Where to Construct and How to Design Footbridges

A machine learning-based decision-support tool

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This study proposes a decision-support tool for footbridge planning by addressing two key questions: where to construct and how to design footbridges. Combining quantitative and qualitative methods, the tool comprises two complementary stages: a prediction model and a design guideline. First, built environment features were explored and collected from locations with and without footbridges in Ankara. Later, three tree-based models (Decision Tree, Random Forest, XGBoost) were trained to predict the need for footbridges at given sites, addressing the "where" question. The model performances were tested through data type transformations and different train-test splits. To provide robust and reliable predictions, the role of randomness was not overlooked, and the top four consistently predicted locations across different data splits for all the models were obtained. XGBoost showed higher performance in traditional terms; however, all the model outcomes were consistent with real-world patterns, as the dataset shows high relevance to the problem domain. The second stage introduced a human-centric approach to address the "how" question by a design guideline developed by synthesizing field observations, pedestrian expectations, and Türkiye's regulatory criteria, addressing the "how" question. Ultimately, the "where" and "how" were asked together to decide whether to construct a footbridge at a given site, and model predictions were reviewed in context by the authors using the design guideline. By incorporating machine learning, real-world data, and human-centric perspectives, this study offers a comprehensive understanding of footbridge planning.

Keywords: *Footbridge, Prediction Model, Design Guideline.*

INTRODUCTION

With policies favoring motor vehicle accessibility over pedestrian accessibility, urban growth has been revolving around major road networks, increasing the dependence on motorized transport, ultimately leading to conflicts between motor vehicles and pedestrians. In such built environments, pedestrians remain one of the most vulnerable groups.

Eachyear, pedestrians, motorcyclists, and cyclists account for more than half of the fatalities due to road crashes globally (World Health Organization, 2025). In Türkiye, road accident death and injury rates reached their highest level in a 10-year period in 2023, and pedestrians accounted for 22.2% of the fatalities (TURKSTAT Corporate, 2024).

Despite these unfortunate statistics, the interventions in conflict areas still predominantly favor motor vehicle dominance at the expense of pedestrians. Since interventions to motor vehicle accessibility often face social and political opposition, restructuring pedestrian mobility through crossing facilities has often become the primary alternative (Anciaes and Jones, 2018) in such environments.

Footbridges, in particular, have become one of the most prevalent examples of such facilities in conflict areas, since they, in theory, minimize the potential harm separating pedestrians from motorized transportation at grade. However, a review of footbridge-focused literature reveals a discrepancy: Despite these structures being specifically designed for them, pedestrians often avoid using footbridges.

Background search and Research Motivation

The relevant literature provides evidence for the key factors that encourage and deter pedestrians from using footbridges. In Beijing, Guo et al. (2014) conducted questionnaire and field surveys in an area with at-grade and grade-separated facilities, and used a multinomial logit model to reveal the most influential factors in pedestrian decisions. They reported that when convenience and time-saving are prioritized, grade-separated facilities are the least favored option. The effects of time-saving and distance-saving on footbridge usage have also been reported in earlier decades by Moore and Older (1965) and Ribbens (1996). In 2020, Patra, Perumal and Rao video captured pedestrian movements in an area with two signalized crossings and a coexisting footbridge in Mumbai and later investigated the low footbridge usage by using a binary logit model. They reported that pedestrians prioritize time-saving, easy access, and convenience. The increase in age decreased footbridge usage. Banerjee, Raoniar and Maurya (2020) collected data across 14 footbridge locations in 6 Indian cities by field and questionnaire surveys, and later compared random forest, generalized linear model, and gradient boosting machine models for predicting future pedestrian preferences. They reported that the increase in age had a negative effect on using footbridges, which highlights the impact of accessibility, and the most influential factors were personal safety concerns due to poor level of lighting, inadequate walkable widths and stair dimensions, availability of obstructions, human congestion, and gender. These findings align with a previous study in three English neighborhoods by Anciaes and Jones (2018). They conducted stated preference surveys and used mixed and conditional logit models; the findings revealed that pedestrians even preferred to walk more to avoid grade-separated crossings due to their inconvenient use, lack of accessibility, and personal safety concerns, especially by older people, disadvantaged people, and women.

