ≤ 100
D	37 < Score ≤ 69
E	Score ≤ 36

4. Result

The objective of the study is that Hacettepe Sıhhiye Campus, which is a significant region in terms of passenger and vehicle traffic, is both a school and hospital area, so the passenger and vehicle traffic increases at certain hours and days. It was observed that vehicle traffic increases at certain times, but this causes difficulties in transportation. Therefore, efforts are being made to prevent this by making improvements in the area.

Table 6 was prepared according to LOS by HCM method. When different road widths were used for various times, it can be seen that road service quality was changed from D to A. As another word, widening of the road was sought as a solution for these problems. Therefore, an attempt was made to eliminate this problem as much as possible by increasing the number of lanes on the road. Firstly, the service quality of the road was evaluated. To improve the vehicle and the pedestrian street were widened with certain narrowing. The first condition of the vehicle street consists of a single lane with 3 meters widening. The pedestrian path is 8 meters. Based on the measurements, sections of the pedestrian path were taken in half meters and added to the vehicle road. It is assumed that a two-lane road is created when the vehicle road is 6 meters long, and a three-lane road is created when it is 9 meters long. As a result of the improvements to the vehicle road, the changes in the PLOS values of the road were examined as can be seen in Table 7, 8, 9 and 10 [15,16]. The changes in PLOS values were analyzed using three different methods. Briefly, by narrowing the sidewalks and adding to roads width results of the various methods were compared. Thus, improving effects and changings on the methods were analyzed.

First, the vehicle counts of the road were recorded for one week and the LOS values were calculated. The critical hours were determined by considering the values where the traffic volume is higher than normal. The next week, the LOS values were calculated again for these critical hours. Since the area is a frequently used location by the public and the superstructure is being widened to accommodate the widening of this road, the superstructure data was used. Using these data, the PLOS values of the road were measured. These values were determined using the HCM, Landis, and Australia methods [17]. The following tables show the PLOS values of the road according to the HCM and Landis methods.

Table 6: LOS values depending on the length changes in the vehicle path

Road Width (m)	Road Type	Time											
		08:00-09:00	09:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	18:00-19:00
3	A1	D	D	D	C	C	D	D	C	C	B	B
	A2	B	A	B	B	B	C	C	B	C	D	B
3.5	A1	C	C	C	B	B	C	C	B	B	A	A
	A2	A	A	A	A	A	B	B	A	B	C	A
4	A1	C	B	C	B	B	C	B	B	A	A	A
	A2	A	A	A	A	A	B	B	A	B	C	A
4.5	A1	C	B	C	B	B	C	B	B	A	A	A
	A2	A	A	A	A	A	B	B	A	B	C	A
5	A1	C	B	C	B	B	C	B	B	A	A	A
	A2	A	A	A	A	A	B	B	A	B	C	A
5.5	A1	C	B	C	B	B	C	B	B	A	A	A
	A2	A	A	A	A	A	B	B	A	B	C	A
6	A1	B	A	B	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	B	A
6.5	A1	B	A	B	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	B	A
7	A1	B	A	B	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	B	A
7.5	A1	B	A	B	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	A	A
8	A1	B	A	B	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	A	A
8.5	A1	B	A	B	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	A	A
9	A1	A	A	A	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	A	A
9.5	A1	A	A	A	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	A	A
10	A1	A	A	A	A	A	A	A	A	A	A	A
	A2	A	A	A	A	A	A	A	A	A	A	A

When the Table 6 compared, it can be seen that 'A1' which is the vehicle entrance road is more crowded and LOS values are worse than 'A2' which is the vehicle exit road at morning times. However, when the road widening was changed from 3m to 3.5m, LOS values were improved form D to C. Nevertheless, generally, after 8 m road width, the LOS value was completely improved and LOS values were A for all times.

The 15-minute measurements were taken between 8-14 November between 8:00 am – 7:00 pm. The length of the roadway was measured and certain measures were taken. Sidewalk results can be seen in Table 7.

When Table 7 values were compared, it can be said that for both B1 and B2 sidewalks PLOS values were A for HCM and Landis methods, but Australian method gave

different solution as C for all times. In order to improve the road quality sidewalks were narrowed. Sidewalk widths were changed as from 8 m to 1 m. After the expansion of the roadway, there is almost no traffic obstruction at any hour. Since the area cannot be increased, the pedestrian walkway is shortened in order to widen the roadway. For this reason, taking into account the narrowing of the road, comparisons were made according to the methods HCM, Landis and Australia. The critical hours were determined based on the values measured in the first week. In the following week, the sidewalk values were recalculated in the methods as Table 8.

