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DYNAMIC MODELING OF INFORMATION SEARCH SERVICES - A SIMPLE RESOURCE ALLOCATION MODEL

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"It is true that a fair Librarie, is not onely an ornament and credit to the place where it is; but an useful commoditie by it self to the publick; yet in effect it is no more then a dead Bodie as now it is constituted, in comparison of what it might bee, if it were animated with a publick Spirit to keep and use it, and ordered as it might bee for publick service."

John Dury (1596-1680) in a letter to his friend Samuel Hartlib. Included in The Reformed Librarie-Keeper (Chicago: A. C. McClurg & Co., 1906).

DYNAMIC MODELING OF INFORMATION SEARCH SERVICES

- A Simple Resource Allocation Model

ABSTRACT

Presented is a continuous simulation model of an Information Search Service (ISS). The methodology applied is System Dynamics and the model is written in the DYNAMO simulation language.

The first part of the report analyzes the managerial decision making in a situation where the ISS is organized as a research project with a fixed amount of resources. Simulation runs show the growth from the start of the service to stagnation in an equilibrium state determined by the available resources and applied policies for resource allocation between marketing and production. The influence of different assumptions regarding the user population is also analyzed in some detail.

The second part of the report analyzes the behavior of an ISS when there is a funder who permits expansion of the service in terms of staff, in particular the consequences for growth of different allocation policies are discussed.

Policy conclusions can be drawn from both parts: during the initial growth the focus is on the interaction between the ISS and the market, and in the growth situation the three-way interactions, i.e. between the ISS, its market, and the funder, are considered.

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I. INTRODUCTION AND BACKGROUND

The growth in the volume of scientific and technical information has followed an exponential path since the middle of the eighteenth century. We can get an indication of the present volume of information from figure 1 where is plotted the number of scientific journals and abstract journals founded as a function of date. Correcting for the increase in the number of journals discontinued might change the actual numbers but not the general trend[1].

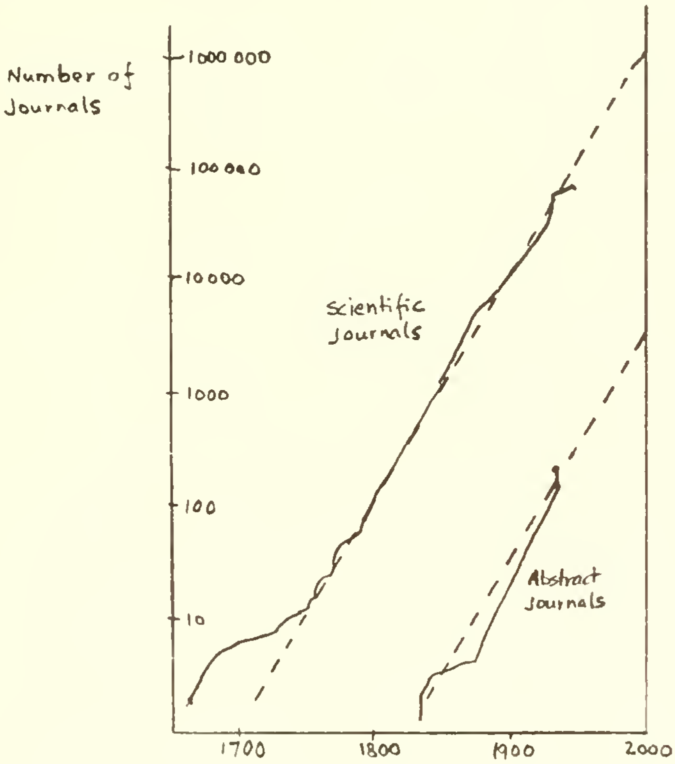

Figure 1.

Traditionally libraries have carried out the functions of access to the scientific and technical literature, both logical access (i.e. providing information about what documents are availaible where) and physical access (i.e. providing the documents). The first attempts to cope with the growth of information volume can be traced to the middle ages when cataloging procedures began to change towards control of the actual documents whereas before that the primary goal of the cataloging procedures was to provide control of their content.[2]

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1) de Solla Price, Derek J., Science Since Babylon, New Haven: Yale University Press, 1961.

2) Bhattacharyya, G., "Subject Headings up to the Middle of the 19th Century: A Generalised View," Lib. Sc., v. 11, n. 1, pp. 29-34.

With the proliferation of scientific journals and the increased importance of the journal article as a vehicle for disseminating scientific knowledge there was a need to improve the mechanism for logical access to this body of information since the library catalogs did not go deeper than to the level of journal volumes. Secondary journals, or abstract journals, were published in response to this need. These journals were published by learned societies or professional associations and contained abstracts and source information about articles in the primary journals of interest.

Considering the continued growth in scientific information it is easy to realize that the publication of abstract journals would have to grow, too, in order to keep up. From figure 1 we can see that this is, in fact, what is happening. So the problem with information volume is only put off temporarily. This problem is further enhanced by structural changes in the composition of the literature which at the same time show an increase in differentiation (reflecting increased scientific specialization) and integration (reflecting increase in interdisciplinary scientific activity)[3] .

Libraries still provide the basic physical access to scientific documents, and although the development of library networks in many respects has been rapid[4] , the problem of detailed logical access to the scientific literature remains. At present we can see a number of approaches to alleviate this problem by applying computer technology.[5] These computerized information services use machine-readable versions of abstract journals or specially produced data bases containing bibliographic information and a description of content ranging from keywords to abstracts.

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3) These developments are discussed in: Rózsa, György, Scientific Information and Society, The Hague: Mouton, 1973, pp. 105-123. A mathematical treatment of the structure of the literature which illustrates the problems for the library system can be found in: Vickery, B. C., "Bradfords Law of Scattering," J. Doc., v. 4, n. 3 (1948), p. 200.

4) Lindquist, Mats G., "Automated Library Networks in the U.S.A. and Canada," Report TRITA-LIB-1058, Stockholm: The Royal Institute of Technology, August, 1974.

5) Knox, W. T., "Systems for Technological Information Transfer", Science, v. 181, 3 August 1973, pp. 415-419.

The service provided by the computerized information services, which henceforth will be called Information Search Services, ISS, is to produce a list of literature references, sometimes with an abstract or summary, in response to a query from a user. In the ideal case an ISS provides access to "the world's" scientific and technical literature. In reality, of course, the coverage of the literature is constrained in many ways. Often an ISS is set up with a particular market in mind, either on the basis of subject specialization or organizational constraints.

From about 1960 to the early 1970's the main function of ISS:s was to provide a "current awareness" service, also called Selective Dissemination of Information (SDI), primarily based on printed secondary journals such as Chemical Abstracts. The users of these services subscribed to searches by submitting an interest profile which was matched against the periodically issued database. The resulting list of references was then mailed to the user. The relative success of the SDI-services, together with the fact that machine-readable information bases were accumulating, motivated attempts to provide retrospective search services. For the users this meant that a new interest or search profile could be matched against the accumulated data base (i.e. backwards in time) and not only against the forthcoming additions. The main problem was to find economically feasible ways of processing the voluminous information. Decreasing costs for information storage and for telecommunications made it possible to experiment and develop systems for these retrospective search services.

Today the situation is such that the principal effort in the documentation field is to develop the retrospective search capability using on-line computing technology and to find economically and organizationally feasible structures for the information services.There are parallels between the development of ISS's and the introduction of abstract journals in the 1840's. Not only did they begin appearing at the same volume-date point, in terms of Figure 1, with respect to their predecessor (see Figure 2); the initial scope of individual services was also limited by mission or scientific specialty and only later were interdisciplinary services provided. In terms of projections for growth it is still too early to conclude anything frome these parallels; for one thing the time period is short but there are also other developments that

affect the growth of the number of ISS such as computing and communication hardware, library networking, and the structure of the publishing industry. What we can conclude is that ISS:s are potentially on the path of exponential growth, and that it is meaningful to study these services.

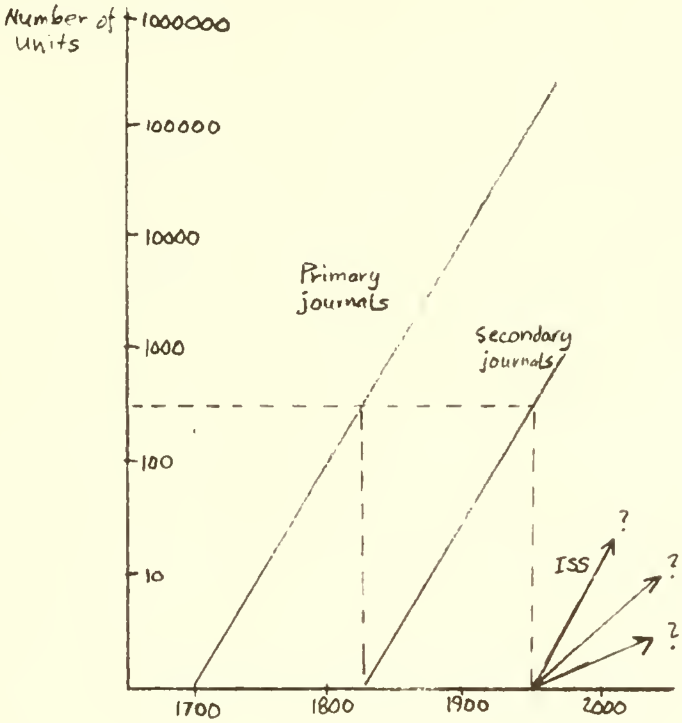

Figure 2.[6]

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6) based on de Solla Price, op. cit.

II. PROBLEM STATEMENT

The problem we are addressing in this study is that of insufficient growth of ISS's. Typically the use of an ISS is such that it is hard for the managers to justify the continuation of the service on economical grounds, and sometimes on grounds of market utility as well.

The difficulty with maintaining growth until an economically self-sustaining level of operation is reached can be a strong inhibiting force on the growth of the number of surviving ISS:s. To a certain degreee this is what happened to SDI services: In the mid-1960's SDI operations were distributed over a fairly large number of independent centers, and today the SDI function is by and large taken care of by a few big centers, or offered as an option by big retrospective search services.

The setting up of an ISS requires quite a large initial investment, and in one way or another a funder is usually supporting an ISS, at least initially. The funder can be a research council or some equivalent organization. For the ISS this usually means that the pressure to reach the self-sustaining level of operation is high. The funder can also be a library, in which case the ISS is regarded as an extension of the library service. Such a symbiosis is quite natural considering that libraries are the providers of actual documents. The survival of an ISS is then partly a function of the decisions made by the funder on basis of his evaluation of the ISS operations.

Although the relevant scope for the study includes, in addition to the ISS itself, both funder and users[7], the root of the problem of insufficient growth is to be found in the ISS/users interactions since we can assume that the funder is responsive to the users' behavior and will not decide to discontinue an ISS that reaches a satisfactory level of operation. For the ISS this typically means that it should recover its costs but does not have to make a profit in economic terms.

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7) Baker, Norman R, and Nance, Richard E.,"Organizational Analyses and Simulation studies of University Libraries: A Methodological Overview", Inform. Stor. Retr., v. 5 (1970), pp. 153-68, discusses the role of the funder for a university library; an earlier conceptual model of behavior in service organizations can be found in: Baker, N. R., "Quantitative Models of Servicer/User/Funder Behavior in Service Organizations", presented at XIV International Meeting of TIMS, Mexico City, August 1967.

There is an identifiable trend towards a decrease in the relative use of scientific information in general[8]. This trend, however, has not yet been analyzed enough to give any causal explanations that are generalizable down to the level of the individual ISS. It could be that this trend is a reflection of the failure of lower level operations (i.e. ISS s) to provide adequate mechanisms for utilizing the body of recorded knowledge.

What, then, are the factors suggesting a need for ISS's? In section I were discussed both the growth in volume and changes in structure of scientific and technical information. To this there might be added a trend towards a decrease in the signal-to-noise ratio in the literature[9] meaning that proportionately more information generated is of low quality which should increase the need for the filtering function which is inherent in an ISS.[10]

Could it be that the need for an ISS is overestimated, and that the insufficient growth, in fact, is what should be expected? From operational experience we can conclude that this is not the case: In several cases a failure to achieve growth has led to second efforts that have been successful[11].

Another possible explanation for the insufficient growth is that the users are not willing to pay for information services since they are used to getting free information service from the library. Again practical experience refutes the hypothesis: It was common for SDI-services to offer their service free during a start-up period and then introduce a fee for the service; the number of users naturally dropped significantly at first but growth resumed fairly quickly and the service typically was back on the original growth path within a year.[12] Similarly the effect of fees for retrospective search

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8) Rózsa, op. cit., p. 113.

9) discussed in Knox, op. cit.

10) the computerized indices improves both the ability to specify what is wanted and what is not wanted even though there is, in principle, an inverse realtionship between the two.

11) see e.g. Carmon, J. L.,"The Operation of a Multi-Disciplined Information Center", presented at the 4th International Conference on Mechanized Information Storage and Retrieval Systems, Cranfield, England, July 1973.

12) based on experiences at the Royal Institute of Technology (Stockholm) and CAN/SDI (Ottawa).

seems to slow down the growth somewhat during the initial phase but is not a strong enough deterrant to stop the growth.[13]

Another theory that has been advanced is that ISS's represent a new type of service/business organization and that the managerial expertise available is not sufficient to lead the ISS:s to a state of economic self-sustainability.

> "... totally inadequate conceptions concerning STI [Scientific and Technical Information] users are guiding the the thinking of many STI/SS [Scinetific and Technical Information Systems and Services] designers and managers. Unless and until research is done that re-shapes current 'mental pictures' of who can or might use STI/SS's, hopes for seeing major improvements in the delivery and utilization of such systems and services are bound to be frustrated" [14]

It is the hypothesis for this study that the insufficient growth of ISS's can be explained by an analysis of managerial policies.

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13) Benenfeld, A. R., et. al.,"NASIC at MIT - Final Report", Report ESL-FR-587, Electronic Systems Laboratory, M.I.T., Cambridge, Mass., February 1975, section 6.

14) Freeman, J. E., and Rubenstein, A. H.,(Eds.),"The Users and Uses of Scientific and Technical Information - Critical Research Needs," University of Denver Research Institute, Denver, November 1974, p. 9.

III. THE STRUCTURE OF AN ISS AND BOUNDARY FOR THE STUDY

To illustrate the structure of an Information Search Service we can relate its functions in terms of "machines" to the overall activity with user access to the scientific literature (Figure 3).

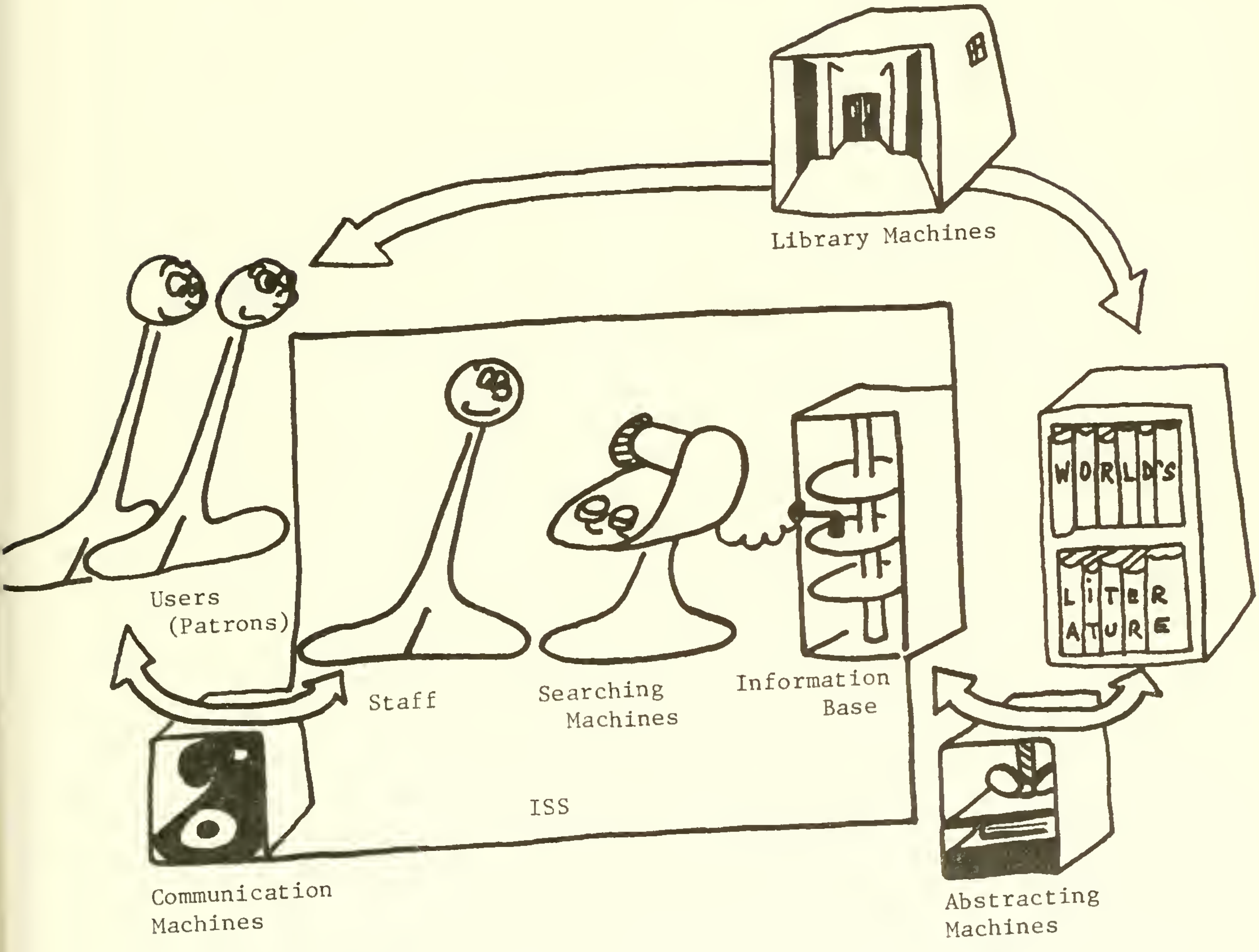

Figure 3.

The function of the Library Machines is to locate a specific document and make it available to the user. The function of the Abstracting Machines is to create a machine-readable description of documents, including a description of the content. For the purposes of this study we assume that the operation of these two types of machines is done by organizations other than Information Search Services.

The function of an ISS

The function of an ISS is, as we have stated previously, to respond to a query, or search request, from a user by performing a computerized search in the information base to locate literature references of relevance to that request.

The language used by the Abstracting Machines is different from that of the typical user and the first task for the ISS staff is to translate the user's search request into the appropriate query language. This process can be described as finding the appropriate key-words, or search-terms . In an on-line environment this process is usually done in stages, so that intermediate search results are, at least partially,displayed and evaluated and on basis of this evaluation the search statement is modified. It is, however, important to have the user be specific about his search request, and frequently he is asked to submit his request in writing by filling out a form. These written search requests are analogous to order backlog in a manufacturing firm, and they are subject to two primary scheduling delays. The subject specialty of the request is matched with the subject competency of the ISS staff and with the coverage of the available information base. The latter matching introduces a delay since because of storage limitations on part of the information supplier it is common to make part of the total information base available at certain times only.

In all on-line information search services the delays due to scheduling and distribution exceed the actual search time at the computer terminal by several orders of magnitude.

The actual role of the ISS staff varies somewhat. In some cases the staff carries out the searches, either with the user by his side or by himself, in other the user does the actual searching with the staff member coaching. In either case the output of the ISS is dependent on the staff resources available.

The physical resources of an ISS are: staff, communication machines, searching machines, and information base.

