Profit follows Form: when an Architect Solves Tenanting Problem

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Abstract

Tenanting decision making has always been a critical success factor for a shopping mall and the tenanting process is strongly influenced by the foot fall of customers. Traditional practices exclude architectural input in the tenanting decision-making process. Locational decisions and area allocation undoubtedly have economic implications but also have spatial ramifications, but the process is handled by the mall management or leasing professionals without considering the architect's perspective. This research investigates the relationship between footfall and spatial configuration in virtual shopping mall layouts using visibility graph analysis and agent-based simulations administering a multi-platform spatial network analysis software, Depthmap X. This analysis establishes the relationship between footfall and spatial configurational variables (metric mean shortest path angle and through vision). Gate count or foot fall has already been identified as a key parameter in influencing the area allocation of and total revenue generation from a store. Now that the gate count is expressed as a function of spatial configurational variable, the revenue generation from and area allocation of a particular store can be expressed as a function of spatial configurational variable. This research establishes the supremacy of spatial configuration in influencing the profitability of a shopping mall. The spatial design is, therefore, not an end, rather a potential tool for strategic decision making. It is not only form and function which are interrelated but also form and profit.

Keywords: Architectural economics; Space Syntax; shopping mall; Tenant-mix; Visibility Graph Analysis.

Introduction

Form and function are two widely discussed components in architectural discourse, while, Hillier et al., (1984) asserted that, "scientific approaches to architecture usually avoid the issue of building form, preferring to focus on function" (Hillier et al., 1984 p.61) and ascribed the reason for this predilection towards functionality as it is scientifically more tractable. The functions of a building are categorized as spatial organization of activities, climate regulation, symbolic expression and economic viability (Hillier & Leaman, 1976). This categorization of architectural functions provides a rubric for explaining architectural quality and that quality is measured in terms of the level of support extended by the later three functions in attaining spatial organization of activities. Van der Voordt & Wegen (2007) portrayed “architectonic quality” in terms of the co-presence of aesthetic, functional, technical and economic aspects of the concerned built space. Economic function is, therefore, embodied into the basic definition of architectural quality.

Architectural economics deals with the relationships between the built form and economics and triggered studies with wide applicability, ranging from selection of structural systems or materials to space branding or stimulating tourism through iconic architecture (Piatkowska, 2012). Primary domain for these studies mostly encompasses optimization of construction and operational expenses (Knippers et al., 2021; Yashchenko et al., 2024). Attributes of the built form in influencing economic performances are mostly overlooked. Even when the built form did attract research attention, it was limited to the influence of aesthetic quality on rental income (e.g. Cheung & Yiu, 2022; Zhang et al., 2024). The role of spatial configuration in inducing “architectural economics” necessitated a scientific investigation.

The shopping mall is one built form where economic sustenance is paramount for its very existence (Salleh et al., 2023), therefore, it can be a fertile area of study to explore the influence of spatial configuration in influencing economic performances. By definition, a shopping mall is the agglomeration of different retail and other commercial establishments, managed as a single property (ICSC, 2004, p.1). The sustenance of a shopping mall depends on tenanting decision making (Salleh et al., 2023); i.e., locating stores of varied type and size, dealing with diverse merchandise for distributing the footfall evenly within the mall and creating favorable atmospherics to entice people into shopping activities (e.g. Hunter, 2006; Brito, 2009; Chebat et al., 2010). Different categories of tenant stores have different capacities of rental payment (Xu et al., 2022; Spasenić et al., 2023). Tenanting decisions cannot focus only on the profitability of the operator, as poorly performing stores will eventually move out leading to high vacancies. A proper tenant mix should fulfil the simultaneous objective of profit maximization for the individual tenant stores as well as the entire shopping mall. Tenanting decisions are nothing but location and allocation of areas of stores and are principally spatial but have implicit economic implications.

The design development of a shopping mall requires input from different stakeholders. The architect is entrusted with the development of an aesthetically pleasant and functionally justified spatial envelope. That spatial envelope is transformed into a functional shopping space with the intervention of mall management and leasing management professionals. Interestingly, the responsibility of strategic decision-making regarding tenanting and rent allocations lies with the mall management and leasing professionals. The potential of spatial configuration remains on the periphery of this decision-making process. This research attempts to identify the impact of built form on economic function by focusing on the relationship between spatial parameters and the economic functionality of a shopping mall.

