Teleshopping and the dynamics of urban retail systems : some numerical simulations

CHAPTER 16

Teleshopping and the dynamics of urban retail systems: some numerical simulations

• Aloys BORGERS, Michel GUNSING, Harry TIMMERMANS

I. – Introduction

It is now well-known that innovations may have dramatic effects on existing equilibria in spatial systems. They have the power to force systems far from equilibrium, creating new structures and equilibria. It is this very fact that has stimulated the increasing interest in spatial dynamics (see e.g. Harris and Wilson, 1978; Beaumont, Clarke and Wilson, 1981; Clarke and Wilson, 1983; Fotheringham and Knudsen, 1986; Birkin and Wilson, 1989; Oppenheim, 1986,1988; Lombardo and Rabino, 1989).

An important new innovation in retailing is teleshopping. It offers people the ability of staying at home. Experiments with teleshopping technologies have recently been set up in many countries, and still other projects are planned to start within a couple of years. Although everyone believes teleshopping will have some effect on the existing retail structure, opinions vary as to the intensity and nature of such effects. Some professionals seem to believe that teleshopping will only play an important role for some consumer groups. For example, Davies and Reynolds (1986) have suggested that three types of consumers may gain benefit from this new technology: high income households with little time for shopping; the elderly; people interested in technological developments in their own right and remote rural dwellers, but little, if any, empirical evidence exists to support this hypothesis. Teleshopping may be a blessing in that it may offer a solution to those people of low mobility or provision of retail facilities in rural areas with limited demand. Others (e.g. Keller and Rotach, 1988) seem to believe that the impact of teleshopping technologies may be more dramatic in that it detracts trade from existing shopping centres, and increases competition.

The aim of the present article is to gain more insight into qualitative changes that might occur in urban retailing systems as a result of the introduction of teleshopping technologies. A multinomial logit model describing the adoption rate of teleshopping is estimated and this model is used to simulate the effects of teleshopping within a hypothetical Christaller-type retailing system. The organization of this paper reflects this research objective. First, we will describe the model underlying the simulations. Then, in section 3, we will briefly report on the operationalization of the choice model, discussing methods of measurement, estimation procedures and estimation results. This is followed by a discussion of the rules implemented in the numerical simulations. The next section then summarizes the results of these simulations. A number of concluding comments are made in the final section.

II. – The model

Let there be given a study area, consisting of I residential zones and J shopping centres. Assume that each shopping centre, j, can be represented by a series of K attributes, X_{jk}, $k = 1,..., K$. Following random utility theory, we assume that consumers attach some utility U_j to each shopping centre j. This utility consists of two parts: a deterministic part, V_j, which accounts for the systematic utility and a random part, ε_j, which accounts for measurement error and random fluctuations. Furthermore, assume that the systematic part of the utility is a linear function of a shopping centre's attributes. Thus,

$$V_i = \sum_k \beta_k X_{jk} \tag{1}$$

The probability, $p_j^{(c)}$, that a random consumer will choose shopping centre j then equals

$$p_j^{(c)} = pr\ (U_j > U_{j'}) \qquad \forall j' \neq j \tag{2}$$

$$= pr\ (V_j + \varepsilon_j > V_{j'} + \varepsilon_{j'}) \tag{3}$$

If it is assumed that the εj are independently, identically Gumbel distributed, it follows that the probability of choosing the jth shopping centre is given by the well-known multinomial logit model :

$$p_j^{(c)} = \frac{\exp\ (V_j)}{\sum_{j'} \exp\ (V_{j'})} = \frac{\exp\left(\sum_k \beta_k X_{jk}\right)}{\sum_{j'} \exp\left(\sum_k \beta_k X_{j'k}\right)} \tag{4}$$