The performance of an ISS is evaluated from different viewpoints: Management evaluate the goal fulfillment, the funder, the users, and the potential users evaluate the service in some utility terms. All these evaluations lead to actions that affect the future operations of the ISS.

The Management Decisions

Management essentially tries to keep the service time, which we call the Delivery Delay for the service, at an acceptable level by allocating staff effort to the "production" function, i.e. carry out literature searches. The resources that are not needed to achieve the delivery delay goal are used for user assistance and marketing. There is a constraint for the allocation policy since a certain minimum effort is required for user assistance. Part of this minimum is spent on administrative work.

A less obvious way for management to increase the productive capacity is to decrease the staff time spent on each query. Such changes can only be done slowly since they involve a learning process on part of the staff and an adjustment time for the users. The time spent per query is strongly related to the quality of the service and is therefore a high level policy variable. In the present study we assume that the quality goal is not changed.

The users and their decisions

The definition of a "user" of an ISS is not unproblematic when there is no formal contract, like a subscription, on which to base the definition.[15] In this study a user is defined as a person who submits a query to the ISS and remains a user for a "normal user time", unless the effect of delivery delays will make him terminate his interaction sooner.

The users submit queries according to their normal propensity to query. This propensity, however, is influenced by the delivery delay they experience: If the service time is long then the propensity to query is lower than normal.

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15) Marron, Harvey, "On Costing Information Services", Proc. ASIS, vol. 6 (1969), pp. 515-20, deals with this and other problems relating to measuring product and service levels for an ISS.

The potential users

The potential users decide to become users on basis of their perception of the value of the service (measured by the perceived delivery delay) and the intensity of the marketing.[16] The entry rate is also subject to influence from the proportion of users to potential users: the word-of-mouth effect, which has a positive influence on awareness and entry rate, grows at first with the number of users but saturates when the proportion of users is high. There is also a general saturation effect which makes it harder to recruit or attract users as the market penetration approaches 100%.

The funder and his decisions

The criteria used by the funder to decide on his support for the service are not easily identified - it is very much a question of his commitment. Low performance can either improve chances for support (because it is needed) or worsen them (because it shows inability to provide good service). A funder who is committed to the service will respond positively to a sustained long delivery delay and increase his support.

One of the key issues in the funder/service interface is economics: compared to typical budget levels for libraries an ISS requires a substantial share, and somehow the cost must be partly recovered by user charges.[17] Therefore an ISS that retrieves more of the cost has a greater chance of receiving continuing support from the funder.

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16) Llewellen, P.A. and Kaminecki, R. M., "Comparison of System Development Corporation and Lockheed Systems in Searching CA Condensates and NTIS Data Bases On-line", presented at 66th Annual Conference of the Special Libraries Association, Chicago, Ill., June 1975., and

Berk, R. A., An Experimental Case Study of the Diffusion of an Information Innovation in a Scientific Community, Ph. D. Thesis, University of Illinois at Urbana-Champaign, 1974., demonstrate the importance of these variables.

17) Gardner, J. J., Wax, D., and Morrison Jr., R. D., "The Delivery of Computer-based Bibliographic Search Services by Academic and Research Libraries," ARL Management Supplement, v. 2, n. 2 (September 1974), pp. 1-6.

IV. MODEL DESCRIPTION

In this section the simulation model of a typical ISS is described. The methodology for the simulation study is that of system dynamics[18] which is based on causal analysis and the thrust of which is to study the structure of systems to identify possibilities to improve system performance. Specific reasons favoring this approach for the study of Information Search Services are:

- the interaction between users and the service constitute closed feedback loops

- qualitative behavioral variables and relationships are of great importance as influences on system behavior

- there is a lack of empirical data, especially for parameters relating to evaluation of system performance

The structure of the simulation model is given in Figure 4 which shows both the main activities contained in the model and the parameter groups and assumtions that are inputs to the study.

At the center of Figure 4 is the actual operation of the ISS which provides the service, describable in product and process variables, to the users. The users and potential users evaluate the service and respond by submitting more queries or by deciding to become users respectively.

Management evaluates the operations and decides on resource allocation, resource acquisition, and marketing. Similarly the funder evaluates the operations; he considers both the users' viewpoint and his own criteria and decides on support for the ISS.

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18) Forrester, J. W., Industrial Dynamics, Cambridge, Mass.: MIT Press, 1961, and Principles of Systems, Cambridge, Mass.: Wright-Allen Press, 1968 describes the philosophy and methods of the system dynamics approach.

An introductory text is: Goodman, Michael R., Study Notes in System Dynamics, Cambridge, Mass.: Wright-Allen Press, 1974.

Applications of system dynamics that are of special relevance to this study are: Roberts, E. B., The Dynamics of Research and Development, New York: Harper and Row, 1964,
and Nance, R. E., Strategic Simulation of A Library/User/Funder System, Ph. D. Thesis, Purdue University, 1968.

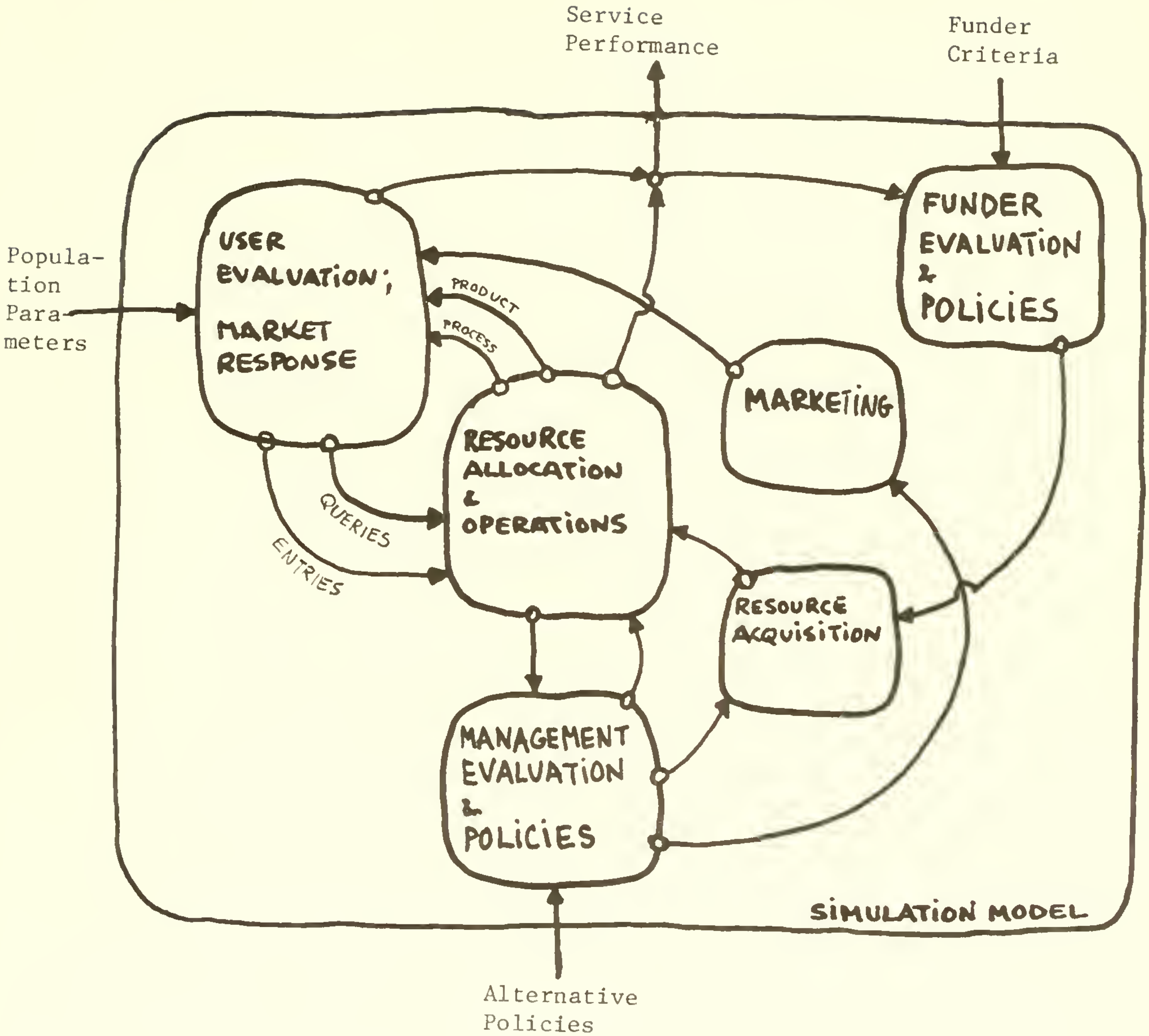

Figure 4.
The structure of the simulation model.

The system dynamics approach to the study of complex systems stresses the analysis of feedback loops. Managerial decisions are well suited for this type of modeling since they are based on information about the state of the system and since their execution affect the state of the system in the future time period. Similarly the users' decisions are well represented by feedback loops.

The loops affecting the level of users are shown in Figure 5.

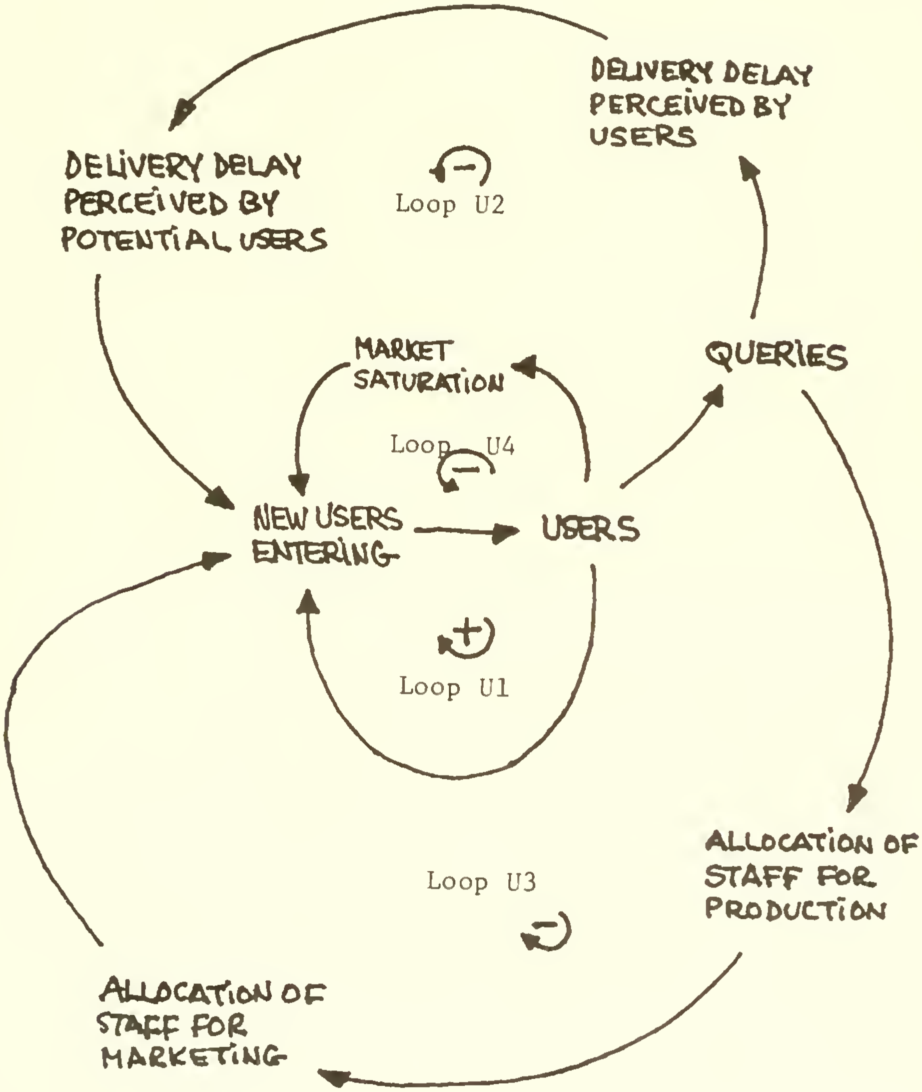

Figure 5.
Loops affecting the level of users.

Loop U1 represents the natural tendency for growth in the number of users: there is an intrinsic need for an Information Search Service[19] and the most important factor affecting the growth is awareness of the service which is, in turn, largely determined by word-of-mouth although the marketing effort by the ISS might prompt the actual decision to become a user[20]. Thus until the ISS has reached its service capacity the number of users will grow at an increasing rate.

In the model ISS1 the normal growth rate (UGN) is 0.0374 which, with a normal termination rate (TRN) of 0.02, means that when the ISS has 800 users there will be 56 new users per month. A termination rate of 0.02 implies a "normal time to remain a user" of 50 weeks.

The other three loops affecting the level of users are negative loops controlling the growth. Loop U4 contains a multiplier from market penetration on user entry rate. This multiplier represents the increasing difficulty in recruiting new users when more and more potential users have actually become users. Table 1 shows how this multiplier depends on the fraction of users to potential users. The initial increase and subsequent decrease to unity represents an additional effect due to the fact that the probability of a user to come in contact with a potential user at first increases with an increase in the number of users and then decreases. The final decrease in the multiplier value is a straightforward saturation effect.

Loop U2 represents the effects of delivery delay on the entry rate; if the delivery delay is long compared to the standard of the potential users (the delivery delay normal - DDN) they will not be as willing to become users. The user termination rate will also increase, but in this model these two effects have been lumped together into the multiplier from delivery delay on entry rate - MDDER. Table 2 shows the value of MDDER as a function of delivery delay perceived over DDN.

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19) Ahlgren, Alice, "Providing On-line Search Services Through the Public Library," Proc. ASIS, vol. 12 (1975), pp. 156-7, shows that this is true also outside research oriented academic communities.

20) Benenfeld, et. al., op. cit. (NASIC Final Report), p. 1 - 4.

U/PU	MPUER
0	1
0.2	1.05
0.4	1.1
0.6	1.05
0.8	0.80
1.0	0

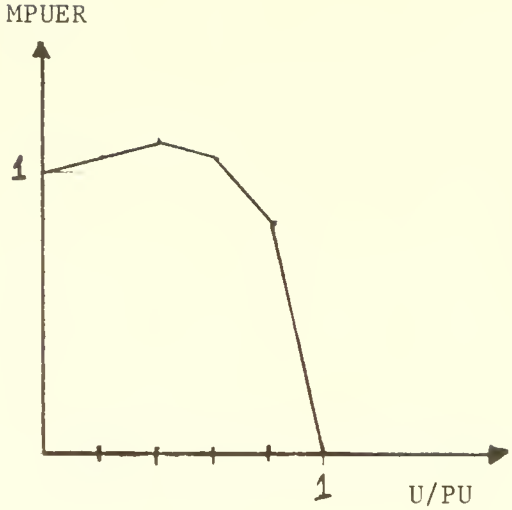

Table 1.

DDPP/DDN	MDDER
0	1.6
0.5	1.47
1.0	1.0
1.5	0.47
2.0	0.3
2.5	0.3
3.0	0.3

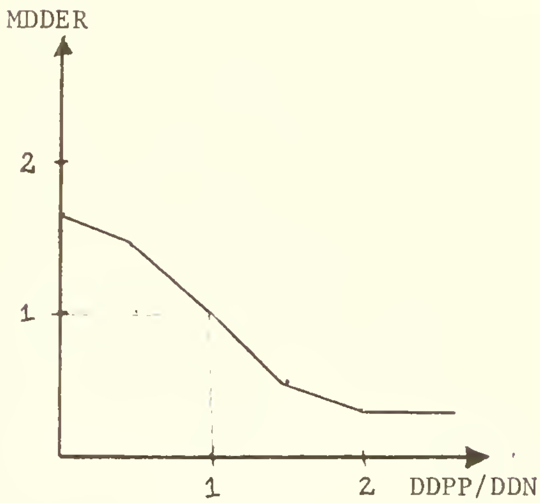

Table 2.

Loop U3 represents the effect of marketing and user assistance on the entry rate. As the number of queries varies so does the need for and subsequent actual allocation of staff for production. Since the staff allocated to production is unavailable for marketing an increase in the allocation for production will decrease the marketing effort which will have a negative effect on the entry rate. It is unrealistic to assume that the total staff effort can be shuffled between the two activities; there is a certain minimum effort needed for customer assistance and marketing[21]. In the normal run for the model ISS1 it is assumed that this minimum is 20% of the total staff resources.

Table 3 gives the value of the multiplier from assistance and marketing on entry rate, MASST, as a function of the ratio between the desired, or normal, staff effort allocated for assistance and marketing, ASTND which is a function of the number of users , and the actual allocation, ASM. The normal value for assistance is assumed to be 0.001 staff per week and user. This means that during one year a user requires two hours of staff time to remain satisfied. The shape of the curve in Table 3 shows a non-linearity. When resources for marketing are in excess of the actual "satisfactory" level the effect on the entry rate is often dramatic. The general explanation for this is that when the "needed" marketing effort is exceeded there is a change from marketing on the defensive, where the goal is to prevent users from leaving and where the users essentially come to the service, to an offensive marketing where new communication channels are used to reach the potential users.

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21) actual average values for the resources spent on marketing and customer assistance is anything between 10 - 35 % of total staff effort;

Gardner, J. J., <u>et. al.</u>, <u>op. cit.</u>, p. 6 gives examples of explicit policies to allocate a minimum of 15% of the operating budget to marketing efforts.

ASTND/ASM	MASST
0	2.0
0.25	1.9
0.5	1.78
0.75	1.53
1.0	1.0
1.25	0.8
1.5	0.62
1.75	0.5
2.0	0.37
2.25	0.25
2.5	0.2
2.75	0.15
3.0	0.1

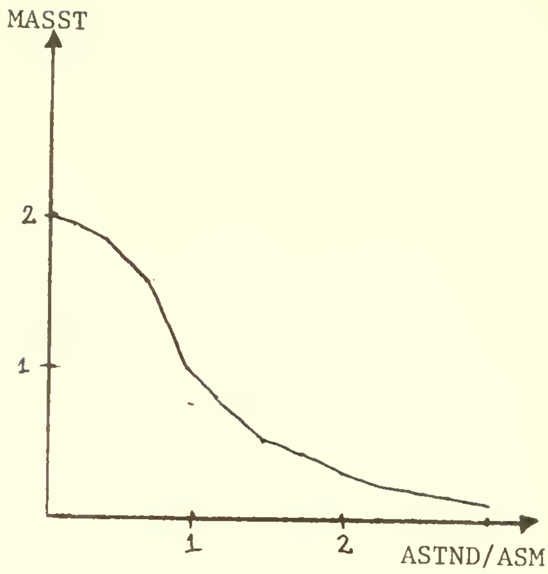

Table 3.

DDPU/DDN	MDDPQ
0	1.5
0.5	1.25
1.0	1.0
1.5	0.8
2.0	0.65
2.5	0.57
3.0	0.5

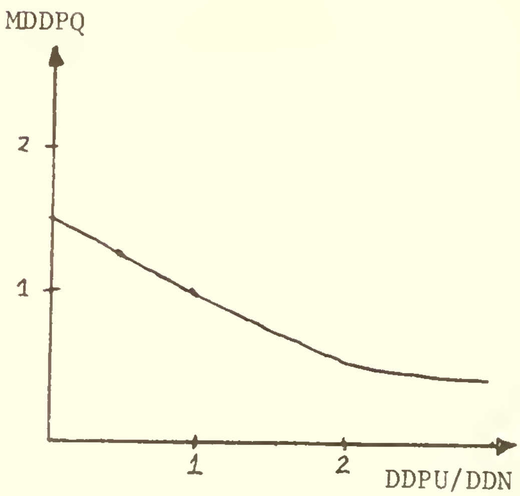

Table 4.