Despite decades of research investigating what pedestrians expect from footbridges, these structures continue to be non-preferred by pedestrians. This ongoing interest in the topic indicates that some critical expectations have not yet been effectively reflected in footbridge designs. Hence, the initial motivation of this study has become to reveal the overlooked factors affecting footbridge designs, thus, pedestrian perceptions of footbridges. For this purpose, the researchers conducted on-site observations in footbridge locations in Ankara, Türkiye, to gain insights into the shared characteristics of footbridges and their locations.

Ankara as the Case Study Context and Researcher Observations

Ankara is a notable example of a vehicle-oriented city with its arterial roads cutting through the city's active settlements, coupled with narrow sidewalks, and a convenient source of observation with its numerous footbridges on major roads (Figure 1). The combination of limited space for pedestrian mobility at grade and vehicular traffic in the city creates a challenging environment for pedestrian

safety and accessibility, leaving pedestrians reliant on the crossing facilities.

Figure 1
Typical Ankara footbridge example (Photographs taken by the authors)

While the above images of a typical Ankara footbridge illustrate the pattern in the built environment features of footbridge locations, they also capture one of the most common and critical issues in footbridge construction, which leads these structures to remain avoided: the neglect of site-specific constraints and human-centric aspects in the location selection and design processes. While these structures are constructed in locations of need, they can further restrict pedestrian mobility if these aspects are not regarded in both processes (Eloğlu, 2025). As shown, in cases where the sidewalk widths are not sufficient, footbridges cannot accommodate different types of accessibility elements and cannot facilitate crossing for pedestrians of all ages and physical conditions. Even if these elements are included in the designs, they either cannot meet mandatory criteria or occupy a large portion of free space at ground level. In such cases, footbridges not only drop the pedestrians using them off adjacent to the roadway but also restrict the movement of pedestrians moving at the ground level and expose them to risks even more before their construction.

With these aspects in mind, the on-site observations demonstrate that footbridges are being used as quick intervention tools after conflicts arise without being subjected to prior planning.

RESEARCH PROBLEM, OBJECTIVES, AND METHODOLOGY

The current manner in footbridge construction overlooks the interconnected nature of their locations and their design frameworks, recreates the very consequences of the conflicts that footbridges intend to resolve, and ultimately transforms these structures into urban barriers against pedestrians (Eloğlu, 2025).

The body of footbridge-focused literature provides contextual insights into the key factors affecting pedestrian footbridge usage; however, it does not address how to inform designs to meet pedestrian expectations. Motivated by this gap, this study addresses what has been overlooked and emphasizes that the relationship between footbridges and their surrounding environments directly affects their design frameworks, thus the perception of footbridges. It argues that where to construct and how to design footbridges cannot be answered separately, and proposes a decision-support tool comprising two complementary stages: a prediction model (as the quantitative phase) and a design guideline (as the qualitative phase).

DEVELOPING THE PREDICTION MODEL

To answer where to construct footbridges, the researchers collected information on where the need for footbridges has already occurred. Hence, the first step was to identify the shared features of the locations with existing need, in other words, existing footbridges. For this aim, Ankara was selected as the source. A challenge here was the absence of publicly available data, whether on footbridges' surrounding environmental features or simply on their exact placements in the city. Hence, the researchers requested the footbridge locations in the city and obtained a KMZ file containing pinpointed location coordinates from Ankara Metropolitan Municipality via e-mail in 2024, March, covering the footbridges within its jurisdiction. Based on the research scope, only 155 footbridges

spanning over vehicular roads remained, and their coordinates were exported into a CSV file.