The possibility of teleshopping can be incorporated in the model in a straightforward manner. Assume that consumers also hold some utility for teleshopping and that this utility is some linear function of some characteristics of teleshopping. Let U_t denote the utility for teleshopping and let C_l ($l = 1, 2, ... L$) represent the vector of characteristics that define a teleshopping facility. Thus,

$$U_l = \sum_l \gamma_l C_l + \varepsilon_l \tag{5}$$

It follows that the probability that a consumer will choose teleshopping is given by:

$$p_t^{(c)} = \frac{\exp\left(\sum_l \gamma_l C_l\right)}{\exp\left(\sum_l \gamma_l C_l\right) + \sum_{j'} \exp\left(\sum_k \beta_k X_{j'k}\right)} \tag{6}$$

while the probability that a consumer will choose the j th shopping centre is given by:

$$p_j^{(c)} = \frac{\exp\left(\sum_k \beta_k X_{jk}\right)}{\exp\left(\sum_l \gamma_l C_l\right) + \sum_{j'} \exp\left(\sum_k \beta_k X_{j'k}\right)} \tag{7}$$

Because the probability of choosing some shopping centre is likely influenced by the distance separation between the consumer's place of residence and the shopping centre, and in addition, the probability of choosing teleshopping might be influenced by the provision of retail facilities in a residential zone, the above model should be disaggregated according to residential zones. Let d_{ij} denote the distance between residential zone i and the j th shopping centre. The probability p_{it} that a consumer located in residential zone i will choose teleshopping will be equal to:

$$p_{it}^{(c)} = \frac{\exp\left(\sum_l \gamma_l C_l\right)}{\exp\left(\sum_l \gamma_l C_l\right) + \sum_{j' \in A_i} \exp\left\{\left(\sum_k \beta_k X_{j'k}\right) - \theta d_{ij'}\right\}} \tag{8}$$

Likewise, the probability that a consumer located in residential zone i will choose shopping centre j will be equal to:

$$p_{ij}^{(c)} = \frac{\exp\left\{\left(\sum_k \beta_k X_{jk}\right) - \theta d_{ij}\right\}}{\exp\left(\sum_l \gamma_l C_l\right) + \sum_{j' \in A_i} \exp\left\{\left(\sum_k \beta_k X_{j'k}\right) - \theta d_{ij'}\right\}} \tag{9}$$

where A_i denotes the choice set associated with residential zone i.

Let us now assume that the average expenditure is denoted by e and that the population size of residential zone i is given by P_i. The total expenditure, E_i, in residential zone i is given by

$$E_i = P_i e \tag{10}$$

The distribution of the spending power in the shopping centres across the system is then given by

$$E_{ij} = P_i \, e \, p_{ij}^{(c)} \tag{11}$$

The turnover in shopping centre j, T_j, is thus equal to

$$T_j = \sum_i P_i \, e \, p_{ij}^{(c)}, \quad j \in A_i \tag{12}$$

while the turnover for teleshopping equals

$$T_t = \sum_i P_i \, e \, p_t^{(c)} \tag{13}$$

To model the retailers' behaviour, let us now assume that retailers in shopping centre j face some critical threshold D_j which reflects the minimum turnover required to stay in business. Assume that the total number of retailers located in some shopping centre j, N_j, is some multitude of this threshold. That is,

$$N_j = \text{FIX}\,(T_j \,/\, D_j) \tag{14}$$

where FIX denotes that the ratio is not rounded. This ratio reflects the basic model of locational behaviour, viz.

$$p_j^{(r)} = \begin{cases} 1, & \text{if } T_j \geq (N_j + 1)\, D_j \\ 0, & \text{otherwise} \end{cases} \tag{15}$$

The probability $p_j^{(r)}$ that a retailer will locate at centre j equals 1.0 only if the level of turnover in shopping centre j permits the opening of an additional shop. Equations (8), (13) and (15) suffice for modelling the dynamics of the retail system. Equation (8) can be used to predict the probability of choosing some shopping centre as a function of its attributes, the attribute of competing centres and the characteristics of teleshopping. Turnovers in shopping centres are then given by equation (13). These levels constitute the inputs for equation (15) which governs retailers' locational behaviour. In the present analysis, some additional operational decisions were made, but these are described later on when we discuss the numerical experiments.

