WORKING PAPER

QUANTITATIVE DIFFUSION AND SUBSTITUTION ANALYSIS AND THEIR BUSINESS APPLICATION

Andreas Eggler

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IIASA
International Institute for Applied Systems Analysis

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FOREWORD

A most natural question for applied research relates to its relevance. Is the research addressing important policy issues, e.g. in form of case studies, but also whether the conceptual and formal models developed constitute a useful tool in practical applications, once they become applied outside the original research institute setting in which they have been developed.

The author illustrates in his paper how models of diffusion and product and process substitution developed at IIASA, which are essential elements in the process of technological and economic change, can be of useful relevance in practical business applications. Although, long recognized as valid tools for instance in marketing, the author goes beyond of simply providing a practical guide of the use of these models and their role in other instruments for defining business strategies. He clearly illustrates the importance of a careful and systematic analysis of the whole environment any unit of analysis, be it product or process innovation, is embedded in, pointing at the necessity of a multivariate and multiattribute approach in the analysis of technological change and its impact on business strategies.

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QUANTITATIVE DIFFUSION AND SUBSTITUTION ANALYSIS AND THEIR BUSINESS APPLICATIONS

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Quantitative Diffusion and Substitution Analysis
and their Business Applications

"If we could first know where we are
and whither we are tending,
we could better judge what to do
and how to do it."

Abraham Lincoln

I. Summary

Successful innovations expand into a market by either satisfying a new demand for products or services or by replacing existing forms to satisfy demand. The growth of innovations satisfying new product or service demands is referred to as diffusion process, whereas in case existing products or services, etc., are replaced by an innovation we are dealing with substitution phenomena. Empirical investigations have shown, that when the investigation of an innovation and its context has been done properly, most of the diffusion and substitution processes follow S-shaped patterns. The purpose of this paper is to introduce a conceptual framework to distinguish between diffusion and substitution and to find appropriate indicators for the description of these processes. If special conditions hold, the mathematical description of the diffusion and substitution process with S-shaped curves can then be used to describe and eventually to forecast the process. It will be furthermore shown, that this information is useful for decision making in business and actually essential for the development of corporate strategies.

II. The Basic Concepts of Diffusion and Substitution

II.1. Properties of Products and Services

In the context of this paper the expression product will be used for (physical) products as well as for services, processes and technologies diffusing into or competing in a particular market. Despite that we use one term, there may well be competition between the different kinds of products mentioned above, e.g. one can compute employees wages by either using one's own computer or an external service. A product is furthermore not necessarily related to one producer or retailer; there may be different producers or retailers for one product.

To characterize a product, a multidimensional approach has to be applied because of the different utilities and functions every product serves. Porter (1985) calls that function, out of the set of functions and utilities which characterizes the product most and determines its use, **generic function** It is obvious that the price of a product or more specifically the price/function ratio is an important aspect of every product as well.

II.2. General Relationships Between an Innovation and Other Product Categories

Concerning the relationship between an innovation and other products, Mahajan and Wind (1986, p. 18) state the following:

> "Innovations are neither introduced into a vacuum nor do they exist in isolation. Other innovations exist in the market place and may have an influence, either positive or negative, on the diffusion of an innovation. Consequently, before projecting the growth of a product category, it is necessary to examine its relationship to other product categories."

Four such relationships have been hypothesized by Mahajan and Wind (1987, p. 20):

- Independent (example: Modular housing units and electric trash compactors)
- Complementary(example: Washers and dryers)
- Contingent (computer software and hardware)
- Substitutes (black and white versus color television)

Knowledge of the type of relationship is important to understand what happens on the market. For example, by knowing about complementarity of products one can easily determine some upper limitations for the diffusion of a complementary product, e.g. the number of dryers will not be larger than the number of washers installed.

In this paper two main relationships are the focus of concern: An independent innovation causes diffusion, whereas substitute relationships between the innovation and the other products result in substitution. Complementary and contingent types of products will generally have to be analyzed in conjunction with each other.

II.3. Diffusion

Rogers (1965, p.19), one of the pioneers of diffusion research interprets diffusion as follows:

> "The diffusion process is the spread of a new idea from its source of invention or creation to its ultimate user or adopters."

Roger's classical definition of diffusion is a somewhat isolated view of one product alone and ignores the fact that there could be some substitutes. Therefore, the definition of Mahajan and Wind (1986) will be followed in this paper where

diffusion means the spread of an innovation which is independent from other products.

Penetration is a synonym for diffusion.

II.4. Substitution

Porter (1985, p. 273) defines substitution as follows:

> "Substitution is the process by which one product or service supplants another in performing a particular function or functions for a buyer."

In this paper we want to use the approach from Mahajan & Wind defining

substitutes as products with an existing (interactive) relationship.

Distinction Diffusion - Substitution

To find out whether an innovation is faced with substitution or not is not too easy in practice. As mentioned before, products have to be characterized by a vector of their different functions they provide for a user. One has to use these (generic) functions in order to identify substitutes. However, it is not a priori obvious how to derive from a generally complex vector of (generic) functions of a product whether we are dealing with a substitutive type of relationship to other products.

In this paper a very pragmatic point of view is proposed: if there is (are) (a) generic function(s) and this (these) generic function(s) is (are) similar for an innovation and other (competing) products/-services, a substitutive relationship exists. Similarities only between unimportant functions or aspects of products do not constitute such a relationship.

III. Analysis of the Relevant System

III.1. Use of the Model Results

Dependent on the use one makes of diffusion/substitution of an analysis, the level, detail and accuracy of the analysis will be different. It is obvious that more reliable and more accurate analyses need more time and money for investigation. It is necessary to find a clear answer to the question what the goals are — what questions one tries to answer — at the very beginning of any analysis, as this determines the analysis, e.g. the collection of data, the aggregation level, etc.

III.2. System Analysis and Model of the Relevant System

In the field of diffusion and substitution analysis, it is necessary that prior to any quantitative analysis one has to understand in detail the innovation in its context (technological, economic, market, etc. environment).

III.2.1. Finding Substitutes

Porter (1985, p. 274) recommends the following procedure for identifying possible substitutes:

"The first step in substitution analysis is to identify the substitutes and industry faces. This seemingly straightforward task is often not easy in practice. Identifying substitutes requires searching for products or services that perform the same generic function or functions as an industry's product, rather than products that have the same form. A truck differs greatly from a train, but they both perform the same generic function for the buyer: point-to-point freight transportation."

