THE POTENTIAL IMPACT OF BROADBAND COMMUNICATION NETWORK TECHNOLOGY ON CONSUMER MARKETING COMMUNICATION: A COMPUTER SIMULATION EXPERIMENT

Dissertation for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY
MARTIN PAUL BLOCK

1975

This is to certify that the

thesis entitled

THE POTENTIAL IMPACT
OF BROADBAND COMMUNICATION NETWORK TECHNOLOGY
ON CONSUMER MARKETING COMMUNICATION:
A COMPUTER SIMULATION EXPERIMENT

presented by

Martin Paul Block

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Mass Media

Gordon E. Miracle
Major professor

Date October 17, 1975

O-7639

ABSTRACT

THE POTENTIAL IMPACT OF BROADBAND COMMUNICATION NETWORK TECHNOLOGY ON CONSUMER MARKETING COMMUNICATION: A COMPUTER SIMULATION EXPERIMENT

By

Martin Paul Block

The basic purpose is to assess the potential impact of broadband communication network (BCN) technology on consumer marketing communication using a computer simulation model of human time allocations. BCN technology represents the combination of interactive cable television, computer and information processing technology, and terrestial communication satellites. The computer simulation model is used in an experimental mode to determine the impact of a hypothetical BCN system on the allocation of time to daily human activity.

Marketing communication is described in terms of a number of traditional marketing activities, including personal selling, advertising, packaging, point-of-purchase, direct mail, product sampling, publicity and public relations. A typology of consumer marketing communication is then developed using a diagrammatic model of communication with a source, message, channel,

receiver, and feedback. The first type of marketing communication is advertising and promotion which involves the passive consumption of messages by large numbers of consumer receivers through the mass media. The second type of marketing communication is retailing and selling which involves the active participation of both the seller and consumer and is generally a face-to-face situation. The third type of marketing communication is marketing research which can be described as the feedback mechanism from the consumer to the marketer. The impact of BCN technology on advertising would center on the addition of response capability and a larger program offering which should result in more attractive programming commanding a larger share of the viewer's time. The impact of BCN technology on retailing and selling would include both a reduction in shopping-related travel time due to the substitution of communication for transportation and an increase in the time devoted to overall shopping activity because of the reduction in the cost of shopping. The impact of BCN technology on marketing research is not sufficiently tangible to warrant consideration in terms of the allocation of time to daily activity.

The means of describing the impact of BCN technology is found in the methodology of technological forecasting borrowed from military planning.

Technological forecasting can be divided into four methodological groups, dialectical methods which include the scenario approach and the Delphi Method, teleological methods including PERT analysis or normative backcasting, experimental and empirical methods including time series analysis, and analytical methods including the method used here in the computer simulation experiment.

The computer simulation model developed here, named TIMMOD, allows for the vicarious experimentation with various aspects of human time allocation to daily activities, including the hypothesized impacts already hypothesized as a result of the installation of a BCN system. The empirical basis for TIMMOD is the United States Time Use Survey conducted in 1965.

TIMMOD constructs time allocations to various daily activity categories from the selection of random deviates from two basic theoretical probability distributions. The first probability distribution describes the activity selection behavior of the hypothetical population, and the second probability distribution describes the duration of the selected activity. The simulation begins with a single individual, who has a randomly selected waking time and retiring time. According to the appropriate hour of the day, an activity is selected, followed by the computation of the appropriate activity duration. The process continues until the entire day is exhausted. When the first individual has retired, then the process starts again with a new individual. The activity selection distribution consists of a matrix of cumulative percentages by activity category and hour of the day. Uniform random numbers are drawn and compared to this matrix to select a particular activity. The activity duration is determined from a family of Erlang distributions with different parameters to describe different shaped distributions for different activity categories.

The TIMMOD experiments demonstrated impact on the human allocation of time to daily activity categories in that the amount of time allocated to particular activity changed in response to an experimental manipulation of various treatment variables. Examining the experimental treatments each in isolation provides some interesting results. Reducing the amount of time spent in shopping-related travel, for example, reduces the amount of time spent shopping and increases the amount of time spent in home and family activities. Increasing the amount of time spent viewing television reduces the amount of time spent participating in other mass media consumption and reduces the amount of overall leisure time. Increasing the amount of shopping time, that is making shopping a less expensive activity, reduces semi-leisure time which includes the time spent in personal care, study, religious and organizational activity, and reduces overall leisure time. Most interesting, however, is that increased shopping time also causes an increase in the amount of work-related time.

Combining the three experimental conditions mentioned before exhibits little impact on any activity category except the experimental categories. In other words, decreases in shopping-related travel are offset by the increases in television viewing time and overall shopping time, with very little apparent effect on any other activity category. Assuming that the experimental conditions described here are a fair representation of the capability of a BCN system, then it would appear that BCN technology does not represent a major redistribution of the allocation of time as did television. The major impacts of BCN technology appear to be the reduction of travel time with the concomitant reduction in travel expense, and more efficient shopping behavior because of the increased time devoted to it.

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Martin Paul Block

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Communication Arts and Sciences - Mass Media

1975

ACKNOWLEDGMENTS

A number of people have played a role in the completion of this dissertation and I would like to express my gratitude to them. I would first mention Dr. Gerhard J. Hanneman of the University of Southern California, who encouraged me to return to graduate school and pursue doctoral studies, and made this acknowledgment possible. I would also like to thank Dr. John P. Robinson of the University of Michigan for providing me with variance estimates from the 1965 United States Time Use Survey, making the development of the computer simulation model possible.

The role of the guidance committee in the preparation of a dissertation goes without saying. I think in my case the role played was an extraordinary one, requiring more than the usual expression of gratitude. Understanding that merely thanking them here is insufficient, I would like to express my deepest gratitude to Dr. Thomas F. Baldwin, Dr. Gilbert D. Harrell, Dr. Thomas A. Muth, and especially my chairman, Dr. Gordon E. Miracle.

I would also like to thank my wife, Rosemary, and daughters Bianca and Elizabeth for their patience, understanding, and numerous personal sacrifices during the preparation of this dissertation.

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CHAPTER I

INTRODUCTION

Problem Statement

Estimating the future impact of any communication technology is by no means an easy task. Imagine how difficult it would have been in 1935 to have estimated the impact electronic television would have on the style of life in 1965. It would have been hard to believe that electronic television would become the dominant national advertising medium, with the national general circulation magazines such as Collier's, Look, Life, and the Saturday Evening Post having either ceased publication or be struggling for survival. It would also be hard to believe that in just thirty years the watching of electronic television would occupy about 40 percent of all leisure time.[1]

The changes in life-style or behavior patterns in the United States during this thirty-year period can be considered in terms of changes in the allocation of time to various activities. Life-style in one important sense, according to Andreasen, can be looked upon as an allocation problem: "given a fixed resource time, how do different groups apportion available time across various activities?"[2] For example, in 1935 Sorokin and Berger found the average adult to spent about 26 minutes listening to the radio, 29 minutes reading newspapers and magazines, and 14 minutes reading books each day.[3] In 1935 the total average time consuming the mass media was about 69 minutes. In 1965, Robinson and Converse found the average time listening to the radio as a primary activity to be only 8 minutes, 84 minutes watching television, 21 minutes reading newspapers and magazines, and 14 minutes reading books.[4] In 1965 the total average time consuming the mass media was about 133 minutes, or nearly twice the 1935 average. This dramatic change in mass media consumption is almost attributable entirely to television. If television viewing as a secondary activity is added the total viewing time increases to 94 minutes per day. An activity which did not exist thirty years before and accounts for one hour and a half of an average adult's day represents a dramatic shift in the daily behavior patterns of those adults. This shift in the allocation of time is indicative of the profound impact television has had on society.

In 1975 Broadband Communication Network (BCN) technology is in much the same situation as was television in 1935. There is no doubt that BCN technology represents in some degree the wave of the future in all human telecommunication activity. The problem is to estimate the nature and extent of the impact BCN technology will have on society. If it were possible to obtain the time allocation for attending BCN events in 1985 or 1995, then it would be possible to make some estimate of the impact BCN technology has had. It is the main thrust of this work to estimate the future impact of BCN technology through the estimation of the allocation of the consumer's time as a result of the intervention of BCN technology.

The tremendous communication potential of BCN technology broadens its range of application from entertainment and leisure to nearly every category of human activity, with perhaps the exception of night sleep. BCN technology can directly involve work, education and organization activities, semi-leisure activity such as shopping and errands, as well as leisure and entertainment. The range of activity is sufficiently broad to require some arbitrary limitation. Here the range of communication activity will be limited to consumer marketing communication, such as communication involved in shopping and advertising.

There are two reasons for focusing the study on marketing communication. First is the popularity of marketing-related applications of BCN technology in the current literature. Normally the first applications mentioned for two-way cable television technology include pay or subscription television, in-home shopping and ticket purchasing, in-home surveillance systems such as fire and burglar alarms, and other commercially oriented applications.[5] It is only recently that noncommercial applications have been considered, such as in the areas of social service delivery and urban administration.[6] BCN technology has been traditionally viewed in terms of its potential commercial viability.

The second reason for considering consumer marketing communications is the relative importance of such communications to society. A free market economy assumes the free flow of information about available products and services so the best choices can be made by consumers. Clearly, the range of product choice available to consumers would be severely constrained without marketing communications. Marketing communication, including personal selling, advertising, promotion and related activities, is a vital part of the distribution of goods and services process in society.

It is the primary objective of this research to predict the impact of BCN technology on consumer marketing communications. Prediction of future impact will be made in terms of changes in life-style as indicated by the allocation of time to various activities. Although changes in life-style cross all human activity and behavior patterns, the focus will be on activity and behavior directly related to the acquisition of goods and services. A secondary objective of this research is to demonstrate a methodology for assessing the impact of changes in communication systems such as technological improvement.

Technological Approach

The future of BCN technology is most often discussed in the popular literature from an engineering perspective with little or no consideration of the human communication system that it is supposed to augment.[7] BCN technology, like most new electronic technology, is often described in a "gee whiz" manner outlining the performance capabilities of mystical electronic gadgets. Included in such discussions of BCN technology are broad bandwidth bidirectional coaxial cable systems for urban distances, satellite systems for intercity and intercontinental distances, very inexpensive digital logic and memory, user-oriented and human dominated computer terminals, and greatly increased power of data processing computers and networks of computers.

Ralph Lee Smith in The Wired Nation describes the capability of cable in terms of electronic newspapers, mail service, banking and shopping facilities, electronic libraries, educational and cultural programs and community originated programs. A nation criss-crossed by telecommunication facilities with virtually unlimited voice, data, and video resources is the promise of the future. In short, writes Smith, "every home and office can contain a communication center of a breadth and flexibility to influence every aspect of private and community life."[8] While Smith's vision of a future telecommunication system provides an extremely provocative scenario, it nonetheless emphasizes the performance capability of the technology rather than the communication needs in the various human communication systems. In marketing terms, this approach would be characterized as being "product-oriented" rather than being "market-oriented."

Reid suggests that instead of regarding telecommunication as driven by a "technological dynamic" as implied in the wired nation concept, it is possible to consider the human communication need. Technological feasibility is only a necessary, and not a sufficient condition for the adoption of a new technology in a human communication system. As Reid points out, telecommunication should be considered "not as items of electronic hardware, but as channels of human communication."[9] Much more is required than only examining the technology itself to understand its full potential for utilization and its ultimate impact on society.

Multidisciplinary Approach

Reid advocates a multidisciplinary approach emphasizing the human aspects of communication rather than the engineering performance capability of telecommunication hardware. Specifically, Reid suggests that any assessment of telecommunication technology should be based upon the following four factors:

1. What is the pattern of communication needs which telecommunications must try to satisfy?
2. What improvements to telecommunication technology are likely to be feasible, at what date, and at what cost?
3. How effective are such systems likely to be, in terms of satisfying communication need?
4. What secondary impacts would arise from the widespread introduction of such systems?[10]

No single academic discipline is adequate to simultaneously handle all four of these factors, requiring a multidisciplinary approach. Reid suggests a number of research areas which could have potential contribution, including information theory, applied psychology, experimental social psychology, management studies, urban and regional planning, geography, and sociology including content analysis, control analysis, media analysis, audience analysis, and effect analysis. To this list economics and marketing should also be added. Throughout all of these disciplines, the emphasis is on the human aspects of the communication process, and not on the technological aspects. In suggesting priorities for future research, Reid writes:

> The vast bulk of telecommunications research is technological in orientation. . . . This amounts to a wasteful misallocation of research resources, and some shift of effort away from technological research studies towards studies of the human aspects of telecommunications is therefore of the utmost importance.[11]

Departure from the technological approach in assessing new communication systems is not easy, especially when the multidisciplinary implications of such a move are considered. The study of human behavior is not the same as the study of the ordered and predictable world of technology. While a multidisciplinary approach is desirable to handle the complexities of the human aspects, such an approach is often unwieldly. It is necessary to integrate various disciplines along a unified theoretical continuum to keep a multidisciplinary study manageable.

Assuming that human communication involves the sending and receiving of messages through physical space, it is possible to describe the communication event in terms of the time devoted to the event. The allocation of time to a communication event involves a managerial decision by the participants to engage in the communication activity in lieu of other competing activity. A communication event requiring more time implies a greater communication need.

Since communication occurs in physical space, a spatial dimension can also be added. Becker and

Willibald define this dimension as the range, and subclassify the range in terms of local, regional, or nationwide communication.[12] Examining human communication need in terms of the spatial dimension is less interesting than the time dimension because of the fixed nature of physical space. It is difficult to directly manipulate physical distance. While it is possible to locate in physical space to minimize communication distance, it is often impractical because of geographical barriers and similar hindrances. The conquering of distance, as applied to telecommunication, can be interpreted as a reduction in the time required to initiate a communication event.

Communication need can also be considered in terms of the cost in energy and resources that are required by the participants to maintain the communication event. The more energy and resources devoted to obtaining market information by consumers for example, the greater their communication need. It is this dimension of communication need that leads to a discussion of the obvious trade-off between physical movement and telecommunications. Hanneman, for example, discusses the possibility of tele-commuting or going to work via teleconferencing rather than driving on the freeway.[13] Although, as DeSerpa argues, this kind of trade-off can be viewed as a time trade-off as well.[14]

Time is the thread which runs through most of the considerations of human communication need. Time, and in particular models of the allocation and utilization of time, can be the theoretical linkage between the many and varied disciplines recommended by Reid in the multidisciplinary approach to the study of telecommunications. Models of the allocation and utilization of time are found in economics in the form of elasticity models, in management science in the form of time and motion studies, in urban planning in the form of planning and design models, and sociology in the study of leisure time and the problems of senior citizens. Time models occupy minor roles in the marketing literature in consumer behavior, and in the mass communication literature in media consumption studies.

Overview of BCN Technology

A Broadband Communications Network, or BCN, is an electronically sophisticated system of high volume information linkages, such as television, between nodes in a human communication network. BCN technology describes an amalgamation of technology represented by electronic information processing equipment, community antenna or cable television, and terrestial communication satellites. Although the technology is described here in terms of cable television, it is not limited to the distribution of broadband signals by coaxial cable. Other more advanced technologies have been suggested, such as fiber optics and laser communication which would more efficiently perform the same function. BCN technology will be described here, however, in terms of cable television because it is the most immediate and available broadband technology, and it sufficiently demonstrates the potential and function of BCN.