III. – Operational decisions

The impact of teleshopping on a retail system was simulated for a hypothetical system. A four level Christaller-type system consisting of 37 central places was assumed. Consumer shopping behaviour was simulated for three product classes separately: clothing, packaged groceries and produce. These three product classes were assumed to be key products for hierarchical levels *A*, *C* and *D* respectively, *A* being the highest order centre. The values for the model's parameters were chosen as follows: expenditure was varied for the three product classes: it was assumed that the per capita expenditure for the three product classes was respectively fl 30,-, fl 300,- and fl 390,-. The expenditure for a product marginal for *B*-level centres was assumed to be fl. 160,-. These figures were chosen to be consistent with actual turnover levels as published in official Dutch statistics. These values were chosen such that the system is in equilibrium at the start of the simulations. The parameters of the choice model were derived empirically. A decompositional choice modelling approach was applied to estimate the parameters of the multinomial logit model. This approach is based on the assumption that an individual's utility for a multiattribute choice alternative can be uncovered by presenting her/him a series of choice sets consisting of multiattribute profiles and asking her/him to choose from each choice set the most preferred choice alternative. The use of this modelling framework involved the following steps.

First the attributes assumed to influence individual choice behaviour were identified. Ten attributes were selected for teleshopping, each of which was varied across three levels. Likewise, six attributes were selected to vary regular shopping options.

The second step in the modelling process involved the construction of an experimental design. A fractional factorial design of the 3^{10} design was created to vary the attribute levels of teleshopping. This design consisted of 27 hypothetical profiles of teleshopping services. Similarly, a fractional factorial design of the 3^6 design was constructed to vary the attributes describing hypothetical changes in their regular shopping centre. Choice sets were created by pairing at random without replacement treatments from both designs. A constant base alternative, described as "any other shopping centre" was added to each choice set. Respondents were requested to allocate some fixed budget across the three choice alternatives included in each choice set. This task was repeated for three product classes: produce, packaged groceries and clothing. To avoid fatigue, respondents were presented only nine choice sets. These sets resulted from blocking the design on the basis of the attributes that were considered most important. Reweighted iteratively least squares analysis was used to estimate the parameters of the multinomial logit model.

In the context of the present paper, we will not discuss at any length details of the survey nor the results of the analyses. These are reported elsewhere (Timmermans, Borgers and Gunsing, 1989). To simulate the effects of teleshopping, the estimated parameters were used to predict the utility of the various centres. It was assumed that the three product classes were typical for respectively *D*, *C* and *A* centres. The basic utility of each of these functional levels was then calculated by using the estimated multinomial logit model assuming that no changes have occured in these centres. The utility of *B* centres was calculated by averaging the utilities of the *A* and *C* centres.

The advantage of using a Christaller-type system relates to its simplicity. However, it is well-known (see e.g. Beavon, 1977; Timmermans, 1980) that the system is based on some theoretical inconsistencies. To increase the validity of the numerical simulations, we therefore introduced a level-dependent attractiveness function which monotonically increased with hierarchical level. This was accomplished by weighting the estimated utility values of the product classes, the weights depending upon the functional-hierarchical level of the shopping centre. The distance decay parameter was set to -0.25, -0.5, -1.0, -2.0 for products typical for hierarchical levels *A* to *D* respectively. These values were used to simulate a base-line development of the retail system. The results are portrayed in figure 1 which shows that after three iterations the system reaches an equilibrium that deviates slightly from a classical Christaller-type hierarchy.

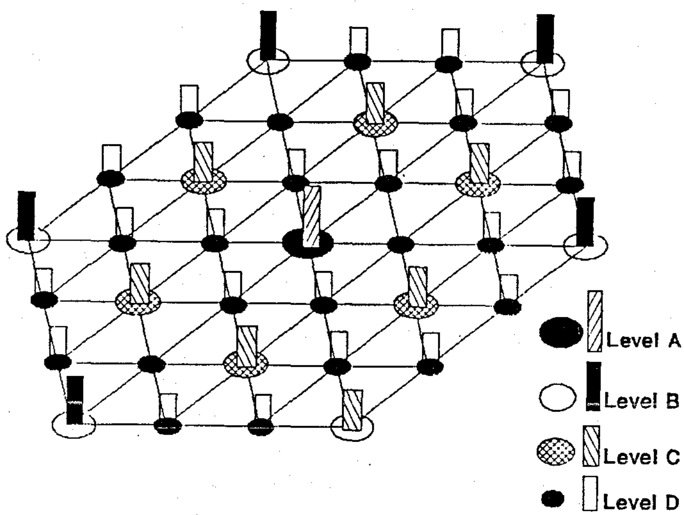

Figure 1. – Baseline development.

