Simulation of Pedestrian Behaviour As Design Criteria for University Teaching Buildings

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Abstract

Pedestrian movement in the built environment is clearly shaped by the nature of a particular environment, with human behaviour shaped by the design of structures. To understand and analyse pedestrian behaviour while moving in open spaces at a very fine scale, simulation modelling is an essential tool. The aim of this paper is to study the impacts of the built environment on pedestrian behaviour and to understand the ways people walk on university campuses. Further, another aim of the study is to show through our simulation model how physical variables affect pedestrian behaviour and thus establish criteria for designing walkable campuses. In a first step, through video recordings, pedestrians were observed walking from the gates of a university campus to teaching buildings. The recorded data was then transformed into numerical values such as speed, delay, and walking type. In a second step, data about campuses were collected, such as walkway length, width and level, and number of pedestrian walkway intersections. Nest, using multiple regression, a mathematical simulation model was designed to test environmental impacts on walking behaviour. In this way, the impacts of the built environment on pedestrian behaviour were revealed.

Key Words: Built environment, simulation model, university campus, walkability, walking behaviour

Introduction

University campus design has been given attention in recent years, with growing interest globally. Campus design has become an important issue for designers, planners, governmental officials, and even advertisers. Studies of urban structures have observed that the design of university campuses is based on many important design criteria such as site properties, climatic factors, functional criteria, circulation criteria, and transportation criteria. Concerning transportation, nearly 75% of transportation inside university campuses depends on walking. When compared to vehicular or public transportation on university campuses, priority is given to walking due to environmental, economic, health, and social factors (Capolongo et al., 2015). Together, these factors mean that walkability and the pedestrianization process are basic criteria for the design of university campuses (Abdullah and Al-Qemqachi, 2017).

Walkability has become an intense topic of research in the planning and design of the built environment throughout the world. Urban planners and designers tend to design walkable communities for their various benefits related to public health, sustainability, economy, and social life (Zakaria et al., 2013) (Sallis, 2009). Therefore, there is a growing need for knowledge about walkability within the built environment. To understand walkability, Abley mentions the definition of walking from the Oxford University Press Dictionary, which states '…to move or go somewhere by putting one foot in front of the other on the ground, but without running'. He then defines 'walkability' as '…the extent to which walking is readily available as a safe, connected, accessible and pleasant mode of transport' (Abley, 2010). Walkability is also defined as a measure that identifies the perceived friendliness, aesthetics, and safety of an urban

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space (Alix Tier, 2014), as well as the extent to which the built environment supports and encourages walking by providing for pedestrian comfort and safety, connecting people with varied destinations within a reasonable amount of time and effort and offering visual interest in journeys throughout the network (Southworth, 2005). Walkability is a measure of how friendly an area is for walking (Rebecchi et al., 2019)... Factors influencing walkability are important concepts in sustainable urban design and are related to the design of urban space. They include the presence or absence and the quality of footpaths, sidewalks, and other pedestrian rights-of-way; traffic and road conditions; land use patterns; building accessibility; and safety (Shelton, 2008) (Lo, 2011). According to a 2010 study, walkability is a key factor in having a sustainable transportation network. It measures the friendliness of an area and considers many subjective factors in the process. Walkable areas help promote sustainable transportation, which encourages transportation systems that have a low impact on the environment and increases the physical health and safety of a community (Christian et al., 2010). Livi and Clifton (2004) mention some aspects of walkability, including functional, safety, aesthetics, destination, safety and security, comfort and convenience, continuity, system coherence, and attractiveness. Seilo (2004) describes walkability as a measure of the urban form and the quality and availability of pedestrian infrastructure contained within a defined area. Pedestrian infrastructure includes amenities developed to promote pedestrian efficiency and safety such as sidewalks, trails, and pedestrian bridges.

