Substitution among Successive Product Generations
– An Almost Neglected Problem in Innovation Diffusion Models

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TRADITIONAL INNOVATION DIFFUSION MODELS: AIMS AND SHORTCOMINGS

The spread of an innovation in the market is a highly dynamic process. Management science has developed a plenty of descriptive or normative methods, models and instruments to model this process. The research reaches back to 1960 with the models developed by Fourt/Woodlock, Mansfield and Bass (Fourt/Woodlock 1960; Mansfield 1961; Bass 1969). These models regard the diffusion of an innovation over time as a quasi natural process -- like the spread of a disease -- neglecting variables that allow to control the speed of innovation diffusion through corporate decisions. However, these fundamental models have been the basis for a variety of developments in this particular field. However, only a few of them consider the variety of influencing elements of the innovation diffusion (for an overview on the different models see e.g., Mahajan/Peterson 1985; Mahajan/Muller/Bass 1990; Maier 1995a). They concentrate on one or a combination of some of the decision variables, e.g., some models have been developed to seek for the optimum pricing or advertising strategies. Some models are simple in structure, regarding only monopolistic markets and neglecting important management decision variables. Some models are little more complex, considering oligopolistic or dynamic market structures. However, management decision variables are mostly exogenous inputs into the model, no feedback between management decisions and the spread of a new product in the market, and the success of a product exists.

This is a necessity resulting from the approach the model builders have chosen. Their aim is the development of models that perfectly fit to empirical data. The empirical data are used to estimate the very few parameters of their models. In order to be able to estimate, they need a simple model structure with only a few parameters. In fact the fitness of these models to historical data is very good, but the explanatory power of these models is very poor. They neglect important elements, interdependencies, structural fundamentals, and do not explain the process of innovation diffusion. Therefore they are insufficient to enhance understanding and to support decisions in this field.

Besides that, the traditional innovation diffusion models are inadequate to solve real world problems, because they do not properly reflect the structural fundamentals. This will be clarified by an example. If we consider the market of high technology products (e.g., personal computers, memory chips, or hard disk drives) we realize that there are successive product generations with increasing maximum sales and a shortening product life cycle time. The introduction of a new product, and even the announcement of an expected new product introduction, influences the sales of the previous product generation. There is a process of substitution and product cannibalism that is not present in the traditional innovation diffusion models. These models only consider one product generation and would use the same model with different estimated parameters for each product generation. Therefore the diffusion processes of each successive and substitutive product would be totally independent. This approach is insufficient to explain substitution processes.

CONSIDERING SUBSTITUTION IN INNOVATION DIFFUSION MODELS

In the literature there are very few models dealing with the problems of substitution.(see, e.g., Fisher/Pry 1971, Norton/Bass 1987, Norton/Bass 1992). The authors seek for simple mathematical representions of substitution processes allowing parameter estimation on the basis of empirical data. Their aim is not the explanation of the underlying structures and the forces driving the substitution processes. Therefore a totally different approach to the problem is necessary. The application of the system dynamics methodology would allow the development of more complex models to investigate and analyse substitution processes. These models can enhance the insight in the problem structure and increase understanding of the complexity, the dynamics and the impact of the influencing factors.

A fundamental application of system dynamics to model the process of innovation diffusion in a monopolistic market was developed by Milling (Milling 1986a). This model has been developed to include more management decision variables (see, e.g., Milling 1986b, Milling 1987) and to include competition among different companies (Maier 1992, Milling/Maier 1993, Maier 1995b). This paper discusses a system dynamics based innovation diffusion model to investigate the characteristics of substitution processes. It shows the fundmental model structure that is capable to generate both, substitution processes among successive products as well as the typical behavior of traditional innovation diffusion models. The model is designed for a monopolistic situation. There is no competition between different companies (see Maier 1995b for a discussion of a competitive system dynamics based innovation diffusion model without sustitution).

COARSE STRUCTURE OF THE SUBSTITUTION MODEL

The coarse structure of the model consists of 2 + n level variables, where n is the number of different product generations to be modeled. The first level variable (*potential customers*) represents the remaining market potential of each period. This is in contrast to the Norton/Bass model which requires one market potential for each product generation (Norton/Bass, 1987). Norton and Bass divide the homogeneous group of potential customers into different market potentials, which in fact is an unrealistic representation of reality. In this model the potential customers are treated as one group comprised in the level *potential customers*. The potential customers are reduced by the sales of a period (*sales*) and increased by the flow coming from untapped market (*new potential customers*) as well as by the number of customers willing to purchase a product repeatedly due to product obsolescence (*obsolescence*). The second level (*untapped market*) represents the number of persons that may become potential customers if the technical power or capability of the products fit to their needs. The other n levels (*adopters*) are modeled as an array variable. They accumulate for each product generation *pg* the number of persons that already purchased a product.

