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Decision Tree Based Prediction Model of Sitting Behavior on Public Spaces

An explorative study on three Public Parks in Berlin, Germany

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ABSTRACT

Understanding how different design features affect the allocation of activities in public space is the basis for urban design practice. Accordingly, there is a large body of literature studying how individual elements of urban design (e.g., greenery, sport facilities, sitting opportunities, sunlight) affect the intensity, type, and spatial distribution of human activities. These studies are usually bounded to the exploration of a small number of variables as the methodological limitations in terms of the data collection and analysis do not allow to capture the entire complexity of the urban environment. However, these limitations might restrict our understanding of many aspects of human behavior as these are simultaneously affected by a multitude of factors and their interactions. As a result, we argue that there is a need for new methods which can account for the multi-dimensional, non-linear relationship between public space and human activities.

This paper presents a methodological approach based on computer-aided data collection as well as state-of-the-art machine learning methods for predictive modeling. To validate the proposed method, we empirically test it on three public spaces (located in Berlin, Germany), focusing on predicting the distribution of sitting activities. The spatial data were represented as a grid with each grid cell containing spatial features related to sitting activities, such as distances to nearby roads, pavement, and visibility. Next, we trained a decision tree model to predict the impact of environmental variables on sitting. Our focus lies on the interpretability of the machine learning model; thus, we demonstrate how the decision tree model can be used to understand the importance of individual features as well as their combination in terms of the effect on sitting activity. Finally, we discuss how this type of model can be applied to explain other types of activities and directly inform the urban planning decisions.

KEYWORDS

Decision Tree, Sitting Behavior, Prediction, Public Spaces

1 INTRODUCTION

1.1 Focus and Scope

Public spaces can often be used as an instrument to increase social cohesion and bonding among their users. However, most of the time, they remained underutilized. Due to the design, location, proper management, and use process, a public space might not utilize its full potential to develop social interaction between different user groups. Good public spaces are always able to catch the attraction of their users through the provision of diverse activities in an engaging way. Sitting, talking, playing and physical activities, social interaction, and communication through various events, listening to music, reading, relaxing, and many more activities can be listed for daily life in an urban public space. People would love to engage in these activities spontaneously, which evolves a public square or park into a good functionality. On the other hand, places that fail to attract people due to lack of activities and vibrance despite having potential can be defined as a failure. So, activities and vibrance are always essential to keep a public place alive.

Sitting is one of the most crucial stationary activities within a public place as it allows people to stay longer and got engaged with the surrounding environment. If people stay longer in a public place, it remains lively for an extended period, and there are always more chances available to create social interaction among the users. So, understanding people's sitting behavior is always vital for a planner to successfully approach an urban public place's design process. If a public place is attractive for sitting, then it is evident that people will stay long and, in the process, get engaged with many other spatial activities which enrich the place's activeness. Sitting as a predominant spatial behavior always interconnects the other activities. It is closely related to the surrounding design features and other activities. So, understanding the significance of nearby design features on public sitting is essential to realize how people will react to a location of a public place in terms of giving sitting preferences. It would always be crucial for a planner to place the design features according to their significance and to know the ideal combination with the other nearby features for encouraging sitting activities. So, it is vital to evaluate their impacts on the sitting behavior of public places.

1.2 Relevance and Importance

From the existing knowledge and research done by many renowned urban planners and researchers, various essential factors can decide in shaping public sitting activities. There are physical factors such as design elements, surrounding environments, and so on. On the other

hand, non-physical factors like surrounding activities, psychological comfort, social circumstances, etc., also act as defining components. Public spaces and sitting activities are strongly co-related. Being one of the most influential static activities, sitting always impacts other activities and behaviors of public space. As it ensures a more extended period of staying for people, lacking sitting activities hampers the vibrance of any public place.

There are many reasons why a public place fails to attract people. One of the most significant causes among them is the lack of places to sit. Even though there is the provision of sitting, due to the lack of ideal positioning of the sitting furniture and combination with the surrounding design features, a public place fails to attract people to stay longer and sit. It results in a public place without people's presence and evolves as empty and barren space without activity in the long run. So, evaluating the sitting behavior of public spaces is essential to rejuvenate a public space's activities and daily life. The design features of public places highly influence public sitting activities. The design features' impacts on sitting activity need to be appropriately analyzed to have a logical idea regarding their interdependence. This research was focused on generating a clear understanding of the significant impacts of design features on public sitting activities to help reduce the problem of dying public spaces without people and activities.

2 LITERATURE REVIEW

2.1 Public Spaces & Sitting

What drives a person to choose a place to sit in a particular location of a public place? There could be many explanations for various reasons and stimulating factors that might affect the psychology of a human being. In terms of sitting place preference, it does not have the same facts that influence the behavior every time. It might vary from square to square, specific location to location, and so on. Various researches and articles describe different strong influences behind it. However, in general, many researchers stated that human psychology will always look for a place to sit at the first point. If there is no room to sit, then the discussion regarding the factors of influence will be meaningless. People tend to sit most where there are places to sit (Whyte, 1980). According to Whyte, sitting places are the most crucial issue to grow people's interest to sit. It does not matter if there are many details present in the surroundings and activities going on in the near vicinity. In his iconic book, *The Social Life of Small Urban Spaces*, he clearly stated that the most attractive fountains, the most striking designs, cannot induce people to come and sit if there is no place to sit (Whyte, 1980). Once there is a provision for sitting, which is available to sit, there will be the question of having a preference over different locations.

What do typical people think before choosing a place to sit in a public space? What manipulates their mind to prefer a position where they can sit with both physical and psychological comfort? The discussion is broad in terms of explaining all the possible influencing factors. Existing knowledge narrates those factors shaping public sitting behavior can be classified into several

categories or groups. It might be physical factors such as design features, surrounding natural and artificial elements, environmental factors, or something related to human psychological comfort. At the same time, it might be the surrounding activities or other spatial behavior of the public square or plaza. Moreover, all the stated facts can have an accumulated impact altogether. It continuously varies from place to place and location to location. As this research topic mainly focuses on the most influential design features complimenting public sitting behavior, it is important to briefly discuss some of the existing research and ideas narrated by famous urbanists and sociologists regarding the facts mentioned above.

2.2 Design Features Shaping Sitting Behavior

In terms of design features that mainly influence the sitting behavior, sitting benches are the most prominent ones to be noted. Again, it indicates the provision of sittable places. The most popular plazas tend to have considerably more sitting space than the less well-used ones (Whyte,1980). That means most vibrant public places logically consisted of more sitting provisions. Among those sitting places, the most used design feature to sit on is the sitting benches. Ideally, siting should be physically comfortable-benches with backrests, well-contoured chairs. It is more important, however, that it be socially comfortable. That means choice: sitting up front, in back, to the side, in the sun, in the shade, in groups, off alone (Whyte, 1980). According to Whyte, there should be a provision of different varieties of sitting benches that provide a different way of sitting, ensuring both social and physical comfort. Famous urbanist Gehl expressed his thought regarding creating different sitting provisions for single and multiple user groups. In his book *Cities for People*, it is stated that users who want to maintain a distance to others long even benches are appropriate. Cooper Marcus and Francis (1998) also suggested two varieties of seating for those single users who want to sit near but not within eye contact with others. Straight seating options such as steps, ledges, or straight benches allow natural spacing between people. They do not imply unwanted eye contact, same as benches situated at a right angle or opposite each other.