At this step the generic problem should be seen in a very broad sense (Porter, 1985, p. 275):

"In the simplest form of substitution, one product substitutes for another in performing the same function in the same buyer value activity. This is the case of a ceramic engine part substituting for a metal engine part. Though the substitution is direct, linkages can still exist. A ceramic part may require different handling, for example. Even in simple substitutions, it is also important to define the function of a product in the activity generically rather than literally — what the product does rather than how it does it. The generic function of a product is often very broad, particularly in consumer goods. A manufacturer of metal downhill skis faces substitution not only from epoxy or fiberglass skis but also from cross country-skis, other winter sports equipment, other leisure products that can be used in winter, and from the buyer taking more leisure time in the summer rather than winter. The generic function of metal skis, most broadly defined, is recreation. The more generally the function of an industry's product is expressed, the greater the number of potential substitutes there usually are."

To simplify the computation, the following definition will be adopted: A functional relationship between products means that they are (potential) substitutes. But if the volume of the products is very different, they can — at least temporarily — be seen as independent. If, for example, the market for the innovation is much larger — for whatever reasons — it does not make sense to consider only the potential market for substitution; e.g. video systems have all generic functions of the Super 8 movie system but opened a much larger market. Today they can be seen as independent (i.e. rather a case of diffusion in the terminology adapted here).

III.2.2. The Product in a Systems Context

The spread of an innovation has to be seen in a systems context. As H. Simon (1988, p. 10) points out, most systems are hierarchical, a property that allows description and explanation of the units of a specific level without the need for a detailed picture of the structure and the levels below. The hierarchical structure of the world enables us to understand it from the top down and in fact to study it one layer at a time with only moderate concern for the layers immediately below and above. But this does not dispense us from the duty of exploring the larger system in which the product is embedded (as illustrated in Porter's statement), a point which is important for the consistency test discussed in chapter V.4.3.

III.2.3. Indicators

After the basic investigations about the competitive situation have shown the structure of the problem, one has now to choose indicators for a quantitative description. Every product has different aspects and functions which could be used as indicators for a quantitative investigation. This fact will be used later to test the results from the quantitative analysis of one indicator by checking it for consistency with the results of other indicators. Furthermore, the spread of an innovation itself can be described by different indicators, e.g. sales can be expressed in number of products sold or turnover with that product. If possible, one should avoid the use of turnovers because of inflation, etc. Cumulative (or stock) indicators can be used as new indicators in order to describe the spread of an innovation; e.g. for the diffusion of a new book title one can use the sales per unit of time (i.e. a flow indicator) or a stock indicator — the number of this book title sold — as an indicator. In general, experience shows that using the quantity which characterizes the number of (potential) users is a reasonable indicator. The cumulative number of the new book title would thus seem to be an appropriate indicator in the above example.

The following scheme gives a systematic survey over different indicators that can be used:

1. Flows
   One can think of quantities per time period, such as sales of a book title per month.

2. Stocks
   Simplified stocks can be illustrated as summed flows, such as the total number a book title sold.

For simple systems with no losses there is a simple relationship between flows and stocks: the stock can simply be calculated by summarizing the flows. In a more realistic system losses do occur. Then one cannot simply compute the new stock by adding the number of products sold in the last period to the old stock. The replacement demand for those losses, i.e. the number of products sold without raising the stock has to be considered. There are many ways one can think of computing such replacement demand. Marchetti (1983, p. 4) proposes, for instance, the use of a logistic curve to model the lifetime of a product sold at any particular point in time.

Finally, a 3-dimensional scheme used by Porter (1983a, p. xii) to classify industries can help to structure the problem of diffusion and substitution in a wider context:

i) Dimension "time of use"
   -durable
   -non durable

ii) Dimension "application"
-Industrial
-Consumer

iii) Dimension "supply"
-services
-products

The following examples will show the usefulness of this scheme:

i) Dealing with non-durables, one does not have to worry about replacement demand at all. For durables, on the other hand, there usually exists a replacement demand.

ii) Industrial or consumer applications make a difference in the motivation of the purchase. For industrial applications often the cost savings is an overwhelmingly important impulse for the investment, whereas, for private consumers, there may be a rather complex combination of functions (utilities) that determines the purchase decision.

iii) The distinction between services and products helps us to be aware of the possible substitution of products by services and vice versa. A substitution of services by products has been illustrated in the example of using a PC instead of an external institution for the computation of employee's wages.

IV. Descriptive Framework for Diffusion and Substitution Analysis

Before describing diffusion and substitution it is necessary to build a theoretical framework in order to organize the empirical data.

IV.1. The Number of Competitors in the Substitution Process

Substitutes can be seen as competitors in a market, with each product holding a market share. At any time the sum of the market shares has to add up to 100% by definition. Using F(i) for the market share of the i-th product, this sum condition can be stated mathematically as follows:

$$\Sigma F(i) = 100\%.$$

IV.1.1. Single Competitor

There is only one product with no competitors to satisfy a given generic function. Therefore, the spread of the product will not be disturbed by any competitor, and by definition we call this constellation diffusion. However, as mentioned before there may be different producers or distributors for that product. As an example one could think of large scale ships before 1830. The only technology available was sail ships (besides smaller row boats) at that time, but of course there were different shipyards producing sail ships.

IV.1.2. Two Competitors (Fisher and Pry, 1971)

Just two competitors share the total market. In the case of ships this situation occurred at the beginning of the last century when steam became an alternative solution for the function of ship propulsion. More and more of the new ships built used steam for propulsion — a substitution process started. The two shares F(1) and F(2) have to add up to 100%. It then follows that only one of the shares F(1) or F(2) can be seen as independent, whereas the other share F(2) or F(1) has to be calculated by the above sum condition.

IV.1.3. Multiple Competition (Marchetti & Nakicenovic, 1979)

Generally, there are more than two products competing on the market. At the beginning of this century diesel engines for ship propulsion became available. It led to a multiple competition of sail, steam and diesel propulsion. As in the previous case, the sum of all shares has to add up to 100% at any time. Generally, with n competitors just (n-1) market shares can be determined independently and the n-th market share results as a residual. If the market shares of the products are not stable in the long run, a multiple substitution takes place.

IV.2. Typical Trajectories for Diffusion and Substitution Processes

Typical trajectories for diffusion and substitution processes are S-shaped. The logistic curve is a prominent example among S-shaped curves, but there are others like the Gompertz curve, the Sharif Kabir curve, etc. (see Grübler, Nakicenovic and Posch, 1988). The use of the logistic curve is proposed in this paper for reasons that will be discussed in chapter V.2.

IV.2.1. Logistic Trajectory

A logistic curve is S-shaped and symmetrical, and can be described mathematically with three parameters (see chapter V). Figure IV.1 shows a logistic (y) and its first derivative (y'), representing the growth rates over time.