Human Behaviour in the Built Environment

A discussion of behaviour requires considering a complex array of patterns and differences. Behaviour can be defined as the sum total of the psyche, including impulses, motivations, wishes, drives, instincts, and cravings (Sadock & Sadock, 2007). Behaviours range from measurable and observable manifestations of humans' internal states, to impulsive reactions to fear or pain, to intentional or unintentional responses to an array of factors. Behaviour is also defined as the range of actions and mannerisms of individuals, organisms, systems, or artificial entities in conjunction with themselves or their environment, which includes other systems or organisms as well as the physical environment. It is the response of the system or organism to various stimuli or inputs, whether internal or external, conscious or subconscious, overt or cov

ert, or voluntary or involuntary (Minton & Khale, 2014). The concept of human behaviour refers to the manner in which human beings act and conduct themselves; the ways in which they work and play, react to the environment, perform their functions and responsibilities, and do things in their daily lives (Reisinger, 2009). Human behaviour is influenced by a variety of environmental factors that play an important role in development and are also influenced by human behaviour themselves. The various environments that influence human beings can be examined at different levels. The first level, called 'micro', has the most immediate influence on individual behaviour and development. It includes the family, local neighbourhood, community institutions, peer groups, and specific family and community cultures. The second level, called 'meso', includes the intermediate influences of social institutions, professional groups, and industries involved in activities such as transportation, entertainment, and health. The third level, called 'macro', includes the influences of national regions and changes in the local economy, politics, culture, social system, or demographics. The fourth and highest level, called 'supra', has the most remote influences on individual behaviour and includes the impacts of international regions and global changes. At this level, the behaviour of individuals, families, communities, and societies is influenced by international and global trends in economics, information technology, politics, and socioeconomic systems and their development, religion, and ethnicity (Reisinger, 2009). Well-designed and well-managed built environments contribute to the generation of economic, social, and environmental value in combination with other factors and can have a positive influence on behaviour and feelings. Human behaviour, experiences, and social interactions in built environments are believed to be the result of mental processes that are influenced by the different features of such environments. These features may be physical, social, cultural, or sensory but they share the power to affect people's behaviour and experience in the public realm. Therakomen (2001) shows that built environments comprise not only physical elements like buildings, streets, plazas, squares, and trees but also the people moving and acting on them and vice versa. According to Therakomen (2001), any single element in an urban environment can potentially mean any number of things, depending on how it is acted upon by other elements and how it reacts to them. How much of the space is used, in part, depends on the space's own design. But a partial influence of the design upon the use of space, which in turn,

depends on who is around to use that space and when. It also depends on uses of other spaces beyond that space.

Walking Behaviour

Walking behaviour is considered an important factor for measuring the walkability level of the built environment. The present world is built towards the supremacy of the automobile, as motorized vehicles are considered as the main mode of transportation. Although there are distinct advantages to this, it makes walking difficult and often unpleasant. Further, walking activities have a close relationship with health. Encouraging people to walk on a regular basis is considered the best way of providing the greatest gains for the health of the general population (Cleland, Timperio, & Crawford 2008). Walking behaviour is very complex, as it involves different aspects and types of activities. Most people walk and at some points in history and even the present day, walking is the only way a majority of people can conduct their daily life. Therefore, it is a human behaviour performed by human beings on a daily basis. Different kinds of walking activities vary in terms of goal, effort, frequency, and duration, among other aspects (Choi, 2014). Humans have the ability to determine their own movement and can walk without depending on others. Different types of people exhibit different sorts of walking behaviour, as there are many factors that affect humans' walking behaviour. According to Mohamaddan (2010), walking behaviour refers to how people perform their walking and is related to the time taken for moving from one place to another, deciding on the walking type and direction, avoiding collisions with each other, and other behaviours that occur during walking. There are many possible factors used to measure walking behaviour. According to Daamen and Hoogendoorn (2003), walking behaviour can be measured by:

– Pedestrian walking speed
– Pedestrian walking direction
– Walking experience
– Group formation

Empirical Study and Methodology

In 1968, the University of Sulaimani, the first university in Iraq's Kurdistan region was founded in the city of Sulaymaniyah (UOS, 2002). The university has two campuses. The old campus, which was established in 1968and comprises 175,000 m2, is located in a central part of the city and has a compact master plan design. The new campus is located on the outskirts of the city and comprises 1.9 million m2. In this study, pedestrian behaviour data were collected for 750 students walking for six teaching building by observing pedestrians through video recordings. All data were then converted to numerical values. Video was recorded from 3rd December 2017 to 21st January 2018 at 8:00 am to 9:00 am, which is the peak hour of pedestrians walking on the campus. After completing the data collection process for pedestrian walking for each selected teaching building, data for the six selected buildings shown in Figure 1 were analysed.