Built Environment Features to Extract, Data Collection, and Research Dataset

First, a column indicating the presence of footbridges corresponding to their coordinate values was added to the dataset. Obtaining the exact locations enabled the authors to explore the shared features of the locations, and the relevant data was collected by cross-checking available information from online mapping sources (Google Maps, Google Earth, and OpenStreetMap [OSM]) and visiting them in person. The details of the data collection process are as follows:

This research highlighted that footbridges have been used as quick intervention tools in intense conflict areas. Therefore, the first shared feature to extract was the roadway types (e.g., arterial roads, local roads) of footbridge locations in Ankara. For this aim, the road type data was collected by checking the relevant labels using OSM (https://www.openstreetmap.org/). For an easier reading of the roads' hierarchical order, trunk roads in OSM were added to the dataset as main arterial, primary roads as medium arterial, secondary roads as minor arterial, service roads as service road, and all the mid-block roads that do not connect neighborhoods were added to the dataset as local road.

The next step was to discover the relationship between footbridges and human activity spaces. While vehicular roads can maintain their high-risk characteristics for long distances, footbridges are only constructed at certain points along the roadways, which indicates that the surrounding functions are important determinants when deciding their exact placements. In this regard, the surrounding functions at the start and ending points of footbridges that are exposed to dense human activity, such as educational and healthcare buildings, commercial buildings, parks, culture and sports centers, and religious buildings, were collected as data. The availability of such functions was added to the dataset as binary data in one column. If these functions were available, they were added to another column indicating their functions; if not available, they were added to the same column as 'none'.

Similarly, crossing facilities are exposed to periodic human flow and high human activity. Hence, the availability of public transportation stops in the vicinity was added to the dataset. The relevant distances were measured using the rulers in Google Earth Pro. Although using the Euclidean distance does not definitively determine the walkable distance for every pedestrian and every geographical location, a measurement for collecting the data was necessary. Thus, it was decided to use 400 m for bus stops and 800 m for rail stations, as commonly accepted walkable distances by the transportation industry (El-Geneidy et al., 2014). The stops within these limits (with an additional 50 m error margin) were added to the dataset as '1', and others as '0'.

Later, the availability of other pedestrian crossings around the locations was added to the dataset with the same methodology, but the limit was 200 m (again with an additional 50 m error margin). This data provided insights into whether constructing footbridges was preferred in the presence or absence of other crossing options. It is important to note that only the facilities located on the exact same roads of coordinates were accepted as available.

Lastly, the data on the features was collected for randomly sampled (using OSM road network data of Ankara via a Python script) 155 Ankara locations without footbridges, so that a Machine Learning (ML) model can capture the differences of built environment features in locations with and without footbridges (Data source: OpenStreetMap contributors, 2025. Contains information from OpenStreetMap, made available under the Open Database License [ODbL]).

The Dataset

At the end of the data collection process, the dataset (Table 1) had two categorical data columns, five binary data columns, and 310 rows (excluding the column names). The column that contained the coordinates of the locations was only added to navigate the researchers in the data collection process; thus, it was excluded before training. The data under the "footbridge needed" column is the label to be predicted, and the model will produce binary predictions indicating "footbridge is needed" and "no need for a footbridge" in given locations.

Table 1
Sample display of the dataset

coordinates	footbridge needed	road type	availability of attractions	attraction function	public transportation	signalized crossing	crosswalk
39.97420183 32.59614303	1	main arterial	1	park	1	0	0
:	:	:	:	:	:	:	:
39.9950169 32.84852021	0	local road	0	none	1	1	1

The road type distribution of footbridge locations is main arterial 50.96%, medium arterial 32.9%, minor arterial 14.84%, tertiary 0.65%, local road 0.65%. For no footbridge locations, road type distributions are sharper: 58.7% local road, 18% tertiary, 14.8% minor arterial, 5.8% medium arterial, 1.9% service, and the rest is main arterial. Although the locations were randomly sampled, this difference is consistent with real life since the dominant type at the city scale is local roads and not arterial roads.