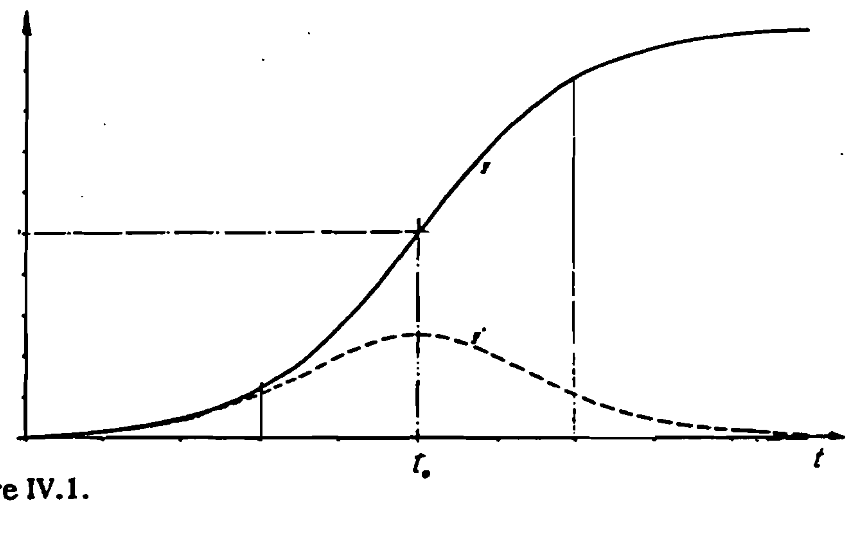


Figure IV.1.

IV.2.2. Growth Pushes: A Sequence of Logistic Curves

The growth of a quantity does not have to follow just one single logistic curve. Figure IV.2 shows as an example, that the diffusion of the railway network in Italy, with the length of the track as an indicator, follows three consecutive logistic trajectories (Marchetti, 1986, Appendix). This shows that it may well happen that after reaching one saturation level — which can be interpreted as a specific market niche — another growth push may occur. The reasons for these pushes can be very different. One should take into consideration technical progress, changes in uses, and the fall of barriers.

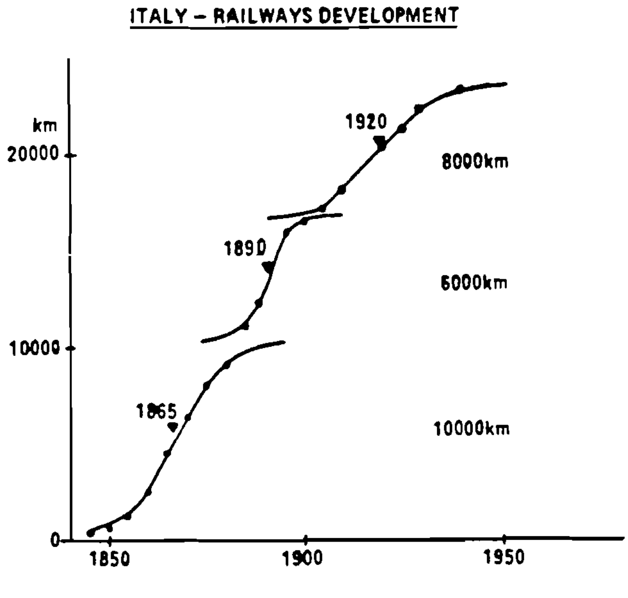


Figure IV.2. Italy - railways development

IV.3. Asymptotic Behavior of the Process

Sometimes the time series describing a diffusion/substitution process are not the main points of interest but the asymptotic behavior of the process, i.e. the fact and the timing of the transition in a particular market from an expansionary to a stationary regime.

IV.3.1. Ultimate Complete Substitution

For the case of an ultimate complete substitution the market share of the innovation will be 100% after a certain time, i.e. the old products will have completely disappeared from the market. What are necessary conditions for such an ultimate complete substitution? A necessary condition is that the innovation serves all generic functions at a better price/function ratio or serves even more functions for about the same price. This condition has to hold at least until the end of the substitution process. For example, pocket calculators totally substituted slide rules, i.e. the share of pocket calculators in the particular market is 100% today. Today's pocket calculators offer not only the same generic functions as slide rules, but many additional functions, and this for a better price/function ratio. Although the price/function ratio of pocket calculators was not necessarily superior to slide rules (when considering the same (limited) set of functions available to slide rules) at the beginning of the substitution process, it certainly is today. The reason for substitution in the first phase has therefore more to be considered in the extended functions (improved performance) of pocket calculators, whereas in a later phase of the substitut- ion process (after considerable price reductions due to the leaning curve effect) the latter price/function ratio can be considered as the principal driving force of the substitution process. Figure IV.3 shows an ultimate complete substitution between two competitors along a logistic trajectory.

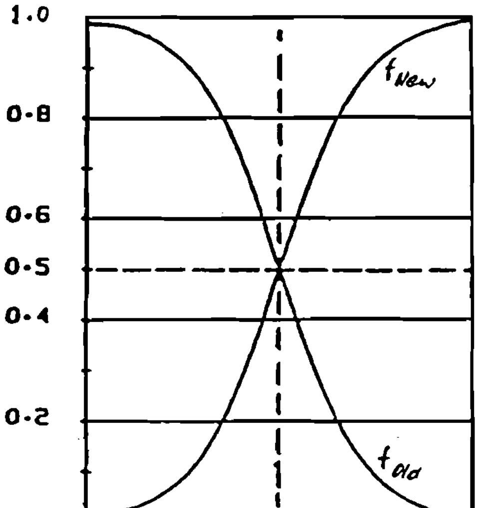


Figure IV.3. Ultimate complete substitution.

IV.3.2. The Case of a Niche

If the conditions for ultimate complete substitution do not hold, the innovation will not completely substitute the old product. This happens, for instance, if the generic function is different, if different products offer different functions, or if the price/function ratio of the innovation is worse than that of the others. The innovation will then reach a level lower than 100% — which can be interpreted as a niche — within a certain period of time. Figure IV.4 shows an example for a substitution of two products of a niche case type with logistic trajectories for the evolution of market shares.