Among other physical features, Trees can be a deciding factor for their shadow casting ability. As Whyte (1980) expressed, trees should be related much more closely to sitting spaces than they usually are. As far as his research is concerned, the pleasure of being under a tree is much nicer while having a pleasant look at the surroundings. He also added that tree provides a satisfying enclosure; people feel cuddled, protected-very much as they do under the awning of a Street Cafe. As always, they will be cooler, too (Whyte, 1980). Another critical factor that alleviates the sitting behavior is the openly accessible area, open green area, or open spaces where activities occurred, usually in a public place. Cooper Marcus and Francis (1998) noticed the significance of varieties in sitting orientation that provides variety while being seated in watching other people's activities, surroundings, and diversity in the sun and shade. People are attracted to other people (Abu-Ghazzeh, 1999, Spooner, 2014). Therefore, the city life view of people has a unique attraction, and people will be attracted to a location where other people are passing by (Cooper Marcus & Francis, 1998; Gehl, 2010). Seating orientation is crucial in terms of having a diverse

view of the surroundings. Lyle (1970) determined that people choose to be where there are other people. Places that are pretty distant from the central circulation and isolated ones were not much used compared to others. Most people have a preference to keep their faces towards the open areas where people engage in activities, or other features are present. Similarly, Mumcu (2002) sort out that seating with a comprehensive view and heading towards the places where the human activities were occupied for a more extended period than the others. So, the importance of the open activity area is quite influential in shaping public sitting preferences. Circulation and sitting, in sum, are not antithetical but complementary (Whyte,1980). It expresses the dominance of pavements, pathways, or circulation spaces in public sitting behavior. People tend to sit in the near vicinity of the circulation area. Not necessarily, the sitting would hamper the circulation instead, and they complement each other.

2.3 Psychological Factors

Sitting should be both physically and psychologically comfortable, as Whyte said. Several factors control the psychological comfort of public sitting. Many psychologists expressed different theories and concepts regarding people's mental comfort while sitting in a public place. All these factors can be defined as comfort factors of public sitting. *Prospect Refuge Theory* is one of the most significant assumptions which can be explained as a crucial psychological factor of manipulating public sitting. Appleton (1975, 1988) revealed that the evolutionary development of humankind had led humans to go for a setting in which, without being seen (refuge), they can see a broad vista (prospect). An unimpeded opportunity to see is called a prospect, whereas an opportunity to hide is called refuge; hence the name prospect refuge theory emerges when these two words combine (Appleton, 1975). In a study aimed to determine a relationship between this theory and sitting behavior, it was found out that prospect and refuge affect the choice of seating (Mumcu, 2009).

Similar affordances of the environment for seating are defined as the *Edge effect* by Gehl (1987, 2010). Places for sitting along facades and spatial boundaries are preferred to sitting areas in the middle of space; people tend to seek support from the details of the physical environment. Sitting places in niches or at other well-defined spots and sitting places where one's back is protected preferred to less precisely defined ones (Gehl, 1987). Users' backs are protected, and the frontal sensory apparatus of users can comfortably master the situation. A complete view of everything in the space is provided, and users are in no danger of unpleasant surprises from behind. Furthermore, the local climate is best there (Gehl, 2010).

3 DATASETS AND METHODS

3.1 Research Questions and variables

In this research, the main focus was to determine the impacts of surrounding design features that manipulate the sitting pattern of people in a public space. It was aimed to detect how people use a

public space for sitting and how they give preferences to sitting locations. Depending on several interrelated queries, the main research questions were set to detect the research outcome in a nutshell.

- What are the major design features that influence sitting activities in a public place?
- How do these influencing design features interact with each other to enhance the sitting preference of any specific location of a public place?

A well-structured research method was defined to proceed towards the outcome to answer these questions. Several significant factors were sorted out from the existing literature studies, where it was investigated regarding their impacts on the public sitting phenomenon by famous urbanists and psychologists. They were classified into two categories of dependent variables and independent variables. Dependent variables were defined as the sitting activities whereas the significant features or design elements were noted down as independent variables which stimulate the sitting activities. Considering the prominent factors extracted from the literature, independent variables can be noted down as sitting benches, pavements, open green areas or open activity areas, playing equipment, child play zone, public art, installations like a statue, fountains etc., which are the designed elements or features directly stimulating the spatial behavior of the public place. On the other hand, sitting activity was classified as the dependent variable, influenced by the available design features or independent variables. It was tried to sort out the relations between those variables by a decision tree prediction to see how they interact with the overall scenario of public sitting. Finally, these variables were put together into diagrams to show the possible relationships between them and the expected direction of their relationships.

3.2 Selection of Study Sample

At the beginning of the methodology phase, three similar public places were selected within the city of Berlin. The main focus while selecting these places was the similarity in design features, shape and configurations, user patterns, and sitting activities to prepare a comparative analysis. In terms of area, they are different as it was tried to categorize them within the small, medium, and large public spaces. The three selected public places were Wartburgplatz, Teutoburgerplatz and Steinplatz.

Figure 1: Selected public spaces as survey samples (Aerial Views), from top to bottom; Wartburgplatz, Teutoburgerplatz and Steinplatz.

3.3 Data Collection Structure

After selecting the public places sample to run the experimental study, a survey structure was formulated. Two different mapping structures were followed to gather the possible amount of required data for this research. A standard unit of area or cell was considered to collect information and compare different locations within the same public space. Each of these standard unit of area can be defined as an experiment cell that focuses on the sitting activities and design features inside the cell. This research also focuses on the sitting preferences of people to investigate the reasons behind it.

3.4 Formulation of Experiment Cell

To collect information regarding the variables from near and far, it was essential to generate a method of data collection that helps to acquire precise data that was looked after. Several dependent and independent variables were sorted out at the beginning inherited from the literature study. It was essential to figure out an easy and effective way to collect information regarding their impacts in the selected public spaces. Generating a standard area unit for data collection was effective as it helps to provide the exact quantity of desired information. Considering the whole square or park at once while measuring the number of variables and their impacts appeared complex. Instead, dividing the public places into smaller grid cells helps collect the desired information within each cell. As the analysis result depends on the grid cell size, it was essential to choose a standard unit of area for the experiment cells to catch the maximum number of sitting activities and surrounding design features. It has appeared that a standard cell unit should consist of 10m X 10m dimension or 100 sqm area considering the shape and configuration of the selected public space samples.