Background

Economics of Shopping Malls

The 'ultimate tenant mix' has always been a retailers' El-dorado for profit maximization. Academic enquiry on tenanting decision-making started gathering momentum from the 1990s and the researchers tried to explain the differentiation of rental potential based on the logic of inter-store externalities (e.g. Sim & Cheok, 1989; Benjamin et al., 1992; Brueckner, 1993; Eppli & Shilling, 1995; Pashigian & Gould, 1998; Zhang et al., 2023; Lundgren et al., 2023). The inter-store externality also guides the location based on the logic of which store gets benefitted or suffered in terms of footfall for proximity with some other store types. The tenanting and rental decisions are becoming increasingly significant and should be taken into consideration at the very early stage of design for shopping centers (e.g. Beyard & O'Mara, 1999; Boix-cots et al., 2024). Studies on tenant-mix policy of shopping malls have been mostly prescriptive, lacking in scientific rationale.

Despite the popularity of inter-store externality, the few configurational theoreticians (e.g. Brown, 1991; Fisher & Yezer, 1993). tried to explain the logic behind tenant-mix through movement of customers within a shopping mall. The movement or foot fall was considered an endogenous variable.

Predicting Navigation and the Grammar of Configuration

Movement or navigation has been identified as a determining factor for profitability of a shopping mall; therefore, its measurement may be considered as an important tool for understanding tenanting decision making. Several models, like queuing models (e.g. Hoogendoorn & Bovy, 2004), transition matrix models (e.g. Helbing et al., 2001), stochastic model (e.g. Ashford et al., 1976), and route choice model (e.g. Hoogendoorn & Bovy, 2004) have explained pedestrian movement within built structures.

Unlike other models, Space syntax analyses spatial configuration and generates numeric tags for basic elements of configuration so that it can be correlated with footfalls for understanding social encounters and co-presence. The technique can be applied to layouts of buildings or urban areas for universal description of spatial configuration in quantitative terms. Graph theory is resorted to for analyzing the interconnection between constituent units of a spatial configuration. The character of the constituent unit depends on the geometrical abstraction based on the pertinent parameter of enquiry. Axialty, convexity and isovist analysis are done for respective parameters of movement, interaction and visibility.

In the Axial Line Analysis method, configurational modelling of a spatial arrangement is done through inserting the minimum number and the longest lines of sight that represent all possible routes for movement within the plan layout. The axial map (the map of the fewest and longest lines of sights or axial lines) (e.g. Ostwald & Dawes, 2011) thus produced, is analyzed to determine the configurational property of the network. Similarly, for convex analysis, the entire space is broken down into mutually exclusive and collectively exhaustive convex spaces such that no convex space possesses an obtuse angle. These units are then analyzed for syntactic properties. There is ample evidence to suggest that human movement in a built space is governed by the syntactic properties of space (e.g. Hillier et al., 1993; Haq & Zimring, 2003; Hölscher et al., 2012)

Research in environmental psychology has established that within a built environment, patterns of visibility and accessibility are stronger predictors of movement than normal metric measures such as distance (Hillier et al., 1996), Turner & Penn (1999), Turner et al. (2001) and Choi (1999). Psychologist Ittelson (1978) and planner Appleton (1975) have also supported the importance of visibility in explaining behavioral interactions with the environment and this has been verified for artificial organisms by roboticists (Yeap & Jefferies, 1999).

Though the concept of visibility was indirectly adopted in the definition of axial lines and convex spaces, the Visibility Graph Analysis (VGA) has been introduced as a research tool for the study of architectural spaces (e.g. Batty et al., 1998; Turner & Penn, 1999; Turner, 2001; Turner, et al., 2001; Desyllas & Duxbury, 2001), including studies in wayfinding (Turner, 2001; Doxa, 2001) and pedestrian movement (Batty et al,1998; Turner & Penn,1999; Turner et al., 2001 and Desyllas & Duxbury, 2001) .