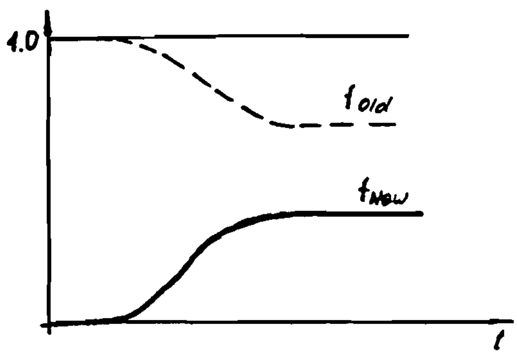


Figure IV.4. Substitution: the case of a niche.

IV.3.3. The Case of Oscillations

Marchetti (1983, p. 22) points out that "... these logistics or quasilogistics can become oscillatory when approaching saturation (a possible solution of Volterra equations often appearing in ecological contexts). It appears here ... that the overshooting can be interpreted as a change in maximum level perception." Metcalfe (1987) interprets oscillations as the interaction of demand and capacity growth.

V. Quantitative Diffusion and Substitution Analysis

> " Applying to human affairs a very simple ecological model, developed by Volterra-Lotka half a century ago, seems to remove most of the fog and to reveal crystal clear structure in long term social behavior -- which by consequence becomes to a point predictable."
>
> Cesare Marchetti

In the previous chapters above the differentiation between substitution and diffusion processes was discussed. The next step is a quantitative description, in which the empirical pattern is modelled (approximated), and if the fit of the model to empirical data proves satisfactory, the model may be used as forecasting tool.

V.1. Use of Logistic Curves

The diffusion and substitution processes are generally described by an S-shaped pattern. Out of the S-shaped patterns, the logistic model has particularly frequently been proposed as an adequate model for diffusion processes. This type of trajectory will be used in the following for several reasons:

- A large number of investigations of different diffusion and substitution processes have shown that they generally follow S-shaped patterns and very often logistic trajectories.

- Among the S-shaped curves the logistic curve can be stated mathematically very simply.

- The differential equation for a logistic curve can be interpreted and an analytic solution exists.

- Learning processes can be described successfully by using logistic curves (Foster, 1985, p. 271).

- Theoretical derivations of the logistic model have been demonstrated for instance by Metcalfe (1987) and Dosi et al. (1986), among others.

V.2. The Mathematical Problem of Parameter Estimation

Assume that a diffusion or substitution process can be described with a logistic curve. Given some data about the development of this diffusion or substitution process, one wants to determine the parameters of the logistic curve in order to model the process and eventually make a forecast. A computer program helps to determine the parameters of the logistic curve such that it best fits with the given data. The fit criteria may be different — linear or nonlinear — a point which will not be discussed here. The uncertainty of the resulting parameters mainly depends on the amount of data and the precision of the data. This detail will be discussed later. The mathematical procedure of this parameter estimation process depends on the number of competitors.

V.2.1. One Competitor — The Logistic Diffusion Analysis

Assume that the growth of the one quantity g(t) follows a logistic trajectory. The equation for the logistic curve is:

$$g(t) = c/(1 + \exp(-at - b))$$

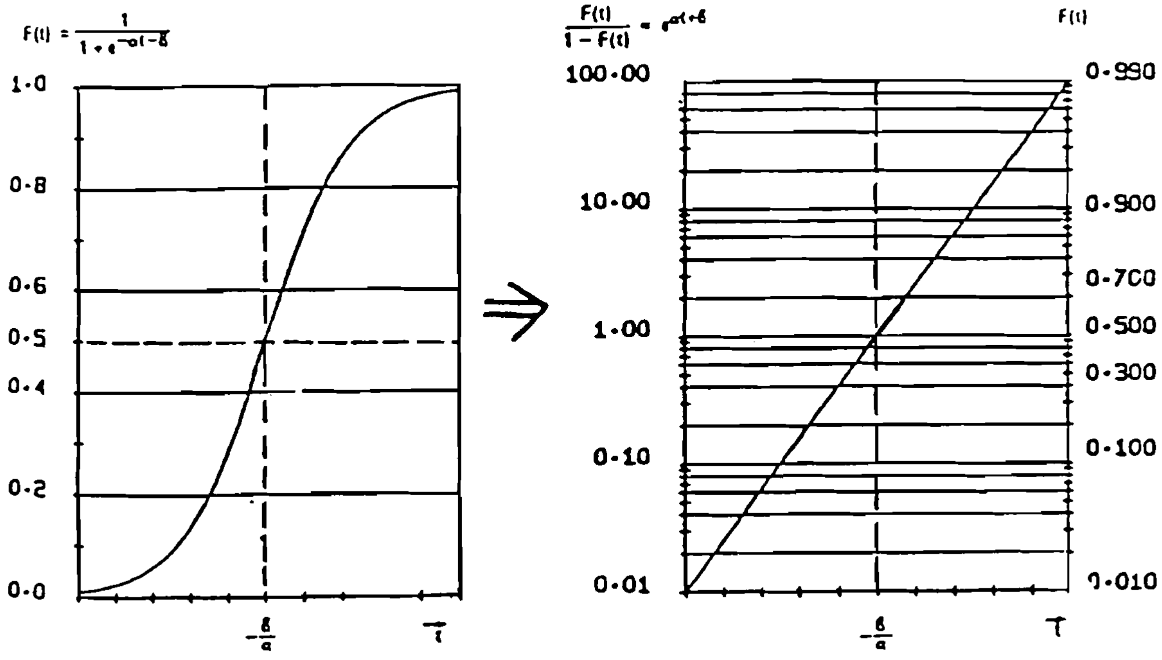
The three parameters a, b and c can be interpreted as follows:

> Parameter a describes the speed of the diffusion process. Frequently called the diffusion coefficient, it is usually interpreted as an indicator for the comparative advantage of an innovation (as first proposed by Mansfield, 1961).
>
> Parameter b locates the curve in time; the ratio b/a is the time when 50% of the saturation level is reached.
>
> Parameter c is the saturation level for the diffusion.

This clear interpretation of the parameters of the logistic curve is a great advantage compared with the other S-shaped curves. If one looks at Figure V.1 as an example of a logistic curve one can find a slow growth at the beginning, followed by accelerated growth (which appears to be exponential) and at the end deceleration until the curve finally reaches (in theoretical infinite time) the upper level c. The knowledge of the saturation level c is of great interest in economic life. Marchetti (1987, math. app. 2) states in this context:

> " The calculation on c is usually of great interest, especially in economics. However, the value of c is very sensitive to the value of data, i. e. to their errors, especially at the beginning of the growth".

For graphic representation and simplification of the parameter estimate process, it is common to consider a linear transform of the logistic curve. By the simple transformation f/(1-f) the S-shaped curve can be transformed into a straight line if plotted with a logarithmic scale. F is the fraction of growth achieved, i.e. g(t)/c or the market share fraction of a particular innovation. This is demonstrated in the figure below.