Another sharp difference is the surrounding functions. 31% of no footbridge locations do not have surrounding attraction functions, whereas 69% of footbridge locations have surrounding attraction functions: educational and health, 29.03%; commercial, 19.35%; park, 14.19%; culture and sport centers, 3.87%; and religious, 2.58%.

Lastly, approximately 98% of footbridge locations have nearby public transportation stops, 22% of them have signalized crossings, and 13% of them have crosswalks, and similarly, the same distribution for no footbridge locations is 92%, 21%, and 23%.

Model Selection and Model Performance Evaluations

Employing an ML-based approach was deemed appropriate for the task, as it enables the discovery of the nonlinear relationships between feature variables. The study aims to answer where to construct footbridges by capturing the complex patterns in the available information. Considering the dataset structure (having two classes), the available data types, and given the small size of the dataset, training tree-based models (Decision Tree [DT], Random Forest [RF], and XGBoost [XGB]) are deemed suitable for the task as they can handle categorical, binary, and numeric data without requiring complex preprocessing, as they do not require large amounts of data and as they are more interpretable and traceable compared to other supervised algorithms.

Before training the models, the first step was to transform the categorical data into binary data using one-hot encoding, representing the categorical variables as independent features with no ordinal relationships. This resulted in the dataset having 16 feature variables. Following, the dataset was split into two subsets as training (70%) and test (30%) sets (splitting was stratified to ensure class balance). Given the size of the dataset, the hyperparameters aimed to encourage splitting and tree growth without overfitting, while also aiming models to utilize as many features as possible.

Table 2
Model hyperparameters

Model	Hyperparameters
DT, RF	min_samples_split:2, min_samples_leaf:1, max_depth:10, criterion:'gini', random_state:42
XGB	max_depth:10, learning_rate:0.2, gamma:1, subsample:0.9, colsample_bytree: 0.9, min_child_weight: 1, objective: binary:logistic',random_state: 42

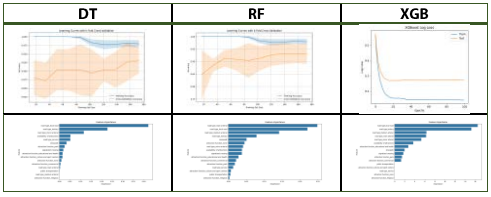
For DT and RF, the Scikit-learn library and the ".fit()" method were used, and for XGB, the "xgb.train()" function was used. Initially, the Gini impurity of the entire dataset was 0.5. K-fold cross-validation was set to 5.

After training and fitting the models, the weighted average of Gini impurities for each subset and the Information Gain (IG) were calculated. The top four features with the lowest Gini impurities and highest IG features (respectively) are as follows: road type_local road: 0.3026, 0.1973; road type_main arterial: 0.3231, 0.1769; road type_medium arterial: 0.4253, 0.0746; availability of attractions: 0.4335, 0.0665. The accuracy scores and the misclassifications after the first training (Table 3), and the learning curves, log-loss, and feature importance (Table 4) are given below.

Table 3
Model performance after first training

Model	Test Accuracy	Training Accuracy	Cross-Validation Accuracy	Confusion Matrix TN - FP FN - TP
DT	0.8494	0.9769	0.9310	41 – 6 8 - 38
RF	0.8709	0.9769	0.9264	42 – 5 7 - 39
XGB	0.8817	0.9493	0.9258	40 – 7 4 - 42

Table 4
Model learning curves, log-loss, and feature importance



XGB showed the best and most balanced accuracy scores among all models, and DT showed the lowest performance with the lowest test accuracy, and with the biggest gap between its scores, which might indicate an overfitting tendency. The false negatives of DT and RF were much higher than XGB. RF utilized each feature, DT utilized 14, and XGB utilized 11 out of 16 features. As shown, the public transportation feature had quite a small effect in DT and RF. This is an expected outcome considering that 98% of footbridge locations and 92% of non-footbridge locations have public transportation.