The frequency bandwidth of standard coaxial cable is 300 MH_z (million cycles per second),[15] which is much wider than a standard telephone bandwidth of 6 KH_z (thousand cycles per second), hence the reference to broadband communications. A television signal requires approximately 6 MH_z of bandwidth to be transmitted, which after allowing some bandwidth for channel separation, leaves the average cable television system with an effective capacity of around thirty-eight channels. Additional capacity can be obtained by adding cables. It should be mentioned that the FCC currently requires only twenty channels.[16] While this bandwidth allows for many video or television signals, it also has the potential to transmit signals in both directions simultaneously. A cable television system has the potential to become a fully two-way or interactive communication system. Cable has the potential to relieve the congestion in the broadcast spectrum and provide two-way communication.

This tremendous potential of cable has led some to speculate that cable communication has the potential of destroying most of the structural limitations of the present broadcast media. The increasing diversity and growth of potential cable television applications makes its reference as Community Antenna Television, or CATV, obsolete, and the BCN reference far more appropriate.

The combination of urban cable systems with satellite communication systems make it technologically feasible to interconnect any number of urban systems throughout the United States and the world.[17] A cable system need not be limited to the extent of its cable run. The combination of urban cable systems and computer technology provides the only feasible solution to the problem of managing return response from a large cable system.[18] In addition to managing a two-way system, the addition of a computer makes it possible to bring the computing power and information storage and handling capability of a computer into the home.

While one-way community antenna cable television systems have enjoyed mild success in some areas, and use of satellite in international communication is commonplace, and the computer industry continues its growth, the three basic components of BCN technology have never been successfully married in any large scale, commercially viable demonstration. The most often cited reasons are economic for the apparent sluggish introduction of BCN technology. The cable industry itself has come upon economic hard times. Baer, for example, says that much of the excitement about the cable revolution has evaporated.[19] Industry over-expansion, coupled with high interest rates and projections of a general economic downturn have burst the speculative bubble. Despite some current pessimism, BCN technology does have a commercially successful future as demonstrated by the number of pilot two-way systems. The current economic hardships, however, point to the deficiencies in relying on engineering performance capabilities in predicting future use of new technology.

Smith describes five operating pilot two-way cable systems as of January, 1975. The systems include Bedford, Massachusetts which is a small system interconnecting six buildings in a military engineering facility, Columbus, Ohio which is the largest of the two-way pilot systems with 718 terminals using the Coaxial Scientific Corporation system which will be discussed later, El Segundo, California using the Theta-Com SRS system has 30 prototype terminals, Irving, Texas has 50 terminals placed near the headend using a standard converter with a five-button digital transmitter-receiver, and Princeton, New Jersey with a system designed by RCA Laboratories.[20] Smith cites two major reasons for the relatively few number of operating pilot tests. The first is the economic problem caused by the added expense of extra equipment including return amplifiers, a computer, and home terminals. The second is the technical problem of sufficiently insulating against radio frequency interference to avoid unwanted signals in the return or upstream circuit.[21]

BCN technology encompasses such direct human communication activity as two-way digital return cable television and teleconferencing; and such derived human communication activity as computer-to-computer communication. BCN is different from narrowband communication networks, such as the telephone system, in its ability to efficiently transport high-volume information such as television signals to every node in a communication network. It is different from the traditional television broadcasting in the ability to transport signals point-to-point, rather than radiating signals outward indiscriminately from a central point. It shares with both traditional broadcasting and narrowband communication networks the ability to interconnect geographically separate networks using communication satellites making the cost of communication essentially independent of distance.

Teleconferencing is often suggested as a means of reducing transportation costs by simulating face-to-face contact through the use of television. Distant parties can communicate as though they were in the same room, without the limitation of a voice-only interaction imposed by the narrowband telephone system. Tele-offices, or going to work through television rather than the freeway, as well as substantial reduction in business trips are obvious applications of teleconferencing technology.[22]

Interactive or two-way cable television normally is used to describe a different system than indicated by teleconferencing, which assumes two-way full video signals. Interactive cable television as it is most commonly described consists of a full video television signal in the outbound or downstream direction, with a digital return signal generated from a push-button response pad in the inbound or upstream direction in a single cable system. Cable television systems are constructed in a tree configuration so that signals are transmitted from an origination point, or headend, outward along limbs and branches. Interactive cable television is almost always described as an in-home system, whereas teleconferencing is most often described in an institutional setting because of the high cost of television origination equipment such as cameras and transmitters.

The general model for the cable system involves only the transmission of television signals from the headend to all terminals in the system simultaneously. Any channel can be viewed at any point in the system, unlike the telephone system which can direct a message to a specific point. The reason for this limitation is that cable systems are not switched, although in the future they may be.[23]

The cost of installing a two-way cable system was mentioned as one of the reasons for the lack of pilot two-way systems. Home terminals have been estimated to cost more than $500 depending upon the number of features associated with the device.[24] Not only is the cost of the home terminals prohibitive, but technical problems caused by rf interference plagued all of the experiments. McVoy and Reynolds have developed a practical and low cost home terminal system by modifying a standard cable converter which is required to extend the channel capacity beyond the eleven VHF channels built into a standard television receiver. With the addition of in-line code operated switches and oscillators each modified converter becomes a remote terminal communicating with a mini-computer. The McVoy and Reynolds system using the modified converters for terminals reduces the cost of a terminal to the $100 to $200 range.[25] This estimate includes the cost of the converter itself. The problems facing two-way cable television are at least partially solved with this system.

Brief History of BCN Technology

Cable television started in the United States in 1948 in communities that were isolated from normal television service by distance and geographical terrain.[26] From the beginning as a local community antenna service, cable has grown into a major industry. Since this first system, cable has grown dramatically until in 1975 there are 3,100 operating cable systems in the United States serving nearly 6,000 communities. These cable systems currently reach a total of 8.1 million subscribers or about 12.5 percent of all television households.[27]

Cable has not yet reached its full potential with approximately 2,500 systems approved, but not built. Cable is also missing the largest urban areas, growing primarily in smaller communities and rural areas. Cable has grown rapidly in the small towns and rural areas, and now must rely upon expansion in the major population centers to continue its growth. A tabulation of markets with and without operating cable systems for the top 300 markets clearly shows the problem. Dividing the top 300 markets into groups of 50 by population, the top 50 have only 16 markets with operating cable systems while the last 50 markets have 40. This tabulation of the top 300 standard metropolitan statistical areas with cable information from the 1974 Broadcasting Yearbook is shown in Table 1.

TABLE 1

PENETRATION OF CABLE SYSTEMS BY SIZE OF MARKET IN 1974

Market size:	Top 50	51-100	101-150	151-200	201-250	251-300
Markets with no cable	34	33	19	16	15	10
Markets with cable	16	17	31	34	35	40

Future growth in the cable industry will most likely come in the larger markets where construction costs are high, competition with broadcast television keen, and government regulation more restrictive. Early projections of cable penetration have apparently discounted this fact. The Sloan Commission in 1971 estimated that cable penetration would be between 40 and 60 percent by 1980.[28] Baer now estimates that 25 percent may be too high for 1980.[29] The problem of building cable systems in urban areas can easily be understood by simply comparing the $75,000 per mile for laying cable in the largest cities with the $4,000 per mile in the rural areas.[30]

To build systems in the larger cities additional services are needed to attract subscribers because of the variety of television fare available off the air. Pay cable is often discussed as a possible remedy, although it has not been an overwhelming success. In

1975 only about sixty systems reaching a total of 65,000 subscribers offered any pay cable.[31] Despite the apparent gloom, most experts agree that cable will continue to grow, but at a rate slower than anticipated at the beginning of the decade. Price summarizes the consensus by writing:

> We are left, then, with a cable technology which, all agree, will grow at medium speed during the next decade. It is almost certain that the innovation will mean a richer choice in entertainment offerings on television for millions of Americans.[32]

To date, almost all the considerations of the problems of the cable television industry have assumed that cable is a one-way communications medium. Two-way services, which could drastically alter the competitive position of cable in the larger metropolitan areas, have not been developed. The reason for the lack of development of two-way services is what Baer terms the "chicken and egg" barrier. The cable industry built on relatively low monthly subscriber fees does not see sufficient revenues from two-way services to justify the large investment. On the other hand, two-way services cannot be developed until the investment has been made.[33]

Until recently, demonstrations of two-way cable have been limited to very small equipment demonstrations. In 1974, the National Science Foundation funded a number of developmental projects to design experiments in the area of urban administration and social service delivery using two-way cable television technology. Michigan State University was the recipient of one of the planning grants to work with the cable system in Rockford, Illinois.

The Rockford system was selected because of the generalizable demographic characteristics of the Rockford community, and the technical excellence of the cable system itself. The Michigan State University research project was conducted in two phases, a design phase followed by an implementation phase commencing in mid-1975. Among the proposed experiments are a program to train firefighters to upgrade their skill using interactive training material as well as simulations, a program to diagnose developmental delays in children under age 5 in the home, a large-scale cable information and referral service based upon a series of interactive television vignettes describing various social services and programs within the community, providing an extension and supplement to elementary science education through teleconferencing and computer-aided instruction, and a series of legal communication applications including an automated legal library, publication of court-generated information, and the taking of depositions. The five proposed experiments involve both teleconferencing and digital return interactive television with a number of institutions in the Rockford community, and hundreds of private homes.[34]

The National Science Foundation has funded Michigan State University to conduct the firefighter training experiment along with experiments being conducted by New York University and the Rand Corporation. In total the National Science Foundation has funded nearly $2 million, which should have some impact on the continued development of cable technology.[35]

Public Policy Environment

In addition to the economic problems incumbent upon BCN technology is an excessive system of public regulation. According to Branscomb the present rules regulating cable television have saddled a new technology with too much responsibility in its infancy before it has had time to develop the economic base necessary to sustain such public commitments.[36] According to Branscomb, the cable industry is regulated by a three-tiered system, including local, state, and federal regulation. A cable operator must meet FCC requirements, conform to any state regulation that may exist, and negotiate a franchise with the local government unit.[37]

Since then the FCC has established very complex rules for what can and cannot be carried by a cable system determined by an intricate set of procedures and formulas in the FCC Cable Television Report and Order issued in 1972.[38] Sardella describes the 1972 rules for the top 100 markets as restricting the importation of distant signals to two channels, requiring channel capacity of at least twenty channels, the provision of three free channels including a channel for public access, local government and educational uses, and provision for mandatory channel capacity tied to usage, allowances for channel leasing, and rules governing programs provided for additional charge or pay TV. The 1972 rules also require these cable systems to maintain a system having the technical capacity for nonvoice return communication.[39] The complexity of the rules makes it difficult for the average cable operator to operate without expensive legal resources. It is difficult for single system operations to survive without the economies obtained in pooling systems and legal resources.[40]

Not only is the regulation that has been imposed upon cable television, as described by Branscomb,[41] excessive but often favors other competing media. An example of this can be seen in the FCC pay television rules. In the struggling cable industry, pay television is often described as the means of providing the financial basis to help develop cable systems, especially in the large urban areas. According to Baer and Pilnick most cable operators consider pay cable programming the service that is most likely to make their systems more attractive and therefore more economically feasible.[42]

Pay cable, however, is regulated by the FCC's "anti-siphoning" rules which attempt to minimize any competitive threat to commercial broadcast television and film distribution industries. The National Association of Broadcasters has been very successful in its lobby against pay television of any kind. Some of the rather severe restrictions placed on pay cable include a ban on all feature films which have a release date more than two years old and less than ten years old. It should be pointed out that films between two and ten years old constitute the bulk of broadcast film libraries. Other restrictions include a ban on sports events that have been seen on broadcast television at any time in the prior two years, and a ban on any series-type programs.[43]

While the sports restriction has been recently eased, the rules for the most part have constituted one more barrier for the struggling technology. The economic and regulatory barriers for cable television, however, do not necessarily negate the future success of the technology. The barriers may only delay the development and make it difficult to predict when various milestones will be passed.

Suggested Applications for BCN Technology

The pioneer article describing how the new BCN technology could revolutionize the entire process of the distribution of goods and services was written by Baran in 1967. Baran considered the feasibility of the development of various aspects of "computer-communications" technology and the resulting nature of the pattern of changes that may occur by the end of this century. The potential impact of BCN technology on marketing is emphasized when Baran writes:

> Our concept of market segmentation is highly dependent upon information flow structures. Change the information flow mechanism by providing instantaneous feedback to the manufacturer and the entire market segmentation process must change.[44]

Baran goes on to describe marketing research, retailing and merchandising, and advertising examples of BCN technology applications.

Bogart in 1973 makes the point that speculation about the future of advertising requires first a consideration of the developments that might occur in the mass media. The mass media, according to Bogart, are in the midst of a "technological revolution which is bound to accelerate in the rest of this century."[45] Changes in the media inevitably carry implications for advertising, buying habits, and retailing practice.

Some of the implications for advertising created by BCN technology have been suggested elsewhere by this author. The first of these include improved research and evaluation methodology with the introduction of automated advertising evaluation systems that will include instantaneous audience measurement with associated purchase behavior measurement. A second area might be an entirely new communication medium, such as a formal consumer forum. Such forums might be either publically or privately controlled and could become a major communication linkage between the consumer and the marketer. A third, and perhaps obvious, implication for advertising will be the introduction of an entirely new advertising message format. Commercials and sales messages may begin to look more like a kind of electronic catalog with ordering or response capability integrated into the production. A fourth implication, partially generated by the other three, will be the increased emphasis on television production, especially at low cost to accommodate local retailers.[46] Dordick and Hanneman point to the need for the application of BCN technology to provide the better and quicker market information needed in the future. BCN technology would mean more information obtained in real-time, using nonlabor intensive methods, about smaller and better specified population segments.[47]

In addition to these few articles dealing directly with the application of BCN technology to marketing, there have been numerous articles about BCN technology and two-way cable television which have compiled lists of applications for the technology. Smith, for example, lists home library services, facsimile data services, delivery of mail, crime detection and prevention, and travel as the major application areas for BCN technology.[48] Travel includes such activities as business and shopping where the communication technology can be used as a substitute for travel. The National Academy of Engineering lists thirteen potential services for BCN technology:

1. Give the subscriber the right to select any one of twelve or more free television channels as the demand develops, including local TV stations, distant TV broadcast signals, locally originated nonbroadcast programming, and nationally distributed cable programming via domestic satellite systems. Sufficient bandwidth exists to provide for cultural, educational, ethnically oriented, and religious channels, as well as entertainment.
2. Provide restricted channels that would be available only to an authorized group such as doctors, etc.
3. Provide the means to order merchandise from product demonstrations on available channels.
4. Permit viewer participation in public preference polling, with optional means for protecting the identity of the responder.
5. Provide warning of fire, medical or intrusion emergencies in the home. This information could be forwarded directly to the municipal emergency service authorities.
6. Provide educational channels with a student response capacity.
7. Provide statistical data relating to television viewing preferences.
8. Provide turn-on service in the home for lights, heat, warning systems, etc.
9. Provide readings of the various meters used for gas, electricity, and water, send the reading directly into the utility company computer, and return the billing to the user.
10. Provide facsimile page-type or strip-type hardcopy or electronic readouts in the subscriber's home for messages or statements.

