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Economic Rationale for Spatial Configuration of Shopping Malls

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***Abstract*— The purpose of this paper is to bridge the gap between retail research results on customer movement in shopping malls and importance of Visibility Graph Analysis in predicting indoor navigation pattern for better understanding of store space allocation, store location and tenanting decision making.**

***Key Words*—Shopping Mall, Tenanting Decision, Through Vision, Visibility Graph Analysis.**

I. Background of the Research

Studies on retail have paid more emphasis on inter-store externalities than on the ‘spatial logic’ in determining lease-price discrimination and store place allocation (e.g. Benjamin *et al.*, [1]; Brueckner [2]; Eppli & Shilling [3]; Pashigan & Gould [4]). These studies attempted to identify an ‘ultimate tenant mix’ as an useful tool for the mall management. Other researchers have argued that the notion of ultimate tenant mix is a vague one (Carter & Allen, [5], quoting Stambaugh, [6]); some notions are just better than others (e.g. Des Rosiers *et al.*[7]).

During the same period, when studies on inter-store externality were gaining popularity, some studies focused on circulation or movement of customers within shopping centres (e.g. Brown [8]; Fisher & Yezer [9]; Sim & Way [10]). They relied on the concept of bid-rent model to explain and analyze the location decision of stores. The explanations for difference in customer distribution were based on the adaptation of central place theory (Christaller [11]), and not on the logic of spatial arrangement. An understanding of spatial configuration within a shopping mall can aid considerably in optimizing design and improve store space allocation and tenanting decision. This paper integrates retail research wisdom and space syntactic measures to illustrate the efficacy of space design as a strategic decision making tool, instead of just an accommodator of functions.

II. Research Objective

Retail researchers have focused on the movement of customers within shopping centres and considered metric distance as the only spatial aspect influencing rental differences (e.g. Carter & Haloupek [12]; Carter & Vandell [13]; Ingene & Ghosh[14]). No study was conducted with characteristics of spatial configuration as independent variables. Thus, there is a gap between the outcomes of the in-store-movement genre of research, which have not been actualized in spatial configuration terms and the architectural input, which, in-spite of dealing with a design-centric holistic view remains insufficient. As space syntax measures predict movement, (e.g. Hillier et al. [15]; Hillier et al. [16]) and influencing movement is almost all of what mall management aspire towards, space planning can be used as a strategic decision making tool in shopping malls. The specific objective of the study is to consider the spatial configuration factors in rationalizing location and tenanting decision in shopping malls.

III. Methodology

A. Bid Rent Analysis

Sim & Way [10] and Brown [8] suggested that a bid-rent model could explain the location decision of stores within a planned shopping centre. Carter &Vandell [13] used an economic model, which is an adaptation of Alonso’s model in ‘closed city’ form. This model is used in this paper to describe profit function for an individual store and solved under the condition of maximization, to establish the relationship of optimal area and rent with customer density. The model is extended to include the profitability of the entire store and to understand the concept of ‘critical density’.

B. Visibility Graph Analysis and Agent based Simulation

For understanding the influence of visibility in navigation, visibility characteristics were studied using visibility graph analysis by syntax 2D and Dethmap X software tools for four mall typologies (Verdil [17]) of equal leasable and service area. Pedestrian movement simulation is done using multi-platform DepthmapX spatial network analysis software (Varoudis [18]; Turner [19]). The agents were released for the analysis from the selected entry points at a release rate of 0.1 per time step. The field of view is of each agent is set at 15 bins, an equivalent to 170^0. The step before turn decision values were set at 3, as for standard agents/automata the result correlates best with natural movement patterns in buildings (Al-Sayed & Turner [20]). The trials are recorded for 500 agents for a standard movement rule.