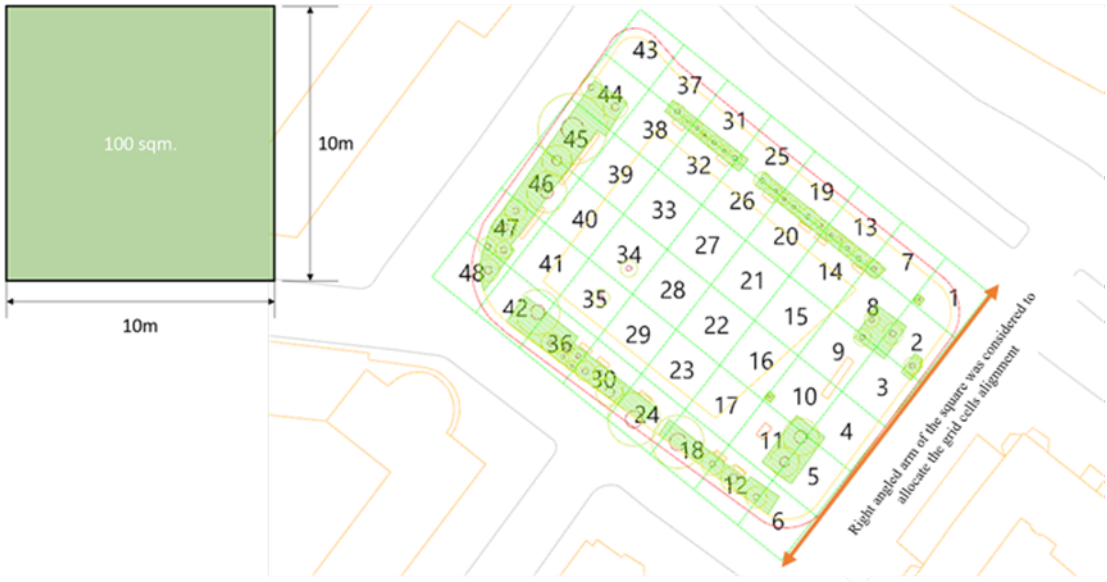

Figure 2: Assigning the standard cell into one of the selected public places before survey.

The smaller the grid cell gets, the smaller the number of sitting and design features captured during the surveys. At the same time, the larger the grid gets, the less accurate the results would be, as analyzing a larger area reduces the model's accuracy. Moreover, running computational analysis tools to calculate distances and generate mappings will be much smoother if a minimum area is considered. So, choosing a dimension of 10m X 10m or 100 sqm area for each cell provided a decent number to deal with, which was neither very large nor small and appeared perfect to some extent to catch sufficient sitting activities and surrounding design features. In terms of any further necessity, the experiment cells area can easily be doubled or tripled while applying them to larger public spaces.

Before proceeding towards the survey, each of the three selected public places was divided into 100 sqm units to focus on cell by cell while collecting all the variables and their impacts. In terms of aligning the grid cells with the public places, most of the time, one specific right-angled arm was considered to align with the configuration of those square grid cells. However, unfortunately, all the three surveyed public spaces do not have more than one right-angled arm to each other. So, sometimes the cells were aligned with any of the specific arms of each public space based on the significance of locations such as alignment starting from a significant node, etc. Nonetheless, the main focus was to cover the whole public place with the grid cells to acquire the necessary data.

3.5 Survey and Data Collection

After setting the standard formats of mapping, the data collection phase was proceeded into the selected public places to run the survey. At first, for each of the three public spaces, it was set to conduct three surveys for three different times. Each survey lasted for 1 hour. With the help of Behavioral Mapping, within that 1 hour, the number of people was counted in terms of sitting activities that lasted for at least 5 mins or longer. Especially within each cell, the position of the sitting activities was tracked and noted down. With the assistance of Existing features mapping, all the significant features and their characteristics, such as texture, color, shape, numbers, etc., were noted down. For each of the surveys of all three selected public spaces, similar procedures were replicated each time to collect desired data for further analysis.

3.6 Data Processing & Classification

After conducting the initial survey within each of the selected public places, the collected data were digitized with the help of a computer-aided design application tool. Each of the public places was digitally reproduced using CAD applications and 3D modeling tools along with help from google earth and map to take accurate references and positions. Collected data and information for each survey period were accumulated within the computer-generated outlines of each public place. Collected data were classified into two major categories of Binary and Continuous numbers. Binary data is mainly represented in the format of Yes/No or 0/1 to represent the existence of any variables both within each experiment cell and in the nearby cells. For example, within each cell of 100 sqm, the existence of independent variables such as sitting benches, pavements, trees and shadow, open accessible green area, playing equipment, etc. were noted down and expressed into the binary data format of yes or no. On the other hand, continuous numbers were used in terms of measuring distances. These distances were calculated from the center of each experiment cell to the nearest point of various existing significant features such as distance from the nearest pavement, nearest roads, nearest open accessible green or activity area to investigate their impacts on the sitting behavior. Also, to evaluate the visibility within each cell, several isovist properties were calculated considering the visual barriers or obstructions, mainly the tree trunks. Prepared binary data set can also be classified into two divisions of analysis parameters. One is within each cell, and the other represents evidence of the same variables within the 15m radius of

each experiment cell. That allows the opportunity to evaluate the impact of the variables from a near and far vicinity.

3.7 Data Processing Tools

Several tools were used during the data processing period in this research. For preparing the digital outlines of the selected public places to survey, two different computer-aided design and drafting tools were used. To take accurate references and fix these public places' positions, Google earth and map are used as a base. To generate the 3-dimensional work model, different 3D modeling computer programs were utilized. In terms of running several data processing analyses to define the characteristics of the selected variables, parametric modeling and analysis tools were used to generate the illustrations and prepare the desired calculations. Some illustrations explaining the data analysis and results were generated using raster graphics editing tools and applications.

3.8 Data Processing Methods

In this section, all the applied processes and tools are discussed to extract the desired data. Most of the analyses were conducted to obtain data for the continuous number categories such as distances, visibility properties, etc. Most of the binary data were directly assembled into the standard data chart from the on-field observation.

Distance Analysis: While calculating the distances as part of the data class continuous numbers, each experiment cell's geometric center was considered the base point to measure the distances. From the center point towards the nearest point of each variable or feature, the distances were calculated to evaluate their impacts on public sitting. Three major distances were taken into consideration. Distances from the nearest pavement to check the validity of the hypothesis stated that people tend to sit near the circulation. Pathways, pavements are quite significant elements considering the sitting preferences in a public place. Additionally, distances from the nearest road are also crucial in checking the impacts on sitting places where it is highly related to noise. As roads are the significant sources of noise in those selected public places in this research, distances from the nearest road helped define their impacts on public sitting. Lastly, distances from the nearest open green area or the activity area represent the impacts of the open activity area on public sitting.

Visibility Analysis: Visibility analysis refers to the isovist properties that help define whether a place is good or bad in terms of visibility. Some of the isovist properties help indicate how much provision a place has in terms of clear vision within the surroundings. As existing researches said, people can recognize other’s facial expressions until a distance of 35m. So, while calculating the isovist properties, the radius distances were kept limited to 35m. Before getting involved in the visibility analysis, it is necessary to have a brief idea regarding the isovist and some of its properties.