11. Provide means for capturing and storing continuous display single pictures from a shared channel (frame grabber) as a means of delivering slide information into the home.
12. Provide channels on a lease or free basis for use in programming by independent persons or agencies.
13. Provide access to premium programming with color and resolution capacities superior to broadcast standards.[49]

Baer has prepared a compilation of proposed services for BCN technology from various reports, FCC filings, corporate brochures, and advertising materials.[50] Included in the list are subscription television, remote shopping, electronic delivery of newspapers and periodicals, catalog displays, ticket sales, banking services, local auction sales and swap shops, television ratings, and market research surveys.[51]

Baran conducted a Delphi Process study in 1970 to obtain estimates of the service characteristics of the thirty interactive cable-related home services. Overall, Baran found the new industry of electronic services to the home is estimated as essentially starting in 1980 and building to a twenty billion dollar industry.[52] Shopping transactions or store catalogs which describe or show goods at the request of the buyer were predicted as early as 1977 and as late as 1990. Other marketing related services such as mass mail and direct mail advertising are predicted as early as 1980.[53]

The list of potential applications for BCN technology spans a broad range of activity in both public service and commercial areas. The list includes services that cover the entire spectrum of economic feasibility. It is obvious that the list was developed heavily emphasizing the performance characteristics of the electronic hardware. This research is an attempt to depart from the more common technological approach and employ the multidisciplinary approach advocated by Reid.

Analysis Plan

Computer simulation used as a research methodology fits well with the multidisciplinary approach. Computer simulation allows the investigator to be eclectic in his approach and combine many different disciplines and methodologies to develop the complex and well-specified models necessary. Computer simulation is also an ideal forecasting methodology because it allows vicarious experimentation. Computer simulation is one of the few research approaches that allow asking fanciful "what if" questions. A hypothetical world having the advantage of a new communication technology can be created using the electronic symbol manipulation capability of a digital computer with much less effort and expense than in the real world.

The first step in this research will be to analyze the existing communication patterns that exist in the marketing process from the point-of-view of the consumer. This will be the topic of Chapter II which immediately follows this introduction.

Chapter III will deal with the problems of technology forecasting and a review of technology forecasting methodology. Also included in this chapter will be a number of examples of telecommunication related technological forecasts, and a detailed examination of computer simulation as a research methodology.

Chapter IV will explain the basis of the simulation model which is human activity analysis. The chapter will begin with a review of the theoretical positions of time as a social variable and a review of time-budget studies. The 1965 United States Time Use Survey conducted by the Institute for Social Research at the University of Michigan will be outlined in some detail because it provides the essential data base for the simulation model. A discussion of simulation and process models based upon human activity data will follow, with special emphasis on urban planning models.

The development of computer simulation time model (TIMMOD) itself will be described in Chapter V. The chapter will begin with a functional description of the model and rationale for its development. This will be followed by a discussion of theoretical probability distributions because of their crucial role in the operation of the model. An explanation of the derivation and transformation of the relevant input data for the model from the published results of the 1965 United States Time Use Survey, and a discussion of the problem of verification of the model will end the chapter.

The simulation experiment which will evaluate the potential impact of BCN technology will be described in Chapter VI. This chapter will begin with a discussion of the importance of the allocation of time and a description of the experimental paradigm used in the research. A discussion of some of the problems and limitations of computer simulation experiments comes next. The treatment conditions, including measures for communication/transportation tradeoff, programming variety, and availability of both marketing and non-marketing services, will precede the actual simulation runs. The simulation runs will then be discussed and interpreted. The implication of different levels of cable penetration will be discussed to end the chapter.

Chapter VII is the final chapter and will contain the summary, conclusions, and recommendations for additional research. In appendices will be the FORTRAN source coding for the TIMMOD main program and all the supporting subroutines.

CHAPTER I--NOTES

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CHAPTER II

APPLICATION OF BCN TECHNOLOGY TO MARKETING COMMUNICATION

Marketing Communication

A number of traditional marketing activities can be described under the rubric of marketing communication, including personal selling, advertising, packaging, point-of-purchase, direct mail, product sampling, publicity, and public relations. The use of the term "marketing communication" implies a consolidation of the communication activity involved in the marketing effort of the firm, which until recently, as Ray points out, has not been seriously attempted.[1]

Stidsen and Schutte describe marketing itself as a communication process rather than as it is traditionally described as a control process. Marketing as a communication process is considered as a dialogue between producers and consumers, whereas marketing as a control process is seen as a well-directed and efficiently implemented producer monologue. The marketing communication process is described by Stidsen and Schutte in terms of four strategic dimensions:

1. The boundaries of marketing concern and responsibility, such as size and dimensionality of the marketing "scene."
2. The set of potential outcomes of a particular marketing effort or of marketing in general given the products and consumers involved.
3. The set of available and potentially available methods of communication between producers and consumers.
4. The division of tasks among various marketing agents (including producers and consumers), and the relative degree of control available to each agent or group of agents.[2]

It is conceptually appealing to consider marketing as a communication process, rather than as a control process. If marketing is to be considered as a communication process, then the focus of this study should be on the methods of marketing communication, or the communication between producers and consumers. The methods of marketing communication are represented by a variety of communication media in a variety of communication situations. For example, marketing communication occurs face-to-face, over the telephone, through the mail, and the mass media. It can occur in situations before, during, and after a purchase or transaction.

Marketing communication methods can be classified in a variety of ways, by function, as is normally the case in the marketing literature, or by elements of the communication situation, as is the case in most behavioral science literature. Classifying methods of marketing communication according to their function provides categories such as advertising and promotion, retailing and selling, and market research. The behavioral science approach typically analyzes the communication situation in terms of a source, message, channel, and receiver. Criteria such as the direction of communication flow, that is the communication being primarily in the producer to consumer direction, about the same, or in the opposite direction; the initiation of the communication, that is either producer or consumer; and the communication channel, such as face-to-face, mediated face-to-face, and mass media. Advertising would be defined as marketing communication that is producer initiated, flowing primarily in the producer to consumer direction through the mass media. Retailing as a communication process would be mainly face-to-face (ignoring direct mail) consumer initiated communication flowing primarily in the producer to consumer direction. Market research as a communication process would be for the most part producer initiated mediated face-to-face (telephone or mail) communication flowing primarily in the consumer to producer direction.

It is interesting to note that almost all of the methods of marketing communication are oriented in the producer to consumer direction. Market research, while characterized as being primarily in the consumer to producer direction, is producer controlled and very low volume when compared to advertising and retailing.

Despite the emphasis on a dialogue between producers and consumers in the marketing concept, most marketing communication is clearly a producer monologue. Stidsen and Schutte describe the problem as follows:

> Perhaps the basic reason for the paucity of consumer-producer communication channels is that marketing is still viewed as selling, the rhetoric of the marketing concept notwithstanding. The necessary technology clearly exists (e.g., telephones, two-way cables, and electronic processing equipment), but the economic rationale for and commitment to giving the consumer a voice in producer decisions is clearly lacking.[3]

The potential impact of BCN technology goes to the very heart of the marketing concept.

Bogart characterizes the mass media as being in the midst of a technological revolution which is bound to accelerate in the rest of this century. Mentioned among other communication technology is two-way cable that will make possible the direct ordering of advertised goods and the display of on-demand information and entertainment. The impact on marketing, and in particular advertising is profound. Bogart writes:

> Changes in media thus inevitably carry implications for the content and targeting of advertising messages. These changes parallel changes in buying habits and in retailing practice.[4]

Bogart believes that technological change in the mass media will have the effect of reducing the mass audience and increasing the number of consumer options.

Ray describes telecommunication technology as the most important "future breakthrough" which will change the very nature of marketing communication. About the impact of telecommunication technology on marketing communication, Ray writes:

> Probably the clearest trend related to marketing communication is that the hardware is changing dramatically. Cable TV, satellite communications, videophones, computer-aided instruction, videotape, holography--all of these and more promise not only to change the media but also to change control of the media. With more channels and home and office information centers, the control of communication will shift from the sender side to the receiver side. Mass media communications will resemble personal selling, and "personal" selling will be conducted through the media to create structural similarity among the elements of the communication mix than currently exists.[5]

Although, not all those who speculate on the future of marketing communication agree with Ray. Banks reports a survey of marketing and advertising executives about the past, current, and future roles of advertising and promotion. Notably absent from the list of future trends is any reference to telecommunication technology.[6] This is akin to speculating about the future of advertising and promotion in 1935 without any mention of the new medium television.

Communication Models

To develop a typology of marketing communication methods, a brief review of communication models is necessary. In 1952, Deutsch characterized two basic types of communication models; flow models such as those suggested by Lashley in psychohydraulics, and cybernetic models as defined by Wiener.[7] This fundamental dichotomy has remained basically unchanged through today. Johnson and Klare speak of "diagrammatic" models and "mathematic" models of human communication.[8]

Diagrammatic models are very common in communication research. The most common type of diagrammatic model is a relatively simple flow model showing the transfer of information from a "source" to a "receiver" in the communication dyad. Osgood, for example, has suggested a model which begins with a source, which encodes a message, which is sent to a receiver who decodes the message. Schramm has modified this basic model so as to include feedback. Westley and MacLean have modified the basic model even more to accommodate mass communication. The Westley and MacLean model complicates the simple dyad model to allow for fortuitous communication and feedback since orientative feedback is not directly in the mass communication situation, as it is in the interpersonal situation. This mass communication model also builds in the role of reporter, and treats this function as an extension of the environment.[9]

An interesting extension of the diagrammatic model is the geometric treatment of communication "networks" as was first suggested by Bavelas in 1948.[10] Although network analysis has progressed substantially since then, its application is primarily in the study of social organization and not appropriate here.

The basic mathematical communication model was developed by Shannon and Weaver in 1949. While this model has all the elements of the diagrammatic models, such as the "information" source which produces a message which is "transmitted" over a "channel" to a "receiver" and "destination," the Shannon and Weaver model also includes the concept of noise.[11]

The concept of noise is a concept central to information theory and can be described in pure mathematical terms. The information theorist considers entropy and redundancy as opposite ends of a continuum, and can define entropy or uncertainty using a simple mathematical formula:

$$H_{max} = \log_2 n$$

The expression H_{max} is the maximum amount of entropy in the system and n is the number of equally probable outcomes. Similarly, there are mathematical equations which describe noise as a function of bandwidth and power of transmission. Information theory is replete which a variety of interesting concepts such as coupling, networks, and channel capacity.

While information theory and mathematical models of communication are interesting, they have only limited application in the development of a typology of marketing communication methods. The primary reason for this is simply the lack of empirical data describing different marketing communication situations. In order to develop a typology, then, it is necessary to rely on simple diagrammatic models to describe the communication situation with such basic elements as a source, receiver, and feedback.

A typology of marketing communication methods can be described in terms of the elements of diagrammatic communication models. Three basic types of marketing communication can be easily identified in these terms that generally correspond to corporate functions. The first type of marketing communication is advertising and promotion. Advertising involves the sending of messages from the advertiser source to the consumer audience receiver through the mass media communication channel. This type of marketing communication does not involve any immediate feedback and is normally characterized as one-way communication. Advertising and promotion are almost completely dependent upon the traditional mass media. It is also one form of marketing communication that is passively consumed.

A second type of marketing communication is retailing and selling. Retailing and selling is a separate category because it involves active participation on the part of consumers, generally does not rely on the mass media, and often requires transportation of either the consumer himself or the goods that are purchased. Transportation is not typically involved in advertising, although the function of retailing and advertising on the surface may appear to be the same. Retailing and selling involve the direct exchange of both goods and information, and either involve face-to-face interaction between the consumer and the seller or a substitute for face-to-face communication.

The third type of marketing communication is marketing research. It is distinct from advertising and retailing in its emphasis on feedback from the consumer to the producer. Marketing research is the only formal communication method in most firms for consumer feedback except sales. It should be pointed out that sales are not really communication in that they represent only choice among a set of constrained alternatives. As mentioned before, marketing research provides only a small amount of return communication. Certainly marketing research cannot hope to create any dialogue between producers and consumers. Also, the producer has complete control over the format and content of the information and is likely to emphasize issues important to producers rather than issues that are important to consumers. No doubt the lack of a more adequate feedback channel from consumers to producers is a contributing factor in much of the consumerist criticism of marketing.

An analysis of the potential impact of a new communication technology such as BCN technology on these types of marketing communication must begin with the communication as it currently exists. Even though a major impact of the technology may be to dissolve the definition between the types of marketing communication such as advertising and personal selling. Potential impacts of BCN technology, then, will be described in terms of each of the three types of marketing communication discussed here. A consolidation of these impacts will be considered later in Chapter VI.

Advertising and Promotion

Advertising and promotion are primarily mass media communication activities. To describe the impact of BCN technology on advertising and promotion it is necessary to consider the impact on the mass media. As Bogart writes, "to speculate about the future of advertising requires that we first consider some of the developments that lie ahead for the mass media with which most advertising has always been linked."[12]

Some of the implications of BCN technology for advertising and the mass media have already been suggested. There is little doubt that BCN technology is growing and is destined to become a very important communications medium, and that the traditional one-way mass media, including both print and broadcast, will become highly vulnerable to the increased penetration of first multi-channel systems, then networks, then interactive television. Also of major importance is that the public interest in interactive television is strong and no doubt a portion of the medium will be devoted to public interest programming.[13] Although the additional channel capacity will easily accommodate commercial programming, public interest programming offered through a BCN may for the first time provide real competition with commercial programming. The public interest in BCN technology is demonstrated by the regulation discussed in Chapter I.

The introduction of BCN technology as an advertising medium will serve to further blur the distinction between advertising and retailing because of the consumer's opportunity to immediately respond. It will greatly increase the efficiency of the advertiser's ability to provide real prospects with little waste. It will involve a whole new message format, namely, interactive television.

Speculation about the future of advertising as a result of the impact of BCN technology might run as follows. First result of the technology would be the introduction of an automated advertising evaluation system aimed at traditional one-way broadcast television. The evaluation system will adopt newer message formats as the technology develops, and provides instantaneous audience measurement with associated purchase behavior measurement. It is a simple matter to include monitoring capability in a BCN system that can provide second by second monitoring of an in-home television set. Unlike conventional television ratings calculated for fifteen minute time segments, second by second ratings are possible. It is possible to collect product purchase behavior by administering a questionnaire on a continual basis with the push-button return for response which would be directly recorded by computer as described in Chapter I. It would also be possible to conduct copy tests having respondents viewing commercials in their homes, reacting to the commercials using the response pad.

A second result of BCN technology might be the establishment of consumer forums. Such forums might be either publically or privately organized and could potentially become the major communication link between consumer and producer to make the producer-consumer dialogue in the communication process conception of marketing a reality. Consumer forums could involve a combination of teleconferencing and digital return interactive television, and might be a governmental service sponsored by consumer affairs agencies, or a trade association, or be a private corporation.

A third result might be the introduction of an entirely new advertising message format, namely two-way television. Commercials and sales messages will begin to look more like a kind of electronic catalog with ordering or response capability integrated into the program. Commercials will no longer be the short repetitious messages as they are now, but probably longer and more detailed messages that would be sought by the consumer in much the same way as a catalog is used.

A fourth, and very obvious, result will be the increased emphasis on television production, especially at low cost to accommodate the local advertiser. It will also be necessary for future television production personnel to be familiar with computer techniques as well as traditional television production to effectively produce future messages using interactive television.