Figure1. Master plan of Sulaimani University new campus showing the selected teaching buildings: B1; College of Language, B2; College of Science, B3; College of Basic Education, B4; College of Engineering, B5; College of Fine Arts, B6; College of Fine Arts, G1: Main Entrance, G2: Secondary Entrance), Source: (Directorate of Building Construction- Presidency of Sulaimani University)

Data Calculation and Results

The independent variables for the spatial distribution of university campus teaching buildings vary in terms of their degree of influence on pedestrian behaviour. Table 1 presents the variables related to the syntactic characteristic of the spatial arrangement of teaching buildings on university campuses.

Table 1: Empirical variables related to pedestrian and campus organisation

Type of Variable	Variable		Symbol	Definition
Non-Physical Variables (Dependent Variables)	Pedestrian Speed		**S**	Average speed of pedestrians from the campus gates to the teaching buildings (m/s)
	Delay		**D**	The average delay (sec.) of pedestrians from the campus gates to the teaching buildings
	Walking Type	No. of Pedestrians Walking in Group	**PG**	Pedestrians walking in a group on walkways
		No. of Pedestrians Walking Alone	**PA**	Pedestrians walking alone on walkways
Qualitative Physical Variables (Independent Variables)	Walkway Length		**WL**	Length of a walkway from the campus gates to the teaching buildings
	Walkway Width		**WW**	Width of a walkway from the campus gates to the teaching buildings
	Level of the walkway (Height)		**WH**	Difference in height (level) of a walkway from the campus gates to the teaching buildings
	Intersections	Walkway with Walkway	**WIW**	The intersection of a walkway with another walkway
		Walkway with Street	**WIS**	The intersection of a walkway with a street
		Walkway with Open Space	**WIO**	The intersection of a walkway with an open space
Quantitative Physical Variables (Independent Variables)	Furniture Number		**FU**	The number of furniture items on a walkway to each building
	No. of Trees		**T**	The number of trees on a walkway to each building
	Walkway Finishing		**FI**	Existence of walkway finishing or concrete face

Pedestrian Speed (S)

Pedestrian speed is the speed of pedestrians when walking in an urban environment. Pedestrians walk at different speeds, but the standard average speed of a pedestrian is about 1.33 m/s (O'Connor & Donelan, 2012). This variable was measured through direct observation of pedestrians walking in the university campuses through video recordings, and the time pedestrians needed to reach their destination was then calculated. The speed for each pedestrian is found according to the following method:

$$s = d/T \quad ……. \quad (1)$$

Since the speed at which pedestrians walk differs, mean speed must be found. For this purpose, the mean speed of 125 pedestrians was determined for each building was calculated with the following equation:

$$\bar{s} = \frac{\Sigma s}{n} \qquad ……. \ (2)$$

Delay (D)

Delay is the average delay of a pedestrian at standard walking speed, which is 1.33 m/s. This variable demonstrates that the factors that affect pedestrian speed also affect pedestrian behaviour. Minimizing pedestrian delay on walkways and streets increases pedestrian convenience and reduces the likelihood that pedestrians will walk on walkways and cross the streets in an unsafe manner (NACTO, 2009).

This variable is measured by determining the average speed of a pedestrian for a particular case and comparing this figure to the standard pedestrian speed (1.33 m/s) to calculate the average delay for each case per time unit (sec).
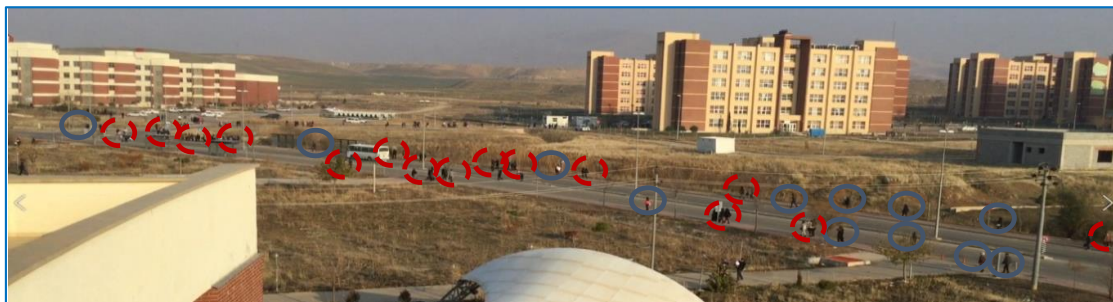
Figure 2. Sample of direct observation of pedestrians walking to College of Languages (B1). The number of pedestrians walking in groups and walking alone was can be calculated