Having estimated the choice model, the effects of the introduction of teleshopping on the retail system can be simulated. These simulations were performed according to the following rules. First, the initial parameter values and the estimated choice models are used for calculating turnover levels in the shopping centres. Next, the model simulates the opening or closure of stores. One way to proceed would be to compare for each shopping centre separately the threshold values with estimated turnover levels and use equation (15) to decide on the opening or closure of stores. However, this procedure would imply that more stores are closed than necessary as indicated by the total turnover in the entire spatial system. Therefore, it was decided to calculate first the total number of stores that needs to be closed given the total expenditure in the system and then simulate which shopping centre is involved by drawing at random from a distribution that is proportional to the difference between turnover and threshold. Threshold values were arbitrarily set to fl. 583.200,-, fl. 1036.800,-, fl. 648.000,- and fl. 280.800,- for *A* to *D* centres respectively. These figures were chosen such as to be consistent with the expenditure figures. It was assumed that in order to open a store these figures should be 10% higher. The opening or closure of stores may change the functional-hierarchical level of a shopping centre and hence its attractiveness which in turn leads to changes in consumers' utilities and hence their choice probabilities. This procedure was repeated in a series of iterations.

IV. – Results

Before discussing the results of the numerical simulations, it is important to place this study in the wider context of spatial dynamics and emphasize certain properties of the simulations that differentiate the present study from others and exert some influence on the results. These properties should be kept in mind when interpreting the results of the numerical simulations.

First, although we started with a classical Christaller-type urban system, it should be evident that some of its properties were lost after initializing the system. Of course, the problem with using Christaller-type systems is that their equilibrium properties result from rigorous assumptions of consumer choice behaviour and the multiplication of functions in central places. As soon as these assumptions are replaced by more realistic assumptions, as in the present study, the urban system loses some of its equilibrium properties.

Second, it should be realized that the urban system on which the numerical simulations are based is bounded. This implies that the introduction of teleshopping, which occurs only within the system, will exert some spatially differentiating effect in the sense that it will detract trade from the shopping centres within the system, but not from those located in external zones. Consequently, especially the shopping centres located at the periphery of the hypothesized urban system will experience extra competition as the utility of the centres located in the external zone remains stable, while the utility of the centres located within the system may decrease as a result of decreasing demand. This property may be considered a problem from a theoretical viewpoint, but is rather realistic if teleshopping indeed is not simultaneously introduced across space as should be expected.

Third, unlike many other studies of spatial dynamics, adjustments in the retailing structure are not continuous in the present study, but occur rather only if the turnover is less than the threshold. Hence, changes in the number of establishments and the functional hierarchical level of a shopping centre or central place only occur in discrete steps.

Keeping these considerations in mind, we can now discuss the results of the numerical simulations. To gain insight into the effects of the introduction of teleshopping in a retailing system, many scenarios were developed. Lack of space does prevent us from reporting on all findings. Hence, we will concentrate on three scenarios. The first scenario is based on the assumption that teleshopping will be generally introduced within the system. The second scenario is based on the assumption of a hierarchical top-down diffusion of teleshopping. The third scenario can be considered as a reverse of the second one: it is assumed that teleshopping will enter the retailing system at its lowest level and will then diffuse across the system to the higher level shopping centres. All three scenarios assume that the ultimate adoption of teleshopping facilities will be approximately 15%. This saturation level is derived from the empirical analyses underlying the present simulations. It is assumed that this level will be reached in 25 years, and that the adoption process can be described by the well-known S-curve. In operational terms, this meant that while keeping the estimated parameters of the utility function constant, the corresponding utility values for teleshopping were set such that the market share of teleshopping was approximately 15%. These parameter values were used for the year 2015; the values for the remaining years were calculated by intrapolating the utility values for teleshopping according to a logistic growth curve based on the standard cumulative normal distribution. The adjusted, estimated multinomial logit models were then used to predict market shares for the three product classes.

Scenario 1: Simultaneous introduction of teleshopping

The results of this scenario are portrayed in figures 2, 3 and 4. These figures demonstrate that after 10 years the turnover in the *A*-level centre for clothing is lower than its corresponding threshold, implying that the *A*-level centre lost this activity. Likewise, in the equilibrium situation, three *B*-level centres are lost. These centres are regularly located. One of the *B*-level centres drops to a *D*-level. *C*-level centres appear to be most stable. Finally, 12 *D*-level centres lose their activity, many of which are situated at the periphery of the hypothesized retailing system. The system reaches its equilibrium six years after the simulation period.