While speculation such as this may be interesting, it does not provide much insight in the problem of assessing the future impact of BCN technology. When considering the impact of BCN technology on advertising and promotion, it is clear that the discussion will center on television advertising, with the impact on other competing advertising media considered as secondary. A BCN system provides the potential for both increased diversity and attractiveness of television program material. Increased diversity is made possible through greatly expanded channel capacity as discussed before. Attractiveness of the medium should be greatly enhanced by the increased diversity as well as the opportunity to provide interactive program material.

Unfortunately there is no direct way of determining the effect of increased program diversity and interactive programming. The best substitute is the experience of one-way cable television which can provide some indication of the effect of increased program diversity.

Agostino did a study of television consumption behavior in terms of channel use between cable subscribers and broadcast viewers. The study consists of a comparison of thirty-one cable households and thirty-one noncable households in several American Research Bureau markets. The comparisons are made on the basis of ARB diary reports. The study, although based on a very small sample, has a number of interesting findings. Agostino summarizes the major findings as follows:

1. individual television viewers whether by broadcast or cable generally watch only three to five channels;
2. use of channels increases only slightly as the number of available channels increases;
3. cable viewers in three of the five markets utilized more channels than broadcast viewers;
4. cable subscribers view more prime time television than broadcast viewers;

5. heavy television consumers utilize more channels and distribute their viewing more evenly across channels than low consumers;
6. household viewing groups generally use only three to six channels;
7. households with children utilize more channels and distribute channel use more evenly than households without children;
8. market differences have greater influence on the number of channels used, than differences of reception type;
9. though some differences among viewing groups have been noted, all viewers tightly concentrate their viewing time on the local network-affiliated stations;
10. the expanded channel choice offered by cable service does not alter this concentration on network programming;
11. but does alter the relative popularity of the local network stations.[14]

Overall, Agostino found relatively little impact of television consumption behavior as a result of cable service. Prime time viewing of network programming accounts for the majority of the behavior. Such homogeneity as led Robinson to describe television's role as "electronic innkeeper to the less active minds of society."[15]

Robinson also believes that the best prediction of future use of television is "status quo." There seems to be a predictable limit to the amount of time people will spend watching television, and that in the near future television in the United States may be approaching its maximum audience, simply because nearly every household has at least one television set.[16] In general it appears that one-way television, whether it is cable or not, will continue to be consumed in approximately the same way as it is today.

There is one difference, however, that might be overlooked because of the small sample size in the Agostino study. Agostino reports the mean total viewing time in number of fifteen-minute units per week for individuals with cable as 101.34, and without cable as 90.86.[17] Cable subscribers appear to spend over 10 percent more time per week watching television than noncable subscribers. However, Agostino does not report this result as being a statistically significant difference. However, some mention should be made of the statistical test applied by Agostino as being a two factor treatment by level analysis of variance. The variability across markets, ranging from 70.68 to 110.81 for individuals with cable for example, is statistically significant. Treating different ARB markets along with the type of television reception would seem less important if the number of markets were increased beyond five. Also, even if the difference between those with cable and without cable were significant, many other factors could account for the difference than merely the availability of cable. For example, those more interested in viewing television would be more likely to be cable subscribers.

With no empirical evidence available, it seems most reasonable that households spend more time watching television as a result of BCN technology. It will be assumed here that making the cable system two-way and providing interactive programming would make watching television even more attractive. In the absence of any contradictory evidence the overall time spent viewing television per household would increase as a result of the application BCN technology. Without BCN technology, the time spent viewing television would remain approximately the same. The increase in television viewing time, then, will be considered as the major impact of BCN technology on advertising and promotion.

Retailing and Selling

Retailing and selling has been described here as a type of marketing communication involving either face-to-face communication or some substitute for face-to-face communication. Retailing and selling, or shopping, clearly involves some form of transportation, either the consumer must go to the seller or vice versa. For the most part, shopping implies some kind of physical exchange of goods and services.

The communication substitute for some of the transportation in the shopping process is an obvious result of the application of BCN technology to the process. Clearly much of the transportation involved in the shopping process does not involve the physical movement of goods, but rather moving in space to obtain information to make a purchase decision. Examples are comparison shopping or window shopping. The use of catalogs and the telephone in shopping illustrate the need for information. Although, as Tauber warns, the shopping process offers other benefits than simple exposure to products.[17] Tauber suggests a number of motivations for shopping other than obtaining simple product information, including personal motives such as role playing, diversion, self-gratification, learning about new trends, physical activity, and sensory stimulation; and social motives such as social experiences outside the home, communication with others having a similar interest, peer group attraction, status and authority, and the pleasure of bargaining.[18] Tauber believes that retailers should do more than emphasize the promotion and distribution of goods as they traditionally have, and should consider themselves as being part of the social-recreational industry. As Tauber points out:

> As businesses which offer social and recreational appeal, retailers must acknowledge that they are competing directly for the consumer's time and money with other alternatives that provide similar benefits.[19]

However, neither Tauber's nor any other research indicates which of the shopping motives are the most important.

Since shopping with a BCN system is essentially an in-home activity, it is worthwhile to examine some of the characteristics of present-day urban in-home shoppers. Gillett cites estimates that in-home sales accounted for 9 percent of total general merchandise sales in 1970 and could reach 11 percent by 1975. Catalog sales have increased at a rate almost twice that of all general merchandise sales.[20] Shopping convenience and the reduction of shopping time and effort are the usual reasons given for the increase in in-home shopping.

Gillett in a study of 210 Grand Rapids homemakers found that the in-home shopper is not a "captive" market, but are better described as a "modern" shopper. Women buying at home are also active store shoppers and do not find store shopping difficult or unpleasant. In-home shoppers are convenience oriented and flexible in their choice of shopping behavior. Also important, is that in-home shoppers are more affluent and better educated than other shoppers. Those shoppers that dislike in-home shopping tend to buy little at home, are lower socio-economic status and are somewhat older.[21] Gillett's study includes only telephone and mail shopping, not door-to-door solicitation.

Anderson identified convenience-oriented consumer using data from a consumer panel reporting convenience food consumption. Anderson supports Gillett's conclusion describing the convenience-oriented shopper as enjoying higher socio-economic status.[22] Reynolds did a mail survey of female homemakers in Georgia to determine factors that affect catalog buying behavior. Reynolds found that current catalog buyers do not perceive current shopping conditions as either too frustrating or unentertaining, but the opposite. Reynolds concludes: "Barring a continued major problem in mobility as a result of gasoline shortages and assuming a continuing thrust by merchants to provide enjoyable shopping environments, convenience is not likely to regain a major position as a determinant of catalog buying."[23] Rather, Reynolds found that the catalog shopper is most influenced by the product offering and selection found in the catalog.[24]

Not all in-home shoppers are more affluent and better educated as was found by Peters and Ford in a study of in-home cosmetic customers in Wisconsin. Peters and Ford found that the in-home shopper has less access to a car, tends to be less educated, has lower income, and is less likely to be in a household with a professional household head.[25] Peters and Ford, however, limit their consideration of the in-home shopper to the door-to-door solicitation. Other forms of in-home shopping were not considered.

The difference in the socio-economic status of in-home or the "modern" shopper and the "traditional" shopper points to one of the most profound potential impacts of BCN technology on consumer marketing communication. As Thorelli points out, there tends to be a greater concentration of market information among the more educated and higher income groups in the world.[26] The more affluent and better educated consumers not only are more likely to take full advantage of retailing innovation, but they also control more market information. Clearly the differential in market information is an important dimension in determining the "haves" and "have nots" in society.

BCN technology can greatly facilitate the flow of market information, but not necessarily equally across all socio-economic groups. Katzman makes the point that new communication technology tends to increase the amount of information transmitted and received in a society and that all members of the society tend to receive more information that they would without it. However, the use of new communication technology will tend to be higher among those who already have higher economic and educational status.[27] Rather than close the gap between information-rich and information-poor consumers, the impact of BCN technology may well be to widen it. Those consumers who are presently more affluent and better educated will be more likely to take advantage of innovative shopping services, thus making them even more efficient shoppers, and thus even more affluent. BCN technology may not serve to equalize the distribution of goods and services across society, but serve the opposite purpose. Because of the potential of BCN technology to reinforce the position of affluent consumer, it carries with it serious public policy implications.

While the problem of unequal distribution of market information is most serious, it does not lend itself to empirical speculation. Unfortunately this analysis must be limited to less value laden descriptions of the shopping process. Bucklin did a survey of home-makers in Oakland, California to test the following general hypotheses about shopping behavior:

1. The consumer will shop more extensively where the cost of shopping is low.
2. The consumer will shop more extensively when she initially knows little about the product which she is buying and the stores that sell it.
3. The consumer will shop more extensively when the value of the product is high.[28]

In general Bucklin found support for all three hypotheses. The first hypothesis that consumers would shop more if the cost of shopping were lower is supported by evidence that consumers contacted more stores for a given product in a centralized downtown area or large plaza than in outlying, smaller retail centers. Similarly there was evidence supporting consumer's willingness to shop more for higher-priced items and when no brand was known or store preferred.[29]

Unfortunately Bucklin's study cannot provide quantitative estimates of the relationship between cost of shopping and propensity to shop. It is clear that if shopping is made easier, or lower in cost, that more shopping will occur. The potential impact of BCN technology should be primarily on this point, that is reduction of shopping cost. The fact that consumers shop more for higher-priced items and when they do not have strong brand or outlet preferences should remain the same whether or not a BCN system exists. This leaves two expected results of the application of BCN technology to marketing communication. First is a reduction in the amount of travel time associated with shopping, which is the communication substitute for transportation aspect of the application of BCN technology discussed earlier. Second is an increase in shopping time resulting from the reduction of the cost of shopping as indicated by the Bucklin study. It is assumed that shopping via a BCN system is not more efficient than is shopping in the traditional manner. Finding the desired goods in the store would be equivalent to waiting for the product to appear on the television screen.

Marketing Research

Marketing research provides the primary source of consumer feedback in the producer-consumer dialogue discussed before. The most immediate applications of BCN technology to consumer marketing communication are research applications. A BCN system could totally revolutionize marketing research methodology, adding an entirely new method of communication in interactive television.

Dordick and Hanneman describe five alternative marketing research strategies applying BCN technology. The first alternative is described as the combinational application which uses one cable channel in a one-way mode to provide program material to consumer homes. The material can be anything from product descriptions to commercials. Data can be collected using traditional techniques such as telephone or mail interviews. The second alternative is the dual channel coincidental method which allows for the showing of commercials to a portion of the cable audience allowing some experimentation. The third alternative would allow character generated questions with a touchtone telephone reply. This alternative would partially solve the problem of the traditional data collection methods, but limits response to highly structured questions. The fourth alternative would be to use the distributed video disc to provide product and message preview information. Respondents would view the disc at their leisure and supply response data. The fifth, and most interesting alternative is the full use of two-way cable technology. Two-way cable allows the combination of the best features of the other alternatives while allowing the response through the upstream digital return channel of the cable system.[30]

The use of two-way digital return interactive television allows the researcher to test concepts, test advertising copy, monitor television media behavior, and monitor purchase behavior. Probably the most serious limitation of the application of such technology to the marketing research process is the problem shared with mail research, that is who in the household is responding to the particular questions. This problem is a serious one for mail research. As Nuckols and Mayer point out, there is serious doubt of mail's ability to reach a particular household member.[31]

The application of BCN technology to the consumer feedback process also allows the creation of consumer forums as mentioned before. BCN technology has the potential to remove some of the communication format control held by the marketer in the traditional research situation. A number of "hot lines" and other techniques have already been employed by some marketers in an attempt to open the channel of communication. Unfortunately, existing communication technology has limited such efforts to telephone and mail systems.

Because of the relatively low volume of research communication, there is little reason to expect that the application of BCN technology would have any direct effect on the life-styles of consumers. No doubt improved research techniques would provide better information to decision-makers, and as a result consumers would be provided with better products and services. Unfortunately this is an indirect impact, and extremely difficult to measure.

Summary

There are three potential changes in marketing communication related activity which have been identified that may be descriptive of the result of the application of BCN technology. The first of these is an increase in the amount of time spent watching television because of the increased attractiveness due to BCN capability. The increased attractiveness can be attributed to increased program diversity, but primarily to the addition of the return channel and the interactive mode.

The second potential change is a decrease in the amount of time spent travelling in shopping related activities. This is the communication-transportation tradeoff dimension of the application of BCN technology. The decrease in travel time is directly related to the number and type of shopping services available through a BCN system.

The third potential change is an increase in the time spent engaged in shopping activity. Because the cost of shopping should be drastically reduced by the application of a BCN system, consumer interest in shopping should increase along with the time engaged in the activity.

CHAPTER II--NOTES

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CHAPTER III

TECHNOLOGICAL FORECASTING METHODOLOGY

Forecasting New Technology

Technological forecasting is a relatively recent development among the tools of scientists and social planners. Technological forecasting as a serious professional activity has been developed primarily by those engaged in the administration of military research and development since 1965. Bright and Schoeman describe the state of the art of technological forecasting prior to 1965 as follows:

> There was virtually no published methodology for forecasting technology. Past practice had been to use expert opinion. Opinion was not a very satisfying predictive device, as was evidenced by the highly uneven record of scientists and engineers with unassailable records of technical competence.[1]

After 1967, technological forecasting became a popular topic for seminars and short courses along with related topics such as research and development planning, and corporate planning. In 1969 three journals involved with technological forecasting were introduced, Futures, Technological Forecasting and Social Change, and Long Range Planning.

The major reason for the general neglect of technology among economists and social scientists, as Ayres points out, is the widespread notion that technological change is inherently unpredictable. Largely responsible for this, according to Ayres, is the popular mystique of science as having "an incomprehensible internal dynamism relying mainly on the workings of creative genius--resulting in perpetually unexpected breakthroughs."[2] Recently, however, science and technology are becoming less regarded as a phenomena themselves, and more as a vital feature of society and economic change.

Martino provides a working definition of technological forecasting as "prediction of the future characteristics of useful machines, procedures or techniques."[3] Ayres adds to the definition of a forecast as being "a reasonably definite statement about the future, usually qualified in the sense of being contingent on an unchanging or very slowly changing environment."[4] Ayres also makes the point consistent with Reid's view of telecommunication research, that technology is generally created in response to societal needs.[5] Thus, it would seem certain that technology is not driven by a mystical technological dynamic, but rather a societal demand for technological progress.

Heiss, Knorr, and Morgenstern describe four kinds of technological advances that should be recognized in

any attempt at predicting the future impact of technology. First are marginal improvements in known technologies. Examples of such marginal improvement are in the increased mileage and durability of automobile tires because of belted tire constructions and cord material, and in the availability of television program material because of the development of the UHF frequency spectrum.

Second are the combined application of known and improvable technologies in order to perform a completely new task. The example given by Heiss et al. is the NASA plan to put a man on the moon. Predictions about these types of technological improvement are not particularly difficult, although the exact timing is always subject to question because the level of financial and intellectual effort required are not always readily available.

The third kind of technological prediction is much more difficult, that is technology developed because of the great benefits it promises. This is the case where a large amount of resources are devoted to the development of technology in order to achieve certain economic, military, or social goals. Generally new technology must be invented to solve the problem, such as a cure for cancer, making it extremely difficult to predict.