⌐⌐⌐ Pedestrians Walking Alone (GA)   ⌐⌐⌐ Pedestrians Walking in a Group (WG)

Walking Type

Pedestrian behaviour while walking in an urban environment determines the walking type. There are two walking types:

1. Pedestrian Walking in a Group (PG): Walking in a group is the most common pedestrian behaviour and the most common walking type. Pedestrians walking in a group are mainly driven by self-organised processes based on local interactions. While most studies of pedestrian behaviour consider only interactions among isolated individuals, up to 70% of pedestrians actually move in groups, such as friends, couples, or families walking together (Moussaidd et al., 2010). Figure 2 shows the different types of pedestrians walking in groups.
2. Pedestrians Walking Alone (PA): Pedestrian walking alone is another type of pedestrian behaviour and walking type. Pedestrians walking alone travel at a faster speed than those walking in a group. Studies have shown that the majority of pedestrians do not walk alone but in groups (Coleman, 1961; Aveni, 1977; Moussaidd et al., 2010).

These two walking types were measured through direct observation of each sample in a specific period time using video recordings. The number of pedestrians walking alone and the number walking in groups to each building were then calculated. Figure 2 shows pedestrians walking alone.

Walkway Length (WL)

A walkway is a continuous, unobstructed, and mainly raised passage or path for pedestrian circulation that provides accessibility and connects different sections in an environment (WSDOT, 2016). Walkways are the main paths that pedestrians use when walking. The walkway length on the university campus is the length of each walkway from the nearest gate of the campus to each teaching building measured in metres. The value of this variable was determined for each teaching building on the university master plan. Figure 3 shows the length of the walkways pedestrians use to reach their destinations.
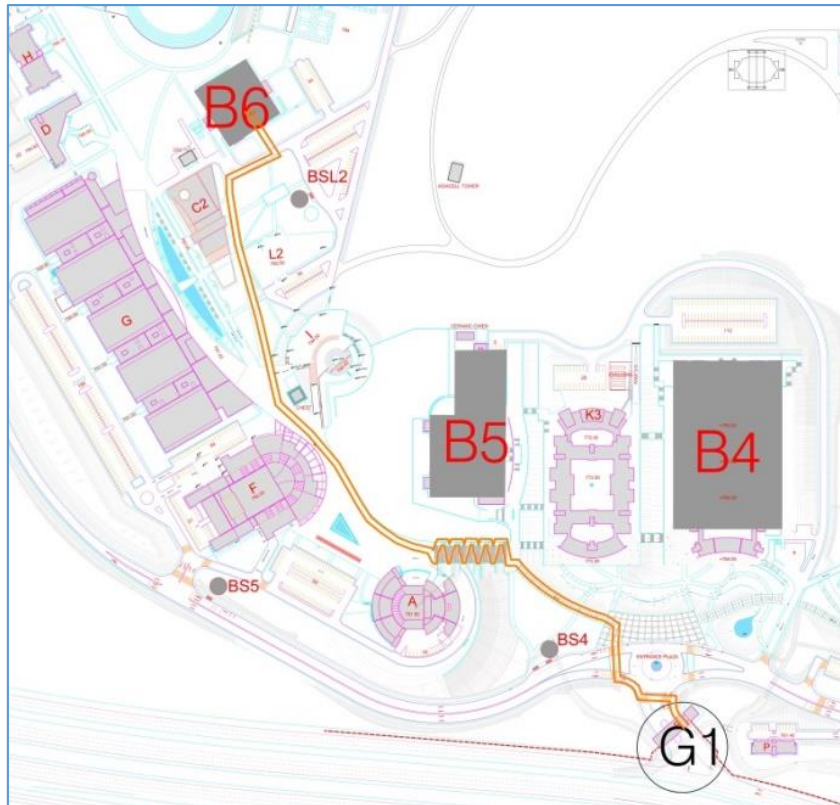
Figure 3. A sample of the walkway length on campus masterplan from main gate G1 to B1 (Directorate of Building Construction- Presidency of Sulaimani University)