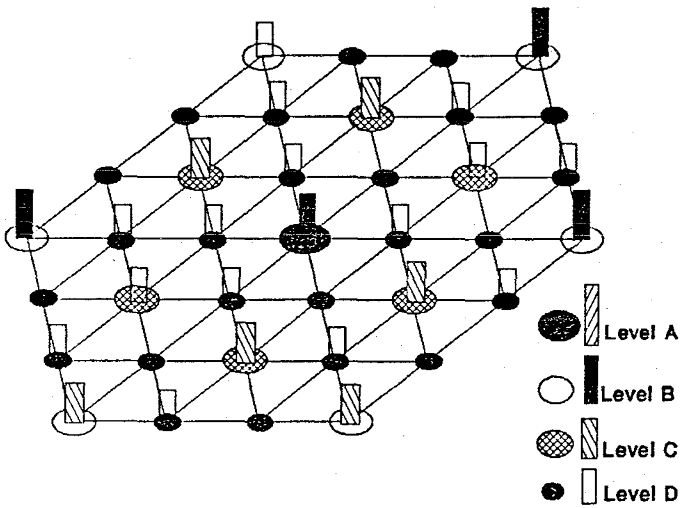

Figure 2. – Scenario 1. Simultaneous introduction of teleshopping, market share 15%.

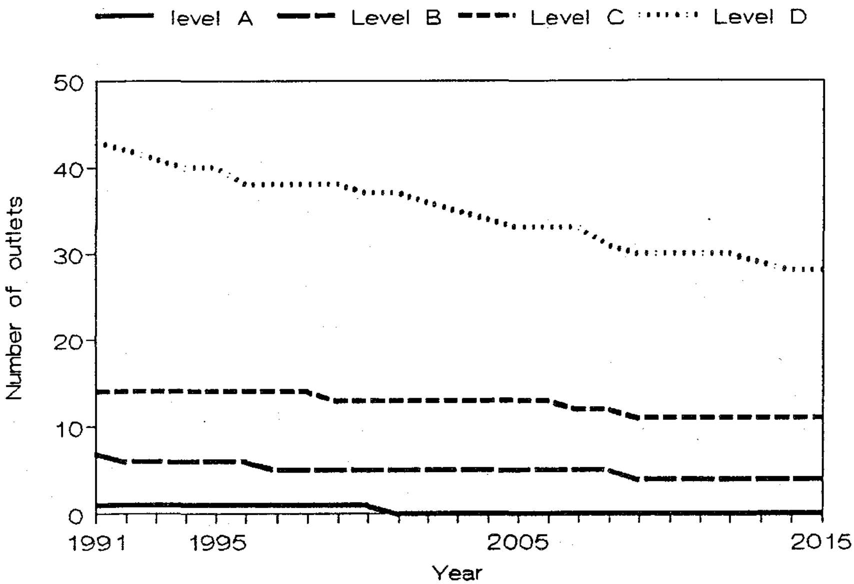

Figure 3. – Number of outlets per level (Scenario 1).