Isovist is a method of measuring visual properties associated with a particular arrangement of boundaries (spatial configuration). An isovist relates to the part of an environment that can be seen from a single observation point (Benedikt, 1979). Various parameters are derivable from an isovist, such as the area, the perimeter, compactness, and occlusivity. The area of an isovist describes how much one can see from a particular vantage point. The value compactness indicates the relationship between area and perimeter in relation to a perfect circle. It gives an idea of how complex or compact the field of view is. Occlusivity explains the number of open edges. An open edge denotes an edge line of the visual field which is not touched by physical boundaries (e.g., walls). (Schneider and König, 2012) Along with these isovist properties, one more entity was named Min radial, which denotes the minimum distance of the visual obstruction. In this research case, min radial calculation proved crucial as the visual obstruction elements are mainly the tree trunks. So, min radial also expressed the nearby presence of a tree.

3.9 Final Data Output

After conducting previously described analysis and procedures, all the necessary information regarding different variables were collected together. All the data were assorted inside one standard spreadsheet for one survey within each of the three selected public places. Later each individual survey data was aggregated considering the presence of sitting activities to have one final data input chart for one individual public place (figure 3).

		Binaries,Within each cell 10x10m															Binaries,Within Nearby Cell (15m radius)									Numbers,Within each cell 10x10m						
		Activities/Dependent variables						Features/Independent variables									Features/Independent variables									Distances from the center			Visibility from the center			
Cell ID	Total Users	Sitting	Talking	Eating/Drinking	Movement/Playing activities	Reading	Listening Music	Bench	Pavement	Tree	Shadow	Closed Green	Open green	Playing equipment	Child Zone	Public Art/Installation	Bench	Pavement	Tree	Shadow	Closed Green	Open green	Playing equipment	Child Zone	Public Art/Installation	nearest pave	Neurest road	Nearest open green/activity area	Isovist Area	Compactness	Occlusivity	Min Radial
1	0	no	no	no	no	no	no	no	yes	no	no	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	no	no	0.37	1.13	16.90	3559.19	0.18	167.80	5.40
2	0	no	no	no	no	no	no	no	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	0.00	4.62	14.06	3302.95	0.15	175.59	3.76
3	0	no	no	no	no	no	no	no	yes	no	no	yes	no	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	0.00	4.86	15.65	3432.68	0.14	204.91	6.27
4	0	no	no	no	no	no	no	no	yes	no	no	yes	no	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	0.00	5.10	17.36	3440.78	0.17	172.38	7.08
5	0	no	no	no	no	no	no	no	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	no	yes	no	no	0.00	5.34	19.06	3205.87	0.14	187.08	4.65
6	0	no	no	no	no	no	no	no	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	0.44	1.06	21.09	3477.66	0.39	71.64	5.01
7	0	no	no	no	no	no	no	no	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	yes	no	no	no	0.00	1.95	10.24	3411.59	0.11	228.47	5.62
8	0	no	no	no	no	no	no	no	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	0.00	11.95	4.09	3028.11	0.08	262.52	1.89
9	5	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	yes	no	no	no	0.00	14.86	5.80	3290.48	0.07	303.15	4.66
10	2	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	0.00	15.10	7.50	3225.89	0.10	271.97	5.76
11	2	no	no	no	yes	no	no	no	yes	yes	yes	yes	no	yes	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	0.00	12.08	9.21	2914.23	0.10	231.75	4.02
12	3	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	0.00	2.09	12.18	2386.16	0.23	110.71	0.33
13	0	no	no	no	no	no	no	no	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	yes	no	no	no	0.00	1.84	9.44	3174.27	0.06	332.03	4.23
14	0	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	yes	no	no	no	0.56	11.84	0.00	3122.43	0.06	317.47	4.94
15	0	no	no	no	no	no	no	no	yes	no	no	no	yes	no	no	no	yes	yes	yes	yes	yes	yes	no	no	no	4.06	21.84	0.00	3358.85	0.05	364.96	12.44
16	1	yes	no	no	no	no	no	no	yes	no	no	no	yes	no	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	2.35	22.58	0.00	3349.51	0.08	303.26	6.47
17	1	yes	no	no	no	no	no	no	yes	no	no	no	yes	no	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	0.65	12.59	0.00	3161.33	0.09	257.03	8.03

Figure 3: One final data chart based on one individual survey at Steinplatz, 16.06.2021.

4 ANALYSIS & RESULTS

4.1 Analysis Process

In this research, a decision tree was used to evaluate the impacts of different variables on public sitting. A decision tree is a decision assist tool that uses a tree-like model of decisions and possible conclusions. A decision tree is a flowchart-like formation in which each internal node serves as a "test" on a feature (e.g., if a coin flip shows up heads or tails), every branch stands for the consequence of the test, and every leaf node expresses a class label (decision taken after computing all features). The variables are mainly the significant features of a public place. While using this data analysis tool, the model was trained to evaluate the patterns of a target variable based on the input variables, which are the design features. Decision tree clustering was used as

most of the collected data were of two major classes, YES and NO. The decision tree model was fed all the final processed data for each of the public spaces one by one. The whole analysis part was conducted in several phases. At first, for each sample public place, one aggregated survey data chart was inserted into the model to run the analysis and see how it predicts the relation for one individual public place. The exact process continued with the rest two public places. After One round of individual data analysis, all the three public places data were combined and fed into the model. Later the model predicted the target variable 'sitting activity' based on the input variables for all three public places combinedly.

4.2 Analysis: Evaluating Sitting Behavior

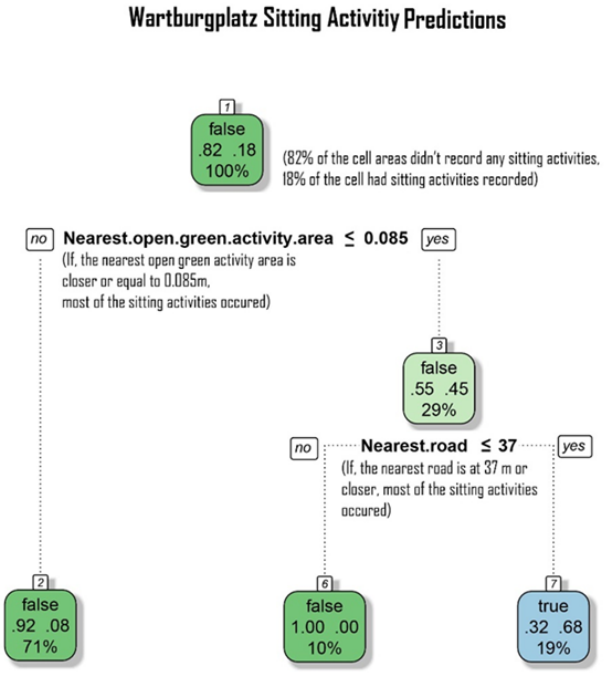

Figure 4: Decision tree predictions for Wartburgplatz sitting activities.