Walkway Width (WW)

 Walkway width is another dimension of walkways and is measured in metres. The width of walkways on the university campus also affects walkability. Walkway width affects pedestrian behaviour as the width changes the amount of personal space, which in turn affects behaviour. The width of walkways changes according to the usage of the walkway and the type of environment (WSDOT, 2016). The value of this variable was manually measured using a standard metric tape measure for each teaching building on the master plan of each case.

Walkway Level (Height)

The level or slope of a walkway is the difference in height between the starting and ending points. Walkway level is considered critical in designing walkways for walkability as pedestrians should feel comfortable when walking on walkways with moderate height. According to the National Association of City Transportation Officials, a walkway's running slope should be no greater than 5% (NACTO, 2009). The value of this variable was determined for each case on the master plan for each university campus.

Walkway level affects pedestrian behaviour as any increase in the level reduces walking speed, which has an effect on walking behaviour.

Intersection

 An intersection is a junction in a walkway designed for a specific purpose, which then continues to the destination. Walkway intersections change the properties of walking based on their design. In urban environments, there are transportation networks with walkways that intersect different elements, including the following:

1. *Walkway Intersecting Walkway (WIW):* This represents the intersection of a walkway with any other walkway. This variable affects pedestrian behaviour as pedestrians change their walking mode at intersections due to other pedestrians walking on the intersecting walkway. This variable is measured by counting the number of walkways intersecting the main walkway for each case.
2. *Walkway Intersecting Street (WIS):* This represents the intersection of a walkway with streets on the university

campus. At such intersections, pedestrians must continue walking, sometimes on the street, to reach their destination. This variable is measured by counting all streets intersecting walkways of the selected buildings.

3. *Walkway Intersecting Open Space (WIO):* This represents the intersection of a walkway with an open space or a building's surrounding landscape. This variable is measured by counting the number of open spaces or building surroundings that intersect a walkway.

Figure 4. A sample showing a walkway intersecting a walkway (WIW), street (WIS), and open space (WIO) on the new campus of Sulaimani University

This variable affects walking behaviour because pedestrians change their walking mode due to other activities or other pedestrian flows around open spaces. Figure 4 shows a sample of walkway intersections for the selected case study. After recording video of pedestrians for the selected teaching buildings on the university campus, data were analysed and compiled in Table 2 for use in later statistical analysis.

Table 2: Collected and calculated data related to the pedestrians on the new campus.

Selected Teaching Buildings	Days	WL	WW	WH	WIW	WIS	WIO	Fu No.	T. No.	F I	S	D	PG. No.	PA. No.
	Day 1	910	1	19.3	8	4	4	3	63	1	1.2	-0.13	235	205
	Day 2	910	1	19.3	8	4	4	3	63	1	1.22	-0.11	217	210
	Day 3	910	1	19.3	8	4	4	3	63	1	1.2	-0.13	227	208
B1	Day 4	910	1	19.3	8	4	4	3	63	1	1.2	-0.13	244	215
	Day 5	910	1	19.3	8	4	4	3	63	1	1.19	-0.14	237	214