A study investigating the correlation between movement and visibility in urban pedestrian space (Desyllas & Duxbury, 2001) demonstrated the efficacy of the VGA method over the Axial Line Method wherein the VGA studies yielded the better correlation (r2= 0.625) compared to the axial method (r2= 0.429). Similar results were obtained from a department store (Turner & Penn, 1999) where VGA representation yielded a higher correlation than axial line method. Studies on pedestrian flow and visual accessibility of a public area also found a strong relationship by employing the VGA method (Parvin, 2007).

For visibility graph analysis, a grid overlaid on the plan diagram of the considered spatial configuration. The analysis depends on the concept of intervisibility (i.e., unobstructed straight line) between the center points of those grids. Every center point is connected to the entire set of center points that con be connected using unobstructed straight line. Several analyses can be done on that. Every measurement has spatio-behavioral significance (Tahar & Brown, 2003). The measures can be broadly categorized as "visibility measures" and "metric measures". Like other methods of syntactic analysis, visibility measures can be both global and local depending respectively on the entirety of the spatial configuration or a part of it. Global measures include "integration", "mean depth", "entropy", for example while local measures include "control", "clustering coefficients" to name a few. In addition to the visibility measures, VGA yields few metric measures, i.e., 'metric mean shortest path distance', 'metric straight-line distance' and 'metric shortest path angle'.

Apart from the above-mentioned measures, 'through vision' has been introduced in depth map software tool for analysis of VGA (Turner, 2007a). Through vision (TV) is defined for a "dense grid visibility graph". In contradiction with other methods of VGA, this analysis takes into consideration all the points of a "dense grid" and can be expressed by the number of inter visibility lines through that grid (e.g. Turner et al., 2001) and correlate well with bipedal human movement in a straight line (e.g. Peponis et al., 1990; Haq, 2003; Dalton, 2003). The Through vision values correspond well with pedestrian behavior both at an urban level ($r2= 0.62$, Barnsbury Area, Penn & Dalton, 2018) and at a building level ($r2= 0.68$, Tate Britain Gallery, Hillier et al., 1996).

Regarding a metric measure for describing movement, the straight-line distance alone is the spatial property in determining movement in malls (Carter & Vandell, 2005) but studies in the field of space syntax suggest that angular analysis gives a 'realistic' notion to people's movement (Turner, 2001) compared to metric straight-line distance. This paper takes the two parameters metric mean shortest path angle (MMSPA) and through vision (TV) in describing indoor navigation pattern.

Methodology

VGA and Agent-based Simulation

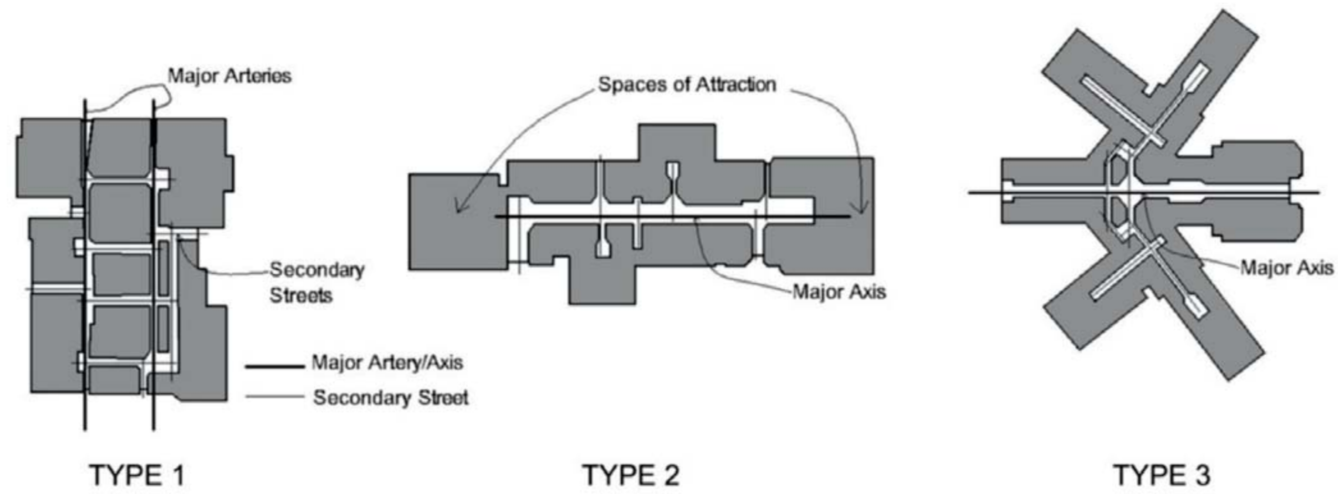
Measuring the influence of spatial configuration on navigation patterns within a shopping mall is difficult in real life situations as other factors influencing navigation cannot be eliminated. To test a ceteris paribus assumption, therefore, virtual built environment has been adopted (i.e., Reffat, 2008; Yan & Kalay, 2005). Research results exhibit a strong correlation between real and virtual data sets that puts virtual reality as a powerful tool in predicting navigation (e.g. Franz et al., 2005; Orellana & Al Sayed, 2013; Boustila et al., 2016).