V.2.2. Two Competitors (Fisher and Pry, 1971)

The substitution process between the two products is assumed to follow a logistic trajectory. The sum of the two market shares has to add up to 100%. Therefore, given the parameters to describe the trajectory of one product, the other trajectory results as 100% minus the former one. Figure V.2 shows an ultimate complete substitution between two competitors. For this substitution type, the parameter c for the final (saturation) level is 100%, and does not have to be estimated.

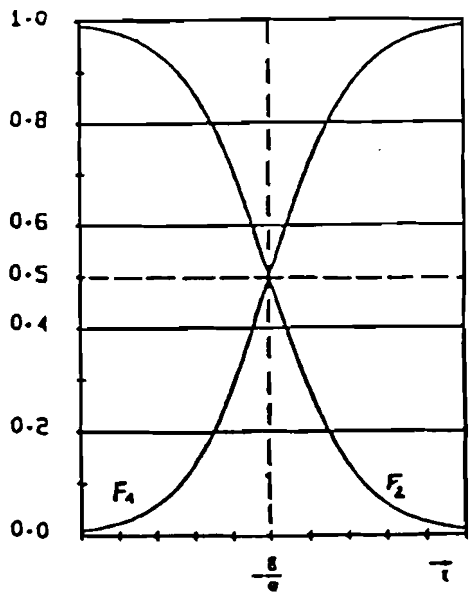


Figure V.2. Binary substitution model (Fisher and Pry, 1971)

IV.2.3. The Multiple Logistic Substitution Model According to Marchetti and Nakicenovic (1979)

Generally, there are more than two competitors on a market. Concerning the different competitors, one could think of the following cases: There might be a final winner or different competitor emerging at different times in the market, etc. Marchetti and Nakicenovic (1979) developed a method to cope with these different cases. Simplified, the method works as follows: Given a general number of competitors, call this number n, involved in the substitution process. One describes (n-1) of the quantities by logistic trajectories. Every new competitor passes three stages: growth, stagnation and decline. The oldest of the growing quantities (in its stagnation phase) is defined as residual quantity after considering the logistic growth and decline trajectories of the remaining competitors. Figure V.3 shows the substitution between the different sources of primary energy over the last 150 years (Nakicenovic, 1984, p. 24) as an example. Different competitors enter at different times in the market. Furthermore, none of the competitors ever cover 100% of the total market of primary energy.

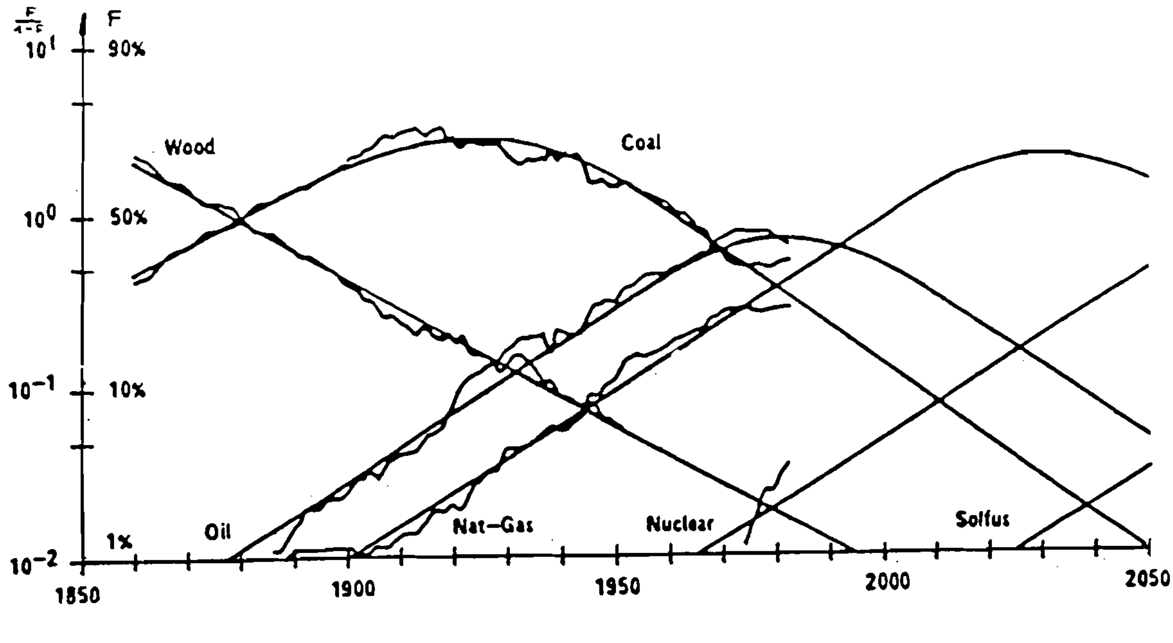


Figure V.3. World primary energy substitution (Nakicenovic, 1984).

V.3. Limits for Diffusion and Substitution Analysis

V.3.1. Limits due to the Quantity and Quality of Data

The parameters for the logistic curve computed by an algorithm very much depend on the quantitiy and quality of the data fed into the algorithm. Debecker and Modis (1980, p. 7) did research in this field and came up with the following result:

> "A rule of thumb general result is that given at least half of the S-curve range and a precision of better than 10% on each historical point, the uncertainty on M (the saturation level) will be less than 20% with 90% confidence level."

Therefore, one cannot make simple statements on how much data has to be given for a meaningful analysis. Sometimes the process is simply not advanced enough to make a forecast based on the given data. In such cases, one has to look for analogies with

- other countries or
- similar products

or derive the parameters of the model from theoretical considerations.

V.3.2. Limits of the Diffusion and Substitution Analysis due to the Market Structure

A question that arises quite often from CEOs is whether or not it is possible to make a forecast on the sales of their products by using logistic diffusion and substitution analysis. To answer this question, one has to recall the procedure for this analysis: Starting point was a specific product which serves a special generic function. One then tries to make a forecast for the total market volume of all products/services fulfilling that particular generic function. If there are possible substitutes, an additional forecast on this substitution process in terms of market shares is necessary. Given the information about these two processes a forecast in absolute terms for the different products can be made. But the market is usually split up between different companies. To compute the number of products sold by a company one has to multiply the total market of this product with the company's market share. The company's total sales of one product therefore depends on the change in the volume of the total market demand, the share of different products satisfying this demand, and on the company's market share in the production/sales of these products. In general it is not possible to compute a company's market share with a logistic diffusion or substitution analysis. But if the market shares are fixed — think about a cartel — or if the company is the only supplier for one product — it then holds a monopoly — the results of the logistic diffusion and substitution analysis yield the forecast of the company's sales of the product. Generally the situation is complex and not easy to forecast. But ignoring this complexity with just isolated views on the company's product is very often the reason for fatally wrong forecasts.