	Day 1	445	1	18.1	4	4	1	0	31	1	1.27	-0.06	271	289
	Day 2	445	1	18.1	4	4	1	0	31	1	1.28	-0.05	237	354
B2	Day 3	445	1	18.1	4	4	1	0	31	1	1.27	-0.06	254	273
	Day 4	445	1	18.1	4	4	1	0	31	1	1.27	-0.06	268	311
	Day 5	445	1	18.1	4	4	1	0	31	1	1.27	-0.06	264	281
	Day 1	565	1	18.1	8	5	2	2	83	1	1.26	-0.07	194	204
	Day 2	565	1	18.1	8	5	2	2	83	1	1.27	-0.06	172	201
B3	Day 3	565	1	18.1	8	5	2	2	83	1	1.28	-0.05	205	186
	Day 4	565	1	18.1	8	5	2	2	83	1	1.23	-0.1	191	214
	Day 5	565	1	18.1	8	5	2	2	83	1	1.25	-0.08	173	208
	Day 1	212	1	5	4	2	2	4	125	1	1.31	-0.02	213	264
	Day 2	212	1	5	4	2	2	4	125	1	1.3	-0.03	211	317
B4	Day 3	212	1	5	4	2	2	4	125	1	1.32	-0.01	192	297
	Day 4	212	1	5	4	2	2	4	125	1	1.32	-0.01	205	333
	Day 5	212	1	5	4	2	2	4	125	1	1.31	-0.02	212	268
	Day 1	445	3	16.7	6	4	3	9	82	1	1.14	-0.19	105	81
	Day 2	445	3	16.7	6	4	3	9	82	1	1.14	-0.19	95	75
B5	Day 3	445	3	16.7	6	4	3	9	82	1	1.14	-0.19	94	68
	Day 4	445	3	16.7	6	4	3	9	82	1	1.13	-0.2	101	92
	Day 5	445	3	16.7	6	4	3	9	82	1	1.15	-0.18	92	71
	Day 1	905	5	30	15	5	9	57	222	1	1.06	-0.27	102	131
	Day 2	905	5	30	15	5	9	57	222	1	1.06	-0.27	77	210
B6	Day 3	905	5	30	15	5	9	57	222	1	1.05	-0.28	86	206
	Day 4	905	5	30	15	5	9	57	222	1	1.05	-0.28	91	173
	Day 5	905	5	30	15	5	9	57	222	1	1.07	-0.26	81	192

Simulation Modelling

Advanced mathematical modelling in the form of multiple regression was used to simulate pedestrian behaviour on the university campus. The mathematical model was used to show the influence of different variables on pedestrian behaviour with the aim of establishing design criteria for university campus design. Regression analysis is predictive modelling technique used to investigate the relationship between dependent and independent variables. A mathematical equation expresses the relationship between two variables by assessing previous values and predicting future ones. This method is also used for regression of a dependent variable (Y) and independent variables (i.e., X1, X2, … Xn); thus, it predicts independent variables that affect the dependent variable. Linear regression models are generally expressed as follows:

$$Y = \alpha + b1\,X1 + b2\,X2 + b3\,X3 + \ldots + bn\,Xn \qquad \ldots\ldots\ldots (3)$$

where Y is the predicted or expected value of the dependent variable; X1 through Xn are (n) distinct independent or predictor variables; α is the intercept or constant, which is the value of Y when all of the independent variables (X1 through Xn) are equal to zero; and b1 through bn are the estimated regression coefficients (beta). Each regression coefficient represents the change in Y relative to a one-unit change in the respective independent variable.

Using (SPSS 20), two models were created for simulating pedestrian behaviour:

Model for Pedestrian Walking Behaviour

To use mathematical models for both pedestrians walking alone and pedestrians walking in a group, the numerical values of both dependent and independent variables shown in Table 2 were analysed through multiple linear regression. The

methods were measured to ensure each variable helped achieve the study aims and to establish the structural properties of university campus design that affect pedestrian behaviour.

Table 3 shows that the independent variables affecting pedestrian behaviour (PA) are statistically significant according to a t-test (P ≤ 0.05).

Table 3: Regression coefficient results for pedestrians walking alone

Model			Standardized Coefficients		Unstandardized Coefficients	t	Sig
Dependent Variable	Independent Variable	Constant	Beta	Std. Error			
		209.102					
	WW		-0.6	4.827	-37.356	-7.74	0
	WH		0.508	1.864	4.853	2.604	0.01
PA (Pedestrians Walking Alone)	WIW		1.645	4.314	38.293	8.877	0
	WIS		-0.811	8.326	-61.872	-7.431	0
	WIO		-1.301	5.21	-48.195	-9.25	0
	Fu		-0.348	0.578	-1.517	-2.623	0.01
	Fi		0.233	23.956	36.981	2.544	0.012
				49.057			

The following multiple linear regression equation was obtained using the standardized beta:

YPA = 209.102 - 0.6WW + 0.508WH + 1.645WIW - 0.811WIS - 1.301WIO -0.348Fu + 0.233Fi ……………… Model (1)

Table 4 shows that the independent variables affecting pedestrian behaviour (PG) are statistically significant according to a t-test (P ≤ 0.05).