Pen & Turner (2001) and Turner & Penn (2002) applied agent-based simulation in virtual environments to predict navigation. They used Exo-somatic visual architecture agents in virtual built environments where these agents are endowed with visual information available from the visibility graph analysis of that space. The agents (automata) are computer programs that mimic humans with vision and act as a pedestrian should have in a real spatial configuration. As the automata have access to the VGA information of a virtual built environment, they abstract human within a space. They exhibit exploratory behavior, essential for a pedestrian in a shopping environment as they are empowered with autonomy (free to move in any direction) and cognitive power (visual) (e.g. Batty et al., 1998; Batty, 1999; Koh et al., 2008). The path selection logic relies on the choice of longest line of sight. Research results show that the correlation between agent-based simulation and real pedestrian data is significant ($r2 =0.76$, Turner and Penn, 2002; $r2= 0.67$, Turner, 2003).

Test Scenario: Layout Analysis

To test the relationship between the spatial configuration and navigation pattern within them different mall typologies have been used. Verdil (2009) identified four basic typologies as commonly used mall layouts: cartesian system, dumb bell, tree and hybrid combining the characteristics of two or more typologies. The hybrid typology is not considered in this research as there is no novelty in the spatial configuration. It uses elements of other typologies. The Cartesian system is essentially a grid network where the entire system can be decomposed into one or more major arteries and secondary arteries connected with the primary ones mostly at right angles with each other. In this arrangement small islands develop within the system. Dumb bell is the most popular shopping mall typology. Here a central axis plays a significant role with attractors or anchors at both ends. These anchors entice buyers, and smaller stores are arranged along the axis relying on the logic of impulse buying. Secondary streets, though they may exist in this arrangement, are mostly insignificant, they are not used as shopping streets. The tree system, as the name suggests, emulates a tree, where the main circulation axis resembles the tree trunk and secondary shopping streets are connected to the main trunk and resemble branches. Representative layouts of all the three mal typologies are shown in .

Figure 1:Shopping mall layouts with different typologies selected for analysis. From left, Type 1 (Cartesian), Type 2 (Dumbbell), and Type 3 (Tree)