Following, to enrich the available information for the models. the binary variables under 'public transportation', 'signalized crossing', and 'crosswalk' columns were transformed into numeric data, indicating the distances of these facilities to their corresponding coordinates. For this aim, distances exceeding their respective limits (presented in the data collection section) were added as '11111' to the dataset. By exaggerating the distance difference, the models were enabled to capture the availability of the features since the related binary columns were to be excluded. After data type transformation, the test, training, and cross-validation accuracies (respectively) were as follows: DT: 0.8709, 0.9907, 0.8994; RF: 0.8709, 0.9953, 0.9218; XGB: 0.8709, 0.9585, 0.90. The results indicated that while XGB results were more balanced, the complexity of the task increased DT and RF as they got overfitted to their training sets. Thus, the dataset was returned to its initial version.

Following, model responses to how the data is divided were investigated. Since the number of data could not be increased, model responses to data variability were examined by testing different random states. To provide a measure of performance consistency against randomness, the dataset was divided by a random state ranging from 0 to 42. The mean accuracy scores and standard deviation (std) are given in Table 5.

Table 5
Mean test and training accuracy scores and standard deviation

Model	Mean Test Accuracy - std	Mean Training Accuracy - std
DT	0.8919 - 0.021	0.9630 - 0.008
RF	0.9019 - 0.022	0.9630 - 0.008
XGB	0.9109 - 0.022	0.9375 - 0.01

XGB had the highest mean test accuracy with the smallest gap between training accuracy, generalizing better than others; however, the mean and standard deviation values show that all models show consistency across different splits in their own contexts.

Considering the consistency results, selecting the best-performing model for the predictions would overlook the key role that randomness plays for all the models, and the results would overfit to certain instances. Thus, the top four repeatedly predicted locations (FP) across 43 different random states for all the models were obtained.

By this approach, more robust and reliable predictions were provided, and dependency on a single test-training split was prevented. The predicted location row numbers and the number of times that they were predicted (respectively) by the models were as follows. DT: [(229, 16), (236, 15), (290, 14), (173, 14)]; RF: [(177, 19), (229, 16), (236, 15), (290, 14)]; XGB: [(156, 17), (229, 16), (244, 16), (177,15)]. All three models agree with row 229. DT and RF agree with rows 236 and 290. RF and XGB agreed on row 177 (Table 6). In total, seven locations were predicted.

Note that the dataset was processed using Pandas in Python, the header was automatically recognized, and zero-based indexing was applied. Therefore, the row numbers reported in this study are -2 compared to the corresponding rows in the original CSV file (predicted row 229 refers to row 231 in the dataset).

The predictions were obtained at this stage; however, the need for footbridges in none of the predicted locations was validated until the *how* question was asked. Thus, before discussing the ML-based outcomes, the second half of the decision-support tool was developed. The details of the process are provided in the following section.

Table 6
The top four repeatedly predicted locations across different random states

model	row	road type	availability of attractions	attraction function	public transportation	signalized crossing	crosswalk
XGB	156	medium arterial	1	educational and health	1	1	1
DT	173	medium arterial	1	commercial	1	1	0
RF, XGB	177	medium arterial	0	none	1	1	1
DT, RF, XGB	229	medium arterial	1	educational and health	1	1	0
DT, RF	236	minor arterial	1	park	1	0	1
XGB	244	minor arterial	1	educational and health	1	0	0
DT, RF	290	minor arterial	1	educational and health	1	1	1

DEVELOPING THE DESIGN GUIDELINE

After obtaining "footbridge needed" predictions, a design guideline is developed around human-centric aspects of footbridge designs. This step is a complementary step to the quantitative stage, enhancing the real-world alignment of ML-based outcomes and extending the scope of the research. By synthesizing site-specific constraints of footbridge locations, which directly affect their design frameworks, pedestrian expectations identified through reviewing previous research, and Türkiye's mandatory criteria into a guideline, pedestrian expectations are translated into actionable design principles, and the "*how*" question is answered.