The loops affecting the level of queries in process are shown in Figure 6.

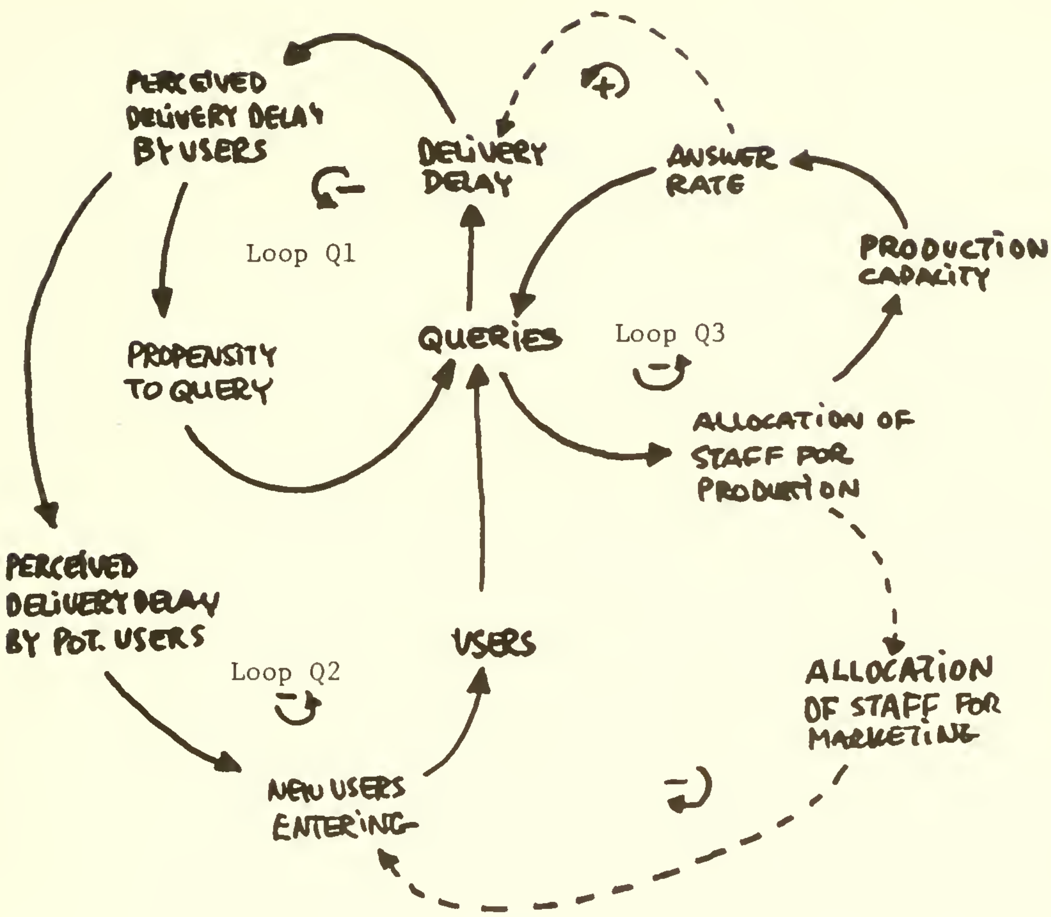

Figure 6.

Loop Q2 is the same as loop U2 in figure 5 and is repeated here since it also affects the level of queries. Loop Q1 represents the effect that users, when perceiving a good service (in this model in terms of delivery delay), show an increase in their propensity to query. Table 4 shows the value of the multiplier from delivery delay on the propensity to query as a function of the ratio between perceived and normal delivery delay. The relative flatness of the curve is explained by the fact that the multiplier represents only an additional effect on the propensity to query which is primarily a characteristic of the user population. In the model the parameter representing the information need is the "normal propensity to query" (PQN).

Loop Q3 is different from the other two loops since instead of representing the users' evaluation and responses it represents managerial decision making. The direct effect on queries of the staff allocation decision is to increase the production capacity when queries are increasing, and thus enable an increase in the answer rate which will decrease the level of queries.

The answer rate (AR) is formulated as the number of staff allocated to production times their productivity in terms of potential query responses (SPQR). In ISS1 the capacity is set to 10 queries per staff and week.

Figure 6 also shows a dysfunctional effect, in terms of control of the query level, of the resource allocation decision. As the answer rate goes up the delivery delay gets shorter which eventually will stimulate the users to submit more queries and potential users to become users.

The loops affecting the level of staff are shown in figure 7. Staff is increased by hires and decreased by a leave rate. The leave rate is a straightforward average depending on the normal time people stay at the ISS; the parameter value for "time on job" (TOJ) is set to 200 weeks.

The hire rate is a function of desired hires, both from a need to replace the leaving staff and to increase the total number of staff, and the support given by the funder. Both the desired expansion and the support from the funder are functions of the ISS performance. For the first set of runs these two loops will be inactive, representing a trial period with a fixed level of staff.

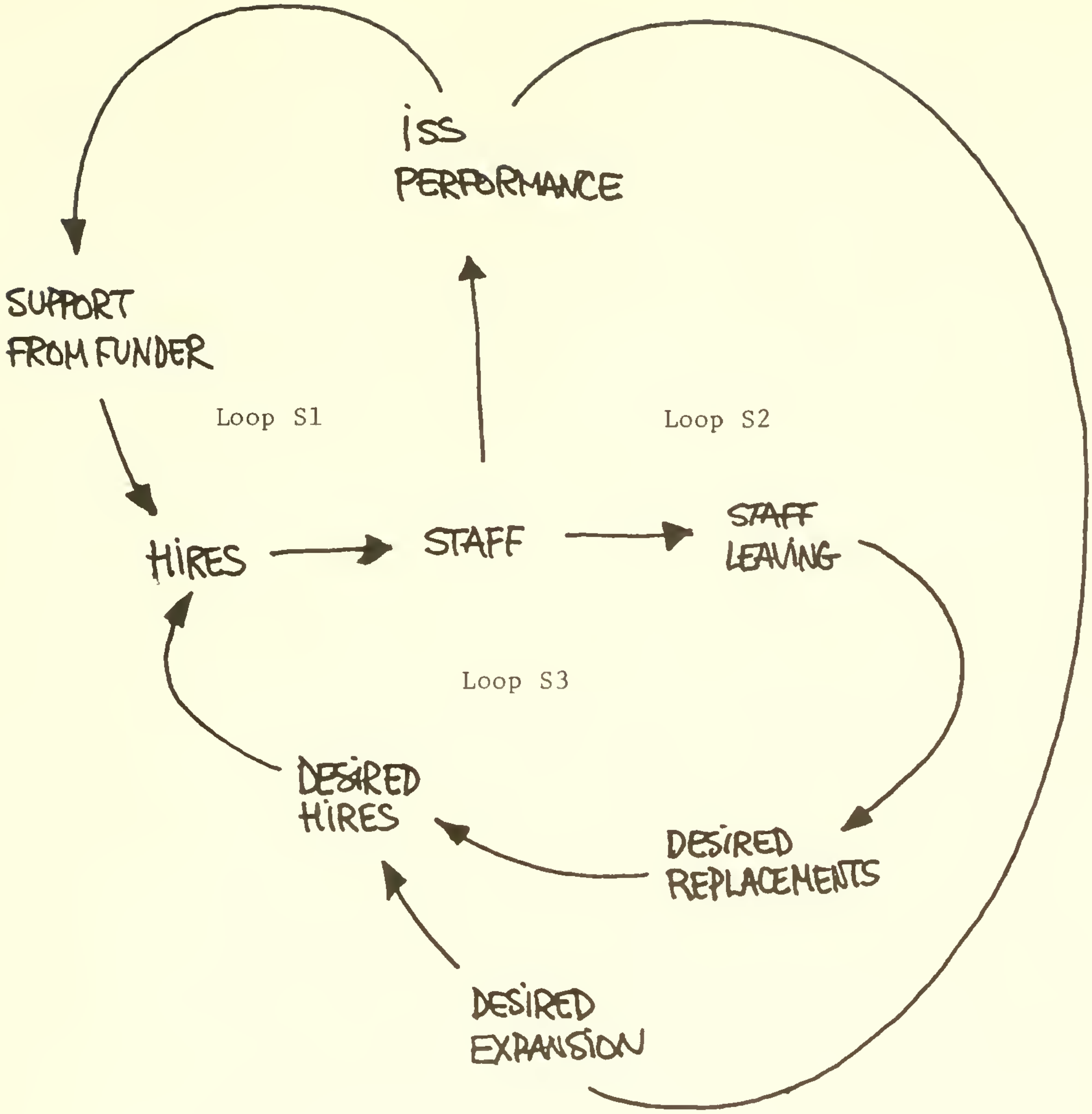

Figure 7.

In the initial simulations of ISS1 the only performance measure for the ISS is the delivery delay. The delivery delay perceived by the funder is a delayed version of the users' perception since it is assumed that it takes some time before the users' perception is communicated and registered by the funder. The funder's commitment is decisive for the development of the service. A low performance will make a committed funder more willing to support the service since it will be taken as a sign that resources are not adequate. A critical funder, on the other hand, can take low performance as an indication of hopelessness and reduce the support.

The effects of the resource allocation decision are illustrated in Figure 6, since the allocation is designed to keep a desired delivery delay by preventing a build-up of queries in process.

The primary effect is to increase the production capacity and the answer rate wich will decrease the level of queries. There are, however, two secondary effects: the effect on delivery delay has already been discussed in addition an increase in the allocation of staff to production will decrease the marketing effort which will have a negative effect on the entry rate for users, and thereby decrease the query rate.

The model ISS1 consists of the three levels: Queries, Users, and Staff, together with mathematical specifications for the feedback loops discussed. An overview of the model is given in Figure 7.

The effects of the resource allocation algorithm are illustrated in Figure 6, since the allocation is arranged to keep a desired lot entry delay by preventing [illegible] of [illegible] in process.

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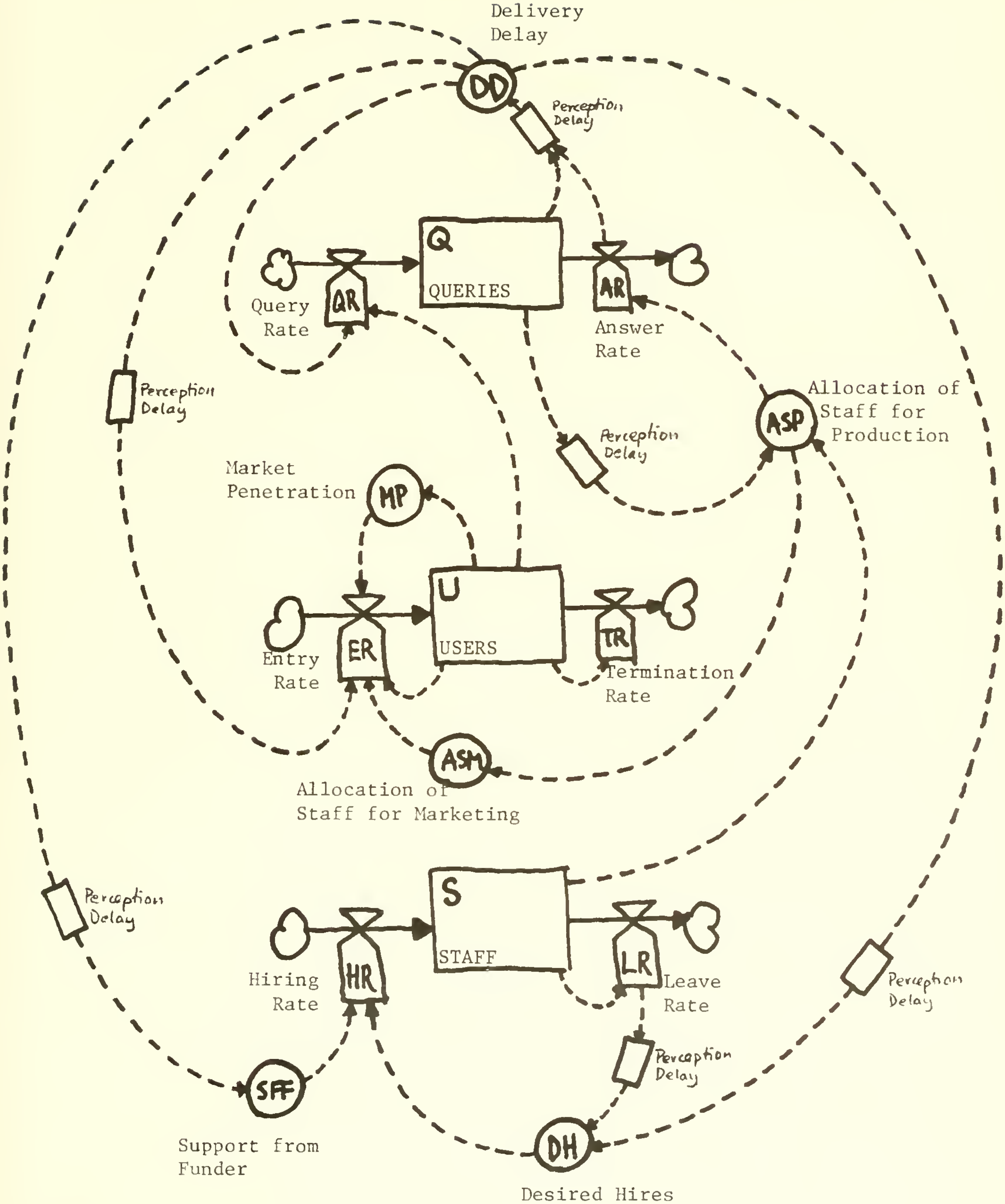
Delivery
Delay
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QUERIES
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ASP
Perception
Delay
Market
Penetration
MP
U
USERS
ER
Entry
Rate
TR
Termination
Rate
ASM
Allocation of
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LR
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Figure 7.

V. MODEL BEHAVIOR WHEN RESOURCES ARE HELD CONSTANT

The first simulation run with ISS1 show the growth of a typical ISS. The service has three staff persons, and it is assumed that the run represents a trial period during which there is no expansion of staff. It is common to consider the first years of the ISS operations to be a research project or an experimental activity. The time period is usually longer than a year since the setting up of an ISS requires a relatively large investment. The information bases need not be acquired by the ISS itself; instead access to the bases of information "wholesalers" can be bought. This will make the monetary investment smaller but the organizational investment is still substantial, especially in staff education.

Figures 8 and 9 show the development of several variables over time. Figure 8 contains the system levels (users, queries, and staff) together with the entry rate, the query rate, and the fraction of staff allocated to production. Figure 9 contains the values of the multipliers which operate on the query rate and on the entry rate - these multipliers represent feedback effects in the ISS/user interaction.

The "natural" growth of the ISS is amplified during the first three quarters when there is not enough workload, in terms of queries, to conflict with the marketing activities. Users are attracted to the service by relatively intensive marketing and by a delivery delay situation that is practically at par with their requirements. Somewhat before the end of the first year, however, when the number of users is about 600 and the entry rate is 35 new users per week the effect of insufficient staff is having a dramatic effect on the entry rate which drops very quickly.

Due to the reactive character of the allocation policy applied in this model - the ISS management will only allocate resources to production when there is an established need for so doing on basis of a build-up of queries in process - the fast growth in terms of users will lead to increasing difficulties in keeping the delivery delay short. The adverse effects on the existing users' propensity to query are counteracted by an increase in the allocation of staff for production and all through the first year the propensity to query does not go much below normal (see Figure 9). The effect of delivery delay on entries takes a bit longer to be noticeable; the potential users do not have a first hand experience of the service and there is a delay before the users' perceptions are

known. Once the potential users have made an assessment of the service it is difficult for the ISS to change it ; the people who have decided that the service is not good enough to try will naturally be less inclined to pay attention to information from the ISS. At the end of the first year the multiplier from delivery delay on entry rate (MDDER) is about .86 which means that some potential users find the delivery delay too long to become users.

During the first year the awareness of the service is growing and the word-of-mouth effect contributes increasingly to the rate of growth in users.

During the second year the entry rate is substantially lower. The main reason is, of course, that there are not enough resources to market the service - it is even difficult to give adequate assistance to the existing users. But there is also an effect from the "oversell" during the first year: The resulting longer delivery delay has lead to a lower propensity to query for the users (figure 9) - they are not stimulated to submit "extra" queries and some users even submit less than what they normally would. Knowledge of the longer delivery delays have now reached outside the circle of users and is deterring some potential users from entering. The effect among the potential users indicate an overreaction and it is so strong that it leads to a decrease in the number of users.

In quantitative terms the simulation run with ISS1 shows an information search service which with a staff of three after a little more than two years (120 weeks) has grown and reached a level with 15 new users entering the service per week. The number of queries is 24 per week (or about 100/month), and the percentage of queries that are submitted by "old" users is a little bit more than one third. The number of users is a construct in this model and it is not without problem to compare the model with reality since there is no easy way to identify a user in real life; the number of users after two years is, for ISS1, 791. Rather than comparing the level of current users it is easier to compare the total number of users served, i.e. the number of people who have submitted at least one query to the ISS - for ISS1 this number is 2123, and the total number of queries answered is 2036. An explanation in real terms of the phenomenon of fewer answered queries than user entries is that due to negative effects from delivery delay some users have decided not to wait for their query to be answered (as was described previously it is the scheduling delay that is the major delay not the actual searching).

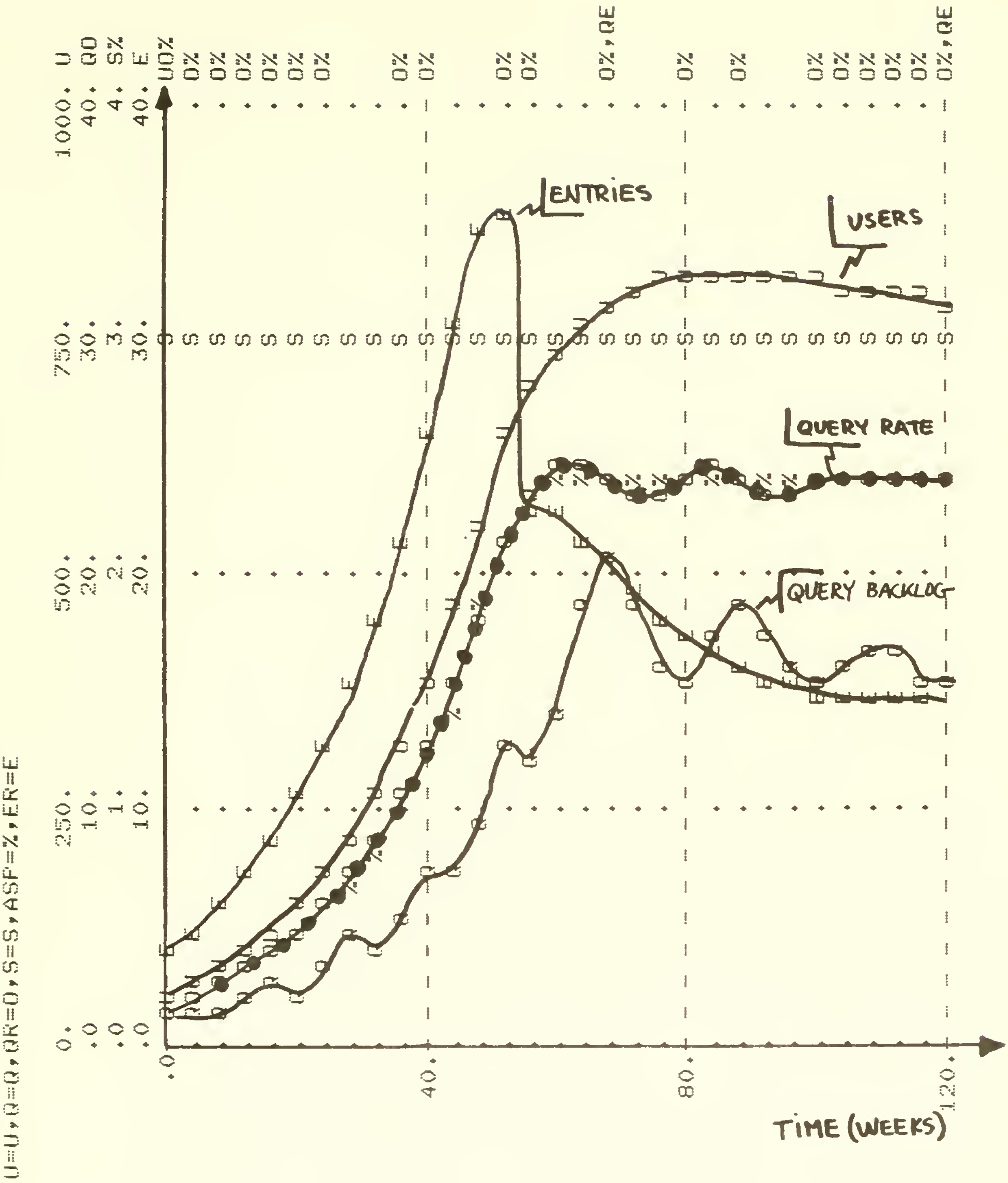

Figure 8.