IV. Analysis

By solving the bid rent equation, it is found that tenanting, rent and store space allocation decisions depend on the customer density distribution near the particular store within the shopping mall. Total rent from a store of a particular type can be determined from the relationship shown in Eq.1:

$$A.r = [\frac{C_F}{a.d^{k_3}.(p - C_O).k_1.(1-k_2)}]^{\frac{1}{k_2}}[(a.d^{k_3}.(p - C_O).k_1.\frac{1-k_2}{C_F})^{\frac{1}{k_2}} - C_M] \quad (1)$$

Where, in a planned shopping centre with *n* number of stores,
p_i = Average price per unit of goods sold for that store; a_i = Quantity of goods sold per purchasing customer visit; A_i = Area of the store; $f_i(A_i)$ = Proportion of customer traffic per unit of store area, that actually leads to purchase; d_i= Density of customer traffic at store; C_F= Fixed cost C_{Oi}=Operating Cost or cost of goods sold; C_{Mi}= Maintenance cost (maintenance, utility, tenant finish-out); r_i= Rent per unit area of the store; $f(A).A= k_1.A^{k_2}$, where $0< k_2<1$, considering decreasing returns to scale; k_3 is the density elasticity of demand.

From the effect of different variables on total rent per store, inclusion of a new category of store (when customer density falls below a critical point for that previous store (1) and the leasable area is still vacant) is beneficial only when, C_F and (p-C_O) more than and C_M, k_1,k_2,k_3 less than the previous category of stores to cut the curve of the former's from below. Figure 1 explains the logic.

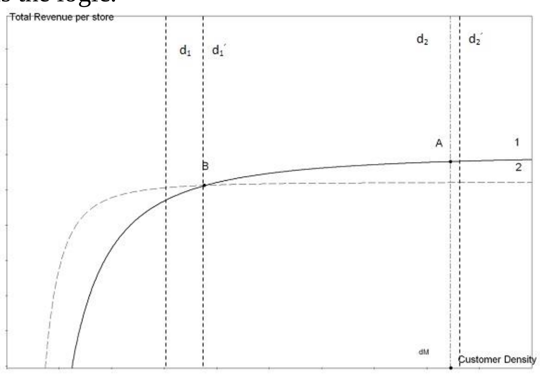

Figure 1 The logic of introducing new store types in a shopping mall

From the VGA and Agent Based Simulation, it is found that, customer density of a particular location is a function of Through Vision (*v*) and metric mean straight line distance (*t*) from the access point, such as,
$d=f(t,v)$, where, $\delta d/\delta t<0$ and $\delta d/\delta v>0$.

V. Findings And Discussion

The space and rent allocation decision of a shopping mall can be explained through a conceptual model under the logic of profit maximization:

$$Max\sum_{i=1}^{m} A_i.r_i + \sum_{i=m+1}^{n}(A_j.r_j - \frac{\sum_{i}^{m} A_i.r_i(ford_1^{'}tod_2^{'}) - \sum_{i}^{m} A_i.r_i(ford_1tod_2)}{\sum_{j=m+1}^{n} A_j}.A_j) - (FC + A_c.MC)$$

Subject to:

$$\sum_{i=1}^{m} A_i + \sum_{j=m+1}^{n} A_j = A_{LE}$$

$A_{LE} + A_c = A$ (Total built Area of the shopping mall)

$$d_i + d_j \le D^*$$

$$\sum_{i}^{m} a_i.f_i(A_i).A_i.d_i^{k_{3i}} + \sum_{j=m+1}^{n} a_j.f_j.(A_j).A_j.d_j^{k_{3j}} \le Q^*$$

$$A_i^L \le A_i \le A_i^U$$

$$A_j^L \le A_j \le A_j^U$$

$$d=f(t,v)$$

$$A_{LE}, A_c, A_i, A_j, r_i, r_j, d, a, FC, MC \ge 0$$

Where, $i=1,2,3,...m$; $j=m+1,...,n$ and where, $d_1^{'}$ (with anchor lower density)> d_1 (without anchor lower density) and $d_2^{'}$ (with anchor upper density) ≥ d_2 (without anchor upper density); and A_i= Area of the Non-anchor stores; r_i= Rent per unit area of the non-anchor Stores ; A_j= Area of the Anchor stores; r_j= Rent per unit area of the Anchor Stores; *FC*= Fixed Cost of the mall; A_c= Common Area; *MC*= Maintenance cost

VI. Conclusion

Space Planning, thus, is not an end, rather a tool for strategic decision making concerning location and rent of stores in a shopping mall based on through vision values and metric mean straight line distance of the configuration. It is not only 'form' and 'functions' that are closely related but also 'form' and 'profit'.

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