The fourth kind of new technology is that which nothing is currently known about and comes as a complete surprise. Obviously this kind of technological change is impossible to predict. Although, as Heiss et al. point out, there have been relatively few complete surprises in new technology. Among those mentioned are aspirin in 1900, the nuclear bomb in 1930, and lasers in 1950.[6]

Technological forecasting methodology is then best suited to predict the first two kinds of technological change, marginal improvements in known technologies and the combined application of known and improvable technology to perform new tasks. BCN technology is clearly in the second category, that is combined application of known technology to perform new tasks. As described in Chapter I, BCN technology represents a combination of cable television technology, computer and information system technology, and communication satellite technology. BCN technology represents far more than just the marginal improvement of existing television technology. BCN technology also makes possible completely new applications of telecommunications.

Technological forecasting methodology can be conveniently divided into four methodological groups, including dialectical methods, teleological methods,

experimental and empirical methods, and analytical methods. Each of the methodological categories will be considered separately.

Dialectical Methods

The dialectical approach is founded on the notion that both the future and past history are the result of a sequence of conflicts. The dialectical method itself is divided into two major approaches, the scenario approach and the Delphi Method.

The scenario approach is perhaps the most commonly used of all of the technological forecasting methodology, yet it is by far the most mystical. The scenario approach is not capable of systematic explanation as are the other methodologies described here. The approach involves the consultation of a large volume of relevant material and literature, and then the application of intuitive judgment to describe the future. The scenario approach is much the same as that of the historian. Judgment and intuition are crucial in developing the forecast.

It is very easy to dismiss scenario forecasts, granting them only some mild entertainment value. However, scenarios form the basis for technological forecast, or any statement at all about the future. As Heiss et al. point out, the scenario provides the framework for speculation and is necessary to begin the process of making any predictions.[7] Although, it is probably safe to say that scenarios describing short-term predictions about relatively slow changing phenomena will in general be more credible than longer-term predictions.

The scenario itself is an exercise in the sequential plotting of events as they could happen. Generally when the scenario approach is used several different future conditions are described, with one representing a medium projection, and others representing a high and low projection based upon various associated phenomena. The scenario itself is an intuitive extrapolation of the emerging trends evident to an expert.

A more formal dialectical method is the Delphi Method. The Delphi Method is probably the best known of technological forecasting methodologies. The Delphi Method has been used to make forecasts of future conditions in a variety of industrial and governmental settings, including the assessment of possible levels of demand for a company's product. Jolson and Rossow found the Delphi Method to be preferred over the hunch of a single decision maker or a consensus of a group following face-to-face discussion in assigning prior probabilities in a marketing decision to be made under uncertainty.[8]

The Delphi Method, developed by the Rand Corporation, is a unique method of eliciting and refining group judgment. The salient features of the method are anonymity, controlled feedback, and group response. During a Delphi sequence, the group members are not made known to each other. The interaction of the group members are handled completely anonymously. The group interaction is conducted through the use of questionnaires, with the individual or agency conducting the sequence extracting the relevant pieces of information and presenting back to the group. This is the way that feedback to the group members is controlled. Instead of reporting a simple majority viewpoint, the Delphi sequence presents a statistical response ensuring that the opinion of every panel member is taken into consideration. The basic theory behind the Delphi Method is that with repeated measurement the range of responses will decrease and converge toward the midrange of the distribution, and that the total group response will successively move toward the correct or true answer. It should also be mentioned that the Delphi Method is intended only for use with groups of experts in the appropriate field. Convergence with nonexpert panels simply does not occur.

Martino outlines a number of advantages and disadvantages associated with the Delphi Method. Some of the advantages include: (1) the sum of the information available to a group is at least as great as the information available to its members, and (2) the number of factors which relate to a given area which can be considered by a group is at least as great as the number available to any one group member. While it is true that a group does involve the pooling of resources, it has been found experimentally to be true that a group tends to be more willing to take risks than an individual. This last advantage is especially important in the forecasting field.

Among the disadvantages outlined by Martino for the Delphi Method is the opposite of the pooled information advantage, that is, there is at least as much misinformation available to the group as to any of its members. Other problems include the potential for exerting social pressure on its members, which can contribute to the "bandwagon" effect. A group can become more interested in reaching agreement than in developing a well thought out forecast. It has also been shown experimentally that it is not the validity of arguments in a group that carry the group opinion, but the number of arguments. This phenomenon makes it possible to influence the group simply by sheer volume of argument, and opens the possibility of one individual dominating the group, even though he is anonymous. It is also possible that certain group members have vested interests in certain points of view and spend their time attempting to convert the others, rather than to reach a well thought out forecast. It is also true that a group of experts that come from similar backgrounds are likely to share a common bias, especially in the area of technology.[9]

While there are numerous variations and examples of the Delphi Method which could be considered here, they are beyond the scope of this brief introduction to technological forecasting methodology. Teleological methods are considered next.

Teleological Methods

Teleological methods explicitly recognize the interaction between the forecasts made and the future itself. Teleological methods are considered by Ayres as "inventing the future."[10] Teleological forecasts are goal oriented, in that they typically assess future goals, and then work back to the present. Heiss et al. suggest that a better term for this kind of technological forecasting is technology assessment.[11] The essential point of such forecasting methods is that the world without a particular forecast is different from the world with the forecast. The future is directed toward the particular goal.

Technology assessment involves two major techniques, the normative "backcast" such as PERT analysis, and cost-benefit analysis. PERT analysis, or Program Evaluation and Review Technique, is an advanced approach to planning complex projects involving many interrelated and interdependent tasks. In PERT, a sequential network of activities is constructed with time estimates for completion of the necessary activities. The PERT network is normally represented by a flow diagram consisting of the activities and interdependencies. Activities are normally circles, and the relationship between events are normally lines. The "critical path" becomes the longest path in time to complete the project. Obviously the use of a technique such as PERT in technological forecasting is goal oriented.

Another teleological method is the cost-benefit analysis. Such analysis applied to technological forecasting focuses on a measure applicable wherever a functional goal can be defined referred to as "cost-effectiveness." Cost-effectiveness refers to a technique for demonstrating the tradeoffs between sunk costs and results achieved. The application of cost-effectiveness as a measure normally implies that a choice must be made from a number of alternatives. Ayres suggests a number of criteria which can be applied to optimize cost-effectiveness:

1. To maximize "military value" within a fixed budget
2. To maximize the probability of achieving a designated capability within a fixed budget
3. To minimize the cost of achieving a designated capability

4. To maximize technological cross-support and spinoff while achieving a minimum goal within a fixed budget
5. To do any of the above subject to additional constraints.[12]

Techniques such as cost-effectiveness and PERT come directly from military planning.

<u>Experimental and Empirical Methods</u>

Experimental and empirical methods are data oriented technological forecasting methods. While a number of quantitative analyses developed in statistics, econometrics and survey research can provide data on which to base forecasts, the technique most commonly associated with this method is the time series analysis.

Time series analysis is a technique which allows past experience to guide future expectation through the numerical representation of some set of empirical observations. The fundamental process involves the extrapolation of trends from a mathematically described series of historical points. The technique is often objected to, as Martino points out, because the forecaster cannot describe events which lie beyond the range of his data points. Martino argues that such extrapolation is possible because of continuity. For example, if in some area of technology there has been a continuous progression of successive technical approaches, it is not unreasonable to expect it to continue. To argue otherwise is to advocate discontinuity, or that despite a more or less regular innovation in the past, the present represents a halt.[13]

There exists a vast amount of literature describing time series analysis, with the majority of the recent literature highly mathematical in nature. The reason for this, according to Heiss et al., is because of the extraordinary complexities which a time series may show.[14] At the risk of some oversimplification, Ayres describes two simple types of curves which are used either singly or in complex combinations. The first is the periodic or cyclic wave form with a single dominant period, such as a sine wave. The second are continuous curves with at least two derivatives, and at most one minimum or maximum and no points of inflection. Examples of this include a simple straight line or an exponential curve.[15] Simple linear regression is an example of the application of the latter type of curve. Common mathematical smoothing techniques such as moving averages and exponential smoothing can also be added. It is beyond the scope of this brief introduction to consider these techniques in any detail.

It should also be mentioned that despite the apparent quantitative sophistication of some of the curve fitting procedures, forecasts based on the curve are still dependent upon a number of subjective factors.

Subjectivity is involved in both the selection and processing of the input data and the interpretation of the output.

Heiss et al. mention two potential pitfalls in applying time series analysis in technological forecasting outside the ability of the mathematical function to adequately describe the trend. First is in an aggregation series there is usually a great change in composition. An example is in the Gross National Product which in 1935 did not include a number of very large industries today, such as electronics, television, computers, jet engines and nuclear reactors. Second is in an individual series there may be a problem with homogeneity through time. An example of this can be seen in the substitution of plastics for metals in a large number of products.[16]

Time series analysis is a valuable tool for determining the limits or boundaries around a particular forecast. However, time series analysis should be applied with caution.

Analytical Methods

Analytical methods involve the model oriented approach to technological forecasting. The analytical method is termed by Martino as the "black box" approach to forecasting.[17] Analytical forecasting models are generally theoretically based models trying to explain the interrelationships between variables. The variables can be endogenous or explained within the model, as well as exogenous as inputs that are historically given or inputs under the control of the investigator. The distinction between empirical methods and analytical methods is often unclear, but is generally defined in terms of the starting point of the forecaster, whether it be in data or a subjective view of some relationships that can be converted into a model. Generally speaking an empirical method must involve some kind of model, and an analytical method must ultimately involve some data.

To employ the analytical method it is assumed that it is possible to identify the elements of the particular process and all interactions. Analytical models can only provide forecasts when certain elements in the situation are going to change. Analytical methods can be divided into two general types, deterministic and stochastic. Deterministic models are generally mathematically sophisticated models which offer unique solutions to a forecasting problem when the situation can be sufficiently simplified to fit the requirements of the model. Stochastic models, while mathematically sophisticated, do not offer unique solutions, but rather offer specific case results. Stochastic models make use of various random processes and are normally considered in terms of computer simulation. Computer simulation is capable of handling far more complex situations than is a deterministic mathematical model.

As Martino indicates, the current state of the art of technological forecasting analytical models is quite primitive. Existing models have only limited utility for very practical forecasting purposes.[18] A relatively well-known example is the Limits to Growth computer simulation model developed by Meadows, Meadows, Randers, and Behrens.[19] The main reason for the lack of analytical models is the amount of effort necessary to develop them. But as Martino speculates:

> The primitive state of current models, far from being a cause for discouragement, should actually be a cause for hope. If the limited amount of effort which has been expended can produce results even this good, we can expect that much better results will be obtained when considerably more effort is applied to larger quantities of data in many varied situations.[20]

Before continuing the discussion of computer simulation applied to technological forecasting, several published examples of forecasts of telecommunication technology will be presented.

Dialectical Methods Applied to Telecommunication

The "expert opinion" approach is by far the most popular technique for forecasting the future of telecommunication technology in general. Numerous publications describe long lists of future applications and uses for telecommunication technology similar to the lists described in Chapter I.

Hinshaw provides a provocative pair of scenarios describing the future as a result of the impact of telecommunication technology. In the first scenario as social disorganization and environmental degradation reach new highs, a new and powerful union of social and behavioral science and the technological sciences emerge. After all homes are required to have at least one basic two-way terminal, social stability is brought about by strictly imposed government regulation. In the second scenario Hinshaw describes a far more attractive future where telecommunication technology is recognized as a medium for the creation of wholly new communities and as a tool for exchanging information. Instead of less human interaction as in the first scenario, more interaction develops.[21] While Hinshaw expresses a preference for the latter scenario, he believes the first to be the more likely future. He provides an extremely interesting bit of speculation and a very good example of the scenario approach.

Baran, as described in Chapter I, provides one of the first examples of expert opinion forecasting telecommunication technology as a marketing setting. Baran describes the future as follows:

> Imagine consumers in the year 2000. Much of the shopping will be done from the home via TV display. Think of the screen as a general

> purpose genie. Pressing a few buttons on a keyboard allows interaction with a powerful information processing network. The information network sends back a modified image to the TV display in response to selections. . . . [22]

Carne in less interesting language outlines the capabilities of the new communication technology by promising tomorrow's businessman the ability to:

1. Talk face-to-face with associates regardless of distance.
2. Participate in nationwide meetings without leaving his office building.
3. Perform a large number of executive functions from his home.
4. Have access to unlimited computer resources.
5. Own and operate private telecommunication facilities.[23]

These capabilities are predicted by the mid-1980's.

Barnett and Greenberg argue for the justification of the cost of $60 per home for wiring the city with the following points. First is an increase in the number of available channels. Second is an increase in the number and diversity of program offerings at a reduced cost. Third is improved picture quality. Fourth is a cost saving for both homes and broadcasters because it is less expensive to wire a city than it is to build a transmitter and purchase antennas. Fifth is the benefit of frequency spectrum saving, and finally increased flexibility in communication opening the door for additional services such as shopping. They do point out some negative points, however, in the increased cost to build in rural areas, the fact that it is cheaper use conventional broadcasting systems in the larger an areas, and high programming costs which would be urred to fill the twenty channels.[24] Despite all of problems, including the regulatory environment, nett and Greenberg intuitively conclude that "the mise and potentials of wired city television and er wired city services are so extraordinary that imately we may have them."[25]

Empirical and Analytical Methods Applied to Telecommunication

Young's economic analysis of the telecommunication ustry is an example of a mixed empirical-analytic roach to forecasting. The analysis concentrating on expenditure on research and development in the ustry found expenditure in the category to be very h, yet returns to capital and labor in direct pro-tion to be very low. It should be mentioned that ng's analysis restricts the telecommunication ustry to the telephone industry and employs econo-ric regression analysis.[26]

Ohls attempted to develop an investment theory cific to the CATV industry. Ohls, however, did not e use of any empirical data, restricting the consid-tion to economic theory only. It would be necessary add data to apply the Ohls model to a forecast of potential for economic growth for CATV, assuming rational investors. Ohls considers a number of factors in his optimum investment analysis including the number of channels and the amount of local-origination programming, the number of common carrier uses such as leasing channels, and the acceptance of advertising.[27]

Perhaps the best example of technological forecasting applied to any BCN related technology is the Park "impact model." Park began with the assumption that the future impact of cable television on broadcasting depends in large part on how cable continues to grow. The model begins by fitting a logistic growth curve to the penetration of cable television. A logistic growth curve is generally a good descriptor of growth within a finite limit and is given by the following equation:

$$Y = e^{a-b/T}$$

The size of the growing entity is given by Y, here the number of cable television subscribers. T is the elapsed time since the growth began, and a and b are parameters of the logistic distribution. The base of natural logarithms is standardly noted as e. The ultimate, or maximum, number of subscribers is a function of the a parameter and is expressed as e^a. This obviously will depend on other factors such as the number of households in a given service area, H, and the fraction of all households expected to subscribe, F_i, if the system offers services of type i. The ultimate size of the system, then, can be expressed by the following equation:

$$e^a = F_i H e^u$$

An error term, u, is introduced to represent all other factors.