Table 7: PLOS values for pedestrians. [November 9,8am-7pm]

Time	Sidewalk	HCM	Landis	Australia
08:00-09:00	B1	A	A	C
	B2	A	A	C
09:00-10:00	B1	A	A	C
	B2	A	A	C
10:00-11:00	B1	A	A	C
	B2	A	A	C
11:00-12:00	B1	A	A	C
	B2	A	A	C
12:00-13:00	B1	A	A	C
	B2	A	A	C
13:00-14:00	B1	A	A	C
	B2	A	A	C
14:00-15:00	B1	A	A	C
	B2	A	A	C
15:00-16:00	B1	A	A	C
	B2	A	A	C
16:00-17:00	B1	A	A	C
	B2	A	A	C
17:00-18:00	B1	A	A	C
	B2	A	A	C
18:00-19:00	B1	A	A	C
	B2	A	A	C

Table 8: PLOS values depending on the length of the pedestrian path using the Highway Capacity Manual (HCM)

Side	Width														
	8 meters	7.5 meters	7 meters	6.5 meters	6 meters	5.5 meters	5 meters	4.5 meters	4 meters	3.5 meters	3 meters	2.5 meters	2 meters	1.5 meters	1 meter
B1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B
B2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B

Looking at the Table 8, 9 and 10, changes were shown every half-meter on the pedestrian path and the vehicle road. When all the results are considered, the quality of the pedestrian road decreases, and the road quality increases on the vehicle road. The total length in the field is 11 meters. The most suitable interval is the interval where the length of the vehicle road is 7.5 meters, and the pedestrian path is 3.5 meters. Accordingly, this road value increases from 'D' to 'B' at the most important hours. However, the pedestrian sidewalk decreases from 'B' to 'C'.

Table 9: PLOS values depending on the length of the pedestrian path using the Landis Method

Side	Width														
	8 meters	7.5 meters	7 meters	6.5 meters	6 meters	5.5 meters	5 meters	4.5 meters	4 meters	3.5 meters	3 meters	2.5 meters	2 meters	1.5 meters	1 meter
B1	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B
B2	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B

Table 10: PLOS values depending on the length of the pedestrian path using the Australia Method

Side	Width														
	8 meters	7.5 meters	7 meters	6.5 meters	6 meters	5.5 meters	5 meters	4.5 meters	4 meters	3.5 meters	3 meters	2.5 meters	2 meters	1.5 meters	1 meter
B1	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D
B2	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D

When literature studies were compared with this study the importance of the study can be seen more. For illustrated this, Wibowo and Nurhalima [18] investigated the situation of pedestrian walkways in certain regions for Bandung Technology Institute and a study was conducted to improve the service quality of pedestrian walkways. Three different methods were used as HCM, Trip Quality and Australian. According to these methods, there are very different PLOS values on the pedestrian way. In this study, the value of HCM method is 'A', the value of Tripquality method is 'C' and the value of Australian method is 'D'. While the Tripquality and Australian method are more realistic results, the HCM method is insufficient for the pedestrian walkway. As a result of the study, it was concluded that factors such as "surface quality/maintenance, effective width, support facilities" should be more appropriate to increase the level of service of pedestrian paths. In this study, Hacettepe Sıhhiye study, it was planned to improve the effect of pedestrian and vehicle streets on each other. Since the values of vehicle streets have a higher value, more vehicle streets were improved. Due to the unsuitability of the terrain, the widening of the vehicle road will lead to the narrowing of the pedestrian road. Therefore, the relationship between them was established and the degree of mutual influence was considered. In this process, 3 different methods were used for the values of the pedestrian paths. HCM, Landis and Autralian methods were studied. The value is "A" for HCM method, "A" for Landis method and "C" for Australian method. Considering the methods, the Australia method provides realistic results. Generally, when the results of the studies were compared it can be said that HCM method does not provide adequate results. When the parameters used in the method were only pedestrian density and roadway length are used. However, factors such as the quality of the sidewalk (e.g., pits, soil) and obstacles on the sidewalk (signs, trees, structures, bike lane) are not considered for

calculations. Thus, this method can be inadequate in most cases and does not provide realistic results.

5. Conclusion

The aim of the study is determining by comparing the methods of LOS and PLOS and solving the traffic problem at the pediatric emergency entrance of Hacettepe Sıhhiye Campus. The results of this study can be summarized as follows:

Vehicle street LOS values were determined using the literature study. These values were used to determine the critical hours of the road with the heaviest traffic. According to the results, LOS values appear at "D" value during important hours as especially mornings. This situation is at a level that cannot be resolved with traffic regulations and lighting. Therefore, roadway width was changed. Since there is no suitable area because of it is at the center of the city and a hospital area, the widening was made as narrowing the sidewalks. When the roadway was expanded above a certain level, the value could be increased from "D" to "B". However, despite the changing of the pedestrian sidewalk, optimum performance could not be achieved on the vehicle road. Widening dimensions could be critical. When investigating by using three different PLOS methods, it can be said that HCM method can be generally inadequate. However, considering both pedestrian and vehicle traffic behaviors, Australian Method can give more optimum results.

Comparing studies in literature about street improvements, it can be highlighted that there are not many studies that are categorized by pedestrian routes. Especially, hospital areas behaviors can have critical effects. However, due to the inadequacy of some of the methods used, it has been determined that new and more compatible methods are needed for each area. Considering the inadequacy of these studies in the literature, the needing for this study can be significant.

Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contribution Statement

E. Cicek: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing; **T. B. Ozdemir:** Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Visualization, Writing – Original Draft; **O. Kaplan:** Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Visualization, Writing – Original Draft; **T. Yusel:** Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Visualization, Writing – Original Draft; **M. O. Punar:** Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Visualization, Writing – Original Draft.

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