Synthesizing Site-Specific Constraints, Background Search Findings, On-Site Observations, and Mandatory Criteria

The literature provides evidence that pedestrians avoid these structures when human aspects are not regarded in their designs, and on top of that, this research argues that site-specific features directly affect their design frameworks (details presented in the background search and research motivation section). In particular, the study argues that the widths of available sidewalks must provide sufficient infrastructural support for footbridges to achieve user-friendliness.

One of the most commonly reported factors affecting pedestrians in the literature is convenience (Patra, Perumal and Rao, 2020; Banerjee, Raoniar and Maurya, 2020; Anciaes and Jones, 2018; Guo et al., 2014).

Lack of ease in accessing and using the structure deters people; thus, the integration of different accessibility components is of critical importance during the design phase. Elevators should be included in the designs, since they reduce physical effort, but due to their energy dependency and limited usage capacity, which might result in human congestion at grade, ramp, or stairs, should also be included. However, each accessibility and substructure components cover a certain amount of area and define the available space for pedestrians at grade. Thus, if the setback distances of the components from the surrounding buildings and the roadways do not allow various accessibility component integration and do not provide safe and distanced space from the roadway for those who move at grade and who use the structure, footbridges might become urban barriers and even fail to comply with mandatory criteria, as illustrated in Ankara footbridge images. Additionally, crossing time and distance being greater than at-grade deters pedestrians, which suggests that the length of the deck should be as short as possible; however, the functions to be connected by the bridge should be considered in this decision.

After outlining design correspondences of site-specific and human-centric aspects, and the relevant mandatory criteria TS 12576, 2012; TS 9111, 2011; TS EN 81-70, 2007; Türkiye Highway Traffic Regulation, (1997) that must be followed in Türkiye are incorporated, and all aspects were synthesized into the design guideline (Table 7).

Category	Parameter	How to Design?
Site-Specific Physical Constraints	Setback Distances	The min. setback distance of the outermost footbridge component from the roadway side should be 150 cm, allowing two wheelchairs to pass side by side. Similarly, min. distance of the innermost footbridge component from the spaces with specified functions should be 150 cm. Footbridge abutments and accessibility components should be in sizes that do not occupy the sidewalk width to ensure while the footbridge is offering accessibility, the sidewalks maintain their functionality for pedestrians at grade level. The sizes of such components should leave a gap equal to or greater than the minimum setback distances.
Bridge Deck and Height	Length Orientation, Width and Clearance	It is recommended to keep the length of the bridge deck as close as possible to the length of the spanned roadway. Reducing the crossing distance and time to complete the crossing act, can encourage pedestrians to use the footbridge. Thus, it is recommended that the bridge orientation ensures passage in the shortest possible distance. However, the orientation, therefore, the length of the deck, primarily depends on the functions of the areas to be connected by the structure. The min. width of the bridge deck should be 150 cm, allowing two wheelchairs to pass side by side, however, increasing the available space is recommended. The min. clearance under the bridge deck should be 4.5 meters.
Accessibility Component	Ramps, Stairs and Elevators	The slope of footbridge ramps should not exceed %6, allowing disadvantaged pedestrians to comfortably use the bridge. A min. of 150 cm width should be provided along the ramps. Flat areas of 150×150 cm should be placed at the starting and ending areas of ramps and for every 9 m. If the total ramp length exceeds 30 m, additional landings of 250x250 cm should be placed. The min. step tread should be 30 cm, the max. riser height should be 15 cm. Risers should be closed designed with no protrusions that can cause falling accidents. These criteria should be maintained on each step of the stairs. Landings of a min. of 200 cm should be placed for each 180 cm vertical distance. The gap under the stairs should be closed up to 220 cm in height to prevent people from hitting their heads. If elevators are selected as accessibility components, it is recommended to combine it with other accessibility elements that do not rely on energy sources thus, in case of a failure, the structure can remain accessible at a certain level. If elevators are selected, the following cabin dimensions should be provided: For 6 people: 100 x 125 cm; for 8 people: 110 x 140 cm; for 17 people: 200 x 140 cm.