Table 4: Regression coefficient results for pedestrians walking in a group

Model			Standardized Coefficients		Unstandardized Coefficients	t	Sig
Dependent Variable	Independent Variable	Constant	Beta	Std. Error			
		209.972					
	WW		-0.875	2.696	-50.798	-18.603	0
	WH		0.421	1.041	3.751	3.603	0
PG (Pedestrians in Group)	WIW		1.129	4.06	24.527	6.041	0
	WIS		-0.226	7.836	-16.06	-2.049	0.042
	WIO		-1.27	4.904	-43.873	-8.947	0
	T		0.652	0.137	0.788	5.767	0
	Fi		1	15.682	148.087	9.443	0
				36.356			

The following multiple linear regression equation was obtained using the standardized beta:

YPG = 209.972 – 0.875WW + 0.421WH + 1.129WIW - 0.226WIS - 1.27WIO + 0.652T + 1Fi …................. Model (2)

Conclusion

1. The university campus as a built environment has many designed physical elements that affect pedestrian walking behaviour, such as walkways, paths, streets, landscapes, and teaching buildings.
2. Walkways are one of the most important designed elements in any built environment and are effective for formulating pedestrian walking behaviour.
3. Walkway design characteristics such as walkway length, walkway width, walkway level, and the number of intersections with walkways have different impacts on walking behaviour.
4. The university campus as a designed built environment affects pedestrian walking behaviour based on the design and characteristics of pedestrian infrastructure.
5. Walkways have qualitative and quantitative characteristics, each has different impacts on pedestrian walking behaviour on university campuses, where some characteristics positively affect walking behaviour and others negatively affect it.
6. A walkway's qualitative and quantitative characteristics affect pedestrian behaviour on university campuses differently. The study has concluded two mathematical models showing the impact of different independent variables (i.e., walkway characteristics) on pedestrian behaviour. The two models are as follows

For pedestrians walking in a group, the model is:
YPG = 209.972 – 0.875WW + 0.421WH + 1.129WIW - 0.226WIS - 1.27WIO + 0.652T + 1Fi

For pedestrians walking alone, the model is:
YPA = 209.102 - 0.6WW + 0.508WH + 1.645WIW - 0.811WIS - 1.301WIO - 0.348Fu + 0.233Fi

According to the simulation models, independent variables affect pedestrian behaviour (dependent variable) in different ways:

First Category: These independent variables include walkway intersections, which is a quantitative characteristic of walkways. The independent variables that affect pedestrian behaviour the most of the following intersection types:

WIW: Walkway intersecting walkway (WIW) is the most influential variable with a beta weight of (1.645) and a direct relationship.

WIO: Walkway intersecting open space is the second most influential variable with a beta weight of (- 1.301) and an inverse relationship.
WIS: Walkway intersecting street is the third most influential variable with a beta weight of (- 0.811) and an inverse relationship.

Second Category: These independent variables include the qualitative characteristics of walkways that have medium effects on pedestrian behaviour. These are:

WW: Walkway width affects pedestrian behaviour (dependent variable) with a beta weight of (- 0.6) and an inverse relationship.
WH: Walkway height affects the independent variable with a beta weight of (0.508) and a direct relationship.

Third category: This category includes other significant independent variables with lesser effects on the dependent variable that are still significant. These are:

Fu: The number of walkway furniture items affects the dependent variable with a beta weight of (0.348) and a direct relationship.

Fi: Walkway finishing affects the dependent variable with a beta weight of (0.233) and a direct relationship.

Acknowledgements

Nomenclature

D	is the delay
Fi	is the finishing of the walkway
Fu	is the furniture number on walkway
PA	is the pedestrians walking alone
PG	is the pedestrians walking in group
WH	is the difference in walkway level
WIO	is the walkway intersecting open space
WIS	is the walkway intersecting street
WIW	is the walkway intersecting walkway
WL	is the walkway length
WW	is the walkway width

Subscripts

d	is the distance walked
n	is the number of pedestrians' speeds
s	is the pedestrian Speed
$\bar{s}$	is the mean speed
$\sum s$	is the sum of all pedestrian speed
T	is the time need for the pedestrian to reach destination

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