Expanding the b parameter to represent a possible curvilinear relation across the number of households, the following equation is derived:

$$b = b_1 + b_2 H + b_3 H^2$$

The b parameter represents a how "stretched out" is the growth curve. As Park points out, the larger the number of households the more stretched out the growth curve is expected to be. Combining these three equations Park derives the overall estimation equation used in the analysis. The equation is expressed as follows:

$$\log Y = \log F_i + \log H + b_1(-1/T) + b_2(-H/T) + b_3(-H^2/T) + u$$

The equation becomes an appropriate subject for ordinary least square regression.[28]

Using data for a large number of cable systems obtained from such sources as the <u>Television Factbook</u>, Park is able to estimate the relative impact of a number of variables including the number of distant signals carried by a cable system, the attractiveness of television programming as indicated by audience shares, and other variables such as public service programming. Upon completion of the analysis, Park reached four major conclusions:

> 1. Reduction in aggregate station revenue due to cable penetration is perhaps not large enough to justify any great concern. . . .
> 2. Stations in larger markets, now sheltered by FCC policy, would on average be little hurt by unrestricted cable growth.
> 3. Stations in smaller markets, for which FCC policy now provides no protection, would suffer severe revenue restriction due to cable at ultimate penetration. . . .
> 4. In the near term, say through the 1970's, non-network UHF stations stand to gain substantially from cable growth, because cable puts them on the same technical footing as competing VHF stations.[29]

The Park Impact Model represents the most sophisticated forecasting effort of BCN technology yet published.

Computer Simulation

The availability of computer and information processing resources to those engaged in technological forecasting makes the application of computer simulation seem like a logical extension of the resource. Computer simulation seems at an intuitive level at least to be superior to the rather simplistic "seat-of-the-pants" approach evidenced in some dialectical methods. The direct application of deterministic mathematical models en yields unsatisfactory results, largely because of difficulty in adequately describing the real world uation in mathematical terms. Computer simulation ers to some degree a solution to this problem.

Abelson says that the advent of simulation techues to the social sciences has been so widely heralded t "many practioners and students of a variety of dislines are clamoring to use these techniques."[30] zenbaum, in an even stronger statement, says that e time is not far off when no social science theory t cannot be reduced to a computer model will be given credence or respect because its non-reducibility only mean its ambiguity."[31] Certainly what would true of social science theory ought to be partially e for technological forecasting.

The general approach adopted in computer simuion techniques is often referred to as functional lysis. Kline, in describing the general leitmotif communication research, uses a passage borrowed from ton to describe functional analysis: "Functional lysis, to a great extent, is concerned with examining se consequences of social phenomena which affect the mal operation, adaptation, or adjustment of a given ial system: individuals, subgroups, social and tural systems."[32] From the point of view of munication research, the functional approach

clearly adopts the point of view of the strategist, and is no doubt the orientation that the technological forecaster would be most comfortable with. This conceptual framework makes the computer simulation approach very attractive to the applications-oriented model developers because it forces problems into their "real-life" contexts.

Schultz and Sullivan describe the use of computer simulation as a research methodology in three ways. First, computer simulation can be a technique for theory building and comparison which accounts for the interest in the technique among scientists and scholars. The second major use is as a teaching and training device such as the popular marketing games. Third and last is the use of computer simulation as an aid to practical decision-making in organizations which is the business and marketing application of the technique.[33] It is this last use of computer simulation that makes the technique appropriate to technological forecasting. Computer simulation is not a panacea, or magical machine that solves all problems by merely "feeding them into the computer." Computer simulation is nothing more than a _tool_, albeit a unique and sophisticated kind of tool.

Implicit in the definition of computer simulation is the concept of isomorphism between some real world phenomena and a computerized model. Schultz and

Sullivan describe a computer simulation as an operating model of a real system.[34] Abelson defines computer simulation as the "construction of models of behavior which can be exercised or run on a computer so that certain aspects of the computer's symbolic behavior imitate or simulate real-world behavior."[35] Pool describes phenomena which can be simulated as any phenomena which has a describable pattern or nonrandom behavior. For a simulation to be computerizable, "there must exist somewhere a complex structure of propositions and/or data values. But note that we have had to use the expression and/or. It is not necessarily true that a simulation is no more useful than its data."[36]

The minimal conditions for a computer simulation of any human behavior process are set forth by Dutton and Briggs. Among these are:

1. Examines a behavior process.
2. Gives a theory which describes and explains the process without amiguity.
3. Shows how the process is affected by its environment.
4. Be formulated in such a way that inferences about the process may be verified by observations.[37]

In order to be computerizable, then, it is necessary to have an empirically verifiable and unambiguous system. In order to be simulated, it is necessary to have a describable process and an "open system." The idea of the system being affected by its environment is central to the conceptualization of computer simulation. A closed system would be nothing more than a continuous processing loop.

Abelson specifies two basic requirements for models or processes that would lend themselves to computer simulation. First is the requirement for a dynamic model, that is something that will happen over time. Second is the requirement for well-specified independent and dependent variables, as well as a clear statement of the relationships between these variables.[38] Abelson defines six features possessed by a well-specified dynamic model that is capable of being simulated. These features are:

1. Units: a set of elements or entities defining the units of concern to the investigator, the units which embody or "carry" the processes of interest.
2. Properties: a set of variables (and constants) which attach to each unit and define its state at a given moment.
3. Inputs: a set of stimuli or task variables putting the postulated processes into relevant motion and possibly intervening during the later course of these processes.
4. Processes: a set of specifications of what is supposed to "happen," that is, of which properties of which units are to change as what function of the inputs of other units.
5. Phasing: the organization of the sequence in which the processes are to occur.
6. Consequences: one or more of the final properties of key units or aggregations of units; the crucial events, outcomes or states of affairs about which the model is capable of making predictions.[39]

Computer simulation makes possible a more realistic approach to problem solving. Newell and

Meier describe heuristic problem solving in terms of "simulating" the techniques and procedures that might be employed by intelligent problem solvers.[40] Computer simulation can lead to the generation of useful relationships that may not otherwise be apparent as well as incorporate the problem solving technique of the intelligent investigator or forecaster. Computer simulation, then, can serve a heuristic function on at least two levels, first by actually generating new relationships and guiding further research, and second by incorporating the process into the model itself.

Pool, Abelson, and Popkin suggest that computer simulation can provide a way of analyzing fanciful questions scientifically, that is the "what if" question. Computer simulation allows the investigator to model a hypothetical world, with all of the relevant complexities, and manipulate the model for any one of several purposes; "such as prediction, postdiction for analysis, exploration of alternatives for sensitivity testing, and exploration of policy alternatives."[41] The ability to ask the "what if" question is one of the major attractions of computer simulation to technological forecasting.

Schultz and Sullivan have succinctly expressed the advantages of computer simulation:

1. It provides a method for vicarious experimentation.
2. It allows more complete models with greater degree of complexity--a holistic approach, and can be eclectic, permitting combinations of theories and methodologies.
3. It permits manipulation of an iconic model of time.
4. It allows random or pseudorandom variables to be introduced directly into the model.

The disadvantages of computer simulation are:

1. It provides specific case results requiring replications to produce more general results.
2. It usually requires more effort in constructing the model.
3. It can lead to more apparent realism and consequently greater danger of forgetting the limitations of the model.[42]

The applications of computer simulation are generally divided along two dimensions: (1) application area, that is social science versus business applications, and (2) level of analysis, that is macrobehavioral processes versus microbehavioral processes. Some examples of microbehavioral processes, where the individual is the unit of analysis, include socialization processes, other reference group processes, individual processing of social communication, and social exchange considerations in decision-making. Some examples of macrobehavioral processes, where the group is the unit of analysis, include social organization, population dynamics, polity processes, and information dissemination. The TIMMOD simulation which is described in Chapter V is a microbehavioral simulation, that is the individual is the unit of analysis.

When computer simulation is considered in its business application, that is an aid to practical decision-making, Schultz and Sullivan suggest four general ways that computer simulation can help. Among these are:

1. Can increase the general understanding of interest as an aid in making future decisions.
2. Can guide the development of alternative plans or courses of action.
3. Can evaluate the merits of alternative courses of action.
4. Can provide for verification and control, that is can provide norms and/or standards against which performance can be measured.[43]

All four of these suggested aids can assist in the technological forecasting situation. Newell and Meier suggest several applications for computer simulation in business. Among these are inventory systems, job shop scheduling, PERT networks, risk analysis and capital investments, waiting lines, and forecasting.[44]

Kotler and Schultz describe four basic uses for simulation in marketing. These include:

1. Simulation as behavioral modeling.
2. Simulation as a way of introducing and handling uncertainty.
3. Simulation as a computational technique for measuring parametric sensitivity.
4. Simulation as a heuristic technique for finding an approximately optimal solution.[45]

These uses for simulation, of course, are very similar to the advantages of computer simulation described by Schultz and Sullivan. Kotler and Schultz mention one of the primary disadvantages of simulation techniques

when they say, "Although simulation methodology often produces new and useful perspectives, the analyst should always try to anticipate whether the view will be worth the climb."[46]

Abelson nicely summarizes the discussion of computer simulation when he says that the power and novelty of the computer simulation technique lies in its ability to synthesize.[47] It is this ability to synthesize that makes computer simulation attractive to technological forecasting.

Before considering some examples of computer simulation in areas relating to telecommunication, the problems of designing computer simulation experiments and the very difficult problem of computer simulation model validation will be discussed.

Problems in the Design of Computer Simulation Experiments

Naylor, Balintfy, Burdick, and Chu outline nine major steps necessary in planning a computer simulation experiment. The first of these is a formulation of the problem. Research objectives must be formulated which include questions to be answered, or hypotheses to be tested, or effects to be estimated. Almost as important as a good problem statement is a decision on the objectives of the research, and the criteria for evaluating the degree to which the objectives are fulfilled by the experiment. In a technological forecasting situation there may not be hypotheses in the same sense as in the development of theory, but a clear statement of either the questions to be answered or the effect to be estimated is mandatory.

The second step is the collection and processing of real world data. It is at this step where the distinction between analytical and empirical methods blur. The use of data, or information, at this early stage is vital in understanding the process to be simulated, and may well suggest hypotheses and mathematical models to be employed later. Data for a computer simulation must be collected and recorded. It is also important that data be converted to machine sensible form for later input into the model.

The third step involves the formulation of mathematical models. This step consists of three parts, including the specification of components, the specification of variables and parameters, and the specification of functional relationships. Among the considerations in this step are a determination of the number of variables to be included in the model, the mathematical complexity of the model, the computational efficiency of mathematical procedures, the realism, and the compatibility of the model with the type of experiments to be conducted with it.

The fourth step involves the estimation of operating characteristics from real world data. It is at this point that the rules for the manipulation of real world data are determined for the model, for example the use of theoretical probability distributions to represent certain empirical phenomena.

The fifth step is the evaluation of the model and parameter estimates. This step is considered by Naylor et al. as the first step in testing the model. Six important questions need to be asked at this point:

1. Have we included any variables which are not pertinent in the sense that they contribute little to our ability to predict the behavior of the endogenous variables of our system?
2. Have we failed to include one or more endogenous variables that are likely to affect the behavior of the endogenous variables in the system?
3. Have we accurately formulated one or more of the functional relationships between our system's endogenous and exogenous variables?
4. Have the estimates of the parameters of the system's operating characteristics been estimated properly?
5. Are the estimates of the parameters in our model statistically significant?
6. On the basis of hand calculations how do the theoretical values of the endogenous variables of our system compare with historical or actual values of the endogenous variables?[48]

The sixth step is the actual formulation of a computer program. This begins with a system design normally represented on a flow chart. The program is then coded and debugged.

The seventh step is one of the most difficult, validation. Generally speaking two tests are normally considered appropriate; how well the model postdicts historical data if it is available, and how well it predicts future data. The problem of validation will be discussed in more detail later.

The eighth step involves the design of simulation experiments. As with other forms of experimentation, the problems of determining an appropriate experimental design are the same for a computer simulation experiment. Treatment and control conditions must be allocated so that the research hypotheses can be adequately tested.

The ninth and final step involves the analysis of the simulated data. This is the step where the computer simulation is run and the simulated data are generated. The appropriate test statistics are then calculated as required by the experimental design. The results of the simulation experiment are then interpreted.[49]

Naylor discusses four basic design problems in computer simulation experiments. The first of these is the problem of stochastic convergence. Since most simulations are designed to produce estimates of population averages, it is reasonable to expect random fluctuation in the averages generated. Remembering that simulated characteristics are normally generated through a stochastic process, "sampling" error is expected. The problem is that convergence toward the "true" average occurs slowly. The mathematical relationship is an inverse square as shown by the following equation:

$$S_e^2 = \frac{S^2}{n}$$

In this equation it would require four times the n, or sample size to reduce the standard error of the mean, S_e, by one half. The standard deviation of the population is represented by S.

The second problem in simulation experiments is the problem of size or too many factors. This problem is common to all experiments. It is very easy to design an experiment with too many factors and levels to handle reasonably. It is easy to let the number of cells required in an experiment to get very large. The problem is probably not as critical in real world experiments because the limitations imposed by available sample sizes. It is easy to overlook the problem when working with a computer.

The third problem is that of motive. It is important that the experimenter design the experiment so that it best satisfies the objectives. Generally there are two types of experimental objectives that can be identified; first is to find the combination of factor levels which minimize or maximize the response variable in order to optimize some process, and second is to make a general investigation of the relationship of the response to the factors in order to determine the underlying mechanisms governing the process.

The fourth problem is the problem of multiple response. This occurs when there are too many response variables. One way of handling the problem is to run an experiment for each response variable. If multiple responses are required for the experiment, then the problem becomes severe because there is very little methodology developed to handle the problem.[50]

The difficult problem of validity for a computer simulation model is much the same as for any other kind of model. The fact that computer simulation often appears somewhat mysterious because it is so complex seems to draw unusual attention to the problem. The problem of validating any model involves a host of practical, theoretical, statistical, and philosophical questions, which are well beyond the consideration here.

The most satisfactory approach to computer simulation model validation is the multistage validation procedure proposed by Naylor. The first stage calls for the formulation of a set of postulates or hypotheses describing the behavior of the system. These postulates are based on the researcher's "general knowledge." The second stage involves an attempt to verify these postulates subject to the limitations of existing texts.

In the case of postulates which cannot be verified empirically, they must either be labelled tentative or declared false and abandoned. The third stage consists of testing the model's ability to predict the behavior of the system. As mentioned before there are two general alternatives, historical verification and verification by forecasting.[51] Numerous statistical tests are available to determine how well a computer simulation model postdicts or predicts, including chi-square goodness-of-fit, analysis of variance, non-parametric tests, and correlation and regression.

Mass Media Related Computer Simulation Models

With perhaps the exception of the Limits of Growth Model described earlier, there are virtually no technological forecasting computer simulation models in the published literature. There are, however, a number of mass media related computer simulation models published in the literature which are of interest.

The grandfather of all the mass media simulations in the Simulmatics Media Selection Model developed in 1962. The Simulmatics Model was designed as a tool to help solve the advertising media allocation problem. In fact the most sophisticated mass media simulations are designed for this purpose.