For the case of Wartburgplatz, 'nearest open green area' and 'nearest road distance' were predicted as the most influential variables for sitting activities based on the input variables from the survey. According to the model, if the cell is directly located on the open green area or within a proximity of 0.085m or less, it expects sitting activities. Furthermore, if the open green areas are closer to the nearest road by 37m or less, the model predicts sitting activities. It is crucial to consider the combination of the branches as the predictions indicate their interrelation while evaluating the sitting activities for any particular public place.

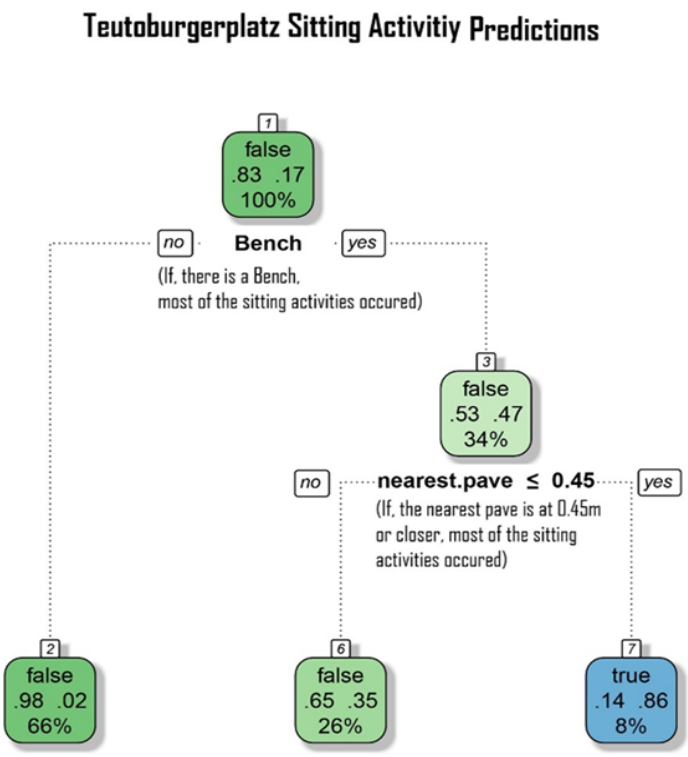

Figure 5: Decision tree predictions for Teutoburgerplatz sitting activities.

For the case of Teutoburgerplatz, decision tree predictions provided ‘sitting benches’ and ‘nearest pavement distance’ as the most influential variables. According to the predictions, if there is a bench within the cell, the model expects sitting activities. Furthermore, if the bench is located in the proximity of 0.45m or closer to a nearby pavement, the model predicts sitting activities. The model evaluated the impacts of sitting benches and their distances to a nearby pavement on manipulating sitting behavior for this public place. It explains the importance of having a bench within proximity of a pavement that best attracts people for sitting activities. On another note, having a bench in the middle of green areas or having pavement without a nearby sitting bench either would not help in the cause of stimulating sitting behavior.

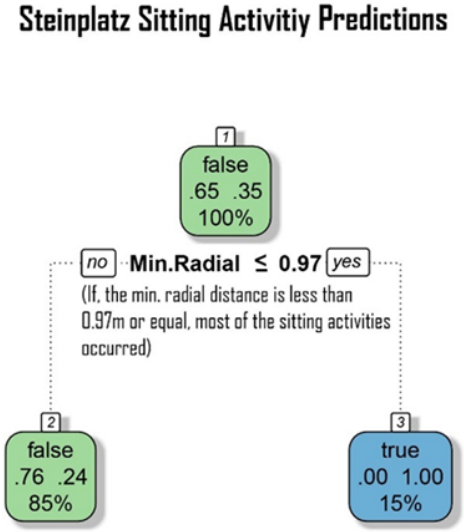

Figure 6: Decision tree predictions for Steinplatz sitting activities.

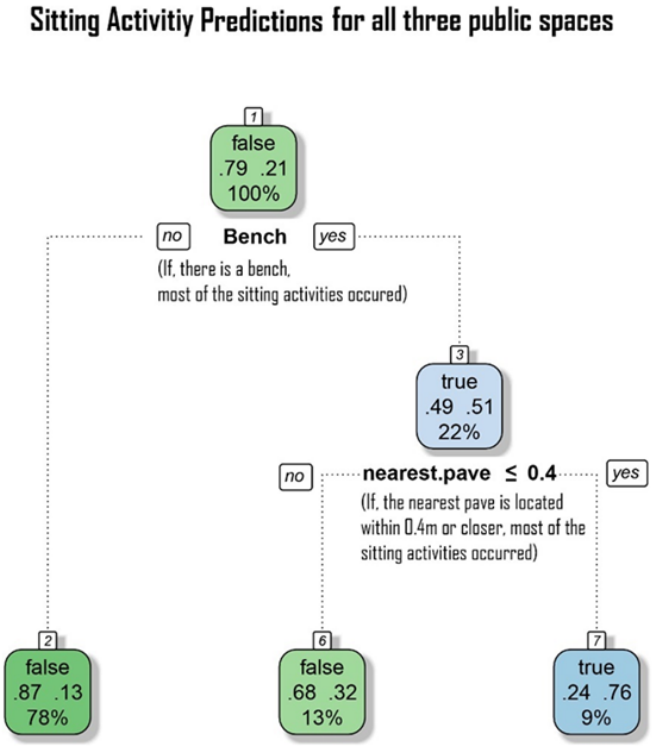

Figure 7: Sitting behavior predictions by decision tree for all the three public places combined.

For the case of Steinplatz, the decision tree model predicted ‘Min. radial distance’ as the most influential factor for sitting activities. According to the prediction, if the Min. radial distance within the cell is 0.97m or less, the model predicts sitting activities. Min. radial is a property of Isovist calculation. It refers to the distance of the nearest visual obstruction. That means, within the cell, wherever there is a design element or features less than 1 m or closer distances, sitting activities were expected by the model. This interpretation indicated that people prefer to sit near any physical object located less than 1 m within this square. It is essential to note that the Min.

radial distance of fewer than 1m does not necessarily indicate an obstacle nearby that would block all the visual access of the surroundings. Instead, it relates to the psychological aspects of public sitting behavior as people tend to seek support from their surroundings while sitting in a public place.

After running decision tree-based analysis for each individual public place, the input data were merged for all three public places to run an overall analysis to observe the combined prediction. All the three public places survey data were combined and fed into the model. Later the model predicted the target variable 'sitting activity' based on the input variables for all three public places. The predictions were more conventional and similar to the individual predictions for Teutoburgerplatz. The combined model predicted the 'Sitting benches' and 'nearest pavement distance' as the most influential variables. According to the combined model, if there is a bench within the cell, it predicts sitting activities. Moreover, if the bench is located in a proximity of 0.4m or nearer to a pavement, the model expects sitting to be occurred.