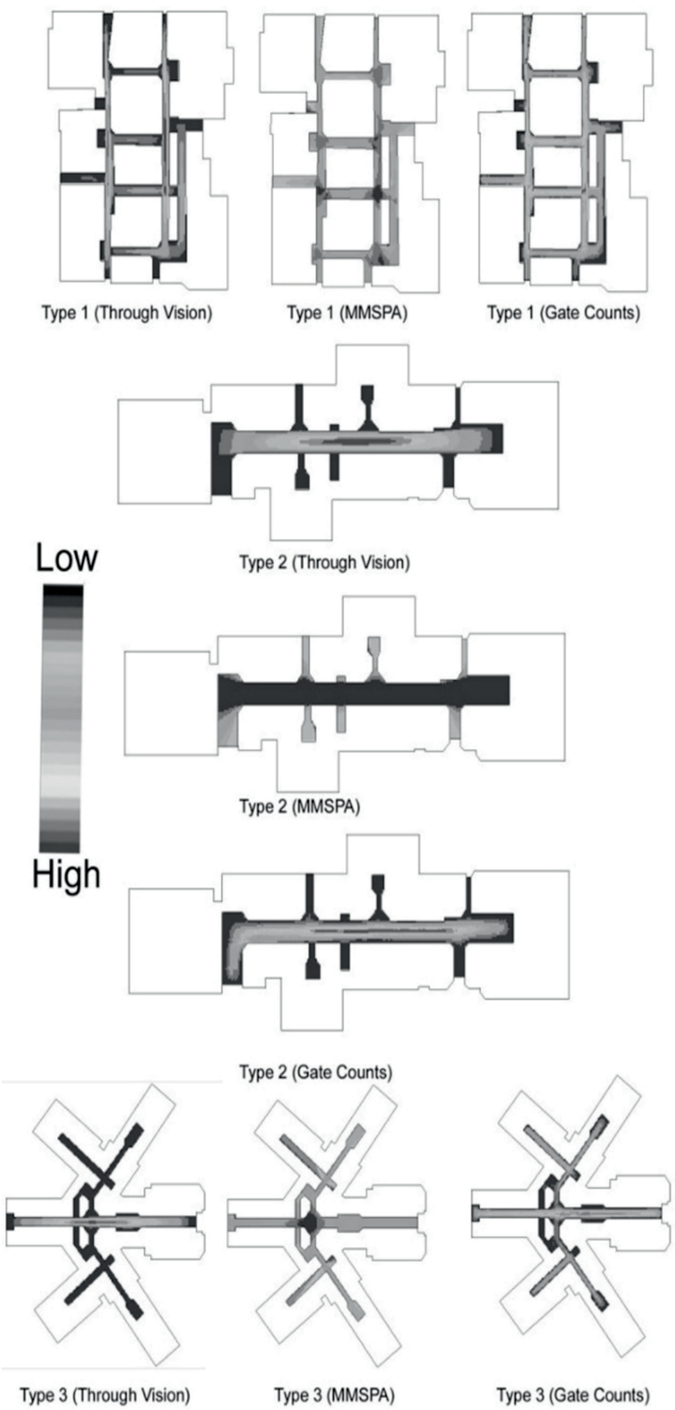


The mall typologies are drawn with equal gross leasable area and equal circulation area. That negates the overreliance on gross leasable area in classifying shopping malls. The spatial configuration is the only differentiator. The Depthmap X multi-purpose spatial networking analysis software (e.g. Varoudis, 2012; Turner, 2001) is used for this analysis. Depthmap X allows layouts to be imported in drawing exchange format (.dxf). Once imported, the internal circulation spaces of all the three typologies are filled with grids of 300 mm X 300mm. The visibility graph is run for the typologies for a radius of "n" (global measure). The agents are then released in all the typologies from random starting points. The field of vision of each agent is set at 15(fifteen) bins, an equivalent to 1700 field of vision. The step before turn decision values were set at 3 (three), as for standard agents/automata the result best correlates with natural movement patterns in buildings (Al_Sayed & Turner, 2012). The trials are recorded for 500 agents for a standard movement rule (Turner, 2007 b).

Results / Findings and Discussion

The visibility analysis for a radius of "n" for all the three virtual layouts provides the values of metric mean shortest path angle and through vision values along with other VGA measures of the corresponding layouts. The agent-based simulation analysis provides the gate count values at each grid of the corresponding layouts. The attribute maps of MMSPA and TV are shown in Figure 2.

Figure 2: Attribute maps of TV, MMSPA and footfall for the three typologies as shown in Figure 1



As we have values of MMSPA, TV (configurational variable) and foot fall (navigation variable), the relationship between them can be explored. The footfall values of every typology are plotted along the vertical axis with MMSPA and TV values of the corresponding layouts are plotted separately along the horizontal axis (Figure 3). Despite configurational differences, it is observed (Figure 3) that footfall decreases with increasing MMSPA values and increases with increase in TV values. From the two relationships it can easily be concluded that the footfall (g) can be expressed as a function of TV/MMSPA.