The basic purpose of the Simulmatics Model was not to find the optimal plan, but to test one or more proposed plans. The basic input to the model is a sample of 2,944 hypothetical persons who supposedly represent a cross-section of the American population. Individual media choices are determined probabilistically from socio-economic characteristics. The process consists of drawing a random two-digit number and cycling it through the various media. If this number is greater than the estimated probability of watching the particular media, then the individual is recorded as having not seen the media or show, and if it is less, he has been exposed. The process is continued until all of the hypothetical population is exhausted and the appropriate number of time periods have been considered. The output is an estimate of the audience profile and the reach and frequency characteristics of the proposed media schedule.[52]

The COMCOM (COMmunist COMmunication) model is a simulation of a mass media system in the Soviet Union described by Popkin. Ideally this kind of model would input demographic, attitudinal, and media data from a panel survey as is done using the Simulmatics Model in the United States. However, this kind of information simply is not available, so the model must estimate these parameters. The model goes through two passes, first to develop a hypothetical description of individuals who constitute a sample of the relevant population, and second a series of messages which constitute

w. The basic exposure measure is derived from a
te Carlo technique. The output of the model is an
imate of the cumulative audience over n periods of
e for the particular communist country.[53]

Kramer developed a comprehensive simulation of
public information campaign in Cincinnati, Ohio to
cate the population about the United Nations in 1947
1948. Survey research data indicated only a slight
nge in attitudes as a result of the campaign toward
United Nations, but substantial changes in attitudes
ut such things as war, relations with the Soviet Union,
control of the atomic bomb. The simulation was
igned to predict reach and frequency of message flow
m known facts about the population, media habits, and
placement of messages in the mass media. The simu-
ion is divided into two stages. The first stage,
wn in Figure 1, is the data disaggregation and inte-
tion stage where such diverse data as population data,
ience cumulation and duplication data are combined
describe the model population. The model begins with
ic population data such as age, sex, geographic
ion, and literacy. Parameters are then estimated to
l in the cells where data are missing. Audience
uts for each media vehicle are provided and an average
bability exposure is calculated. The actual exposure
tribution is a two-parameter beta distribution. To

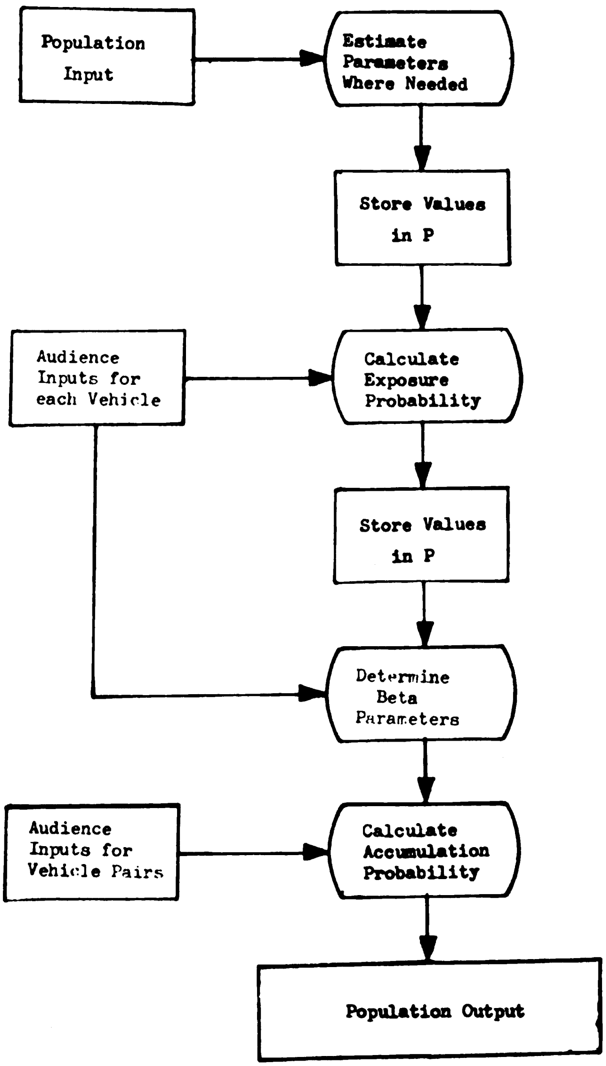

Fig. 1. Kramer Mass Media Simulation Flow Diagram
Stage One: Data Disaggregation and Integration

SOURCE: John F. Kramer, "A Computer Simulation of Audience Exposure in a Mass Media System: The United Nations Information Campaign in Cincinnati 1947-48" (Ph.D. dissertation, M.I.T., 1969).

allow for audience accumulation and duplication the pairwise audience duplication data are entered into the model and probabilities are assigned to population members. The population is then ready to be passed to the second stage, which is shown in Figure 2. The second stage is the processing messages and reporting exposures stage which begins by converting calculating message exposure probabilities from a message audience distribution. The message audience distribution is determined from message audience input for each theme to be considered in the simulation run. The message themes are then entered into the model including the timing. This, in combination with the model population, is used to determine the product of message exposure probability, the vehicle exposure probability, and a "format" factor, to get the net probability of exposure. The net exposure is then aggregated and the model is cycled through the next time period.

The themes for the model were determined from a content analysis of the messages running during the campaign. Twelve themes were identified, such as U.S./ U.S.S.R. hostility, and described in terms of attitudes and exposure across demographic subgroups of the population. The model itself can handle up to 64 media vehicles, 3,000 people in the simulated population, and 400 population subgroups. The major finding is that

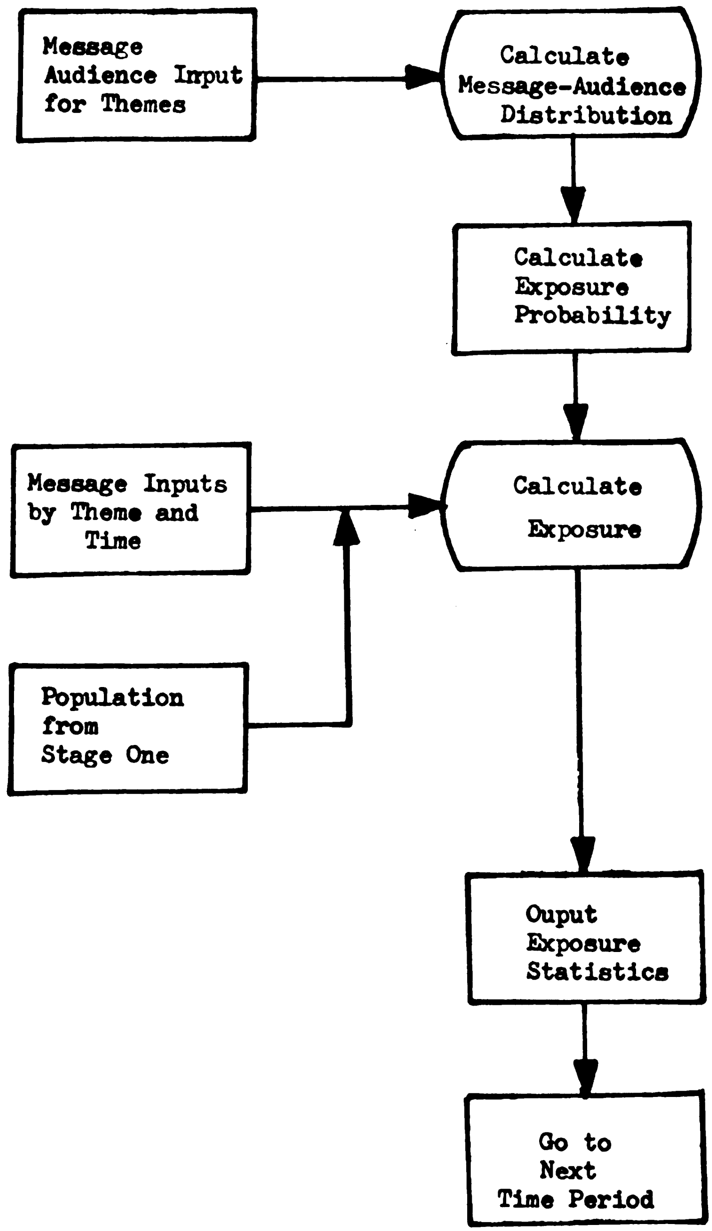

Fig. 2. Kramer Mass Media Simulation Flow Diagram
Stage Two: Processing Messages and Reporting Exposures

SOURCE: John F. Kramer, "A Computer Simulation of Audience Exposure in a Mass Media System: The United Nations Information Campaign in Cincinnati 1947-48" (Ph.D. dissertation, M.I.T., 1969).

themes "which seemed most closely related to large changes in NORC panel were also those themes for which the simulation predicted the highest average exposure."[54]

Schultz and Sullivan describe three problems with the Simulmatics model, namely the construction of a representative hypothetical population, determination of media habits, and last is the determination of the relationship between media exposure and advertising exposure.[55] Gensch created the AD-ME-SIM to remedy some of the problems with the Simulmatics Model. AD-ME-SIM is a computer simulation media allocation model that runs in two stages like Kramer's model, the first stage consisting of the generation of data on the population's viewing habits which is referred to as the data generation stage, and the second stage consists of the identification of the target population and is referred to as the individual weighting stage. There is, of course, a final stage which uses the individual weights generated in the first two stages and is referred to as the media evaluation stage. The limitations of the Simulmatics model are pointed out when the requirements for the input data on reading and viewing patterns are examined. The data requirements for the model are:

1. The demographic, reading, and viewing habits must all come from the same individual.
2. The data must come from real individuals, not hypothetical or imaginary individuals.

3. The sample must be large enough to be significant on a national level.
4. The cost of gathering these data must be low enough to fall within the advertising agencies' budget.[56]

Data suggested as input to this model could come from sources such as W. R. Simmons Associates, who provide relatively complete data on between 16,000 and 20,000 individuals.

In the final or media evaluation stage the user inputs a proposed media plan schedule, a set of weights for the effectiveness of different media, a set of weights for the effectiveness of varying size and color ad forms, a set of weights showing the value of different patterns of exposure frequency, a list of media discounts, a set of weights showing the value of an exposure to different types of persons in the target population, and data showing the reading and viewing patterns over time of a real sample of individuals. Output from the AD-ME-SIM model includes both weekly and cumulative numbers and percentages of people in the target population reached by the proposed media schedule and the cost, the frequency, the number of exposures, but adjusted according to the subjective evaluation of the media and the value of exposures to different members of the target audience.[57]

Another advertising media allocation computer simulation model is the MEDIAC system reported by Little and Lodish. MEDIAC consists of an on-line computer system which selects and schedules media. It consists of a market response model, a heuristic search routine, and a conversational input/output program. The user supplies various media options, a budget, various objective and subjective data; and the system selects options and schedules over time to maximize market response. Although this system contains mathematical optimization routines, it is still a simulation model because of the heuristic search routine and the users' ability to experiment with various media options.[58]

Hartman and Walsh have reported a computer simulation of newspaper readership. The input for this model is socio-demographic characteristics from a small Iowa community, messages about National Defense, and newspaper reading habits. The simulation consists of a triple filter system. The first filter is for individuals who probably received a newspaper on the day being simulated, the second filter screens out all who had not seen the article, and the third filter screens out those individuals who have not read the studied article. The major finding of the simulation was that social status variables improved prediction of readership, as well as becoming more "deterministic," i.e. excluding randomness. This latter finding is no doubt attributable to the fact that the study consisted of only 163 individuals.[59]

SINDI 1 is a diffusion model developed by
nneman and Carroll. SINDI 1 (Simulation of Innovation
ffusion) is a stochastic simulation model of innovation
cliques in any small, relatively closed system. The
stem requires as input, the number of cliques, the
mber of members in each clique, and the number of
tential tellers in each clique, the number of contacts
lowed to external sources, the number of contacts
lowed to a teller once he becomes a knower, the proba-
lity of a nonknower becoming a knower from an external
urce, and the probability of becoming a knower from
urces outside the clique. This model was able to
mulate the diffusion of information about 2,4D weed
ray in a Colombian peasant village.[60]

In addition to these mass media related simu-
tions there are a number of other computer simulations
at also deserve some brief mention. There are numerous
mputer simulation marketing games for use as teaching
vices. Among the more well-known marketing games
e the M.I.T. Marketing Game which is based around
e market for electric floor polishers for household
e, and the Carnegie Tech Management Game special
rsion called MATE (Marketing Analysis Training
ercise) based on a package goods industry.[61] The
NMAR media buying game developed by Schultz, Block,

and Jacobowitz provides a realistic media buying situation for an airline flying in the Texas triangle.[62]

A good example of the application of computer simulation experimentation in physical distribution research is found in the companion work of Speh and Wagenhiem. Using the LREPS simulation model, which is a model of a physical distribution system using dynamic simulation to evaluate the cost and service of alternative physical distribution system designs, Speh experimented with demand uncertainty[63] and Wagenhiem experimented with lead time uncertainty.[64] More examples of computer simulation and related techniques will be discussed in Chapter IV.

CHAPTER III--NOTES

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CHAPTER IV

TIME ALLOCATION STUDIES

Time as a Social Variable

Moore describes time and space as a way of locating human behavior, or "a mode of fixing the action that is peculiarly appropriate to circumstances."[1] All of human behavior can be fixed in a point in both space and time, including communication behavior. Communication involves sending messages through space or distance, as well as devoting time to the process. Communication can be measured in terms of the manipulation of both space or distance, as well as time.

While space and time are interdependent in fixing human behavior, it is possible to consider them separately for theoretical purposes. Models considering only the allocation or manipulation of space are considered static, whereas those models considering the allocation or manipulation of time are considered dynamic. As Moore points out:

> Short of major and sudden geophysical events, space principally acquires any dynamic qualities it may have by virtue of changes in social values, interests and techniques. In other words, space is generally

> a passive condition of behavior, variable only as human behavior makes it so. Time, on the other hand, is intrinsically dynamic, and indeed the idea of dynamic (or static) is impossible without reference to conceptions of time.[2]

Human communication activity can be described in terms of two finite resources, space and time. Spatial models consider the arrangement of the communication activity in space and provide a static picture of the process in terms of distance and potential of communication flow. Temporal models consider the allocation of available time to communication activity and provide a dynamic analysis of the communication process. As Moore describes, "the value of time tends to be judged in terms of its use. . . ."[3] Communication need, as defined by Reid, can be viewed as a trade-off between the allocation of space and the allocation of time.

Models of the allocation of space and distance in social settings generally take the form of a network flow model. Meier proposes a communication theory of urban growth by pointing out that intensification of communications, knowledge, and controls, are highly correlated with the growth of urban centers. Meier explains that the theory begins considering the "utility of agglomeration" for human beings. Human beings require some form of social cohesion for the purpose of genetics, establishing primary relationships necessary for nuture, formation of coalitions for purposes of defense, and formation of coalitions for the exchange of goods. This leads to the accumulation of knowledge and to the selection and recombination of the most useful elements of culture. Technological innovation, such as writing, the invention of the printing press, and the electronic media have caused spurts in the accumulation of knowledge.[4] BCN technology might be expected to contribute to an additional spurt.

While space and distance are important determinants of human activity, sufficient empirical data do not exist to allow physical distance to become part of a human activity model. An exception is the inclusion of mean locus or the distance for out-of-home activities reported by Chapin.[5] The mean locus is as the "crow flies" distance between points such as home and work. Typically human activity studies, or time allocation studies, do not include any measurement of physical distance, but rather consider the problem of movement through physical space as a problem of travel time. While recognizing the importance of spatial measures, it is necessary to concentrate on time.