Standard run of ISS1 - system levels and principal rates.

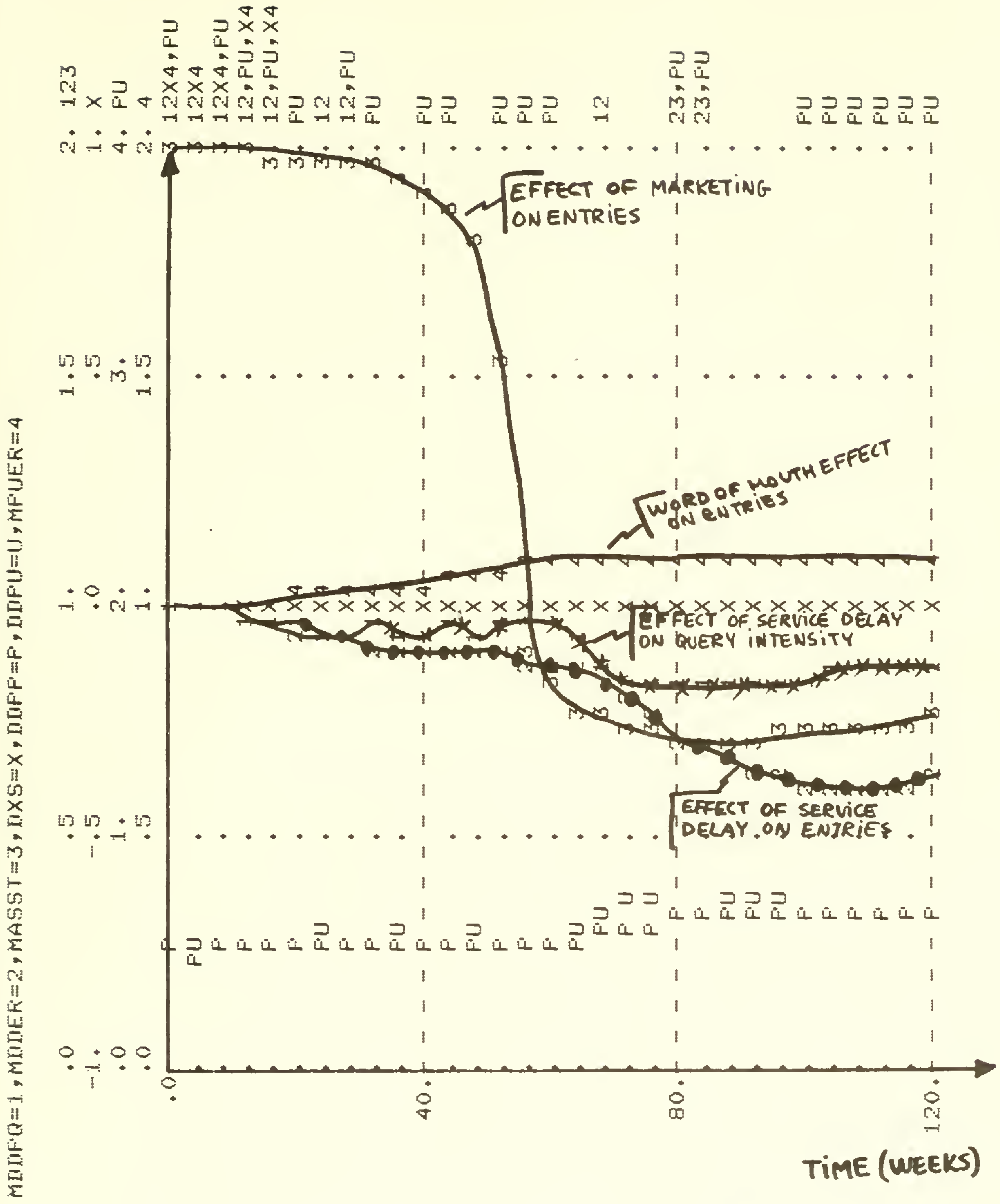

Figure 9.

Standard run of ISS1 - values of multipliers.

In addition to the total number of entries and answered queries the following performance measures are calculated as part of the simulation runs:

SERVIX - a service index formulated as the product of the multipliers affecting the entry rate: MDDER and MASST. This index has no absolute meaning, but it represents the joint effect of marketing and delivery delay as seen from outside the service.

AGOWL - accumulated good-will. The measure is the integral over time of the previous measure, SERVIX, but it is assumed that the "life time" of good-will is two years so there is a decrease over time.

YPUG - yearly percentage user growth. This percentage is calculated continously so the value at each time gives the growth rate for the year preceding that time.

QPUG - quarterly percentage user growth.

Table 5 gives the operational and performance measures for the run with ISS1.

STANDARD RUN ISS1

TIME E+00	SAR E+00	SER E+00	SERVIX E+00	YPUG E+00	QPUG E+00	AGOWL E+00
.0	.0	50.0	1.9929	285.99	65.998	.00
8.	17.1	87.1	1.9729	190.86	47.693	15.85
16.	41.4	143.0	1.9143	138.58	41.319	31.35
24.	79.2	225.3	1.8411	109.60	38.633	46.31
32.	135.0	344.6	1.7780	93.11	37.166	60.72
40.	215.4	516.0	1.7145	83.47	36.203	74.64
48.	335.3	756.6	1.5808	77.71	35.262	87.88
56.	502.2	1012.8	.8004	73.10	30.059	97.96
64.	692.3	1193.4	.6869	65.24	20.004	103.89
72.	884.3	1359.7	.5864	57.87	13.319	108.95
80.	1076.3	1505.7	.5091	50.52	8.007	113.23
88.	1268.3	1639.3	.4780	43.43	4.203	117.10
96.	1460.3	1764.3	.4480	36.80	1.547	120.73
104.	1652.3	1883.3	.4485	30.69	-.217	124.22
112.	1844.3	2003.0	.4563	25.55	-.927	127.76
120.	2036.3	2122.9	.4630	21.22	-1.162	131.35

Table 5.

Performance and operational measures for the standard run of ISS1.

The standard run of ISS1 gives a realistic picture of the development of an ISS in terms of quantifiable variables, and a believable explanation of the behavior with regard to the more or less intangible pressures represented by the multipliers on the entry rate and the propensity to query.

As a further test of the validity of the model structure the effects of an intensive marketing drive were simulated. Starting in the state at time 120 of the standard run, 50% of the staff effort was allocated for marketing for one week. This effort is comparable to what is required for an effective campaign which includes demonstration searches.

Figures 10 and 11 show the behavior of the system over the 40 weeks following the marketing drive. The entry rate goes up immediately (see figure 10) due to the "effect of marketing on entry rate" , the multiplier MDDER which is shown in Figure 11. The number of users consequently goes up, and continues to rise for a while after the campaign is over.

The number of queries in process, or the backlog, rises immediately due to the reduced effort allocated to production, but is being brought down when the staff has returned and are working with full efficiency again. The neglect to keep production up, which was forced by the decision to have the marketing drive, led, however, to a decrease in the quality of the service (as measured by delivery delay), and this caused the existing users to reduce their query intensity which contributed to the reduction of queries in process.

In less technical terms what happened was that the system was "clogged" by entering users, and the delivery delays got longer which reduced the number of incoming queries from existing users.

After about 15 weeks the backlog of queries was reduced to less than what it was before the marketing drive, and some staff resources could again be allocated to marketing, or to "follow up" on the marketing drive, resulting in a second wave of entering users.

The increase in delivery delay that was an immediate effect of the marketing drive also scared some potential users away, as shown by the plot of the "effect of delivery delay on entries" (in Figure 11), and this effect remains for a long time.

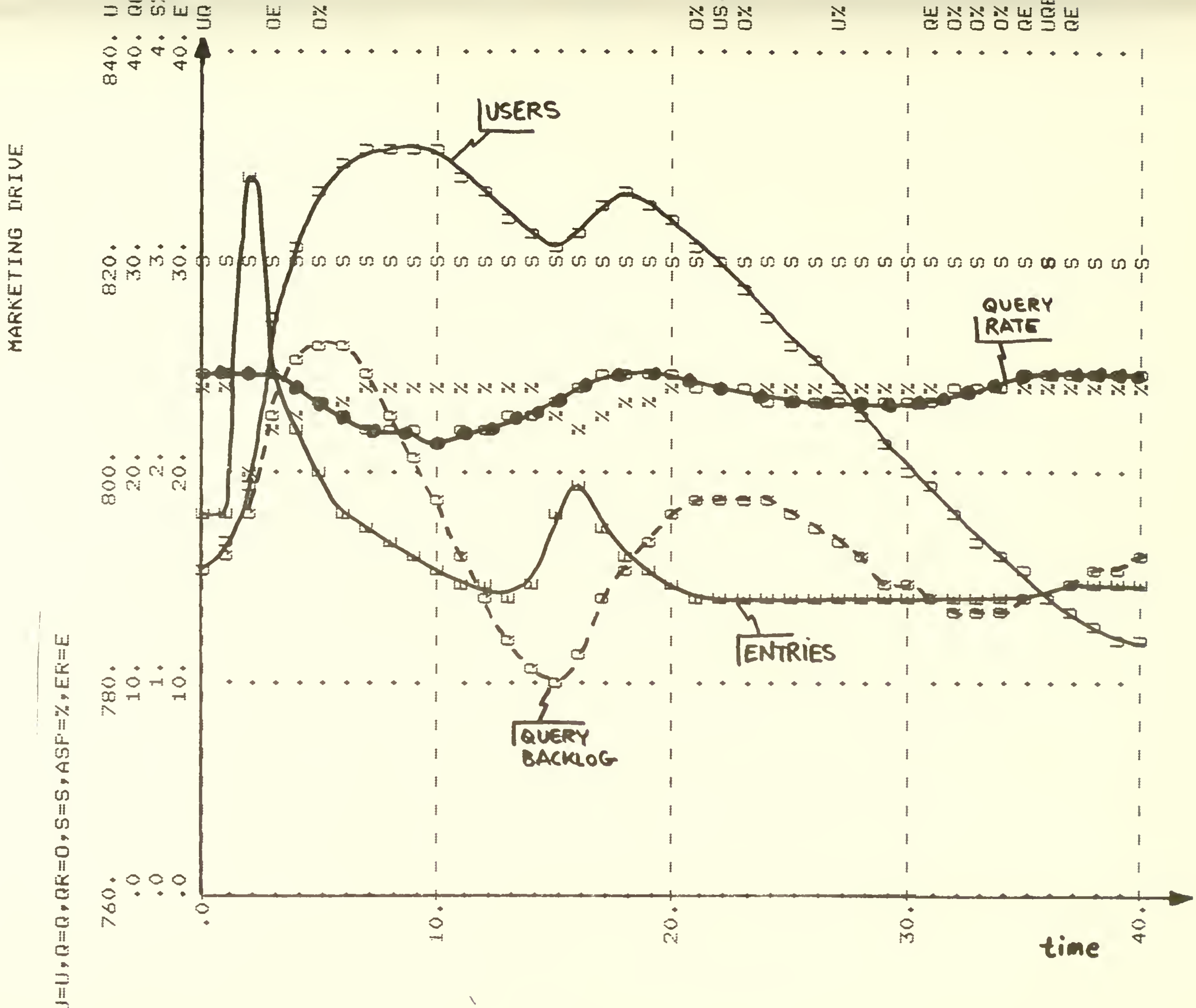

Figure 10.
Marketing drive for ISS1 - system levels and principal rates.

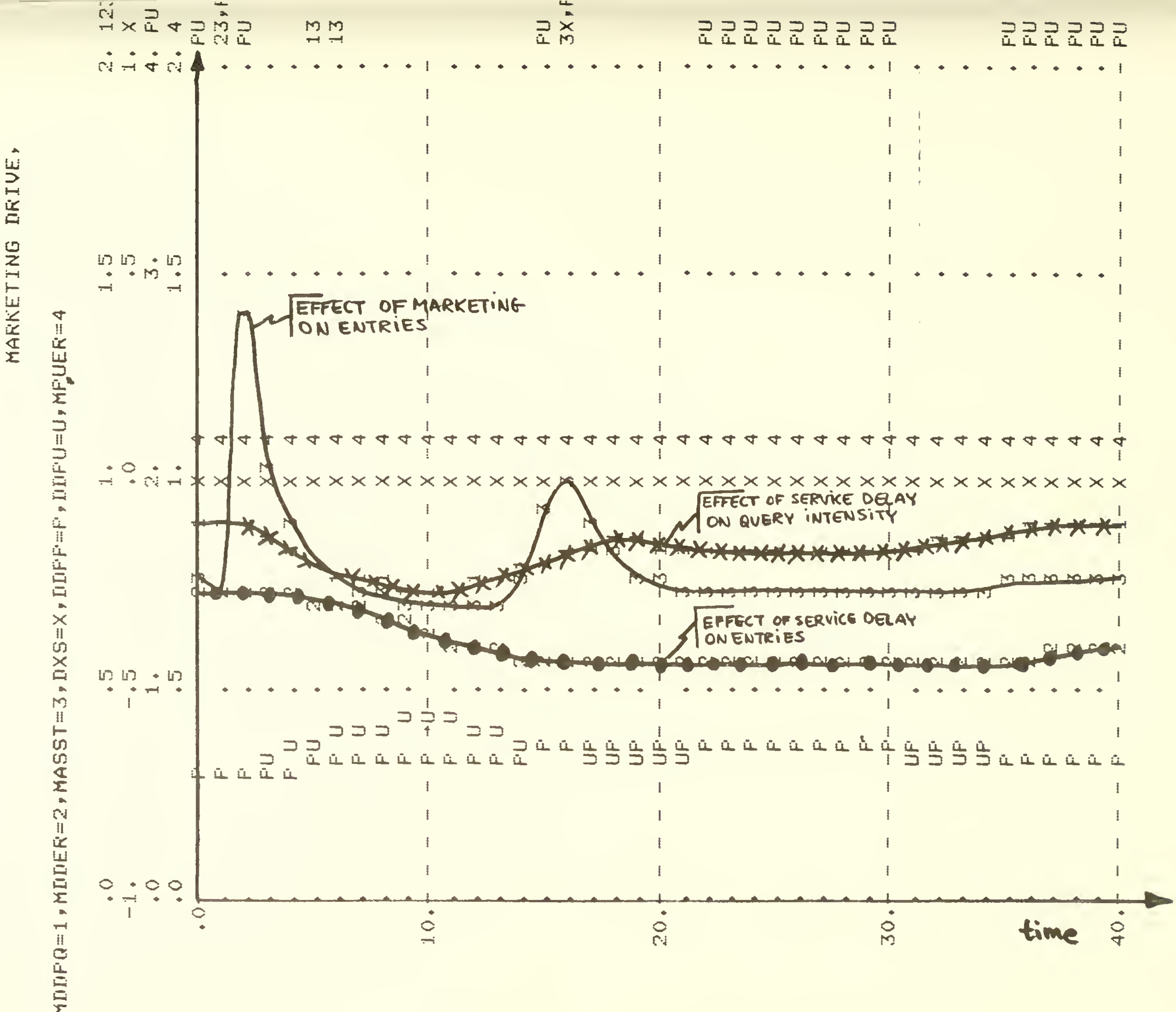

Figure 11.

Marketing drive for ISS1 - values of multipliers.

The users' propensity to query is back to its pre-campaign value after about 18 weeks, but the effect of delivery delay on entry rate is still below its previous value 40 weeks after the campaign.

So on the whole the marketing drive introduced an expected initial growth in the entry rate, but then most of the increase in operational measures was counteracted by adverse effects due to increases in delivery delay. This could also be expected since the load on the system was as much as it could handle even before the marketing drive, and since there was no increase in staff to take care of the new users.

An examination of the operational and performance measures, given in Table 6, shows that the ISS actually is hurt by a marketing drive under the conditions we simulated. The only measure that was better was the value of SERVIX after week 52 but this is not a very significant variable when assessing the effects over several weeks - the accumulated good-will for the year following the marketing drive (AGOWL) is actually less than the comparable run without the campaign.

	Total # of queries	Total #of users	AGOWL
Marketing drive	1232	825	24.46
Continuation without marketing drive	1248	832	24.79

Table 6.

Sensitivity of model behavior to user characteristics

Several runs were made with the model under different parameters describing the users and potential users.

PU - the size of the potential market. Since staff is the limiting resource in the simulation runs of the first two years, and since the potential capacity of the ISS prevents a large market share, a halving of the potential market from 2000 to 1000 potential users will not make any difference in the quantitative operational measures. The number of users, and the entry rate and query rate will be the same. There are however some important differences in the more qualitative measures. The accumulated good-will is higher (137.98), and the value of SERVIX stabilizes around 0.61 as opposed to 0.46 in the standard run (where PU=2000). Furthermore the total number of answered queries (SAR) actually exceedes the total number of entries (SAR=2055, and SER=2030) which indicates a better service than the standard run. The explanation for these differences is that the multiplier from market penetration on entry rate (MPUER) limits the growth, and this limiting force is different from the effects from too long delivery delay and too little assistance since it does not cause "disappointment" which has long term negative effects on the ISS.
It is interesting to note that the total number of answered queries is actually higher (2055 vs. 2036) than when the potential users were 2000. The total number of entries is lower (2030 vs. 2123) but the proportion of users to potential users is higher since the level of users after two years is about 750.

If the PU is 700 the positive effects in terms of SERVIX and AGOWL are even higher. In this case, however, the saturation effect is stronger and the volume of business is lower.(SAR=1903, SER=1749, AGOWL=184.9, and SERVIX at time 120 is 1.06). The ending query and entry rates are practically the same, but there are some minor fluctuations due to the fact that the ISS is not pushed as hard towards production which gives management the possibility to reallocate some resources to marketing and this reallocation is part of the feedback loop: more marketing - more queries - less resources available for marketing.

Since the size of the potential market to a certain degree is controllable by the ISS management, e.g. by restricting the service to certain user groups, there is a policy conclusion to be drawn from these simulations: If the ISS tries to serve too large a market, given the staff capacity, it will hurt the

operations both in qualitative and quantitative measures. A too small potential user pool will give better qualitative results, such as good-will, but the volume of business will be less.