Figure 3: Relationship of through vision and metric mean shortest path Angle with gate Counts for the three typologies shown in Figure 1

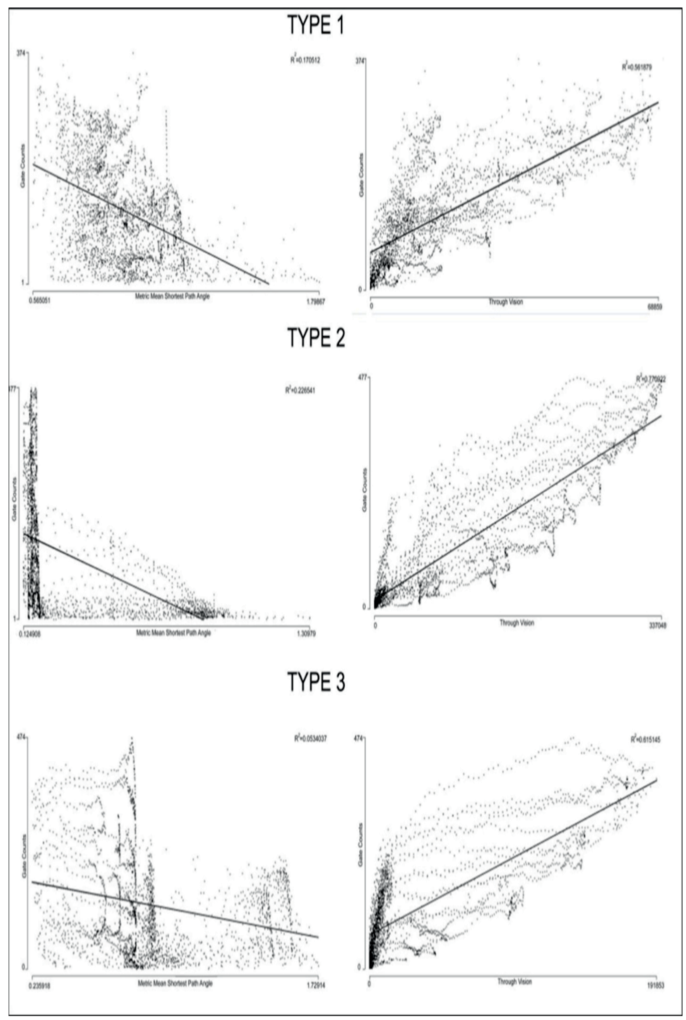
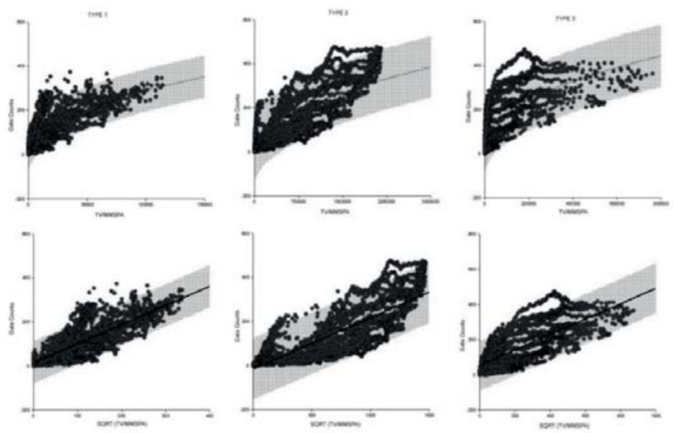


Figure 4: Model fit of the three shopping mall typologies without (Above) and with transpose (Below)



The best fit relationship between footfall (g) and TV/MMSPA is ascertained (Figure 4), by transposing the square root operation on the dependent variable (TV/MMSPA) (Figure 4). The result of the regression analysis suggests that Adjusted r2 value for the configurations (Type 1: r2= 0.613, Type 2: r2= 0.698, Type 3: r2= 0.541) substantially or moderately describes the model (Hair et al., 2011) whereas ANOVA test (Table 1) suggests the regression model predicts the dependent variable significantly well.