V.4. Test of the Quantitative Results (Grübler, 1988, p. 23)

V.4.1. Visual Test

In that case one leaves it to the judgement of the human eye to assess how good a particular model performs in mapping the empirical data pattern.

V.4.2. Statistical Test

The standard statistical measures such as the R^2 or the t-statistics are used.

V.4.3. Consistency Test

Diffusion and substitution processes are driven or retarded by different forces (see chapter VII.3 below). These forces may change as time passes by and therefore it is necessary to check the quantitative results of the analysis for consistency with the change in the driving or retarding forces. For example, the stock of cars in the US showed a saturation around 1930. But this temporary saturation appeared inconsistent with the technological progress in automobile engineering at that time and the still continuing long-term growing demand for transport services.

V.5. Development of a Scenario

If none of the former test falsified the quantitative results, it can be used as a forecast. In this last step one has to summarize the forecast with all the assumptions being made to a scenario.

VI. Application of the Logistic Diffusion and Substitution Analysis

The forecast yield form the logistic diffusion and substitution analysis can be used in different ways:

- as an independent instrument, and
- as an input for other instruments.

VI.1. The Logistic Diffusion and Substitution Analysis as an Independent Instrument

One could think of three different uses as an independent instrument:

VI.1.1. Ex Post Analysis

By making ex post analysis one describes processes which are or almost are finished. This type of historical analysis yields a lot of experience on saturation levels and on time constants for penetration which may be very useful for later analogies, comparison between different countries, etc. Determination of the current position of a product in a life cycle model is a special type of ex post analysis with interesting results for marketing: As marketing instruments, i.e. price policy, distribution policy, product mix and advertisement change (Kotler, 1982, p. 312), dependent on the product's position in the life cycle, this can now be done more reliable as the determination of the position is more trustworthy. In the excursus below the weakness of the tradition life cycle concept will be discussed but after all, the conclusions on the use of the marketing instruments seem to be reasonable.

VI.1.2. Forecast and Scenario

The procedure of generating a scenario has been discussed in chapter V. Here the problem of new competitors will be discussed. In principle it is not possible for the substitution analysis to make any assertion about whether and when a new competitor will arise. If one deals with long term predictions, it is common to use assumptions on future competitors that can be used as an input for the computer program just as if they were real, and the quantitative effects of these assumptions can then be discussed.

VI.2. Use of the Results in Connection with other Instruments

A lot of decision support instruments need some estimate on the future perspective of a product. The logistic diffusion and substitution analysis make such a forecast possible. Below we give a small list of instruments where the results of the logistic diffusion and substitution analysis may be used.

VI.2.1. Use in Portfolio Analysis

The widely known Portfolio matrix which is used to show graphically the position of strategic business units has two dimensions:

- the market attractivity, and
- the relative competitive advantage.

The information whether or not a market is saturated, is a very important aspect to judge the market attractivness. The logistic diffusion and substitution analysis yield information to exactly this point. As one considers the data over a long period of time, one is prevented from being misled by short term market turbulences!

If one considers specific process technologies, used in one industry, the substitution of these technologies is one important indicator for the judgement on the development of the relative competitive advantage.

VI.2.2. Use in Strengths and Weaknesses Analysis

A variety of strengths and weaknesses analysis exist, which aim to show the company's position relative to its competitors. The information about possible saturations and substitutions of products, processes and technologies for example are relevant to judge the relative strengths and weaknesses of a particular market segment or company.

VI.2.3. Stability Discussions for Branches, Companies, Products

The results of the quantitative substitution and diffusion analysis show whether a product is facing substitution and allows an estimate on how fast this process is going on. If this process is going on very slowly the situation can be called stable.

VI.2.4. Use as an Index on the Age of Products

Quite often companies are proud to announce that they make x% of their turnover with products not older than three years. Is this a good indicator for the innovativeness of a company? Would it not be more meaningful to make the statement that the company makes y% of its turnover with products which do not reach z% of their saturation level? This yields more information, and it is worthwhile to check whether this kind of information should be used, for example, in the PIMS program, etc.

VI.2.5. The Difference between Life Cycle Models and the Logistic Diffusion Model

Many different life cycle curves to describe the sales (a flow variable) of products are known, but in general all life cycle curves look like a bell. On the other hand, if one uses the S-shaped logistic curve for the total stock of a product and differentiates it, the result — if there is no replacement demand for losses — is a bell shaped curve for the flow variable (sales) as presented in Figure IV.1. There is the following relationship between the life cycle curve and the flow variables resulting from a logistic trajectory of the stock variable: If the stock of a product with no replacement demand is described by a logistic curve, the resulting flows (in differentiating the logistic stock trajectories) and the flows described in a conventional life cycle model are practically identical! But the assumptions of no replacement demand as postulated before is seldom fulfilled but has to be considered depending on the specific product. That is why there is not one life cycle curve independent of the product. Furthermore the life cycle model ignores substitution processes (i.e. sales may be curtailed due to substitution from another product) and that may be one of the reasons why it is so hard to quantify life cycles in practical applications.

VII. Use of the Results of Diffusion and Substitution Analysis for the Design of Business Strategies

VII.1. The Concept of Strategic Planning

The purpose of corporate strategic plans is to have long term guidelines. Strategic plans are highly aggregated plans with little operative details and give answer to the question what to do rather than how to do it. Two main inputs for the development of corporate strategies are the situation of a branch or an industry and its future development. The branch analysis is one of the first steps for making a diffusion or substitution analysis which then yields an answer to the future perspective of a branch. In other words, the diffusion and substitution analysis as proposed in this paper yield information that is actually necessary to develop strategic plans at the level of the individual businesses.

VII.2. Branch Analysis According to Porter

Porter (1985, p. 141) uses a concept with five dimensions to describe the situation of a branch. Substitution is one of the five dimensions, or basic competitive forces, which may change the competitive situation and the market. The basic competitive forces are:

1. Substitution
2. Jockeying for position among current competitors
3. Threat of new entrants
4. Bargaining power of new suppliers
5. Bargaining power of customers.

VII.3. Quantitative Development of the Market

The scenario developed in chapter V.5 describes the trajectory of the diffusion or substitution process under certain conditions. This quantitative information shows whether the market is young and growing or if it is already saturated or approaching saturation. This information is of course important and valuable for strategy design.

