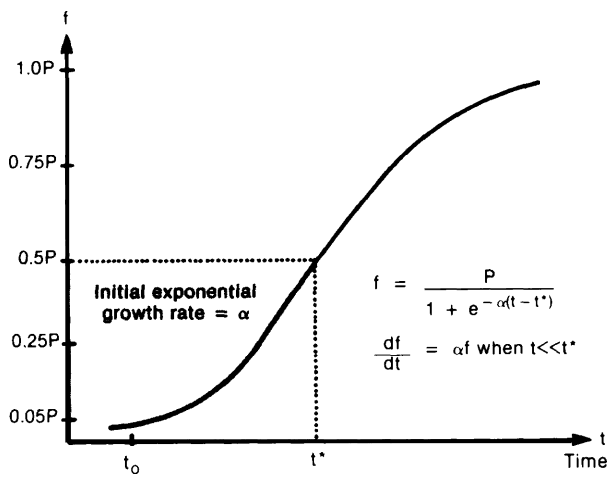
Appendix B

Logistic Substitution Process

The logistic substitution process is one mathematical formulation that can be used to describe the encroachment of one technology on the market of another. In the field of systems ecology a multitude of models have been used for this purpose. However, the more complex models require data that are significantly more detailed than were available for this analysis, and for all their complexity have no more inherent validity than a simple model such as logistic substitution. The most important considerations for any model used for this kind of analysis are that it be based on supportable data and that it make sense.

The logistic substitution curve (fig. B-1) presents a reasonable macroscopic model of the encroachment of a new technology into the market of an established, mature technology. When the new technology becomes available, it penetrates the market slowly at first due to relatively high cost and limited consumer acceptance. As time goes on, cost declines as volume of use builds, leading to an accelerating growth. Growth remains gradual, however, since consumer acceptance can be gained only with time. As the available market approaches saturation, the rate of growth declines.

Figure B-1.— Logistic Substitution Growth Process



NOTES P = Maximum penetration potential
f = Market share (fraction of total market) for new technology at time t
α = Growth constant
t_0 = Time when 5% penetration occurs
t* = Time when 50°/0 penetration occurs

SOURCE, Off Ice of Technology Assessment and Fred B, Wood, et al , *USPS and the Communications Revolution Impact, Optlens and Issues,* George Washington University, Mar. 5, 1977.

In mathematical terms, the key variable is the market share of the new technology, expressed as a fraction f of the total potential market. Ultimately, the entire potential market will be penetrated, and f will equal 1 or the maximum penetration potential P, whichever is less. Initially, the market share fraction f is very small, but grows with time at a rate proportional to the market share itself. Thus, in the early stages of growth, the growth of f per unit of time is expressed as α X f, where α is a constant for the particular technology and market being considered. The factor α will be referred to as the "growth constant" for the particular substitution process. It is a measure of how quickly the technology will penetrate the market. For example, with α = 0.4 (per year), the market share will rise from 5 to 75 percent in 10 years, whereas with α = 0.2 such a change in market share will require 20 years.

The market share at any time can be computed from the equation in figure B-1 if the growth constant α and the time of 50-percent market penetration t are specified. Alternatively, some other point on the curve can be specified along with the growth constant α. OTA chose to specify a particular logistic substitution curve by specifying the growth constant, α, and the time (calendar year) at which 5-percent penetration of the available market occurs. This 5-percent penetration time is designated t_o. The market share f can then be expressed in terms of α and t_o as follows:

$$f = \frac{P}{1 + e^{(2.944 - \alpha (t - t_o))}}$$

$$f = \frac{P}{1 + 19e^{-\alpha (t - t_o)}}$$

where $0 \leq P \leq 1$
$0 \leq f \leq 1$
$0 \leq \alpha \leq 1$

The logistic substitution process has been used once before to model the penetration of mail by EMS technology.[1] However, in that 1977 study the mainstream was considered a single market and

[1] Fred B. Wood, et al., ***USPS and the*** *Communications Revolution: Impacts, Options and Issues,* George Washington University, Mar. 5, 1977.

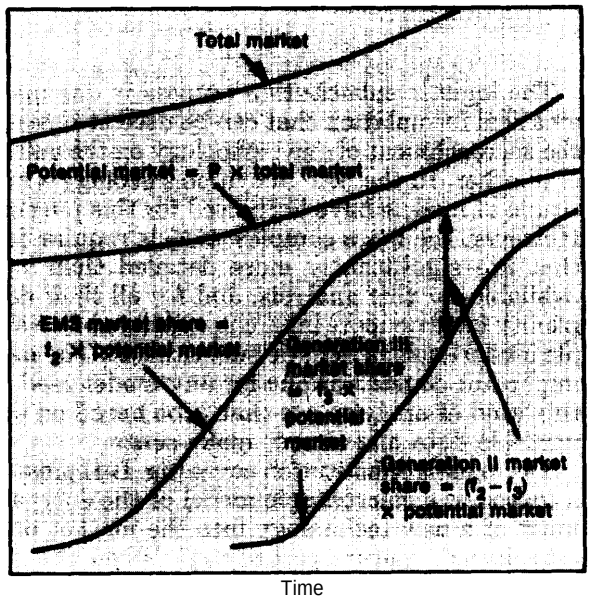
the substitution of EMS a single process. For the purposes of this study, the mainstream was considered to be many different submarkets with varying susceptibility to several different EMS technologies.

The competition between Generation II and Generation III EMS technologies can be described as follows. As EMS technology develops, Generation III systems eventually will most likely be less expensive to use than Generation 11 systems because Generation III employs electronic, rather than postal carrier, delivery. Also, Generation III EMS technology will most likely advance to the point where it will be able to accommodate any format or display capability that can be handled by Generation II. In other words, any mainstream segment that can be diverted to Generation II EMS can eventually be diverted to a Generation III system as well. Furthermore, the switch to Generation III EMS will most likely occur when the economics (to the user) favor Generation 111 over Generation II EMS, and at that point Generation III systems will start to take away market share from Generation II systems.

Thus, in the market penetration model, penetrations of conventional mail by Generation II EMS and Generation III EMS were calculated separately using parameters derived from an assessment of relevant technologies.* The volume resulting for Generation III was then subtracted from the resulting Generation 11 volume, producing a net Generation II volume figure. The net Generation II and Generation 111 volumes were subtracted from the conventional mail volume to obtain the residual conventional volume.

Figure B-2 illustrates the relationships involved in a market segment where a portion of the total message volume is judged suitable for penetration by EMS. First, the total market in this segment is shown as one that grows **at a** constant percentage rate. The potential market for EMS—the portion of the market which is physically suitable for eventual transmission by EMS systems—is represented as a constant fraction P of the total market. Initially, Generation II EMS begins to penetrate the potential market, capturing a market share f_2 of the total market. Later, Generation III begins to penetrate. At this point, the fraction f_2 represents the total EMS market share, and Generation III growth comes at the expense of Generation II. Hence f_3, the result of a separate substitution process, represents the market share for Generation III, while the market share for Generation II becomes $f_2 - f_3$. For the assumptions used in this study, total substitution of Generation 111 for Generation II does not occur in any mainstream market segment within the 20 year timeframe of the market penetration projections.

Figure B-2.—Logistic Substitution Process for Generation II vs. Generation III EMS



NOTES: P = Maximum penetration potential
f_2 = Fraction of total market for EMS at time t
f_3 = Fraction of total market for Generation III at time t
$f_2 - f_3$ = Fraction of total market for Generation II at time t

SOURCE: Office of Technology Assessment,

● See table A-4.