PQN - the normal propensity to query. The lower the propensity to query is the easier it is for management to keep up with the changes in the required allocation of staff for production. In fact, since the reallocation of resources is relatively fast compared to the users' reactions the allocation policy applied in ISS1 will lead to an "over-allocation" to production, which will result in a very short delivery delay which stimulates both the incoming query rate and the entry rate. The entry rate consequently rises faster than in the standard run, but the increased allocation to production caused by the fast build-up of queries in process makes it necessary to take resources away from marketing sooner so the overshoot in entries (ER) is both higher and earlier. This overshoot will make the delivery delay longer, but since it was "too good" in the beginning it remains shorter than the normal (DDN) for quite some time. The increase in the deliver delay will, however, be noticed by the users and they will respond by reducing their propensity to query. After a delay the negative effects will have penetrated into the potential market and the extra stimulus on entry rate from the good delivery delay situation will vanish.

A simulation with PQN=0.02 (in stead of the standard run value of 0.035) shows an ISS which after two years is operating at a level of about 1200 users, with an entry rate fluctuating some around 23 new users/ week and an average query rate of 24 queries/ week. The backlog of queries in process is actually somewhat lower than in the standard run but it fluctuates more due to the larger overshoot and the reactive nature of the policy to reallocate staff resources. Figure 12 shows the system levels and principal rates for this simulation.

The time-plot of the multipliers (figure 13) shows a very different behavior than the standard run. When the propensity to query is low the ISS can provide better service to the users, and the end state of the system is one where the delivery delay is kept at par with what the users require - there is no disappointment because of delivery delay. However, the inadequacy of resources for marketing and assistance is greater. In terms of the operational and performance measures this population of "low frequency" users makes it possible for the ISS to do better; the accumulated good-will is 144.4 (as compared to 131.4 in the standard run). The total number of entries is dramatically higher

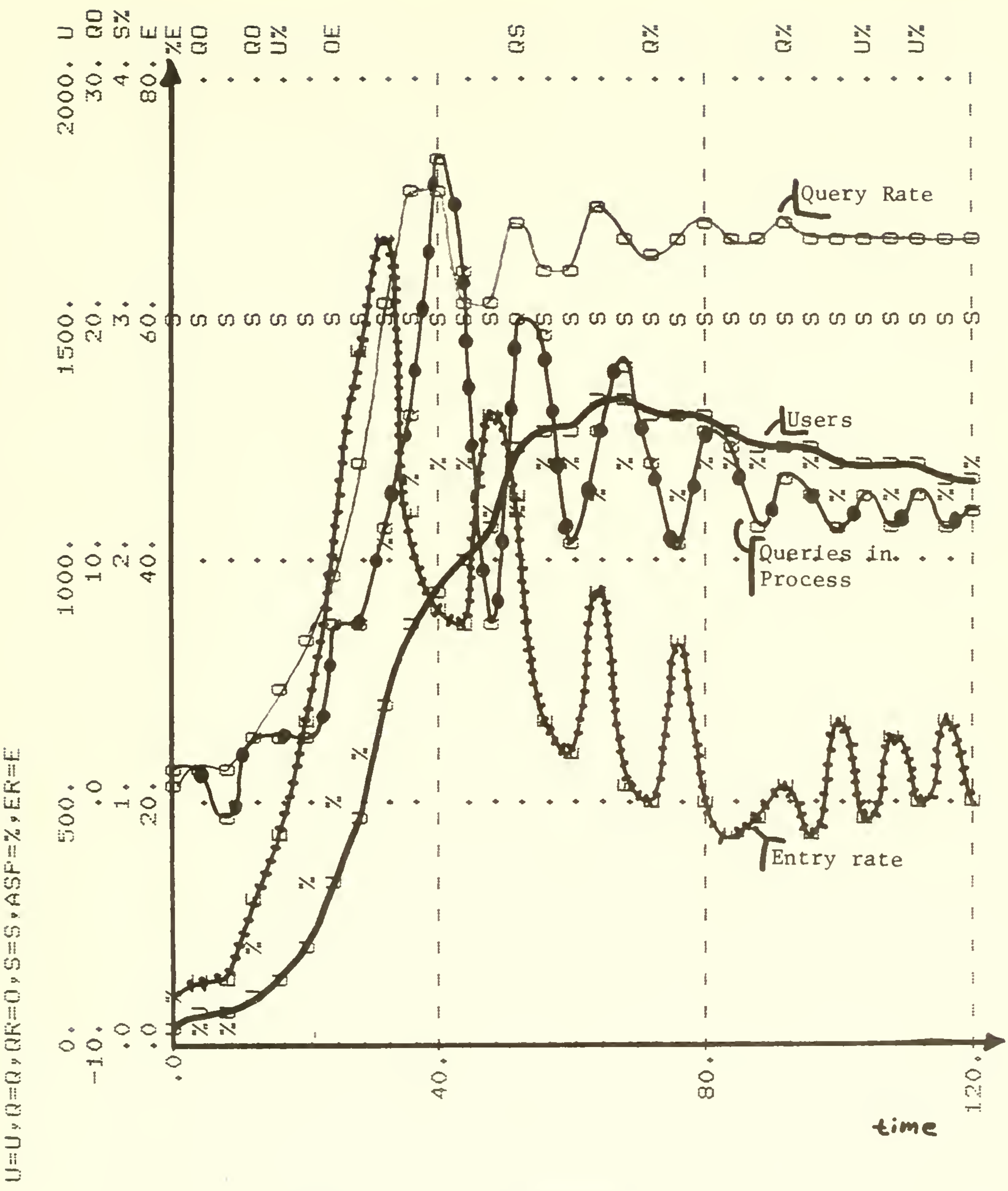

Figure 12.
ISS1 with low frequency users - system levels and principal rates.

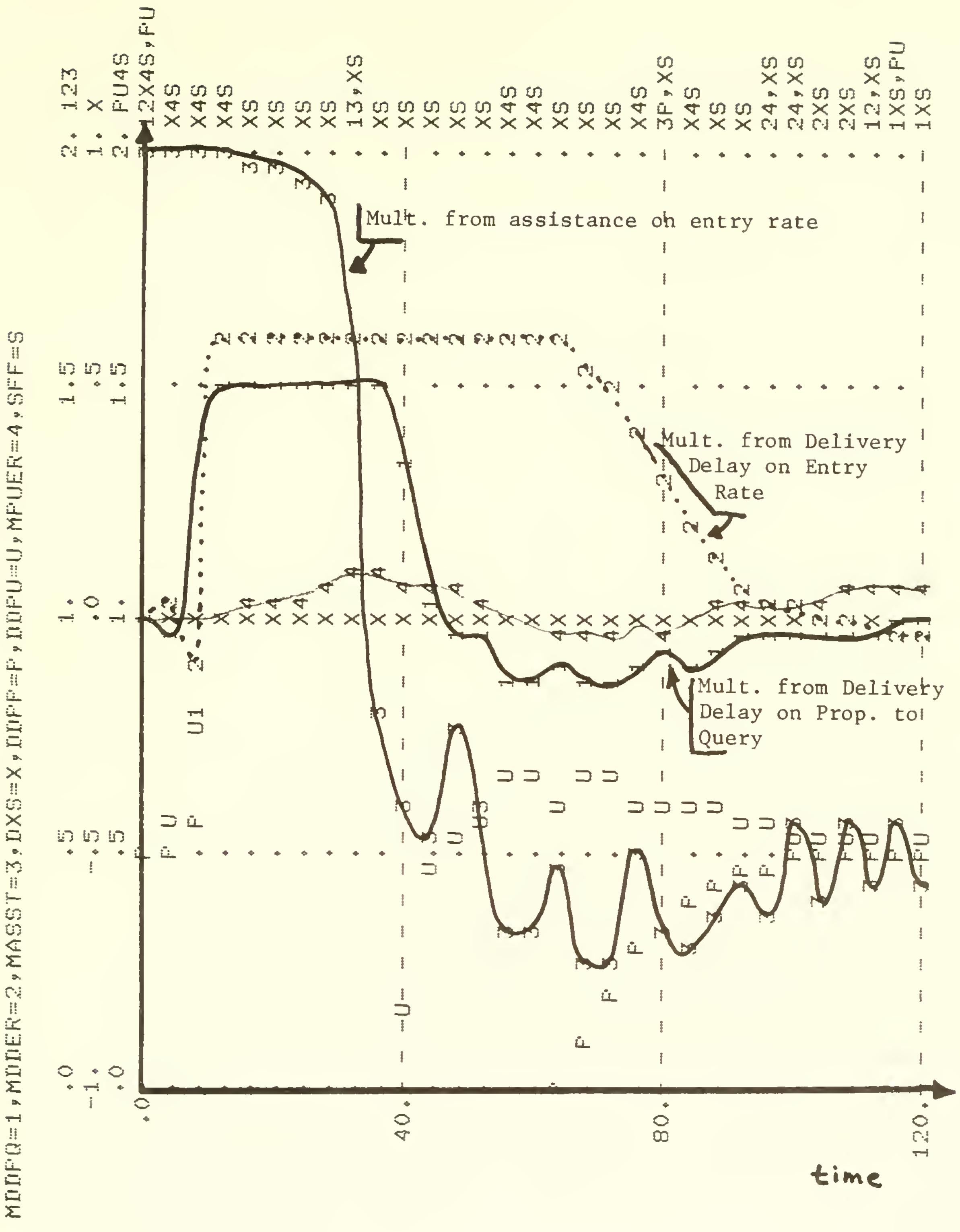

Figure 13.

ISS1 with low-frequency users - values of multipliers.

(3405 vs. 2123 for the standard run) while the increase in total number of answered queries is less so (2229 vs. 2036).

An increase in PQN does not change the outcome of the simulation as much as a decrease. The ISS will reach its capacity sooner than in the standard run and the effect of delivery delay on both the query rate and entry rate will be stronger than in the standard run which will inhibit the growth of users sooner, and the multiplier from assistance on entry rate will end up around unity. With very high frequency users the ISS1 will perform worse in terms of the service index and goodwill; it will have fewer total entries (1673) but slightly more answered queries (2178).

The propensity to query is generally not controllable by the ISS management but is a characteristic of the potential users (and users).

UPT and PPT - the users' perception time and the potential users' perception time. For realistic changes the behavior of the model is not changed significantly from that of the standard run. If the users' perception time is set to an unrealistic two weeks the behavior is more unstable for the period between week 40 and 80 but is similar for the other periods of the simulation.

The model ISS1 was also tested with different assumptions regarding the sensitivity of the users and potential users to the delivery delay. In the simulation runs the different sentivities were represented as changes in the tables for the multiplier from delivery delay on the propensity to query (MDDPQ), the multiplier from delivery delay on entry rate (MDDER), and the multiplier from assistance on entry rate (MASST).

The effects of changing the sensitivity of the potential users to delivery delay for their decision to enter as users are not very dramatic. If the potential users are less sensitive, which is represented by a flatter table, the growth of the ISS will differ from the standard run in the following ways: since one of the inhibitors (negative feedback effects) on the entry rate is made weaker the overshoot in the entry rate will be higher and over the simulation run more users will enter. The number of queries answered will be slightly higher but the final value for the query backlog will be higher. In terms of the performance measure accumulated good-will (AGOWL) runs with a flatter TDDER will naturally give a higher value since less sensitivity to delivery delay also means that there is less loss of good-will for longer delays.

If the decision to enter is less dependent on the delivery delay the initial growth in queries is more stable since there are less variations in the entry rate and the number of users. This stabler growth in queries leads to a stabler growth in the fraction of staff allocated to production so that the maximum production capacity is reached faster which accounts for the increase in the number of queries answered. This increase, however, is not very big.

Making the table for the multiplier from delivery delay on the propensity to query (TDDPQ) steeper dampens the fluctuations in the query backlog but does not significantly alter the behavior of the model. A steeper TDDPQ means that existing users react stronger to changes in delivery delay and since their decisions to submit queries is a faster response than the potential users decisions to enter the service they absorb more of the discontent caused by long delivery delays. A simulation run with a steeper TDDPQ gives a slightly higher AGOWL value (which is based on the effects on potential users) and a lower final value for the propensity to query.

Changing the representation of the potential users' sensitivity to marketing and assistance has a significant impact on the simulation results. Several runs were made with an alternative table for the multiplier from marketing and assistance on entry rate (TASER) which is shown in Figure 14.

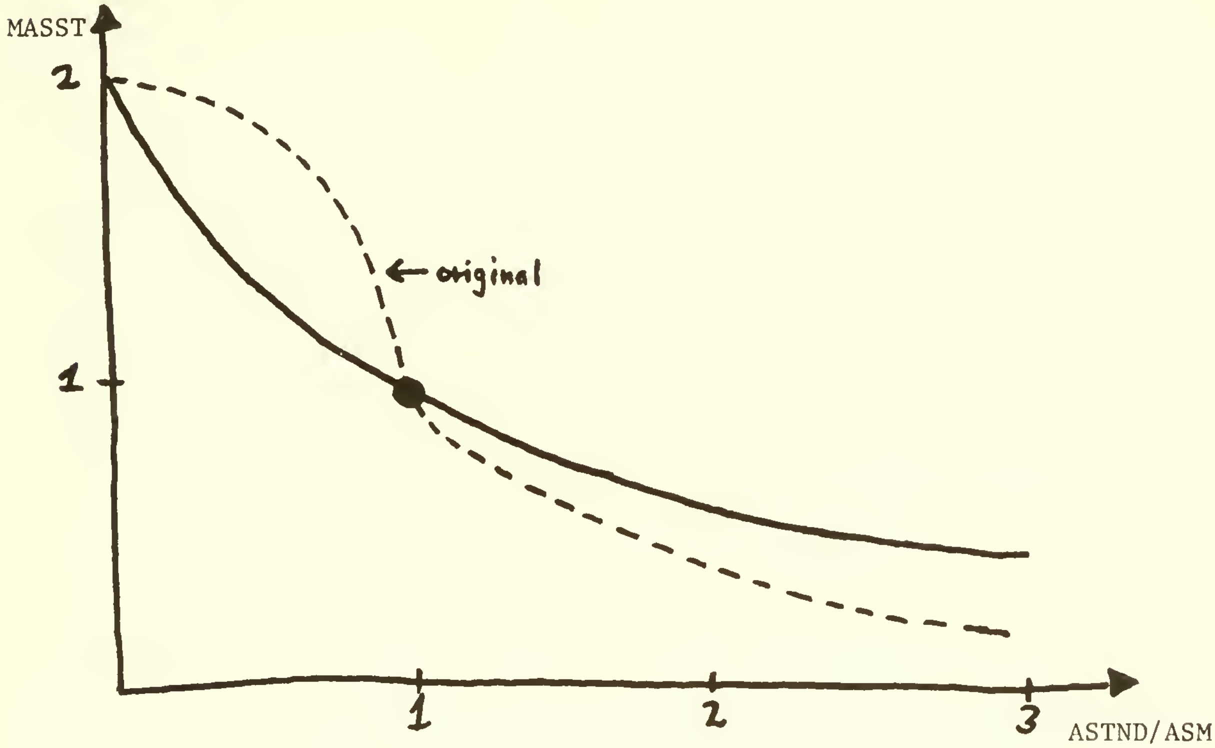

Figure 14.
Alternative formulation for MASST.

The table represents the effect on entry rate from the ratio of needed staff for marketing and assistance (ASTND) to allocated staff to marketing and assistance (ASM). The alternative formulation means that the potential users do not react strongly to marketing efforts and that they are not as easily disappointed to the point of leaving as the assistance given is reduced.

Simulation runs with the alternative table determining MASST show a stabler growth without any overshoot in the number of users which has a final value of 813 (compared to 791 for the standard run). The overshoot in entry rate is not as high and the total number of entries is less (1974 vs. 2122). The total number of answered queries is higher (2074 vs. 2036), and the graph of query backlog shows a reasonably smooth growth to the final value.

The reduced sensitivity to marketing and assistance gives less fluctuations

in the entry rate and consequently in the number of users and this has a stabilizing effect on the whole system. The allocation policy of ISS1 is more successful in keeping delivery delay at the normal value. At the end of the simulation (120 weeks) the delivery delay perceived both by the users and the potential users is equal to the normal value but the multiplier from assistance on entry rate has a lower value indicating that the good delivery delay situation has been attained at the expense of user assistance.

The management implications from the simulations with different sensitivities on part of users and potential users are not exactly clear. How people react to different service quality is very much a function of their "needs" and these are not subject to management decision making. There is, however, also an effect from expectations and it is possible that the managers of information search services can have some control over this.

The simulations with lower sensitivity to marketing show the necessity of finding a balance between the sensitivity of the users and the least allowable effort for marketing and assistance (MMIN). For sensitive users a too low minimum effort for marketing and assistance can cause substantial instability for the ISS.

Sensitivity of the model to details of the allocation policy

DDNM - the delivery delay norm held by management. A shorter DDNM will give greater fluctuations in the level of queries in process since there is an incentive to "overallocate" resources to production. If DDNM is much shorter (0.25, compared to 0.5 in the standard run) there will be growing oscillations until the total staff capacity cannot keep up with the volume, then the effects from delivery delay inhibits further growth in the number of users and reduces the propensity to query. The system reaches essentially the same final state as the standard run but with the backlog of queries a bit higher.

If the delivery delay goal is not reduced as much (DDNM=.35) the fluctuations in Q (queries in process) are not damped as fast, and the entry rate fluctuates during the first 40 weeks.

A delivery delay goal (DDNM) shorter than the market's 0.5 week means that there is an incentive to stimulate business by providing a faster service than what is "required". Initially the delivery delay can be kept below 0.5 and the multipliers on the query rate (MDDPQ) and entry rate (MDDER) are above unity. The multiplier from assistance on entries (MASST), however, is declining earlier, compared to the standard run; this means that the peak in the entry rate occurs earlier and is higher. Consequently there is a greater overshoot in the number of users.

The main overall effect of a DDNM shorter than 0.5 is more business for the ISS both in terms of total queries answered and total entries. The price for this is a small loss in the accumulated good-will and greater fluctuations in the level of queries in process.

If the deliver delay goal is longer than that of the market there will be a loss of business. The accumulated good-will be a little bit higher (132.09) if DDNM is 0.6 but will decrease if the goal is set much lower since the negative effects from the longer delivery delay will dominate.

MMIN - Minimum allocation to marketing. If there is no minimum allocation to marketing, which would mean that the ISS staff would close the doors to the service and work with the backlog of queries, the model shows oscillations in both queries and users. The first 50 weeks are practically identical to the standard run but thereafter the oscillations in Q and ER are growing for 40 weeks, and then continue to oscillate.

This behavior is not realistic, but neither is the "real life meaning" of MMIN=0; it is not possible for an ISS to be in operation and not give some assistance to the users. The model exhibit realistic behavior for a MMIN value of 15% or more.

If MMIN is increased the general effect is that more users enter (due to the effect of marketing) but the total number of answered queries is less (due to lower available production resources). The accumulated good-will increases somewhat with more emphasis on marketing and assistance.

ACT - Allocation change time. The time to change the allocation of resources is set relatively low in the standard run (2 weeks) since, with the exception of regular marketing campaigns, not much organization is required for the reallocation. The ACT represents the sensitivity to the build-up in the backlog of queries - if the ISS management and staff are less concerned about a high backlog, the ACT is longer.

If ACT is long there is a definite loss of business since delivery delays will be longer. The accumulated good-will is not changed significantly when ACT is 5 weeks or 10 weeks. The overshoot in entry rate (ER) is lower and occurs later when ACT is made longer.

In summary the reactive allocation policy analyzed above will lead to user dissapointment in some way. By shifting emphasis from marketing to production delivery delays can be kept at a satisfactory level, but at the price of not having resources to market or giving as much attention (assistance) to each user as would be desired.