Rogers (1983, p. 234) found the following driving forces that determine the rate of diffusion of a product:

1. Perceived attributes of an innovation
   relative advantage,
   compatibility,
   complexity,
   triability,
   observability.

2. Type of innovation decision
   optional,
   collective,
   authoritative.

3. Communications channel
   mass media,
   interpersonal.

4. Nature of the social system
   its norms,
   degree of interconnectedness.

5. Extent of change agent's promotion effort.

The list of driving and retarding forces from Rogers has to be enlarged with the results of an own system analysis. Dependent on the company's possibility to influence the driving variables, the diffusion or substitution process can be controlled. This shows whether it is appropriate to be a competitor of this particular market in the future. This information from a market standpoint is the main determinant for any strategic decision.

If there is additionally a substitution going on, one has to make the same investigations as described above for the generic function a product fulfills, and then look at possible substitutions. Porter (1985, p. 374) found five general fields which influence the substitution between products:

- change in relative price
- change in relative value
- change in the perception of value
- change in the costs of switching
- change in the propensity for substitution

and shows two possible strategic policies:

- pushing the substitution. and
- defending the substitution.

Depending on the situation of the five general fields as mentioned above, Porter gives possible hints on how to act depending on the chosen strategy, i.e. pushing or defending the substitution.

VIII. An Illustrative Case Study

Assume you are the producer of electrical equipment for power transmission. There are two products to solve the problem of electric power transmission:

- overhead lines
- cables.

There are no other possible competitors for the transmission of electric power at the very moment. Assume it is your task to make forecasts for those two products for Austria. The hierarchy of the problem situation shows that it is necessary to study the diffusion of the electric power transmission network for itself and then to investigate whether or not a substitution process between cables and overhead lines is going on. As an illustrative sample from the Austrian electric power transmission network the empirical data of the Power and Light Company for Vorarlberg, which supplies about 300,000 people with electric energy, is given. This database includes the length of the overhead lines and cable network dating back to 1932. The first step is the forecast of the total length of the electric power transmission network with a logistic curve. The result can be seen in Figure VIII.2. The interpretation is as follows: according to the indicator used, the diffusion of the electric power transmission network is by far not finished. The forecast on the saturation level is 12,780 km and in 1986 just 50% of this upper level was reached. Thus, significant uncertainty of the forecast made exists, as the process has barely progressed beyond the 50% mark. Sensitivity analysis, consistency checks and comparison to other regions/countries may help to improve the reliability of the forecast.

The next step is to compute the substitution between overhead lines and cables. The result can be seen in Figure VIII.1. A substitution process was almost nonexistent until the beginning of the sixties. Then a substitution process started which can nearly