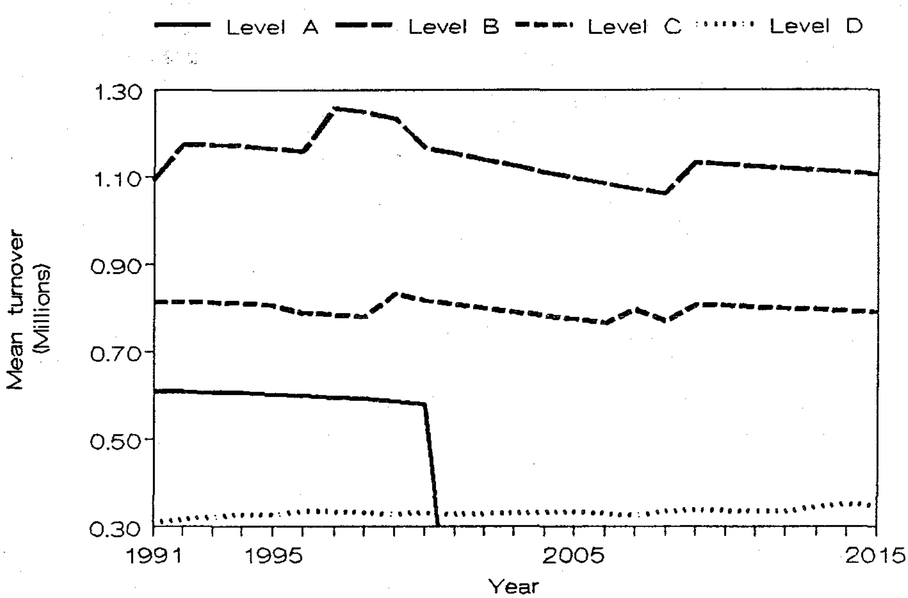

Figure 4. – Mean turnover per establishment (Scenario 1).

Scenario 2: Top-down hierarchical diffusion of teleshopping

Figures 5, 6 and 7 present the finding obtained for this scenario. Compared to scenario 1, the hierarchical diffusion from *A*-level centres to *D*-level centres results in more low level centres and less higher centres. In the equilibrium situation, there are three more *D*-level centres, and one less *C*-level centre. Like in the first scenario, the *C*-level centres are most stable.

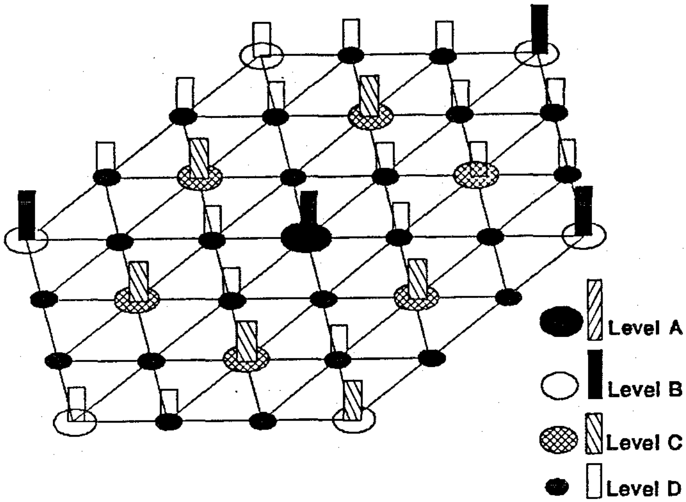

Figure 5. – Scenario 2. Top-down hierarchical diffusion of teleshopping, market share 15%.

Scenario 3: Bottom-up hierarchical diffusion of teleshopping

The results for the third scenario are portrayed in figures 8, 9 and 10. Comparing these results with those obtained for scenario 2 yields the following conclusions. First, as expected, the effect of teleshopping on *A*-level and *B*-level centres is delayed. Second, the number of *D*-level centres drops gradually in this scenario whereas in scenario 2 the effect of the introduction of teleshopping on *D*-level centres is noticeable much later. Third, similar results are obtained for *C*-level centres although the size of the effect is smaller and the timing differs. Finally, the evolution of the average turnover in *B* and *C*-level centres is less stable and shows a much more turbulent picture.

V. – Concluding comments

The results of this study show that the introduction of teleshopping facilities will generate significantly different properties of a retailing system. Unless the introduction of teleshopping facilities coincides with an increase in population