Taking the analysis of the reactive policy into consideration a business (i.e. production) oriented policy can be designed. Compared to the standard run a shorter delivery delay goal as a basis for the resource allocation will give a higher volume of business, as will a decrease of the minimum allocation for marketing. These two changes might, however, cause the system to show great fluctuations since in combination they will cause a faster (from lower DDNM) and stronger (from lower MMIN) growth in entries. These effects would cause severe delivery delay effects, but if the policy combination is supplemented with a change in ACT stability would be improved.

Figure 15 shows the simulation results of such a production oriented policy (DDNM=.35, MMIN=.15, and ACT=5) which represents an ISS which after two years serve about 750 users, who submit 1.8 queries per year (or about one query every seventh month). About 15 new users enter each week, and the incoming query rate is about 25 per week. The delivery delay is kept at par with what the market requires: one half week. As in the standard run the number of staff is three.

The performance and operational measures for this simulation are:

Total number of answered queries - 2334

Total number of entries - 2181

Serviceindex (at time 120) -0.5118

Accumulated good-will - 129.82

This result is high in terms of business, but the price is again a loss in good-will.

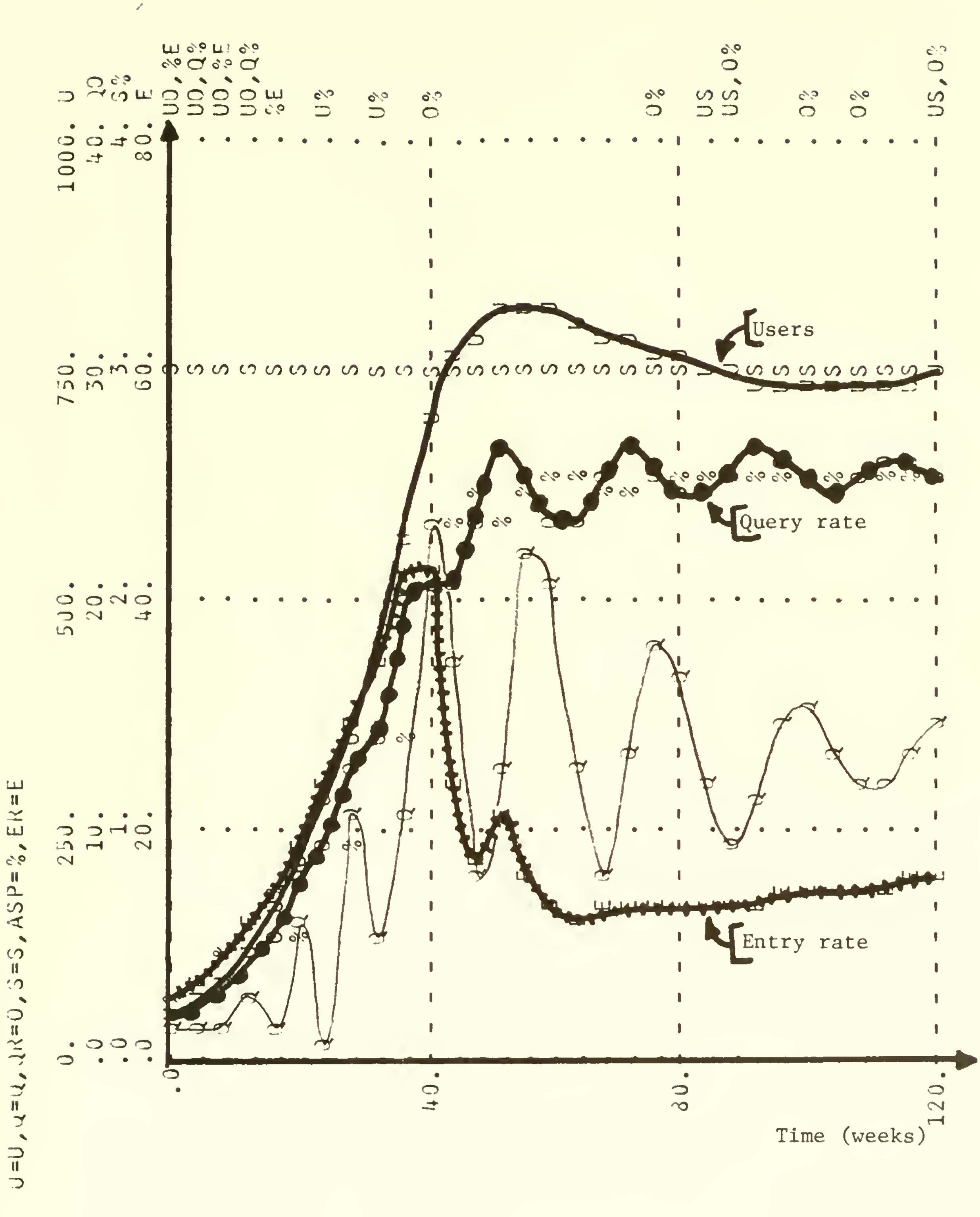

Figure 15 a.

Production oriented policy - system levels and principal rates.

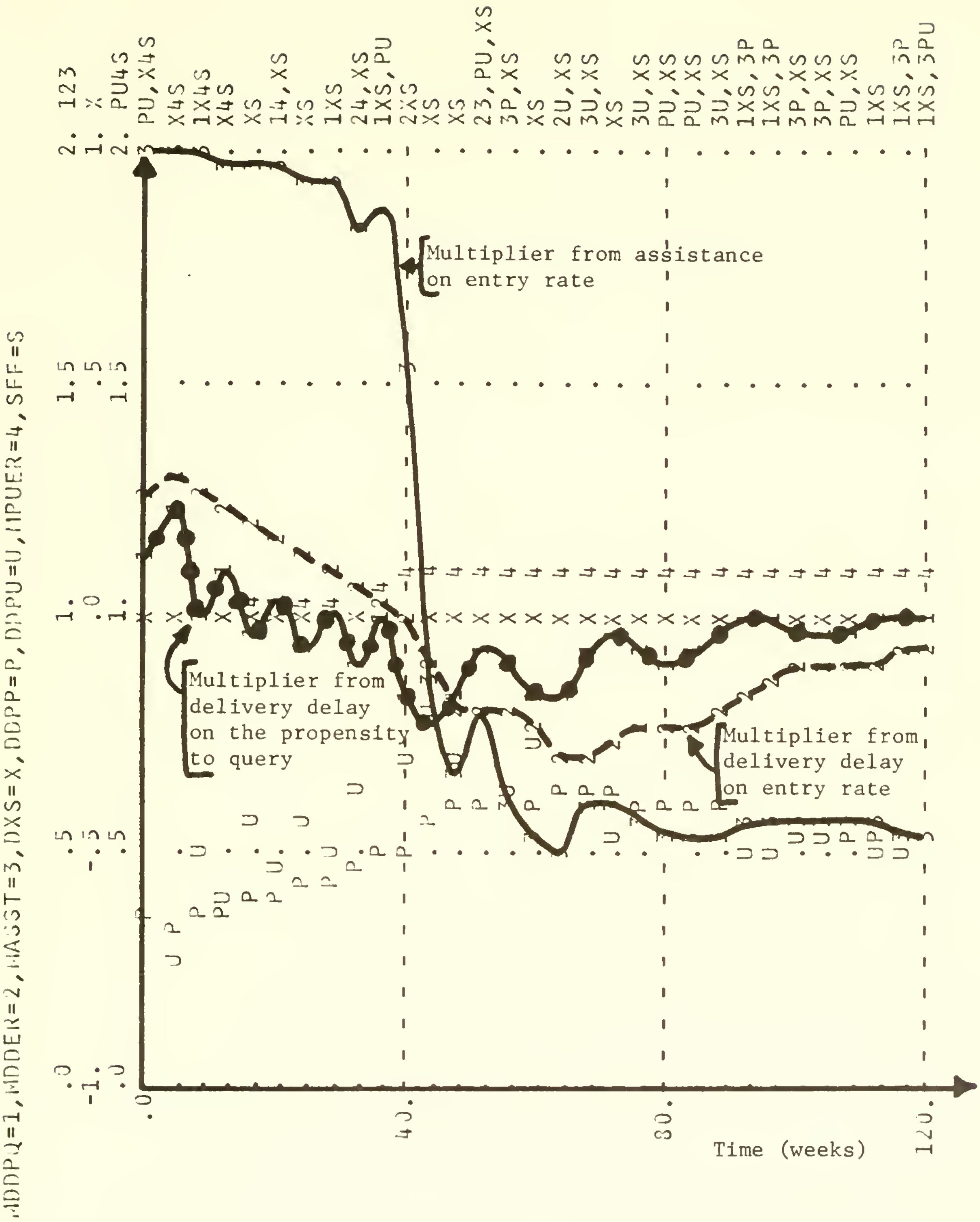

Figure 15 b.

Production oriented policy - values of multipliers.

Further discussion of the simulation results

The initial growth of ISS1 is essentially driven by the relatively high marketing effort during the first year. Low awareness of the ISS is one cited cause of failure to grow[22], and other studies support the necessity of marketing activities for achieving growth[23]. At the same time, however, it is important to keep the delivery delay at an acceptable level since it is one of the principal determinants of the service quality. So the problem facing ISS management is to balance the commitments to the users; accepting a user means, on one hand, a commitment to spend resources on assistance but it also implies a longer term commitment to answer submitted queries.

The difficulty in obtaining an ideal balance where it is possible to give adequate assistance to every user and still keep the delivery delay goal is illustrated by the simulation model: there are delays of various magnitude for the effects of the ISS operations to result in decisions by users and potential users so it is difficult to avoid generating too high expectations which in the model results in the overshoot in entry rate and a relatively low final value for the multiplier from marketing and assistance on entry rate.

Of all the managerial options tried in the simulations with ISS1 the best way to avoid over-expectations is to control the size of the potential market (the parameter PU). The runs with smaller PU gave a substantially higher good-will result. The size of the potential market might, however, be more or less given by the institutional setting and it might not be possible to impose discriminatory rules regarding who may and may not be a user. In this case it is important that the funder of the ISS sees the necessity of a realistic balance between the staff resources of the ISS and the size of the user community.

Restriction of the potential market tends to result in fewer users in spite of the fact that the volume of queries processed is higher. This points to another problem: that of pricing and the resulting impact on the ISS' economy.

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22) Carmon, op. cit.

23) Berk, Robert A., An Experimental Case Study of the Diffusion of an Information Innovation in a Scientific Community. Ph. D. Thesis, University of Illinois at Urbana-Champaign, 1974.

In the simple model, ISS1, there are no equations representing the economics of the ISS operations. Comparison of the different simulation runs, in economic terms, is therefore not possible until the result of the operations is given a dollar value based on the pricing policy. Pricing of information services is a problematic question and there is not much data from controlled experiments with price changes[24]. There are essentially two ways to charge users even though a combination of the two is sometimes seen. One alternative is to charge a fee per query which can be fixed or variable depending on time required or volume of output. The other alternative is to have a subscription-type charge where a user pays say a yearly fee for the right to use the service. With this scheme it is more important to maintain growth in users while the number of queries answered does not affect the economic result.

There is another aspect of the result of the ISS operations that is perhaps more important than the revenue generated during the start-up period and that is the consequences for future growth. When the ISS loses its project status and has to prove itself a service worthy of continuous support both the policies practiced by management and the market responses to delivery delay and marketing will affect the growth.

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24) The economics of information search services was studied as part of project INTREX at M.I.T. and a simulation model is described in: Therrien, C. W., and Reintjes, J. F., "Modeling of Information Services," Presented at the Sixth Annual Princeton Conference on Information Science and Systems, Princeton University, March 1972.
This study, however, deals with the economic feasibility of ISS's in general and is not focused on existing services.

VI. MODEL BEHAVIOR WHEN RESOURCES ARE VARIABLE

After the start-up period an ISS is typically taken out of its project status and is considered a regular service. As such it has to compete with other services and functions for funding.

In terms of the simulation model this new situation means that there will be feed-back effects from the performance of the ISS influencing both the managers'desire to increase the staff resources and the funder's willingness to support the ISS. The ISS performance is, for simplicity, still measured only by the delivery delay. The purpose of this second set of simulation runs is to show that even with this minimal model structure the resource allocation policies, i. e. the balance between marketing and production, will have an impact on the growth of the ISS.

The ISS1 management will assess the operative result and request funding for the expansion it feels necessary. The funding requests are dependent on how well delivery delays can be kept as compared to the long term delivery delay norm held by management (LDDNM). The formulation of the desired expansion of staff (DXS) is fairly conservative as can be seen from Table 7. The conservatism is also manifested by the choice of LDDNM which is set at .5 weeks - the same as the delivery delay norm held by the market (DDN).

LDDPM/LDDNM	DXS
0	-20%
.5	-15%
1	0
1.5	20%
2	35%
2.5	45%
3	50%

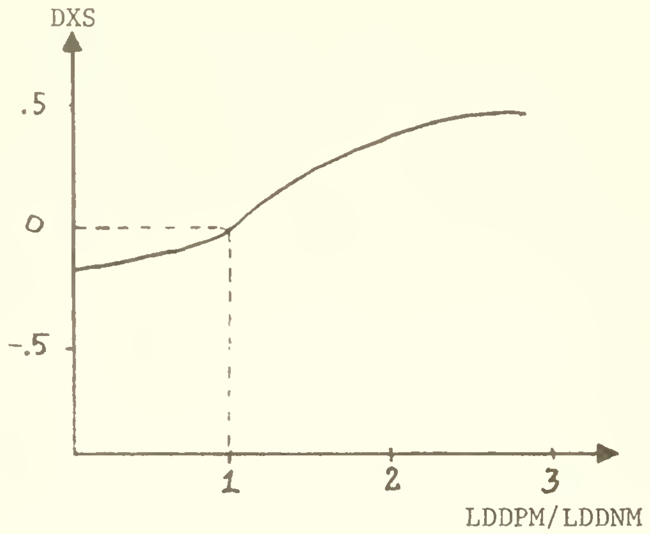

Table 7.

It is assumed that the ISS management makes "responsible" requests for expansion so that when the long term delivery delay perceived by management (LDDPM) is shorter than the norm (LDDNM) management will request less resources.

The funder's assessment of the ISS operations consists of both a critical and a supportive aspect. On one hand the ISS must prove its worth in the marketplace and the criteria used for the critical evaluation are usually economic or some measure of market "penetration", i.e. how successful the service is in terms of growth in queries or users. The critical component will lead to a reduction of support if the growth is not sufficient compared to the funder's norm, but there is also a counteracting force representing "hopes" which is based on some kind of service measure such as "expressed user satisfaction."

The supportive component rests on the realization that low performance in terms of growth can be the result of too little resouces. If the funder is committed even low user satisfaction might lead to an increase in the funder's willingness to support the ISS. To this latter effect there is, however, a time limit so that if user satisfaction does not go up in a reasonable period of time the funder is forced to the conclusion that the ISS does not provide an adequate service to the users.

The formulation of the funder's decision to support the ISS can be made to include many or all of the discussed effects. In ISS1 a simple formulation is used which assumes that the funder reacts to a delayed version of the users' perceived delivery delay compared to the delivery delay norm held by the market. This represents a response to the communicated service assessment (praise or complaint) from the users. Since it is difficult to evaluate a service in terms of benefits or utility it is common that subjective assessments are taken into account. With the organizational coupling to a library which has been assumed it is natural to have the users' evaluation of the service influence the funder's decision for support.

It is assumed that the ERP no-growth cases "represents" the expansion so that when the long time delivery delay perceived by management ([illegible]) is shorter than the norm ([illegible]) expansion will require less resources.

[illegible]

The funder's willingness to support the ISS (Support from funder, SFF) as a function of the ratio of delivery delay perceived by funder (DDPF) to the delivery delay norm (DDN) is shown in Table 8.

DDPF/DDN	SFF
0.0	1.0
0.5	1.0
1.0	1.0
1.5	0.75
2.0	0.50
2.5	0.40
3.0	0.30

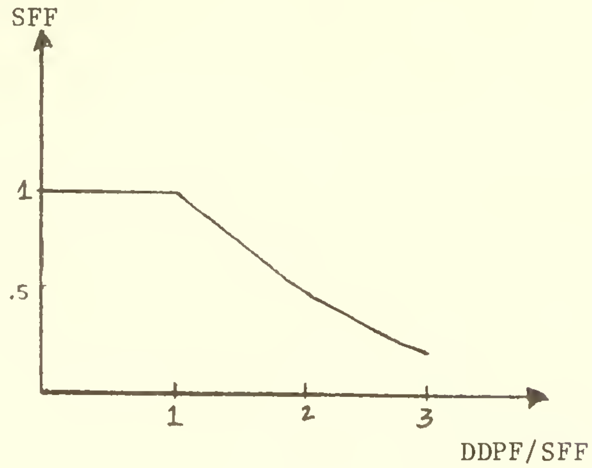

Table 8.

This funder can be described as committed to the service since the willingness to support is never negative. He reacts, however, to long delivery delays by not granting the full expansion of staff requested by the ISS management.

The simulation runs of the growth of an ISS are of the time period week 120 to week 520, i.e. approximately the eight years following the start-up period of 120 weeks. The impact of different management policies is tested in the same way as in section V, and the simulation results should not be interpreted as predictions of how the ISS will grow in terms of specific quantified variables. Analysis of the different simulation runs can, however, give insights about the general effects of certain management actions.

What is analyzed is the consequences for growth from changes in the components of the resource allocation policy, and each run is therefore intialized with the values of the variables at time 120 which result from applying that particular policy from the beginning. This means that if there has been neglect in keeping the delivery delay at DDN during the first 120 weeks, say due to high priority on marketing, then the run with high priority on marketing starts with low values on the multipliers representing the effects of delivery delay.

The funder's willingness to supply the ISS (Support from funder, SFF) as a function of the ratio of delivery delays perceived by funder (DDPF) to the delivery delay norm (DDN) is shown in Table 8.

SFF	DDPF/DDN
[illegible]	0.0
[illegible]	0.5
[illegible]	1.0
[illegible]	1.5
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

Continuation of the standard run

The resource allocation policy in ISS1 has three components. There is a production oriented goal expressed as a delivery delay norm held by management (DDNM) with a constraint that a certain minimum fraction (MMIN) of the staff resources is to be spent on marketing and user assistance. There is also a part of the allocation policy that affects how fast changes in the allocation is made: the time to change allocation, ACT. The standard run has the following parameter values: DDNM=.5, MMIN=.20, and ACT=2 weeks.

The results of the simulation with the standard policy are shown in Figures 16 and 17. These figures show an ISS which for the first 4-5 years after the start-up period has a relatively steady growth in the number of users of 10-12%. After this growth there is a gradual levelling off due to saturation of the market, and at the end of the run, at week 520, the ISS has 1665 users of the potential 2000. In terms of volume of business the ISS has a total of 16425 answered queries and 11077 user entries for the 400 weeks. The final number of staff is 7.15 and the accumulated good-will is 247. The delivery delay situation is not meeting the requirements, DDN, and only towards the end of the run are the multipliers from delivery delay on the propensity to query and entry rate close to unity. The effect from marekting and assistance on entry rate is less than neutral throughout the run meaning that there is some dissapointment amongst the users with regard to the level of assistance given.

Optimization of the Standard [illegible]

The resource allocation policy at LATIS has three components. There is a production criterion goal expressed as a delivery index move with management (DDRM) with a constraint that a certain minimum fraction [illegible] of the staff resources [illegible] writing and [illegible] assistance. There is also a goal of the allocation policy [illegible] significant changes in the allocation to match [illegible] classification [illegible]. The standard [illegible] has the following [illegible] 15, [illegible] 10, and [illegible].