4.3 Results

As this research aimed to investigate the influence of significant design features shaping sitting behavior in public places, at the end of the data analysis, the outcomes are presented here in the result section. The decision tree method of data analysis was used to analyze the final processed data for selected public places. The decision tree models predicted various significant variables that are most influential in terms of public sitting activities. For better understanding and coherence to the aim of the research, the results are framed in reference to the research questions. As the main research question was framed as, what are the major design features that influence sitting activities in a public place? In reference to that, the decision tree-based outcomes indicated the features that predicted as most influential on public sitting activities. Also, the research asked further, how do these influencing design features interact with each other to enhance the sitting preference of any specific location of a public place? The decision tree branches indicated their interrelations which explains the ideal combination of several variables to attract sitting activities in any given location (table 1).

Table 1: Overview of most influential features and their interactions for each public space

	Influencing Factors	Interrelation
Wartburgplatz	Open green area, Nearest road distance.	Open green area within a distance from the nearby road of 37m or less.
Teutoburgerplatz	Sitting bench, Nearest pavement distance	Bench located within a proximity of 0.45m or nearer to a pavement.
Steinplatz	Min. radial distance	Presence of any design elements or features within a distance of less than 1m.
All three combined	Sitting bench, Nearest pavement distance	Bench located within a proximity of 0.4m or nearer to a pavement.

4.4 Interpretation of Results

The results indicated several design features and attributes of public places as the influencing factor for people's sitting behavior in public place. As the research aimed to investigate the features that most contribute to the sitting phenomenon in public places, the results are presenting some significant factors according to the analysis. In reference to the analysis results, the most dominating factor is the presence of a sitting bench which dictates most of the sitting behavior or preferences of sitting among the selected survey samples. In addition to that, open green area, distances from the nearest pavement are few other dictating factors that play an important role in influencing public sitting activities. Moreover, nearest road distances and Min. radial distance were also predicted as essential factors in this research. These results can be interpreted to understand what they are referring to. This section tried to interpret the resulting features and their relevance in reference to the existing literature and the research expectation.

Sitting benches: As specified by the analysis outcome, sitting benches were predicted to have the most impact upon public sitting activities based on the survey data. From the combined decision tree model of data analysis, it was predicted that a sitting bench was mostly involved with the sitting activities within the selected public places. That indicated the high impact of this specific feature on sitting activities. People usually tend to sit where there is a bench. Having a sufficient amount of sitting furniture always increases the possibilities of sitting. Within the selected public places, the sitting activity rate of people was high, especially in the locations or cells associated with a bench. Among three public spaces, two of them had most of the cells assorted with sitting benches recorded the maximum number of sitting activities that happened.

Considering this characteristic, the combined model predicted that the presence of a bench most of the time ensures the maximum number of sitting activities occurred. Though it was also evident from the analysis that presence of a nearby pavement always complemented the scenario within the places of sitting activities. It is also beneficial to note that, for preparing a compact and simplified input data chart, all the sitting furniture such as sitting stones, ledges, or sitting furniture designed around the tree trunks were also categorized into the criteria of sitting benches. If we analyze all the three selected public places from the survey, combinedly within the 266 cells, 56 of them were recorded having sitting activities. Among the sitting activity cells, 27 of them having direct involvement of a sitting bench which denoted that 48% of the cells where sitting activities occurred were associated with sitting benches. Again, in terms of individual cases, Steinplatz and Teutoburgerplatz had a higher percentage of sitting activity cells associated with sitting benches. In, Steinplatz 64% of the sitting activities were directly influenced by sitting benches. Whereas, Teutoburgerplatz stats revealed that 80% of the sitting activities were associated with sitting benches. An exception was found in the case of Wartburgplatz, where 17% of the sitting activities had a direct impact by the sitting bench features.

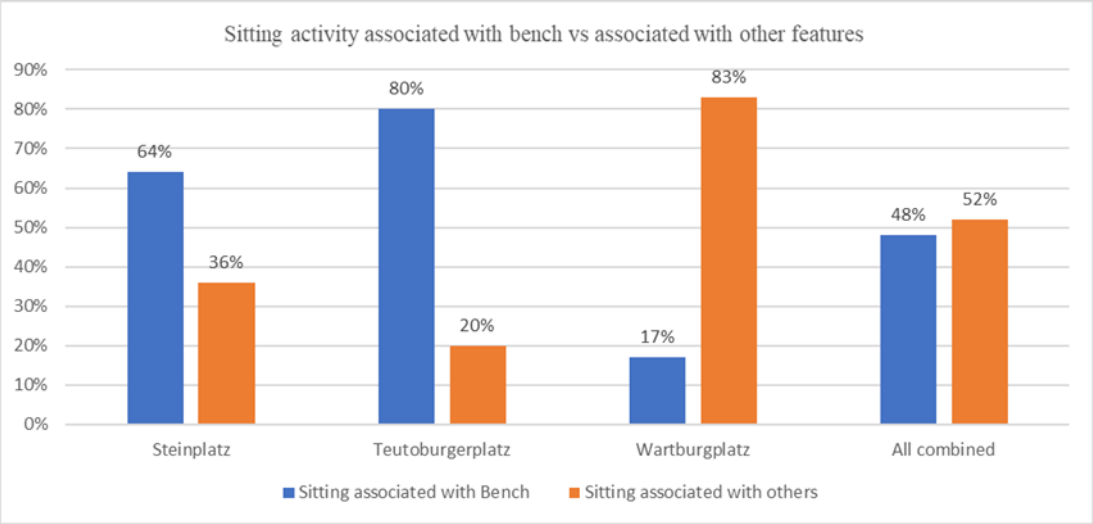

Figure 8: Bar chart showing the percentage of sitting activities occurred within the cell areas of public spaces directly involved with the bench in comparison with the involvement of other features.

Nearest pavement: Among two of the major decision rules predicted by the all-combined decision tree model, distance to the nearest pavement was also noted to be a deciding factor in terms of sitting. The model predicted that most of the sitting activities occurred where there was a nearby pavement within a distance of 0.4m or less. That means there are high possibilities of sitting near the peripheral areas of pavement or circulation paths. The models noticed the characteristics of preferring the sitting locations within close proximity of the pavement or circulation areas from the surveyed public space samples. Especially for the cases of Teutoburgerplatz and Steinplatz, most of the cells where sitting activities were recorded had an average distance of 2m from the nearest pavement or circulation. It indicated the impacts of the nearest pavement on preferring sitting locations within these public places. Exception found in the case of Wartburgplatz where the average distances of nearby pavement from the sitting activity cells were farther away than the other two places. Still, the impact of the presence of a nearby pavement or circulation area can easily be demonstrated because it influenced the other spatial activities and the contribution to the overall scenario within these public places

Figure 9: Bar chart showing the max. and avg. distances from the cells to the nearest pavement where sitting activities recorded within the three surveyed public places.