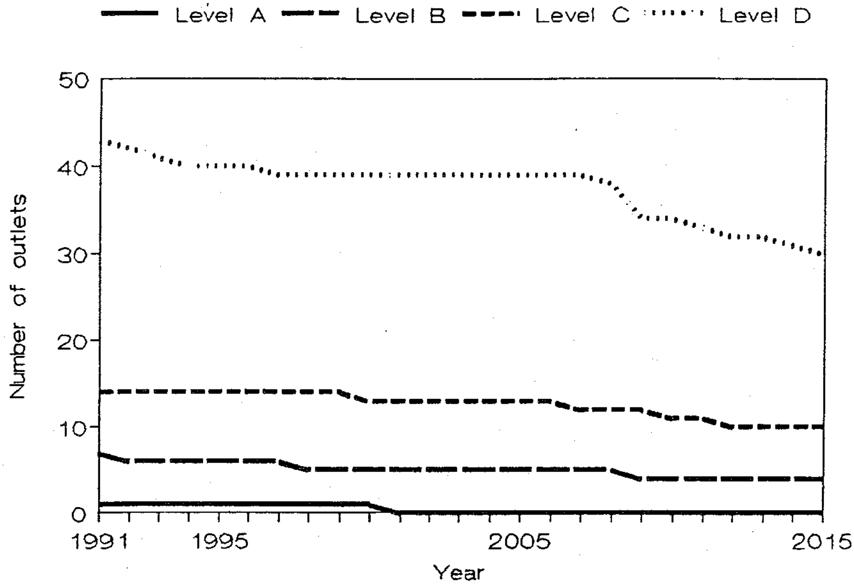

Figure 6. – Number of outlets per level (Scenario 2).

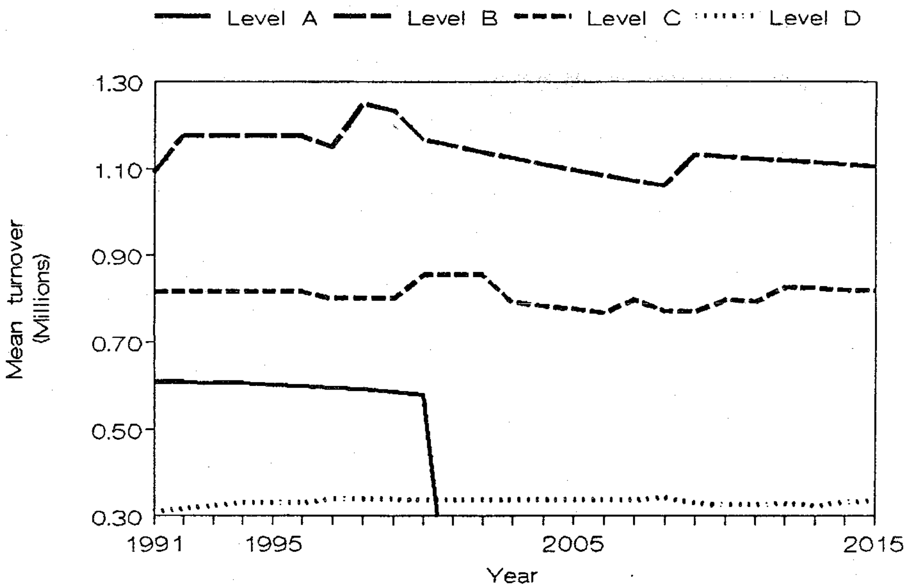

Figure 7. – Mean turnover per establishment (Scenario 2).

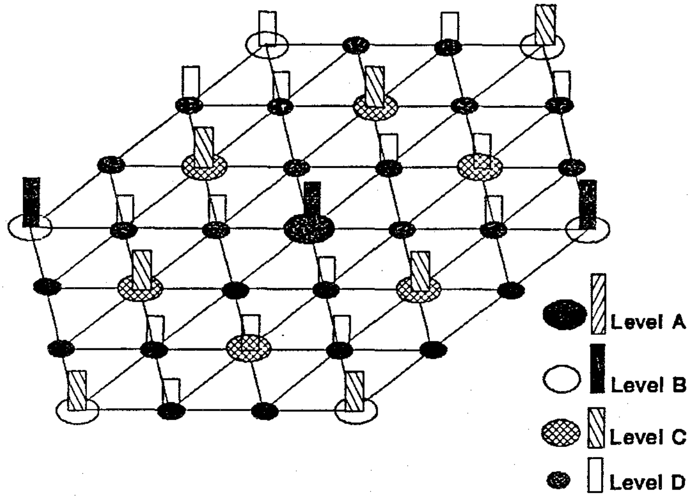

Figure 8. – Scenario 3. Bottom-up hierarchical diffusion of teleshopping, market share 15%.