The resulting [illegible] policy [illegible] 10 and 11. [illegible] after the staff [illegible] in the [illegible] will give the [illegible] of the [illegible] of the [illegible] 1963 [illegible]. The total number of [illegible]. The [illegible] also for [illegible] 108 [illegible] later [illegible] [illegible] group [illegible]

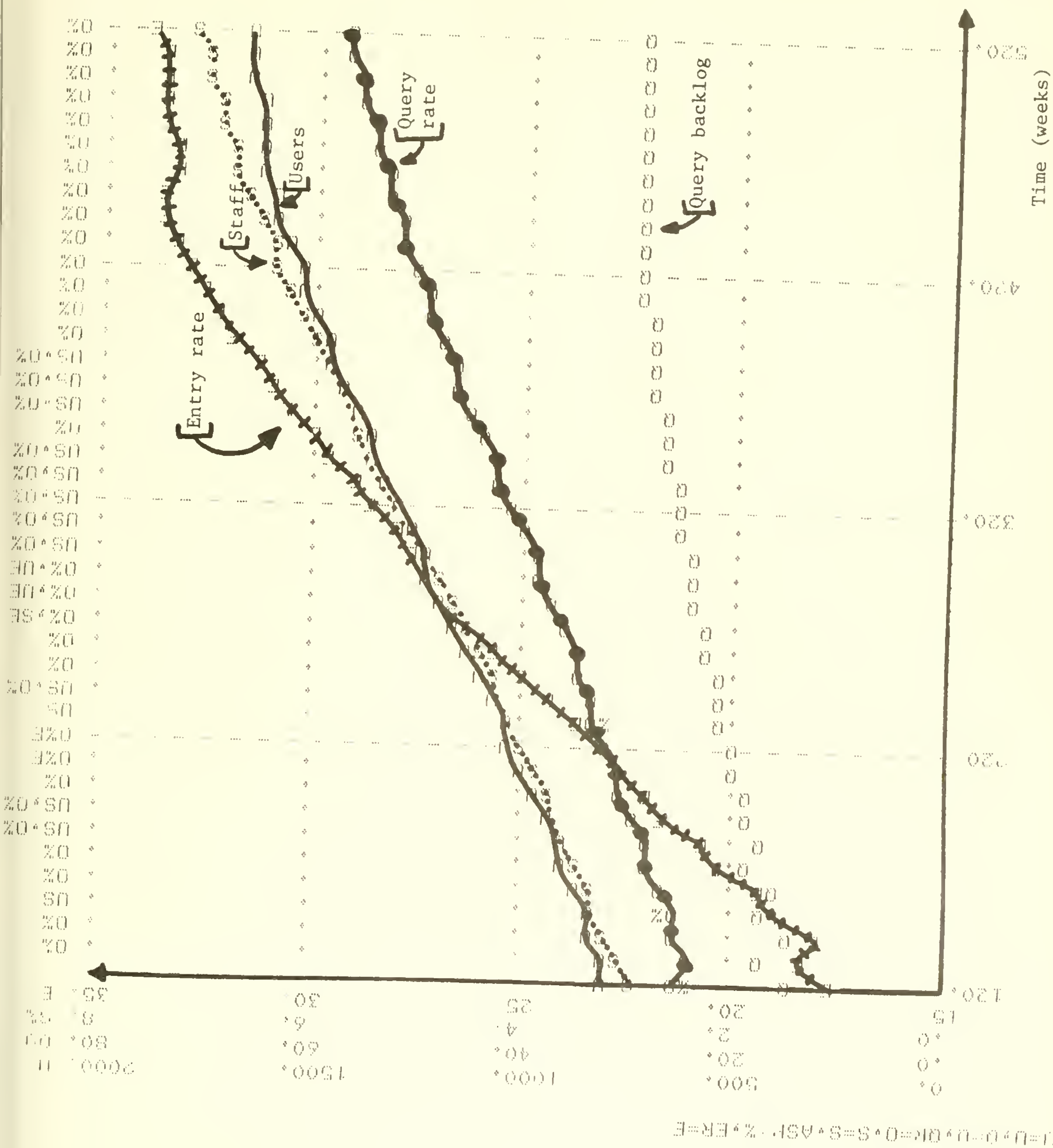

Figure 16.
Continuation of the standars run - principal levels and rates.

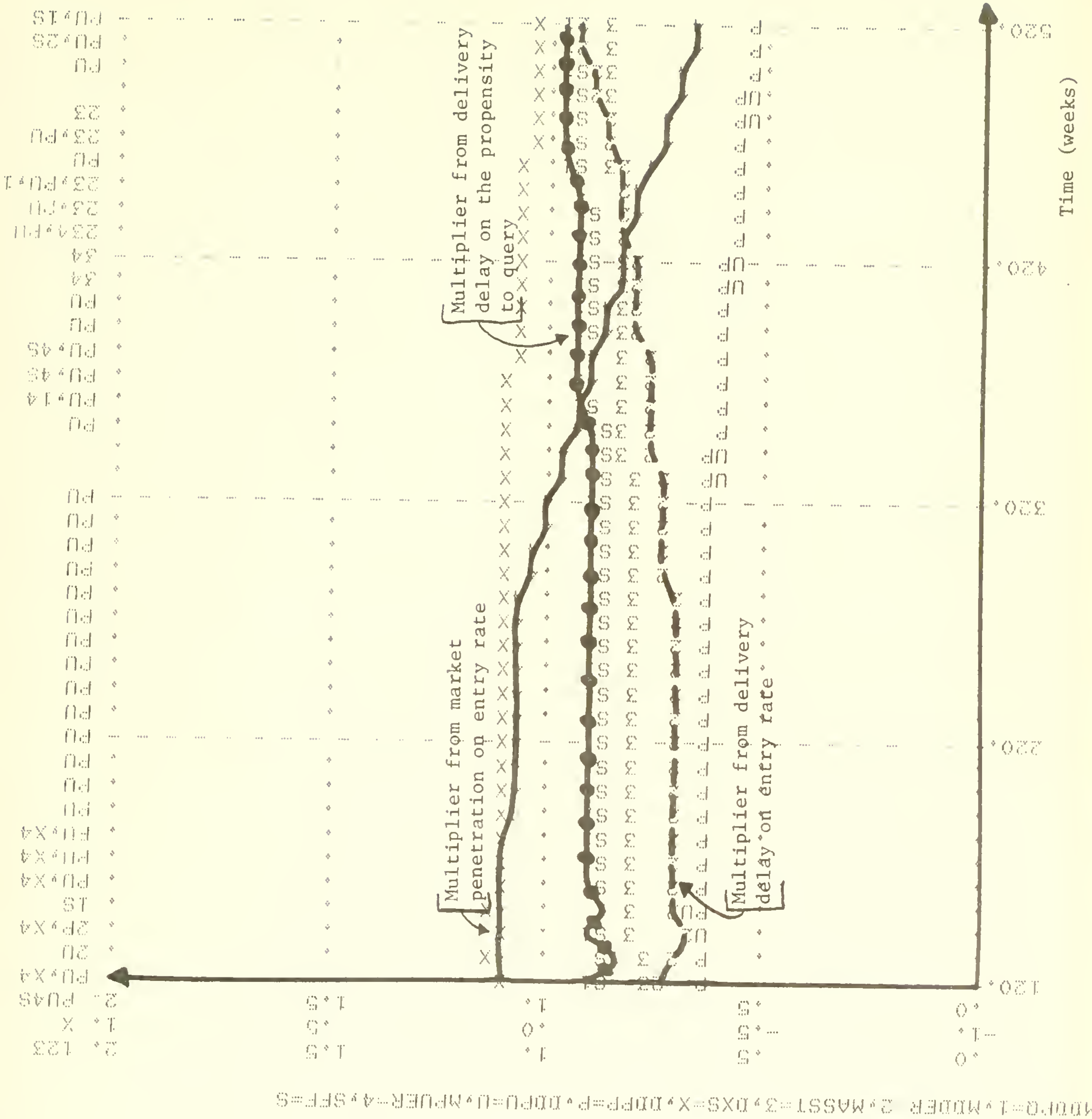

Figure 17.

Continuation of the standard run - values of multipliers.

Consequences of changes in the components of the allocation policy

The results of the simulation runs with different delivery delay goals are shown in Table 9.

Change in parameter	Final value of users	Final value of staff	Final query rate	Total # of queries	Total # of entries	AGOWL
DDNM=.25	1665	7.15	57	16426	11086	247
DDNM=.4	1663	7.13	57	16 261	11101	250
DDNM=.6	1754	7.85	56	16270	11215	260
DDNM=.75	1706	16.1	44	15022	12226	325
Standard (DDNM=.5)	1665	7.15	58	16425	11077	247

Table 9.

Small changes in the delivery delay norm held by management do not affect the result of the ISS operations significantly. If DDNM is .6 there is some improvement in the accumulated good-will (260 vs. 247) but at the price of fewer answered queries. The explanation for this is that by putting a little less emphasis on production there are more resources available for marketing and assistance. The total numer of entries is also somewhat higher than for the standard run.

When DDNM is longer than the DDN required by the market there will be a constant need for more staff and with a supportive funder staff will grow. The negative effects from delivery delay will, however, lead to a lower volume of business in terms of answered queries. In terms of business per staff the result is worse regardless of whether it is counted in queries or users.

Changing the minimum fraction allocated to marketing and assistance (MMIN) affects all the performance variables. Compared with the 20% allocation to marketing in the standard run a decrease will result in a lower volume of business. An increase in MMIN will lead to increases in both users and queries up to a point and if too many resources are allocated to marketing the poor performance in terms of delivery delay will lead to a decrease in the number of users as well as in the query rate.

The results of the runs with different MMIN are shown in table 10. The run with MMIN=30% gives higher final values for all variables compared to the standard run. However, the number of staff is 27% higher and in terms of the final ratio of users to staff and query rate to staff the result is lower than for the standard run. The run with MMIN=30% has a final value of 201 users/staff and about 7 queries/week per staff. For the standard run these ratios are 233 users/staff and about 8 queries/week per staff.

Change in parameter	Final value of users	Final value of staff	Final query rate	Total # of queries	Total # of entries	AGOWL
MMIN=10%	1120	4.6	38	12692	7900	204
MMIN=15%	1008	4.05	37	11943	7271	200
MMIN=30%	1831	9.12	64	18407	12876	382
MMIN=50%	1657	9.45	44	10369	10115	227
Standard run (20%)	1665	7.15	58	16425	11077	247

Table 10.

By having a longer time to change the resource allocation (ACT) resources will be taken from marketing less rapidly and the growth of the ISS will be higher. When resources are constant a long ACT leads to a loss of business but with a committed funder it will lead to greater growth since the resulting longer delivery delay will result in a greater need for expansion and subsequent positive response to requests for increases in staff.

The simulation results with different ACT are shown in Table 11. From this table it seems that if it is possible to retain the allocation of resources to marketing, by responding slower to pressure to re-allocate to production, and let this pressure work on the funder the result of the ISS operation will be better. There is, however, a continuous decline in the ratio users/staff and query rate/staff as ACT is increased and this will have an impact on the economy of the ISS.

Change in parameter	Final value of users	Final value of staff	Final query rate	Total # of queries	Total # of entries	AGOWL
ACT=10	1690	7.37	59	17044	11511	262
ACT=20	1711	7.56	60	17663	11941	281
ACT=30	1767	8.09	62	18403	12745	336
ACT=40	1813	8.63	63	18856	13403	397
Standard (ACT=2)	1665	7.15	58	16425	11077	247

Table 11.

The runs discussed so far show that the impact of changes in components of the allocation policy is different when resources are permitted to increase. In general terms this can be explained by the fact that a committed funder will respond to low performance and improve the possibilities of making the service satisfactory. When resources are fixed the only effect of low performance is to discourage user entries and the propensity to query.

That the effects of policy changes are in principle reversed when there is a committed funder is perhaps not so surprising but the same is also true of changes in population parameters. Thus the growth dynamics are fundamentally different from the dynamics during the start-up period.

A limited set of runs was made with changes in the parameters that had the greatest impact on the results of the simulations with fixed resources. The results from these runs are shown in Table 12. Changes in the representation of the potential users' sensitivity to marketing and assistance, as illustrated previously in Figure 14, gave results practically identical to the standard run when resource expansion was possible.

In the growth situation the size of the potential market (PU) has a greater effect: with fixed resources a 50 percent reduction of PU did not have any impact but with variable resources a 25 percent reduction gives a substantially lower volume of business both in terms of users and queries. The final ratios of users to staff and query rate to staff are also lower than for the standard run. This shows the danger of limiting the size of the potential market too much. A doubling of PU results in more entries and more answered queries but the accumulated good-will is somewhat less due to consistantly lower values on all service related multipliers compared to the standard run.

The simulation run with low frequency users, represented by a propensity to query of 0.02, with variable resources gives the opposite result from the case with fixed resources where a lower propensity to query (PQN) led to more business both in terms of users and queries. Here growth is hindered by the low demand for the service; the "need" for expansion is not apparent since service is kept at a satisfactory level in terms of delivery delays. The low value for the accumulated good-will does, however, indicate that the service in some respect is worse than the standard run and inspection of the plots from the run reveals that the multiplier from marketing and assistance is a mere .5 throughout the run.

In real terms this means that there is not enough resources for marketing and assistance and that the ISS management has difficulties with justifying an increase in resources since demand seems to be satisfied as indicated by the ability to keep delivery delays at the market norm (DDN).

Change in parameter	Final value of users	Final value of staff	Final query rate	Total # of queries	Total # of entries	AGOWL
PU=4000	2259	8.86	70	17207	12551	222
PU=1500	1269	5.53	44	14718	9369	278
PQN=.02	1268	3.29	25	9 644	9816	204
Concave TASER	1668	7.17	58	16468	11087	248
Standard (PQN=.035, PU=2000)	1665	7.15	58	16425	11077	247

Table 12.

This "Catch 22"-like situation is sometimes a reality and the typical management response has been to try to reach out to a larger potential market, i.e. increase the number of potential users. To date such efforts have not been successful which could be taken as evidence for an insufficient real need for the service. Simulation runs with ISS1, however, show that management actions can change the outcome and achieve a growth in both users and queries. The simulations also indicate that the best policy is not to increase the size of the market but to increase the marketing effort. The run with 4000 potential users (PU=4000, and PQN=0.02) gives almost identically the same results as the run with PQN=0.02 while the run with a minimum fraction of staff for marketing of 0.30 (MMIN=0.3, and PQN=0.02) gives higher values for all operational and performance measures:

Ending number of users	1689	Total # of entries	12883
Ending query rate	34	Total # of queries	11839
Ending number of staff	4.8	Accum. good-will	287

VII. CONCLUSION AND DISCUSSION OF FURTHER WORK

The developed model, ISS1, is a simple model of one of the fundamental trade-offs for the management of an information search service , that between production and marketing. The model exhibits realistic behavior for a wide range of parameter values although the emphasis of the study has been on analyzing a relatively successful ISS in an academic environment - in general terms ISS1 is comparable to the NASIC service at MIT.

The simplicity of the model, especially the omission of economic equations, makes it not directly applicable for definitive analysis of managerial allocation policies. The model does, however, illustrate some of the more important interaction effects between the information search service, its market, and its funder and general conclusions can be drawn regarding the impact of different emphases in the marketing vs. production trade-off.

To enable a more comprehensible analysis of the management of ISS's the present model can be elaborated and extended in several ways. The users' decision making is, for example, partly a function of expectations which can vary over time. An extended model should have equations representing these effects.

The managerial decision making should also be formulated in more detail and with greater scope, in particular it should be possible to test and compare policies for expansion other than marketing: greater availability of the service by increasing the number of "outlets", greater coverage of the literature, increase in user education enabling staff to spend less time per user, etc. All of these policy dimensions have different cost structures attached to them and the inclusion of these structures, together with representation of the market responses to pricing policies, is needed for an economic analysis of ISS's. Inclusion of economic variables also makes it possible to make the funder's decision making more detailed and realistic since the fate of information search services is not independent of economics.

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A P P E N D I X

MATHEMATICAL DESCRIPTION OF MODEL ISS1

The basic domponents of system dynamics models are levels and rates, represented in Figure A1 by a box and a valve-like symbol respectively. The level corresponds to a stock variable and the rate to a flow variable. Mathematically the level is an integration over time of the rates. A rate is set by a decision which in turn is based on information about the state of the system and external factors.

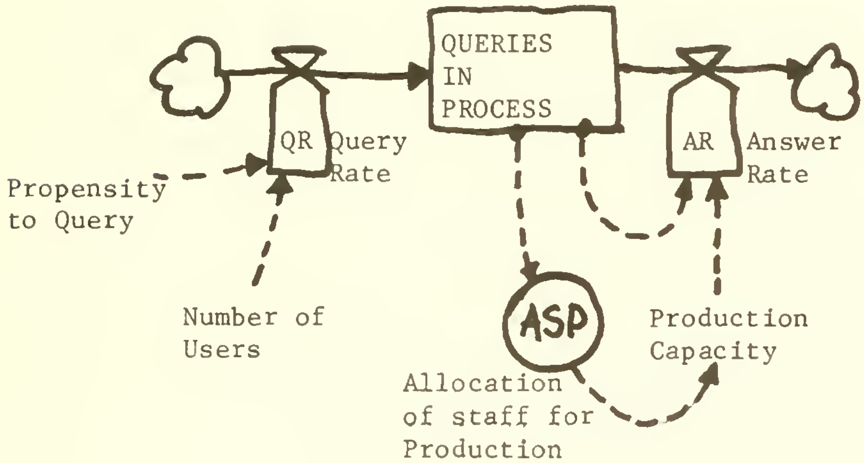


Figure A1.
Example of DYNAMO flow diagram.

In Figure A1 the number of queries in process (measured in queries) is increased by the query rate (measured in queries/week) which represents incoming queries, and is decreased by the answer rate (queries/week). If the rate of incoming queries is greater than the answer rate then, over time, there will be a build up of queries in process.

The query rate is determined by 1) the number of users, reflecting their decision to become users (which was, in turn, based on their evaluation of the system), and 2) the propensity to query which represents the users decision to come back.

Information links are represented by dashed lines in DYNAMO flow diagrams, as can be seen in the representation of the formulation of the answer rate: The answer rate is a function of how much of the staff resources are allocated to production (i.e. answering queries). The allocation of staff for production is a management decision and is based on the number of queries in process which indicates the need for production capacity. The answer rate, then, is a function of production capacity, which is a function of the allocation decision, which is a function of the number of queries in process, which, finally, is influenced by the answer rate. We have a loop, and since an increase in queries eventually will be counteracted (by the increase in the answer rate) we call this a controlling loop.