Open green area: According to the decision tree prediction models, open green area or open grass area was predicted as one of the most significant features influencing public sitting activities. Usually, this feature is directly associated with sitting and other activities and also manipulates the sitting behavior or preference of sitting locations within a public place most often according to the data analysis based on the surveys. Especially in the case of Wartburgplatz, the maximum number of sitting activities were associated with this open green area feature and contributed to the overall sitting activities within the three selected public places. It was recorded many times from the surveys that people choose open green areas to sit directly on the grass. However, there was the evident influence of some other design and environmental features also affecting sitting location preferences. On the contrary, sitting in the other two public places was influenced mainly by sitting benches. Nevertheless, open green areas also had a significant impact as an integral part of the surroundings within those two public places. People tend to see what others are doing and sit nearby. So, this open green area is also essential to patronize other spatial behaviors such as sports and moving activities, children playing, and so on, which indirectly has a massive impact on public sitting and the preference of sitting locations. According to the Wartburgplatz model predictions, most of the sitting activities occurred in a scenario where the nearest open green area is within a distance of 0.085m or less, which interprets that either people are sitting directly on the grass or in locations where it was pretty near to the open green area. That expressed the influence of this feature shaping the public sitting phenomenon and the preference for the sitting locations among the surveyed public places.

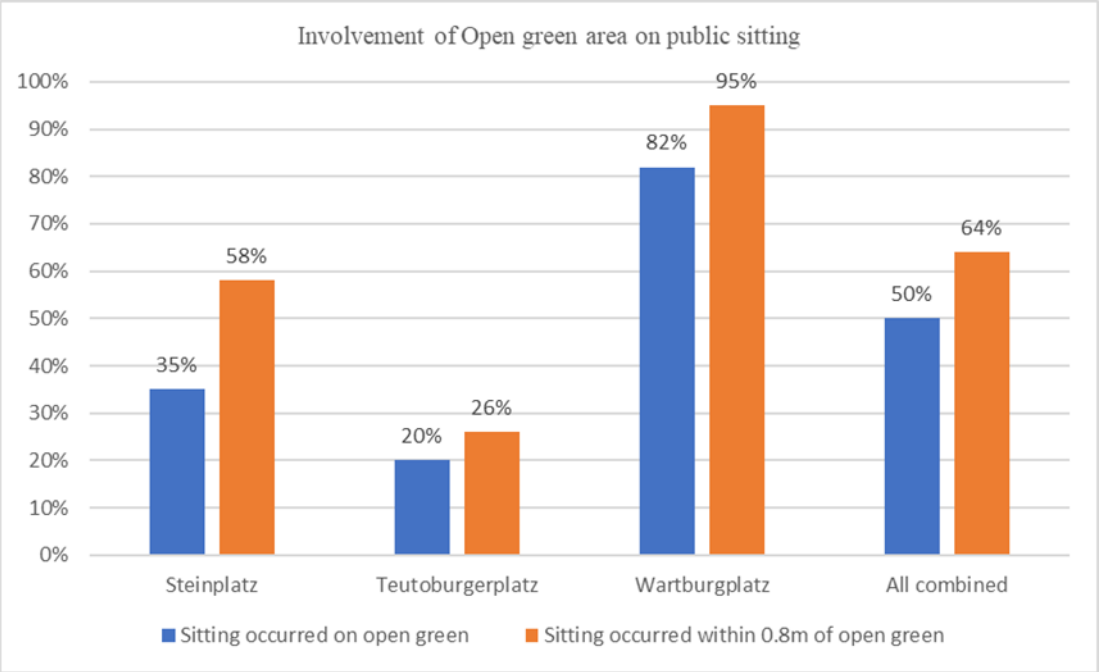

Figure 10: Bar chart showing the direct and indirect involvement of open green area on public sitting behavior.

Nearest road: Wartburgplatz model of data analysis predicted that the distances from the nearest road also impacted sitting activities. The model assumed that the cells where most of the sitting activities were recorded had a minimum distance of 37m or less from the nearest road. That means most of the sitting activities were recorded within the cells far away from the roads. This reflects the impact that people tend to sit in a place far from the noise and chaos. The surrounding roads being considered the primary sources of the noise, the distances indicated the impacts of nearby roads in terms of sitting location preferences within the selected public places. In the case of Wartburgplatz, the average distance from the sitting locations to the nearest roads was 26m, reflecting the model's prediction. However, exceptions occurred for the other two places as they are comparatively smaller in areas. In addition to that, majority of the sitting activities were influenced by the sitting benches within those two public places. Most of the sitting benches were allocated in the peripheral areas of these two public places, resulting in fewer distances from the nearby roads. Though it contradicts the prediction of the decision tree for these two cases, it also can be explained considering some other facts. Especially for Teutoburgerplatz, the whole public place was surrounded by a heavy buffer of trees and greeneries, which cut off the noise from the nearby roads significantly according to the on-site observations and experiences. So, in this case, the fewer distances from the nearby roads did not impact the sitting location preferences much. On the other hand, Steinplatz is relatively smaller in terms of the area from the other two places where the maximum amount of sitting was also associated with sitting benches placed in the peripheral areas close to the surrounding roads. In this case, noise is a factor but despite this, people tend to sit mostly in the peripheral areas within the square.

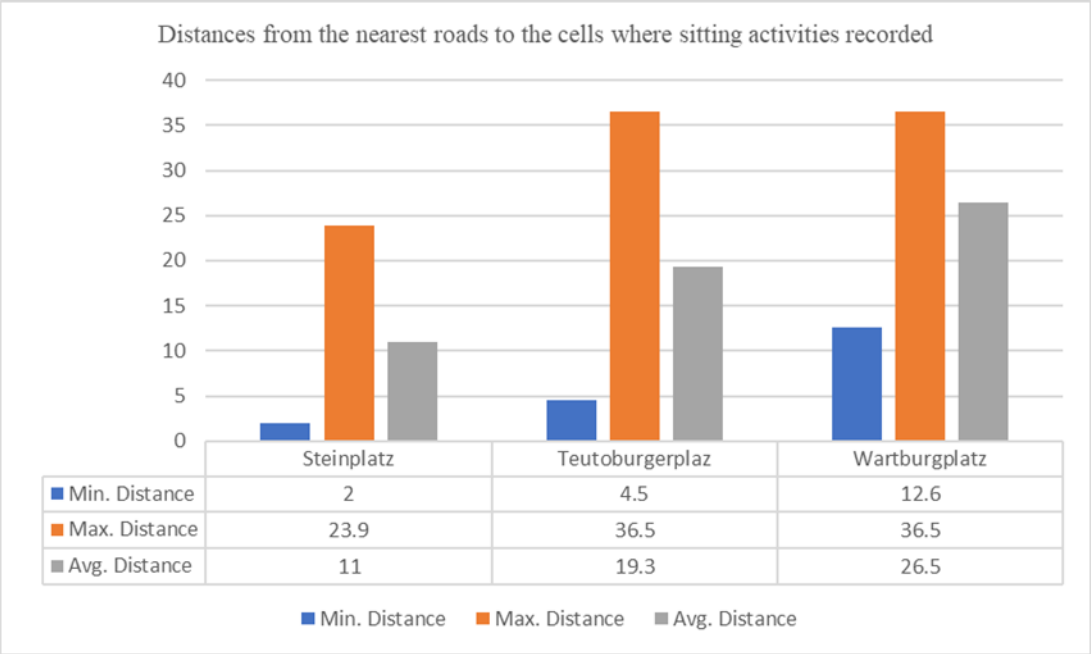

Figure 11: Bar chart showing the min, max. and avg. distances from the cells to the nearest roads where sitting activities recorded within the three surveyed public places.