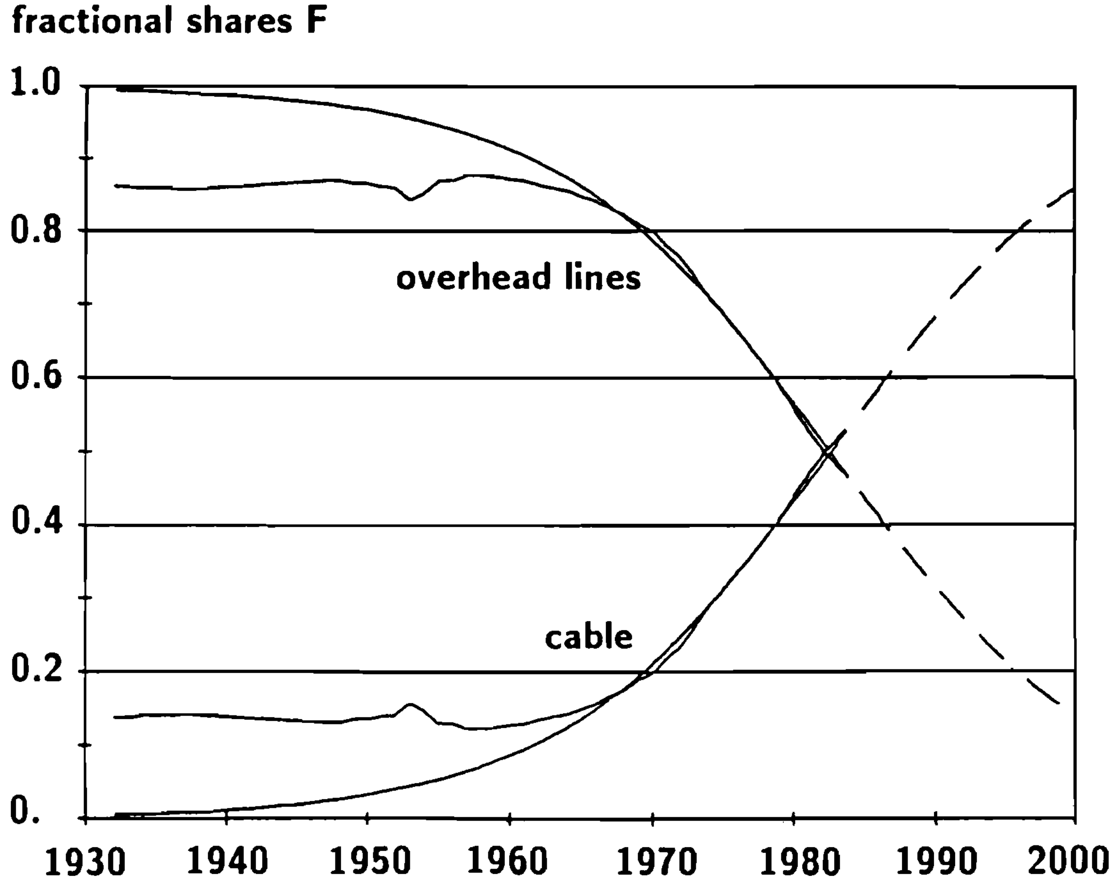


Figure VIII.1 Shares of cable and overhead lines

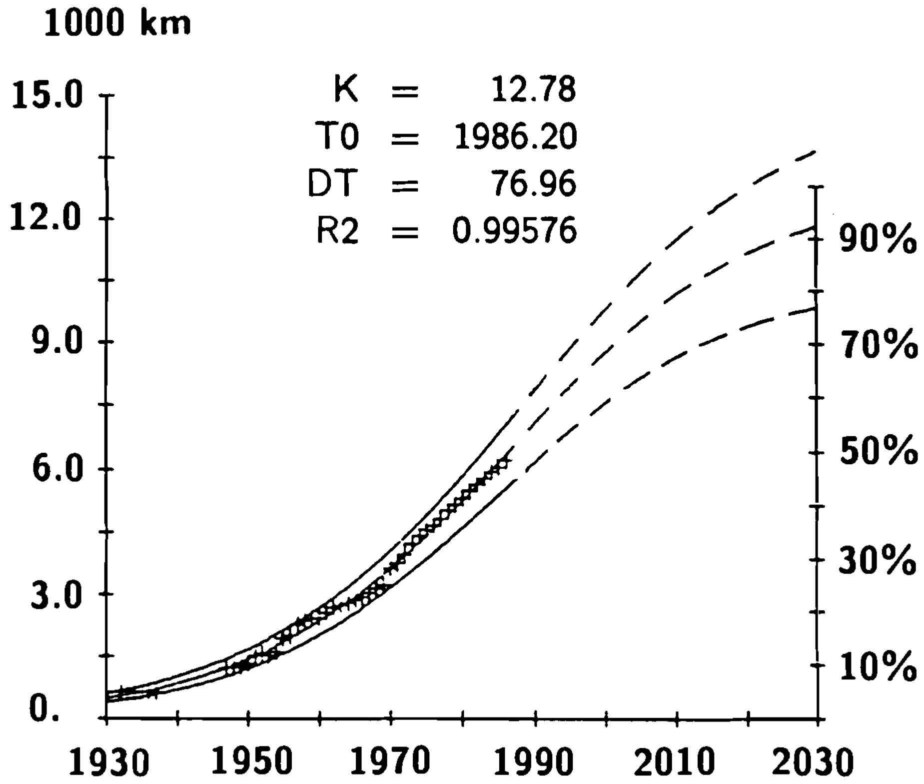


Figure VIII.2 Total length of network

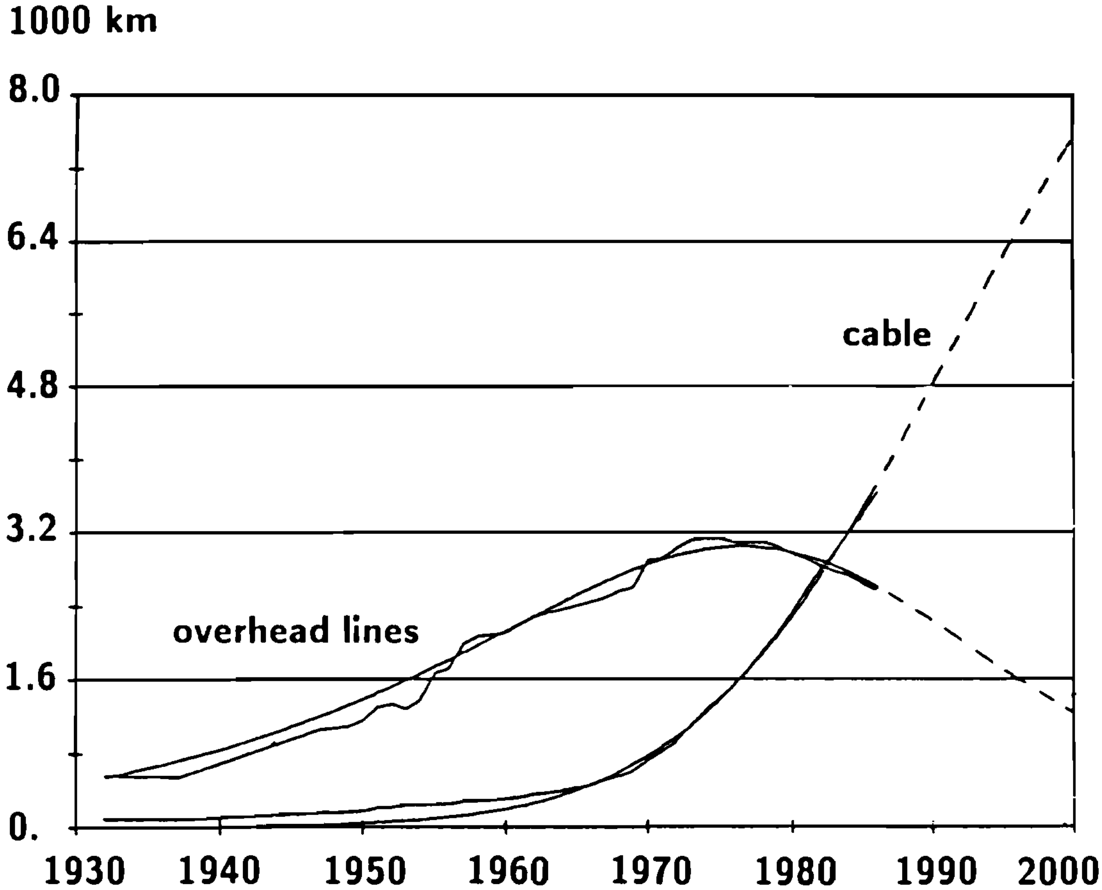


Figure VIII.3 Length of cable and overhead lines perfectly be described as a logistic trajectory. Given the trajectory of the total length of the network and the substitution between overhead lines and cables, one can make a forecast on the length of the cable and on the overhead line network in absolute terms by multiplying the two curves. The resulting non logistic curves for the cable and the overhead line network in terms of absolute length can be seen in Figure VIII.3. Recall here that the length of the cable or the overhead line network cannot be estimated directly with a logistic curve. The example shows how important a system analysis prior to any forecast is! This case study is not a complete analysis as described in the chapters above, but it illustrates some of the basic concepts.

IX. Conclusions and Directions for Research

The framework that was developed for describing diffusion and substitution processes is of great conceptual power as it helps to structure the market into different hierarchical levels. It therefore helps to understand market processes which one then tries to describe by a particular model, such as the logistic one. If the fit of this logistic model is good and some other conditions hold, this model can then be used to forecast diffusion and substitution processes. These results are very important for every manager who develops strategies because he gets unique results about possible market saturation and the speed and time of diffusion and substitution processes. This information can furthermore be used as an input in many different management tools where quite often judgments of the future of products, etc., have to be made. The framework furthermore showed the weakness of the life cycle concept in marketing and offers a good basis for the further development of the life cycle concept in a more complex and realistic context.

Every new logistic diffusion or substitution analysis being done yields new experience. A systematic collection of important diffusion and substitution processes would be desirable. By such a collection a kind of taxonomy of diffusion and substitution processes and their determinants could ultimately be developed. This collection could furthermore be the basis for consistency checks on particular analyses, specially important and valuable at the time of introduction of a product when no (or no sufficient) empirical data are available for analysis.

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