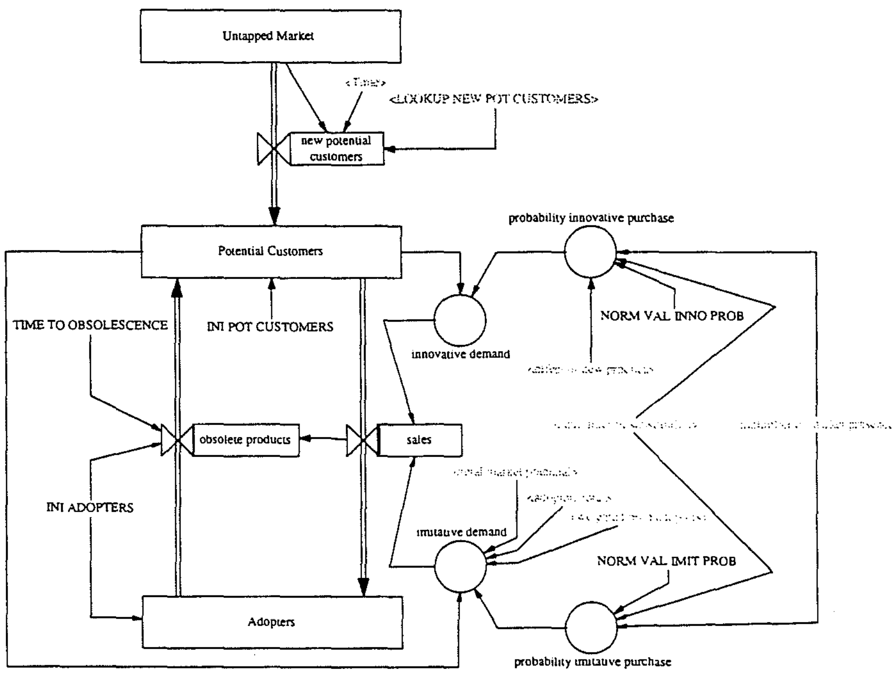

Figure 1: Coarse Structure of the Substitution Model

Most of the other variables are also modeled as array variables, where *pg* is the subscript representing the different product generations. The other variables shown in figure 1 represent the flows between the levels (*sales[pg]* and *obsolete products[pg]*) and the mechanisms to control the substitution and diffusion processes (*probability innovative purchase[pg]*, *probability imitative purchase[pg]*, *effect of new product[pg]*, *multiplier of substitution[pg]* and *multiplier of market presence[pg]*). The sales of a product generation consist of innovative and imitative demand (see Bass 1969, Milling 1986a, Maier 1995a, Maier 1995b for detailed discussion of the principles underlying these equations).

The multiplier of substitution is one central element in the control of the substitution process. It is influenced by the relativ technical capability of a product generation, the price and a factor representing the social pressure to buy the new product generation instead of the older product. Increasing technical capability and decreasing prices cause a higher multiplier of substitution. This coarse structure of the model then is capable to generate the typical product life cycles for different successive and substitutive products.

BEHAVIOR OF THE SUBSTITUTION MODEL

For tests of validity the above shown model was checked against historical data that have been available for four different generations of Intel micro processors (80286, 80386, 80486, and Pentium). Figure 2 shows a comparative plot of the sales computed with the model and the sales data found in literature. Although the goodness of fit seems to be very good, the model is sensitive to changes of some parameters (e.g. technical capability, price, and new potential customers). The parameters used in the model are based on empirical research. However, there are several parameter inputs that were not available and only could be estimated.

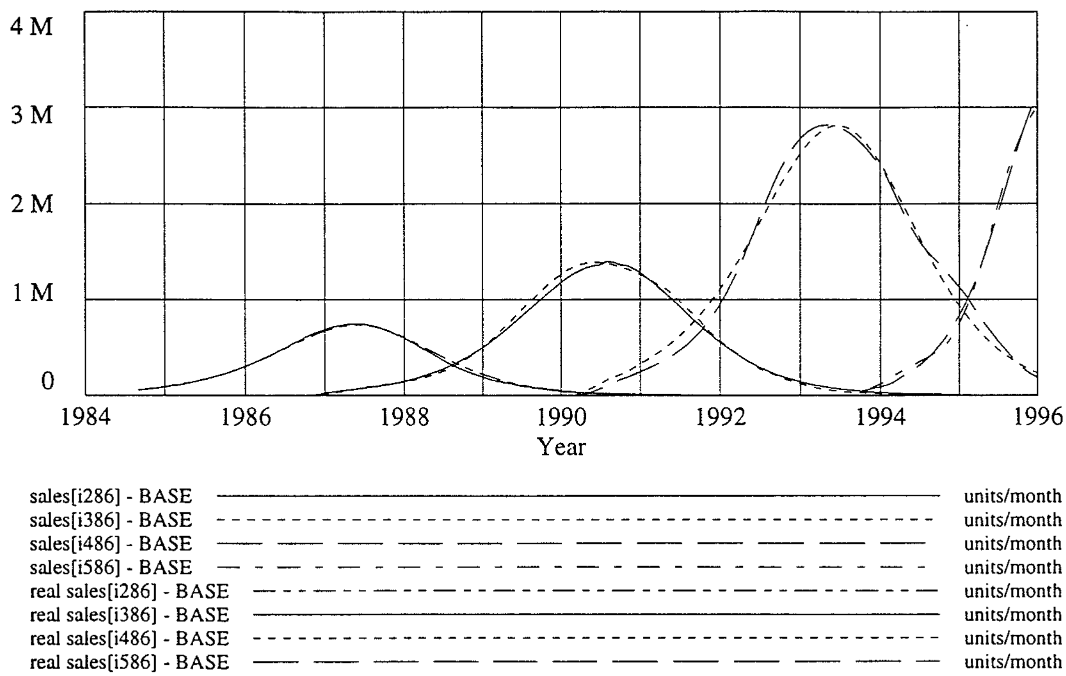

Figure 2: Model behavior in comparison to empirical data

The process of developing this model has given very useful insights in the processes of substitution. The assumption was confirmed that traditional models of innovation diffusion are insufficient to explain substitution processes. These models neglect a lot of elements which are necessary for reality conform model structure. The experiences also shows that the goodness of fit was reached through a more adequate model structure and only in a second round through improved parameter estimations. This confirms: structure influences behavior.

LITERATURE

Bass, F. M. 1969. A New Product Growth Model for Consumer Durables. In *Management Science* 15: 215-227.