Table 1: Analysis of Variance a of the Models for three typologies

Model		Sum of Squares	*Df*	Mean Square	*F*	Sig.b
Type1	Regression	13130307.932	1	13130307.932	5506.477	.000
	Residual	8290978.087	3477	2384.521		
	Total	21421286.019	3478			
Type 2	Regression	40561412.803	1	40561412.803	8085.797	.000
	Residual	17532241.391	3495	5016.378		
	Total	58093654.193	3496			
Type 3	Regression	20939970.273	1	20939970.273	4042.027	.000
	Residual	17784866.169	3433	5180.561		
	Total	38724836.443	3434			
	a. Dependent variable= gate counts b. p< 0.001					

Table 2: Summary of t-test, Constant and Coefficients

Typology			T	Sig.b
Type 1	Constant	16.063	9.899	.000
	Coefficient	.864	74.206	.000
Type 2	Constant	(-15.169)	-7.500	.000
	Coefficient	.231	89.921	.000
Type 3	Constant	49.074	27.479	.000
	Coefficient	.442	63.577	.000
b. p < 0.001				

The t-test (Table 2) result signifies that both the constant and coefficients are highly significant (p<0.001). Considering the best fit of the relationships, the footfall (g) can be described as a function of spatial configuration and expressed mathematically for all three types:

Type 1: $g = 16.063 + 0.864 * \sqrt{(TV/MMSPA)}$

Type 2: $g = (-15.169) + 0.231 * \sqrt{(TV/MMSPA)}$

Type 3: $g = 49.074 + 0.442 * \sqrt{(TV/MMSPA)}$

The general relationship can be expressed as:

$g = \sqrt{(TV/MMSPA)} * \alpha + \beta$ (where α is the coefficient and β is the constant)

From the above equation, it can be established that footfall (g) at a particular location is a function of TV and MMSPA. Both the variables are spatial configurational variables. Therefore, footfall can be expressed as a function of spatial configurational variables. In other words, it can be said that foot fall is not an endogenous variable, rather a result of configuration pattern. Change in configurational variables will impact the foot fall when other factors remain constant. Carter and Vandell (2005), Carter &Allen (2012), and Deb & Mitra (2020) found that the total revenue from a tenant store in a shopping mall is a function of footfall near it. As revenue is a function of foot fall (Deb & Mitra, 2020) and foot fall is a function of spatial configurational variable, revenue can be expressed by a function of spatial configuration variables when other factors remain constant.

Conclusions and Recommendation

Classical retail research relied on the movement of customers (i.e., footfall) within shopping centers and deliberated metric distance as the only spatial parameter affecting footfall and dictating rental and locational differences (e.g. Carter & Haloupek, 2002; Carter & Vandell, 2005). The research outcomes were targeted at retail professionals. On the contrary, the space syntax method, though explains the configurational logic of spatial behaviours, but remains confined to architectural and urban design studies. Thus, a gap exists between in-store movement studies and spatial configuration analysis. Too few studies applied space syntax measures as independent variables in retail environments (Deb & Mitra, 2018) but the sole purpose of those enquiries were the subjective assessments of spatial configuration and not the physical characteristics of configuration. This gap can be bridged through the analysis of retail spatial configurations and its strategic implications in predicting and initiating movement, which in turn influence profitability.

Adoption of the Space syntax approach, and use of VGA methods, as described in this paper, can predict movement within a shopping mall which can then be moderated to the advantage of mall management for allocating appropriate tenant stores in that area (conservative use of space) and introducing design interventions for enhancing footfalls (generative use of space). This is what mall management aspires towards

As the revenue from a store can be expressed in terms of customer movement, and movement can be expressed in terms of spatial parameters, this study relates form and economic function of the shopping malls, and the findings emerge as a potential tool for tenanting decision making. It is not only the form and function which are interrelated but also form and profit. In conclusion, economic function can be explained and influenced by spatial configuration variables and space planning can be used as a strategic decision-making tool and not simply as an accommodator of functions.

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