Min. radial distance: Min radial denotes the minimum distance of the visual obstruction from the vantage point in terms of visibility. In this research case, min radial calculation proved critical as the visual obstruction elements are mainly the tree trunks. Min. radial distance also expressed the nearby presence of a tree or some other elements. In the case of Steinplatz, the decision tree model predicted the impact of Min. radial distances, where the prediction stated that most of the sitting activities occurred if the Min. radial distance is 0.97m or less. It can be explained that people in Steinplatz preferred to sit in a location where there is a nearby tree or some other elements. This fact can also be referenced to the psychological aspect of choosing a sitting location within public places. As existing literature claimed, people prefer to seek psychological support from the surroundings where they sit. The presence of a nearby tree or any other features can be considered as an element of psychological support in this regard.

4.5 Analysis Limitations

Every analysis has limitations or restrictions, which might be considered a severe issue if the error rate is too high. The data analysis method used in this research is also associated with several errors or shortcomings. It is necessary to have a general idea regarding the flaws to evaluate the accuracy of an analysis. To specify the accuracy of this decision tree method or binary classification test, two statistical measures of the performance are defined as Sensitivity and Specificity. Sensitivity can also be defined as True Positive rate, which measures the proportion of correctly identified positives within the performance model (i.e., the proportion of those who have some condition (affected) who are correctly identified as having the condition). Specificity can be denoted as the True Negative rate, which measures the proportion of correctly identified negatives with the same performance model (i.e., the proportion of those who do not have the condition (unaffected) who are correctly identified as not having the condition). There

are several terms such as "true positive," "false positive," "true negative," and "false negative," which refer to the test outcome and the accuracy of the classification. For example, if the condition is a disease, "true positive" referring the amount of "correctly diagnosed as diseased" whereas "false positive" expresses "incorrectly diagnosed as diseased," "true negative" refers to "correctly diagnosed as not diseased," and "false negative" indicates "incorrectly diagnosed as not diseased." Therefore, if a test's sensitivity score is 97% and the specificity is recorded as 92%, the rate of false negatives is 3%, and the rate of false positives is 8% for the analysis.

4.6 Accuracy of the Decision Tree Model

The absolute accuracy of the decision tree models was calculated to evaluate the relevance of the analysis method used in this research. All the models for individual public spaces and combined public places were evaluated in accuracy, sensitivity, and specificity. More or less, all the models performed decently, as the statistics showed (table 2).

Table 2: Prediction model performance.

	Accuracy/Misclassification	Sensitivity	Specificity
Wartburgplatz	88%	70%	92%
Teutoburgerplatz	88%	40%	98%
Steinplatz	79%	41%	100%
All combined	83%	33%	97%

5 CONCLUSIONS

5.1 Summary and Reflections on the Research

This research aimed to identify the significant design features influencing people's sitting behavior in public places and investigate the rationale of sitting place preferences over the different public space locations. Based on the quantitative analysis, it can be concluded that several key features mostly manipulate the public sitting phenomenon. Depending on these features, several other environmental and psychological factors contribute to the overall scenario. The research outcome helps establish the influence of design features such as sitting benches and open green areas having significant impacts on people's sitting preferences in public places. Results showing that having sufficient provision of sitting furniture in the right spot and a good amount of open green area within any public place should increase the possibility of people's sitting to a great extent. This stationary behavior would help enhance the vibrance of public places as it is known that people make the places.

Complementing these features, several other factors such as distances to the nearest pavements and roads play an essential role in defining this public sitting phenomenon. The research showed how people are influenced to prefer a sitting location nearby to circulation or pathway. In the same process, people tend to avoid sitting near a road in a general setting to avoid noise. Having

a good visual provision within the sitting would also add value to the facts as the study investigated that most of the preferred sitting locations in a public place have greater visible access to the surroundings. This always refers to the existing thoughts on the phenomenon of public sitting as people are always interested in others. So, sitting activities are always influenced where there is provision to see what other people are doing. Adding on top, the research outcome also explored the consequences of having psychological comfort within the sitting locations controlling the sitting preferences. People tend to seek psychological support from the surrounding environment. This research discovered that a nearby tree, edge, or other features provide psychological comfort to the users while sitting.

5.2 Recommendations for Future Research

Based on these conclusions, the features influencing public sitting behavior might come in handy while designing a public space. Public spaces can often be used as an instrument to increase social bonding and cohesion, but they remain underutilized most of the time. Due to the design, location, proper management, and use process, a public space might not utilize its full potential to develop social interaction between different user groups. Further investigation can be initiated from this research by searching relations between sitting and social interaction in public places. The survey results of both the sitting and talking activities are closely related as talking activities were tracked in more than 90% of the cells where sitting occurred. So, 'talking/Social interactions' can be highly related to 'sitting' activities and their influencing factors. This further scope of research offers richer interpretation and implications since the results can be considered a measure of active social interaction and help explain further the consequences of sitting activities in public places in the field of urban and landscape planning. If people stay longer in a place, there are more possibilities of social interaction through diverse activities. Future studies could be addressed to understand better the implications of these results to evaluate the importance of sitting activities within public places to generate social interaction and cohesion among people. How sitting influences social interaction within a public space could be an interesting topic of further investigation on the follow-up.

5.3 Contribution of this Research

This research explored the importance of sitting activities in developing a vibrant and attractive public place by discovering the relationship between prominent design features that mainly influence sitting behavior. The outcome established relations between the prominent features manipulating sitting activities and their implications based on the existing literature and researches. The study provided a scientific outlook regarding the public sitting phenomenon and its significance on other spatial behavior of a public place. It also investigated the cause and effects of the most influential design features on people's sitting behavior in public places to set up a bridge between the existing studies and their implications on practical life.

The trained decision tree model can be applied in the design process to predict if any given location will be used for sitting activities or not. Moreover, it can give the designer feedback

before the design is built. Mistakes can be easily corrected in the design phase instead of improving dis-functional public spaces afterward.

As the design of a public space influences the public life quality of its inhabitants significantly, it is necessary to handle the design process and include the characteristics that help to evolve a public space into a good one. This research would help provide an overall idea to the designer regarding the features that directly influence sitting activities in public spaces. The outcome of this research should help the designers and planners implement the strategy of designing a vibrant public place, ensuring the best sittable locations and the ideal combinations of design features. So, the outcome of this research could be implemented further to increase a public space's attractiveness and participant's willingness to use it. That means this scientific research can be used as a tool for diagnosing sitting phenomena in public spaces by soliciting feedback about any given locations of a public space for sitting friendly public place design and promoting social contact between people from multicultural backgrounds and ethnicity to ensure a better urban and social environment.

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