The mathematical notation used in the model formulation would represent Figure A1 with the following equations (the 4th and 5th lines not complete):

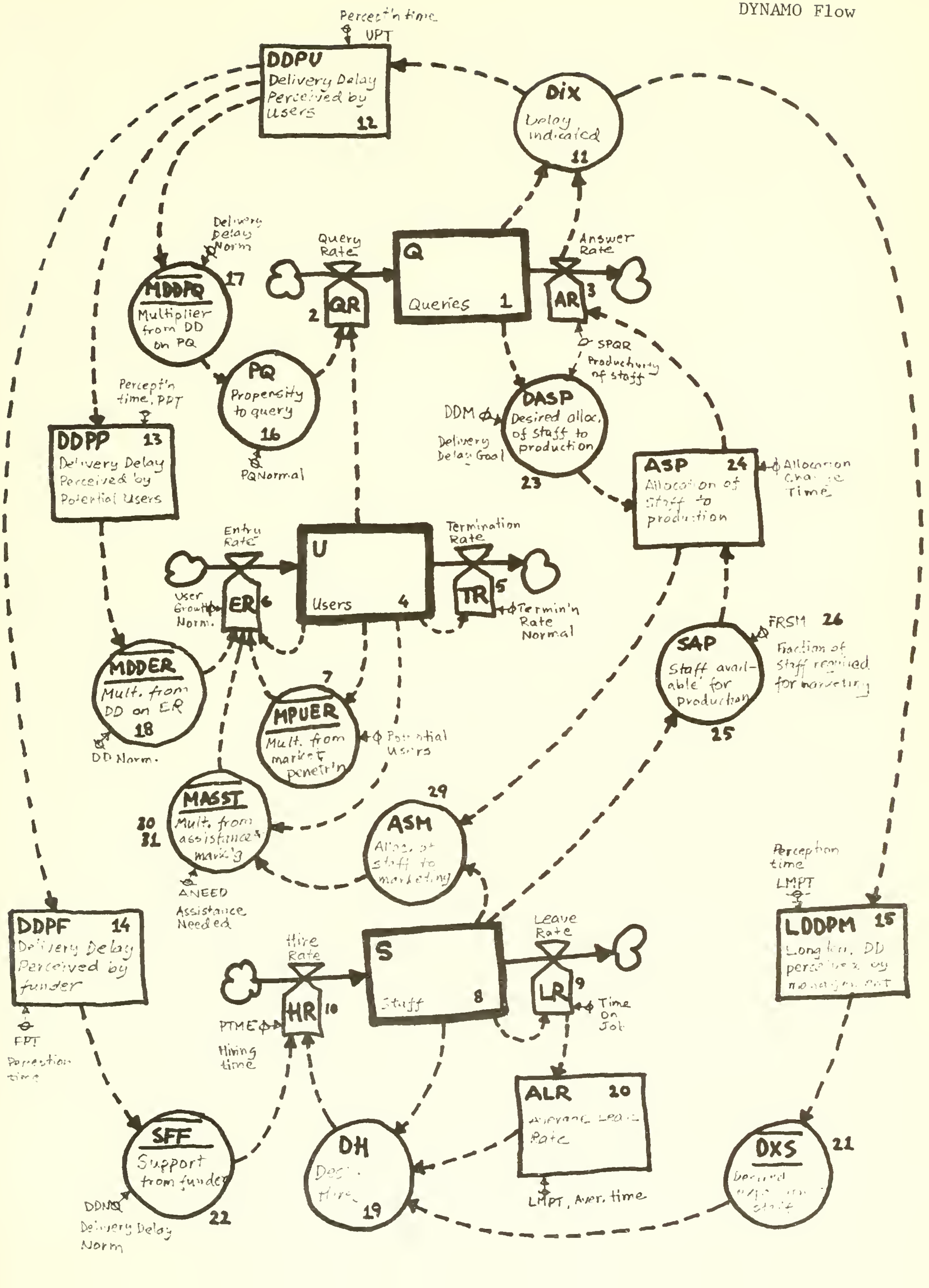
```
L   QIP.K = QIP.J + (DT)*(QR.JK - AR.JK)
N   QIP = 50
R   QR.KL = PQ * U.K
R   AR.KL = PC.K * [some function preventing QIP from going negative]
A   PC.K = [function of available staff and desired prod. capacity]
C   PQ = 0.02
```

The first equation is a level equation, which is indicated by the 'L', and states that the current number of queries in process (the time postscript K indicates the current time) is equal to the number that were in the previous time period (time postscript J) plus the changes incurred by the query and answer rate in the beriod between time J and time K. A level is given an initial value in a line starting with the letter N.

The 'R' lines specify the rate equations for the time interval between the current time (time index K) and the next timestep (index L). The rate equation can contain constants (such as PQ, in the example above), the current value of system levels (such as U.K, assuming that U is the level of users), or auxiliary variables which vary with time but are not themselves levels. Auxiliaries are, however, practically always a function of other system levels. In the example above production capacity is a function of queries which is a level.

DT is the interval between succeding time steps in the simulation.

DYNAMO Flow


Percept'n time UPT
DDPU
Delivery Delay Perceived by Users
12
DIX
Delay indicated
11
Delivery Delay Norm
17
MDDPQ
Multiplier from DD on PQ
Query Rate
2
QR
Q
Queries
1
Answer Rate
AR
3
SPQR
Productivity of staff
PQ
Propensity to query
16
PQNormal
Percept'n time, PPT
DDPP
13
Delivery Delay Perceived by Potential Users
DDM
Delivery Delay Goal
DASP
Desired alloc. of staff to production
23
ASP
24
Allocation of staff to production
Allocation Change Time
Entry Rate
U
Users
4
Termination Rate
TR
5
Termin'n Rate Normal
User Growth Norm.
ER
6
FRSM
26
Fraction of staff required for marketing
SAP
Staff available for production
25
MDDER
Mult. from DD on ER
18
DD Norm.
7
MPUER
Mult. from market penetr'n
Potential Users
MASST
Mult. from assistance & mark'g
30
31
ANEED
Assistance Needed
29
ASM
Perception time
LMPT
DDPF
14
Delivery Delay Perceived by funder
FPT
Perception time
Hire Rate
HR
10
PTME
Hiring time
S
Staff
8
Leave Rate
LR
9
Time On Job
LDDPM
15
ALR
20
LMPT, Aver. time
SFF
Support from funder
22
DDNQ
Delivery Delay Norm
DH
19
DXS
21

```
Q.K=Q.J+(DT)*(QR.JK-AR.JK)                                  1, L
Q=QN                                                        1.1, N
    Q       - QUERIES IN PROCESS (QUERIES)
    DT      - SOLUTION INTERVAL
    QR      - QUERY RATE (QUERIES/WEEK)
    AR      - ANSWER RATE (QUERIES/WEEK)
    QN      - INITIAL VALUE FOR Q

QR.KL=U.K*PQ.K                                              2, R
    QR      - QUERY RATE (QUERIES/WEEK)
    U       - USERS (USERS)
    PQ      - PROPENSITY TO QUERY (QUERIES/WEEK/USER)

AR.KL=ASP.K*SPQR                                            3, R
SPQR=10                                                     3.1, C
    AR      - ANSWER RATE (QUERIES/WEEK)
    ASP     - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
    SPQR    - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)

U.K=U.J+(DT)*(ER.JK-TR.JK)                                  4, L
U=UN                                                        4.1, N
    U       - USERS (USERS)
    DT      - SOLUTION INTERVAL
    ER      - ENTRY RATE (USERS/WEEK)
    TR      - TERMINATION RATE (USERS/WEEK)
    UN      - INITIAL VALUE FOR U

TR.KL=U.K*TRN                                               5, R
TRN=0.02                                                    5.1, C
    TR      - TERMINATION RATE (USERS/WEEK)
    U       - USERS (USERS)
    TRN     - TERMINATION RATE NORMAL (FRACTION/WEEK)

ER.KL=(U.K)(UGN)(MASST.K)(MDDER.K)(MPUER.K)                 6, R
UGN=0.0374                                                  6.1, C
    ER      - ENTRY RATE (USERS/WEEK)
    U       - USERS (USERS)
    UGN     - USER GROWTH NORMAL(FRACTION/WEEK)
    MASST   - MULTIUPLIER FROM ASSISTANCE ON ENTRY RATE
                (DIM.LESS)
    MDDER   - MULTIPLIER FROM DELIVERY DELAY ON ENTRY
                RATE (DIM.LESS)
    MPUER   - MULTIPLIER FROM MARKET PENETRATION ON ENTRY
                RATE (DIM.LESS)

MPUER.K=TABLE(TPUER,U.K/PU,0,1,0.2)                         7, A
TPUER=1/1.05/1.1/1.05/.80/0                                 7.1, T
PU=2000                                                     7.2, C
    MPUER   - MULTIPLIER FROM MARKET PENETRATION ON ENTRY
                RATE (DIM.LESS)
    TPUER   - TABLE FOR MPUER
    U       - USERS (USERS)
    PU      - POTENTIAL MARKET (USERS)
```

```
S.K=S.J+(DT)*(HR.JK-LR.JK)                                    8, L
S=SN                                                          8.1, N
    S        - STAFF (STAFF)
    DT       - SOLUTION INTERVAL
    HR       - HIRE RATE (STAFF/WEEK)
    LR       - LEAVE RATE (STAFF/WEEK)
    SN       - INITIAL VALUE FOR S

LR.KL=S.K/TOJ                                                 9, R
TOJ=200                                                       9.1, C
    LR       - LEAVE RATE (STAFF/WEEK)
    S        - STAFF (STAFF)
    TOJ      - TIME ON JOB (WEEKS)

HR.KL=(DH.K/PTME)*(SFF.K)                                     10, R
PTME=26                                                       10.1, C
    HR       - HIRE RATE (STAFF/WEEK)
    DH       - DESIRED HIRES (STAFF)
    PTME     - HIRING TIME (WEEKS)
    SFF      - SUPPORT FROM FUNDER (DIM.LESS)

 DELIVERY DELAY ETC.

DIX.K=Q.K/AR.JK                                               11, A
    DIX      - DELIVERY DELAY INDICATED (WEEKS)
    Q        - QUERIES IN PROCESS (QUERIES)
    AR       - ANSWER RATE (QUERIES/WEEK)

DDPU.K=SMOOTH(DIX.K,UPT)                                      12, A
UPT=10                                                        12.1, C
    DDPU     - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)
    DIX      - DELIVERY DELAY INDICATED (WEEKS)
    UPT      - USERS' PERCEPTION TIME (WEEKS)

DDPP.K=SMOOTH(DDPU.K,PPT)                                     13, A
PPT=20                                                        13.1, C
    DDPP     - DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
                 (WEEKS)
    DDPU     - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)
    PPT      - POTENTIAL USERS' PERCEPTION TIME (WEEKS)

DDPF.K=SMOOTH(DDPU.K,FPT)                                     14, A
FPT=40                                                        14.1, C
    DDPF     - DELIVERY DELAY PERCEIVED BY FUNDER (WEEKS)
    DDPU     - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)
    FPT      - FUNDER'S PERCEPTION TIME (WEEKS)

LPDPM.K=SMOOTH(DIX.K,LMPT)                                    15, A
LMPT=26                                                       15.1, C
    LPDPM    - LONG TERM DELIVERY DELAY PERCEIVED BY
                 MANAGEMENT (WEEKS)
    DIX      - DELIVERY DELAY INDICATED (WEEKS)
    LMPT     - LONG TERM PERCEPTION TIME FOR MANAGEMENT
                 (WEEKS)
```

EFFECTS OF DD

```
PQ.K=PQN*MDDPQ.K                                            16, A
    PQ     - PROPENSITY TO QUERY (QUERIES/WEEK/USER)
    PQN    - PROPENSITY TO QUERY NORMAL (QUERIES/WEEK/
               USER)
    MDDPQ  - MULTIPLIER FROM DELIVERYDELAY ON PROPENSITY
               TO QUERY (DIM.LESS)

MDDPQ.K=TABLE(TDDPQ,DDPU.K/DDN,0,3,0.5)                     17, A
TDDPQ=1.5/1.25/1/.8/.65/.57/.5                              17.1, T
    MDDPQ  - MULTIPLIER FROM DELIVERYDELAY ON PROPENSITY
               TO QUERY (DIM.LESS)
    TDDPQ  - TABLE FOR MDDPQ
    DDPU   - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)
    DDN    - DELIVERY DELAY NORM (WEEKS)

MDDER.K=TABLE(TDDER,DDPP.K/DDN,0,3,0.5)                     18, A
TDDER=1.6/1.47/1/.47/.3/.3/.3                               18.1, T
    MDDER  - MULTIPLIER FROM DELIVERY DELAY ON ENTRY
               RATE (DIM.LESS)
    TDDER  - TABLE FOR MDDER
    DDPP   - DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
               (WEEKS)
    DDN    - DELIVERY DELAY NORM (WEEKS)
```

LONG TERM DECISIONS

```
DH.K=(ALR.K*PTME)+DXS.K*S.K                                 19, A
    DH     - DESIRED HIRES (STAFF)
    ALR    - AVERAGE LEAVE RATE(STAFF/WEEK)
    PTME   - HIRING TIME (WEEKS)
    DXS    - DESIRED EXPANSION OF STAFF (FRACTION)
    S      - STAFF (STAFF)

ALR.K=SMOOTH(LR.JK,LMPT)                                    20, A
    ALR    - AVERAGE LEAVE RATE(STAFF/WEEK)
    LR     - LEAVE RATE (STAFF/WEEK)
    LMPT   - LONG TERM PERCEPTION TIME FOR MANAGEMENT
               (WEEKS)

DXS.K=TABLE(TDXS,LPDPM.K/LDDNM,0,3,0.5)                     21, A
TDXS=0/0/0/0/0/0/0                                          21.1, T
    DXS    - DESIRED EXPANSION OF STAFF (FRACTION)
    TDXS   - TABLE FOR DXS
    LPDPM  - LONG TERM DELIVERY DELAY PERCEIVED BY
               MANAGEMENT (WEEKS)
    LDDNM  - LONG TERM DD NORM HELD BY MANAGEMENT (WEEKS)

SFF.K=TABLE(TSFF,DDPF.K/DDN,0,3,0.5)                        22, A
TSFF=1/1/1/1/1/1/1                                          22.1, T
    SFF    - SUPPORT FROM FUNDER (DIM.LESS)
    TSFF   - TABLE FOR SFF
    DDPF   - DELIVERY DELAY PERCEIVED BY FUNDER (WEEKS)
    DDN    - DELIVERY DELAY NORM (WEEKS)
```

```
 ALLOCATION OF STAFF

DASP.K=MIN((Q.K/(SPQR*DDNM)),SAP.K)                          23, A
     DASP     - DESIRED ALLOCATION OF STAFF TO PRODUCTION
                  (STAFF)
     Q        - QUERIES IN PROCESS (QUERIES)
     SPQR     - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)
     DDNM     - DELIVERY DELAY NORM BY MANAGEMENT (WEEKS)
     SAP      - STAFF AVAILABLE FOR PRODUCTION (STAFF)

ASP.K=SMOOTH(DASP.K,ACT)                                     24, A
ACT=2                                                        24.1, C
DDNM=0.5                                                     24.2, C
     ASP      - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
     DASP     - DESIRED ALLOCATION OF STAFF TO PRODUCTION
                  (STAFF)
     ACT      - ALLOCATION CHANGE TIME (WEEKS)
     DDNM     - DELIVERY DELAY NORM BY MANAGEMENT (WEEKS)

SAP.K=(1-FRSM.K)*(S.K)                                       25, A
     SAP      - STAFF AVAILABLE FOR PRODUCTION (STAFF)
     FRSM     - FRACTION OF STAFF REQUIRED FOR MARKETING
                  (DIM.LESS)
     S        - STAFF (STAFF)

FRSM.K=SPST.K+SPEND.K+MMIN                                   26, A
MMIN=0.20                                                    26.1, C
     FRSM     - FRACTION OF STAFF REQUIRED FOR MARKETING
                  (DIM.LESS)
     SPST     - MARKETING EFFORT (FRACTION)
     MMIN     - MIN ALLOCATION TO MARKETING (FRACTION)

SPST.K=STEP(SHT,STM)                                         27, A
SHT=0                                                        27.1, C
STM=0                                                        27.2, C
     SPST     - MARKETING EFFORT (FRACTION)

SPEND.K=STEP(EHT,ETM)                                        28, A
EHT=0                                                        28.1, C
ETM=0                                                        28.2, C

ASM.K=S.K-ASP.K                                              29, A
     ASM      - ALLOCATION OF STAFF TO MARKETING (STAFF)
     S        - STAFF (STAFF)
     ASP      - ALLOCATION OF STAFF TO PRODUCTION (STAFF)

 EFFECT OF MARKETING

ASTND.K=U.K*ANEED                                            30, A
ANEED=0.001                                                  30.1, C
     ASTND    - ASSISTANCE NEEDED (STAFF)
     U        - USERS (USERS)
     ANEED    - NEEDED STAFF TO USER RATIO (STAFF/USER)
```

```
MASST.K=TABLE(TASER,ASTND.K/ASM.K,0,3,0.25)                31, A
TASER=2/1.9/1.78/1.53/1/.8/.62/.5/.37/.25/.2/.15/.1       31.1, T
DDN=0.5                                                    31.2, C
PQN=0.035                                                  31.3, C
    MASST  - MULTIUPLIER FROM ASSISTANCE ON ENTRY RATE
               (DIM.LESS)
    TASER  - TABLE FOR MASST
    ASTND  - ASSISTANCE NEEDED (STAFF)
    ASM    - ALLOCATION OF STAFF TO MARKETING (STAFF)
    DDN    - DELIVERY DELAY NORM (WEEKS)
    PQN    - PROPENSITY TO QUERY NORMAL (QUERIES/WEEK/
               USER)
```

PERFORMANCE AND OPERATIONAL MEASURES

```
SAR.K=SAR.J+(DT)*(AR.JK)                                   32, L
SAR=0                                                      32.1, N
    SAR    - TOTAL NUMBER OF ANSWERED QUERIES (QUERIES)
    DT     - SOLUTION INTERVAL
    AR     - ANSWER RATE (QUERIES/WEEK)

SER.K=SER.J+(DT)*(ER.JK)                                   33, L
SER=UN                                                     33.1, N
    SER    - TOTAL NUMBER OF SERVED USERS (USERS)
    DT     - SOLUTION INTERVAL
    ER     - ENTRY RATE (USERS/WEEK)
    UN     - INITIAL VALUE FOR U

SERVIX.K =MDDER.K*MASST.K                                  34, S
    SERVIX - MULTIPLICATIVE SERVICE INDEX
    MDDER  - MULTIPLIER FROM DELIVERY DELAY ON ENTRY
               RATE (DIM.LESS)
    MASST  - MULTIUPLIER FROM ASSISTANCE ON ENTRY RATE
               (DIM.LESS)

NER.K =(ER.JK-TR.JK)                                       35, A
    NER    - USER GROWTH RATE
    ER     - ENTRY RATE (USERS/WEEK)
    TR     - TERMINATION RATE (USERS/WEEK)


YPUG.K=SMOOTH(NER .K,52) *(52*100/U.K)                     36, A
    YPUG   - AVERAGE ANNUAL USER GROWTH RATE IN %
    NER    - USER GROWTH RATE
```

INITIAL CONDITIONS AND CONTROL CARDS

```
QN=1                                                       36.4, C
SN=3                                                       36.5, C
UN=50                                                      36.6, C
DT=.5                                                      36.7, C
LENGTH=0                                                   36.8, C
PLTPER=4                                                   36.9, C
    QN     - INITIAL VALUE FOR Q
    SN     - INITIAL VALUE FOR S
    UN     - INITIAL VALUE FOR U
    DT     - SOLUTION INTERVAL
```

```
PLOT  U=U/Q=Q,QR=O/S=S,ASP=%/ER=E                          37.1
    U       - USERS (USERS)
    Q       - QUERIES IN PROCESS (QUERIES)
    QR      - QUERY RATE (QUERIES/WEEK)
    S       - STAFF (STAFF)
    ASP     - ALLOCATION OF STAFF TO PRODUCTION (STAFF)

PLOT  MDDPQ=1,MDDER=2,MASST=3(0,2)/DXS=X(-1,1)/           37.2
  DDPP=P,DDPU=U(0,2)/MPUER=4,SPP=S(0,2)
    MDDPQ   - MULTIPLIER FROM DELIVERYDELAY ON PROPENSITY
                TO QUERY (DIM.LESS)
    DXS     - DESIRED EXPANSION OF STAFF (FRACTION)
    DDPP    - DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
                (WEEKS)
    DDPU    - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)
    MPUER   - MULTIPLIER FROM MARKET PENETRATION ON ENTRY
                RATE (DIM.LESS)
```

NOTE: After this listing was made there has been an addition to the model. As described on page 32 quarterly percentage growth (QPUG) and accumulated good-will (AGOWL) are calculated as part of the simulations.