Table 7
Design Guideline (adopted from Eloğlu, 2025, and revised according to the scope of this research by the authors)

DISCUSSIONS ON THE RESULTS AND VALIDATING MODEL PREDICTIONS

All of the predictions are on high-risk road types, which is an indicator that the models capture the possibility of conflict areas, and all of them have nearby public transportation facilities, which aligns with the real-world Ankara data: 98% of footbridge locations, and 92% of non-footbridge locations have public transportation.

Except for row 177, predicted locations are nearby high human activity areas, indicating that models capture the pedestrian flow-footbridge need relationship. Rows 156, 177, 290 have both signalized crossings and crosswalks; rows 173, and 229 have only signalized crossings, row 236 only has a crosswalk, and row 244 has neither.

With all these aspects in mind, the necessity of footbridges in the predicted locations was evaluated by the researchers at this stage. Footbridges were deemed unnecessary for row 177, as it does not have a nearby attraction function and has two other crossings, and for rows 156 and 290, as they also have two other crossing options. The researchers agreed with the models on that the combination of road types and attraction function types might suggest footbridges for the remaining predicted

locations; however, those lacking existing crosswalks represent higher-priority candidates. It is easier for crosswalks to be missed or ignored by vehicle users as they do not offer controlled crossing for pedestrians, just as footbridges and signalized crossings do. Thus, their availability suggests that the potential risks from vehicles in their close vicinity are relatively lower, and footbridge construction might be redundant at these sites. Considering these key points, the strongest candidates for footbridge construction locations are identified as 173, 229, and 244.

After contextual researcher evaluation on the necessity, the real-life applicability of footbridge construction at the candidates was re-evaluated by using the design guideline. For this aim, the available setback distances in the locations were measured in Google Earth Pro. Row 173 (39.9220324°, 32.8512263°) has one sidewalk with a width of approximately 3 m. While the minimum dimensions can be met, due to the remaining free space after accessibility components, a footbridge was not applicable. At row 229 (39.9355603°, 32.824926°), approximately 4 m and 3.5 m sidewalk widths meet the minimum space for an elevator combined with a stair or a ramp. If not arranged side by side, around 150 cm of space clearance remains at grade after installation, enabling wheelchair accessibility. Thus, a footbridge is deemed necessary and feasible.

At row 244 (39.9553751°, 32.853142°), there is another footbridge nearby; thus, no footbridge is necessary in the area.

The discussions for rows 173 and 244 indicated that the absence of the setback distance and availability of other footbridge information in the dataset affected the predictions and provided valuable feedback for enhancing the available information for further studies. Besides, although Ankara is a noteworthy case study city for such a task, future research in other locations might require more information for both stages. With a more extensive dataset, the available information might be enriched, and more robust predictions can be obtained, and for future studies, the scope of such a tool can be extended to other crossings.

CONCLUSIONS

This study proposed a decision-support tool that addresses the shared needs at the urban scale in footbridge location selection and design phases. By leveraging observational studies, data-driven approaches, and background search findings, the study offered a comprehensive understanding of footbridge planning. The methodology was formed by three steps, aiming to answer *where, how,* and ultimately, *whether* to construct footbridges. The key findings of the study were as follows:

- In terms of traditional model performance evaluation, XGB results were the most consistent and balanced in each step, and it was the best-performing model. However, instead of validating its outcomes as ultimate footbridge locations, not overlooking the key role of randomness and obtaining the most repeated predictions across a range of different dataset splits for all models provided robust and reliable predictions.
- Asking *where* and *how* questions together and critically evaluating the necessity and feasibility of footbridges complements the ML-based outcomes and aligns them with the real-world complexity of the task.
- The study addressed the overlooked aspects of footbridge planning. It is important to note that this study does not encourage footbridge construction; it argues that they should be constructed when necessary, and by being subjected to planning. Hence, among seven footbridge location candidates, only three were deemed necessary, and only one was validated as "footbridge needed".