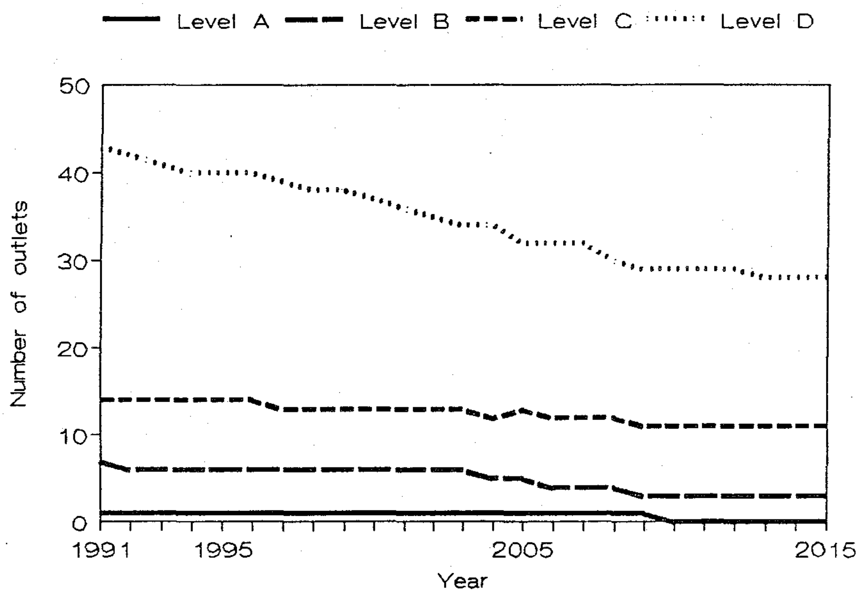

Figure 9. – Number of outlets per level (Scenario 3).

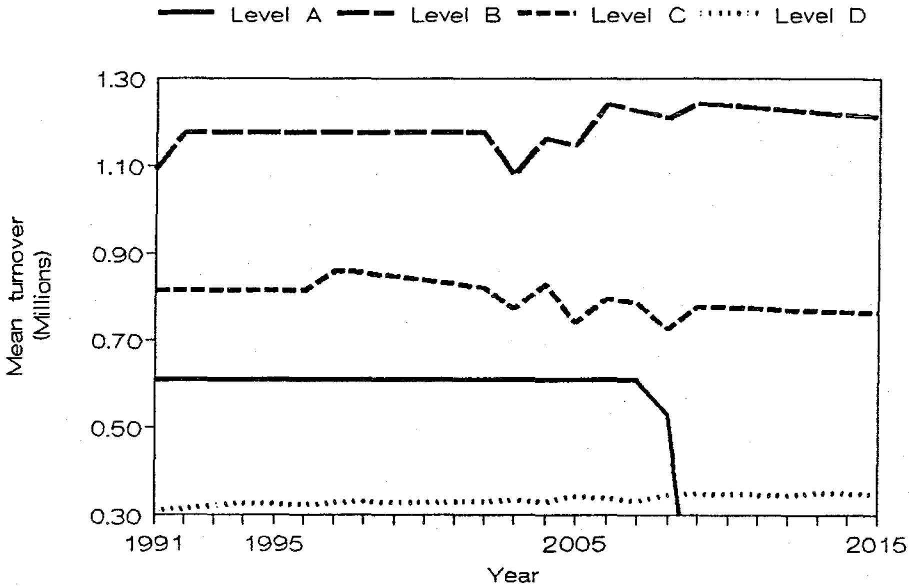

Figure 10. – Mean turnover per establishment (Scenario 3).

and/or demand, teleshopping will detract trade from existing centres thereby creating new equilibrium structures that are markedly different from those implied by classical theory. The findings of the present study suggest that a simultaneous, uniform introduction of teleshopping strengthens the position of the higher order centres. A hierarchical top-down introduction and diffusion is likely to yield a retailing system with relatively strong lower order centres. Finally, a bottom-up diffusion process will generate a retailing system with a strong middle layer. Evidently, these results pertain to the specific system and parameter values used in the present simulations. Future research should learn how these results generalize to real-world systems and different parameter sets.

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SUMMARY

The literature on the impact of modern technology on spatial systems is rapidly increasing. Most of the literature speculates about the possible effects of new technologies by discussing the potential impact it may have on the locational requirements of firms and consumer spatial choice behaviour. The present paper is more theoretical in nature. The effects of the introduction of teleshopping on a theoretical retail system is simulated. The paper reports on the organization of the simulation and its results.