Notes

While this study follows the framework of one of the author's master's theses (Eloğlu, 2025), it proposes a refined methodology. The research dataset is publicly available at https://github.com/badeeloglu/Ankara-Footbridge-Location-Dataset.git

REFERENCES

Anciaes, P. R. and Jones, P. (2018). 'Estimating preferences for different types of pedestrian crossing facilities', *Transportation Research Part F: Traffic Psychology and Behaviour*, 52, pp. 222-237. Available at: https://doi.org/10.1016/j.trf.2017.11.025

Banerjee, A., Raoniar, R. and Maurya, A. K. (2020) 'Pedestrian overpass utilization modeling based on mobility friction, safety and security, and connectivity using machine learning techniques', *Soft Computing*, 24(22), pp. 17467–17493. Available at: https://doi.org/10.1007/s00500-020-05277-w

El-Geneidy, A., Grimsrud, M., Wasfi, R., Tétreault, P. and Surprenant Legault, J. (2014). 'New evidence on walking distances to transit stops: identifying redundancies and gaps using variable service areas', *Transportation*, 41(1), pp. 193–210. https://doi.org/10.1007/s11116-013-9508-z

Eloğlu, B. (2025). *Developing a decision-support tool for footbridge planning and design phases*. Master's thesis. Middle East Technical University. Available at: https://open.metu.edu.tr/handle/11511/113488 (Accessed 10 June 2025).

Guo, H., Wang, J., Sun, D., Yang, J., Ma, X. and Wang, W. (2014) 'Modeling the perceptions and preferences of pedestrians on crossing facilities', *Discrete Dynamics in Nature and Society*, 2014, pp. 1–8. Available at: https://doi.org/10.1155/2014/949475

Moore, R.L. and Older, S.J. (1965) 'Pedestrians and motors are compatible in today's world', *Traffic Engineering*, Institute of Transportation Engineers, Washington, DC.

Patra, M., Perumal, V. and Rao, K. V. K. (2020) 'Modelling the effects of risk factors and time savings on pedestrians' choice of crossing facilities at signalized 118 intersections', *Case Studies on Transport Policy*, 8(2), pp. 460–470. Available at: https://doi.org/10.1016/j.cstp.2019.10.010

Ribbens, H. (1996). 'Pedestrian facilities in South Africa: research and practice', *Transport Research Record*, 1538, pp. 10–18.

T.C. Cumhurbaşkanlığı Mevzuat Sistemi (1997) *Karayolları trafik yönetmeliği [Highway traffic regulation]*. Available at: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=8182&MevzuatTur=7&MevzuatTertip=5 (Accessed 9 December 2024).

Türk Standartları Enstitüsü (2011) *TS 9111: The requirements of accessibility in buildings for people with disabilities and mobility* constraints.

Türk Standartları Enstitüsü (2012) *TS 12576: Urban roads-Structural preventive and sign design criteria on accessibility in sidewalks and pedestrian crossings.*

Türk Standartları Enstitüsü (2007). *TS EN 81-70: Safety rules for the construction and installations of lifts - Particular applications for passenger and good passenger lifts - Part 70: Accessibility to lifts for persons including persons with disabilities.*

TURKSTAT Corporate (2024) Road traffic accident statistics, 2023 (Corrected). Available at: https://data.tuik.gov.tr/Bulten/Index?p=Road-Traffic-Accident-Statistics-2023-53479&dil=2 (Accessed 3 March 2025).

World Health Organization (2023) *Road traffic injuries*. Available at: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries (Accessed 11 March 2025)