Heirich describes four distinct ways time can be used in the study of social change. Time can be used as a social factor in the explanation of changes, as a causal factor between other elements, as a quantitative measure of them, or as a qualitative measure of their interplay.[6] Time as a social factor influences social interaction as a resource and as social meaning. Time as a resource refers to the time alloted to various activities and is the view of time held in most time-budget research. Time as social meaning refers to specific moments in time such as Christmas or time sequence which may indicate priority, such as "work before play." Time as a causal link can be viewed in terms of setting, or space-time relationships, and sequence, or time-time relationships. While time itself is not sufficient to establish causal relationships, it provides the backdrop. Time can provide a measure of the quantitative changes in a relationship such as rate or speed, and duration. Time can also provide a qualitative measure of social change such as a qualitatively different social structure. Time is important to allow the interplay of various social forces which ultimately contribute to a social change.[7]

Economists consider time as a scarce resource. Linder summarizes the position as follows:

> The analysis of the distribution of time, of changes in this distribution arising from economic growth, and of the implications of economic development under an increasing scarcity of time is not something of purely economic interest. It is rather a problem of more general interest, a joint problem for all the social sciences. The distribution of time and changes in this distribution are bound to affect our entire attitude to social problems, our entire philosophical outlook.[8]

Linder argues that consumption should be viewed not only as a problem involving physical goods, but also as a time problem. Consumption involves both the time necessary to consume the goods as well as the goods themselves. Consumption should not be viewed as an instantaneous process, the time at a consumer's disposal must also be considered.

In examining economic growth, Linder categorizes time into five separate groups which he believes to be "unequal from a philosophical point of view." The first category is working time, or the time spent working in specialized production. Working time has impact on both the supply and demand for time to allocate to other activities. The second category is personal work, or services, which can be divided into the maintenance of goods and of one's body. A third category is consumption time, or the time allocated to the consumption of goods. As productivity increases, so does the demand for consumption time. A fourth category is time devoted to the cultivation of mind and spirit. The primary difference between this category of time and consumption time is the role that goods play. Obviously the cultivation of mind and spirit is less affected by consumer goods, that is consumption time. The fifth and final category of time is free time or idle time.[9]

It is the last category of time that has received considerable attention under the rubric of leisure time. An example is Foote's methodological essay on the application of time-budget studies to problems of the aging.[10] Of more interest here is the use of time as a variable in marketing.

Time as a Marketing Variable

According to Schary, far more is known about how consumers spend their money than how they spend their time.[11] Time has been largely ignored in marketing because it has not been part of the accepted framework of consumer behavior. While it has not been the center of attention, models of time allocation have evolved in the traditional economic and consumer behavior literature. Marketing related time allocation models can be divided roughly into two groups: those that assume man to be rational and those that do not. Because of the origin of most of the models in economics, the majority assume man to be rational. Although the difference may be moot, as Bucklin concluded, that for the most part, the economic theory of consumer behavior is supported by the findings of his research as discussed in Chapter II. In particular, Bucklin adds, the generalization that consumers would respond to lower shopping costs by making in-store comparisons is especially strong.[12]

Several rational man time allocation models using neoclassical economic consumer theory have been developed. Becker opened the field with his model evaluating the effect of foregone earnings on leisure time. Addressing himself to the reduction in average working time which occurs along with economic development, Becker makes the point that allocation and efficiency of nonworking time is becoming more important. Becker summarizes the model as follows:

> At the heart of the theory is the assumption that households are producers as well as consumers; they produce commodities by combining inputs of goods and time according to the cost-minimization rules of the traditional theory of the firm. Commodities are produced in quantities determined by maximizing a utility function of the commodity set subject to prices and a constraint on resources. Resources are measured by what is called full income, which is the sum of money income and that foregone or "lost" by the use of time and goods to obtain utility, while commodity prices are measured by the sum of the costs of their goods and time inputs.[13]

Johnson criticizes time allocation models, such as Becker's, that assume the opportunity cost of an hour of leisure is equal to the money wage rate earned by the individual. Johnson proposes a model concentrating on the problem of travel time that assumes that individual behavior is subject to a time budget constraint as well as a money budget constraint, and that work and leisure are distinct decision variables in the utility function.[14] Models that assume the money wage rate tend to overstate the value of leisure and travel time.

Mabry suggests an even more complex set of multiple constraints on the choice of nonwork activity, including time, stamina, and money.[15]

DeSerpa has developed a general theory of the economics of time without any focus on specific problems such as the effect of foregone earnings upon consumer choice, and the valuation of travel time. The essential features of the model include utility represented as a function of both commodities and the time allocated to them, individual decision-making is subject to both a money constraint and a time constraint, and the decision to consume a commodity requires that some minimum amount of time be allocated to it.[16] The economic models of time allocation provide a basis for evaluating the importance of the fundamental trade-off between communication and transportation, and between alternate forms of communication. The difficulty in applying the economic models to the BCN technology problem is the lack of empirical specification, that is the models are neoclassical mathematical optimization models.

Other approaches to consumer behavior are characterized by studies of the convenience-oriented consumer. Mauser predicts, for example, that the affluent citizen of the next century will be oriented "to buying time rather than product."[17] Rathmell describes the newly acquired American freedoms of discretionary time and discretionary mobility.[18] Rathmell believes that discretionary mobility along with the necessary free time releases the consumer from habitual shopping patterns. Consumers will begin to classify shopping as an enjoyable activity, rather than as a routine household chore.[19] Anderson's study, discussed in Chapter II, describes distinct consumer typologies of convenience good orientations. Determinants of convenience orientation include socio-economic status and stage in the family life cycle.[20]

Considering the use or allocation of time as an indication of life-style is suggested by Andreasen. Life-style, according to Andreasen, is a social science concept connoting the totality of behaviors which comprise the characteristic approach to life of a particular individual or group.[21] Andreasen suggests the use of time-budgets, or simply the amount of time an individual allocates to various activities through the day, as a way of measuring life-style. Comparing changes in time-budgets, life-style comparisons across different occupational groups, as well as predictions about future time use can be made. Interestingly, increases in leisure activity, especially away from home, are predicted by Andreasen along with a decline in in-home activities such as television viewing.[22] Andreasen bases prediction on an analysis of the United States Time Use Survey which is the basis for the computer simulation model which is described in Chapter V. Time-budget analysis provides an insight into the future as well as a measure of life-style.

Schary provides an outline of a framework for the consideration of the ways consumer time choice influences marketing. The framework recognizes the different roles that time plays in the selection of work and leisure activities. The nature of the activity chosen will also influence the role of time. For example, if the activity can overlap with other activity, or whether or not the activity is a solo activity or is done in a social setting, as well as the relationship of the activity to other activity. It is common to engage in another activity while listening to the radio; and making a shopping trip often requires travel. Time values also follow a cyclic pattern, and violation of the customary pattern would be expected to create feelings of time urgency beyond those in the normal situation. Underlying all of the classifications of time allocation are the subjective attitudes held by the participating individuals or groups in a particular situation or activity.[23] Schary concludes with the following point:

> Time is an implicit part of every market offering. Products are chosen not only because of price, quality, features, or even the images created through promotional activity, but also because of the potential time expenditures that they entail. Therefore, time should become an explicit element in marketing strategy.[24]

Time-Budget Studies

According to Szalai, it is not known when, where, or by whom the internationally adopted term "Zeitbudget" or time-budget was first used in the technical literature.[25] A time-budget study is for the most part a methodology employed by sociologists and generally involve large-scale survey research. A definition of time-budget research is provided by Szalai:

> Many interesting patterns of social life are associated with the temporal distribution of human activities, with regularities in their timing, duration, frequency and sequential order. Certain techniques of data collection based on direct observation, interviewing and the examination of records permit the establishment of fairly adequate itemized and measured accounts of how people spend their time within the bounds of a working day, a week-end, a seven-day week, or any relevant time period. Investigations of this particular aspect of social life based on the quantitative analysis of such accounts are commonly referred to as "time-budget studies."[26]

Time-budget studies generally go farther than the description of the timing, duration, frequency, and sequential order of various human activities throughout the day; and almost always involve comparison of various groups of individuals in order to make inferences about the groups.

The application of the large-scale time-budget studies, however, have been somewhat limited in any ability to explain time allocation. Taking a critical view of time-budget studies, Linder writes as follows:

> The sociologists, for their part, have made great efforts to perform large-scale time budget studies. They have tried to plot how different individuals or groups divide up their time between various activities. Particularly detailed studies have been made of the use of time spent outside the place of work, time which is devoted to a variety of different activities. However, the theories formed parallel to these studies have been of an ad hoc nature. Attempts at any systematic explanation of time allocation and changes in it are lacking.[27]

Linder, an economist, believes that the results of these time-budget surveys have never really been used, because the importance of time scarcity in the economic sense has been ignored. Linder concedes that if an analysis could yield a dynamic theory capable of making sociological predictions, it could become a useful tool in the study of the future.[28] The computer simulation model described in Chapter V is an attempt, albeit somewhat crude, to develop such a tool for the study of the future.

Historically time-budget studies grew out of family expenditure studies in England and France in the late eighteenth century. Chapin cites Sir Frederick Morton Eden's State of the Poor published in 1797 as one of the first known works to make use of family budget information.[29] Szalai describes Frederick Leplay's use of family budget information in his study of the living conditions of the working class in various European countries in the mid-nineteenth century. Szalai also describes Eduard Engel's Das Rechnungsbuch *der Hausfrau und seine Bedeutung im Wirtshaftsleban der Nation* published in 1882. Engel drew attention to various regularities in family budgets and formulated his laws. One of the most well-known of Engel's Laws is that as income increases in the lowest categories of family income the greater part is spent on food. Upon further rise in the standard of living, increases in income are spent proportionately less on food, and more on other things.[30] Time-budget studies continued in the Soviet Union since the very beginning of the communist government and were viewed as important tools in economic planning.[31]

In the United States some of the earliest experience in using time allocation came from the "time and motion" studies of factory management by Frederick W. Taylor done in the very early part of the twentieth century.[32] A number of studies with a sociological orientation followed, including studies of farm housewife's use of time and the use of leisure in suburban areas. The most well-known of the early studies is the Sorokin and Berger study of the Boston area published in 1939.[33] The Sorokin and Berger study is the source of the 1935 time-budget data cited in Chapter I.

The Sorokin and Berger study is considered the forerunner of the contemporary time-budget studies. The problems addressed by Sorokin and Berger in 1939 are quite similar to those of current day time-budget studies and were expressed as follows:

1. What kind of activities occupy the individual's twenty-four hours?
2. How often is each activity repeated during the twenty-four hours?
3. How much time does each activity take?
4. What are the individual motives for each activity? Does the activity have one or several motives? Does the activity have the same or different motives with different individuals? And, vice versa, does the motive manifest itself in identical or different activities with different individuals, or with the same individual at different hours of the day?
5. What part of the twenty-four hours does an individual spend alone and what part with another individual or with groups? Who are these persons and groups? What activities cause the individual to spend his time with each of these? What is the length of time he lives and acts in association with each of these?
6. How accurately can an individual predict his behavior twenty-four hours, forty-eight hours, one week, and one month in advance?
7. Finally, what are the differences, if any, in all of the above respects between individuals of different sexes and different ages? Are there any tangible and uniform variations in the above aspects of human behavior on different days of the week?[34]

Szalai summarizes the topics covered in the early time-budget studies as follows:

1. the share that such broad categories of activity like paid work, housework, personal care, family tasks, sleep and recreation have in the daily, weekly or yearly time-budget of the population;
2. characteristic time expenditures of certain social groups or strata on more or less specified types of everyday activities;
3. the use made of "free time," especially: leisure.[35]

Contemporary use of sociological time-budget studies include the analysis of activity patterns as demonstrated by Brail and Chapin,[36] analysis of social patterns as demonstrated by Schneider,[37] analysis of mass media consumption as demonstrated by Robinson and Converse,[38] and analysis of technological progress as demonstrated by Staikov.[39]

The research strategy employed in sociological time-budget studies defines the activity patterns as dependent variables and certain preconditioning and predisposing factors as independent variables. An activity pattern generally refers to a tendency for people in a given population to behave in a certain way. It has the properties of duration, position in time usually designated by start time, a place in a sequence of events, and a fixed location in space. Activity patterns are expressed in terms of an activity classification scheme.[40] Chapin provides an example of an activity class with "shopping." A problem with time-budget studies is directly related to activity classification schemes. For example, if the concern of the study is with shopping as a phenomenon of the culture, then the shopping classification is probably adequate. If the concern is with something like public transportation planning, then shopping would have to be redefined to include such activities as driving from the home to the shopping center, buying groceries, then driving home again.[41] The development of an appropriate activity classification system is one of the major methodological issues in time-budget research.

The independent variables, or preconditioning and predisposing factors, are divided into two groups by Chapin. The first group consists of subsistence needs and the second group consists of culturally, socially, and individually defined needs. Chapin outlines these factors as follows:

1. Subsistence needs
    a. Basis of motivation: need for sleep, food, shelter, clothing and health care.
    b. Requisite means of satisfying needs: for example, income-earning opportunities from vocational training, education, medical care, social service, etc.
2. Culturally, socially, and individually defined needs
    a. Basis of motivation: felt needs for security, status, achievement, affection, and social contact; outlets for exercise of personal talents, ingenuity, prowess, and skill; need for mental release, for example, the release of feelings of joy, fear, frustration, or alienation; and need for physical release, for example, physical exercise as well as rest and relaxation.
    b. Requisite means of satisfying needs: opportunities for seeing kinsmen, friends, neighbors, and others; opportunities for participation in church, voluntary organizations, and civic activities; opportunities for creative activity, for engaging in recreation and other diversions, and for rest and relaxation.[42]

The resultant research strategy, then, is to postulate varying combinations of these motivations in explaining activity choice.

Time-budget studies have been used to predict the future. Holman predicts a tripling in the amount of discretionary time available to Americans from that available in 1950 by the year 2000. The prediction is based upon a secondary analysis of a number of published time-budget studies including Sorokin and Berger.[43] Although, it should be pointed out, the Holman analysis does not include the development of any mathematical model.

Staikov suggests that time-budget studies can provide a way of measuring technological progress. The social value of technological progress, according to Staikov, depends on the total amount of time which can be saved by use of the technology. Staikov also makes the point that technological progress can only be understood by examining all of man's activities. By introducing a new technology, time spent in one activity category may be decreased, but then there must be an increase in other types of activities.[44] The use of time-budget information to evaluate technological progress, then, must be comprehensive with respect to all categories of activity.

There are a number of contemporary large-scale time-budget studies which could become the empirical base for the development of a computer simulation model to evaluate the impact of BCN technology. The Multinational Comparative Time-Budget Research Project was organized in 1963 and includes social scientists and time-budget projects from Belgium, Bulgaria, Czechoslovakia, France, East and West Germany, Hungary, Peru, Poland, U.S.A., U.S.S.R., and Yugoslavia. The project was organized around the following aims:

1. To study and to compare in different societies variations in the nature and temporal distribution of the daily activities of urban suburban populations subjected in varying degrees to the influences and consequences of urbanization and industrialization;
2. To develop methods and standards for the collection and evaluation of data pertinent to temporal and other dimensions of everyday activity which, apart from their interest to social theory, are also of considerable importance for the organization of working life and for the creation of satisfactory conditions for the enjoyment of leisure;
3. To establish a body of multinational survey data on characteristics of everyday life in urban surroundings under different socio-economic and cultural conditions which could serve as the basis for testing various methods and hypotheses of cross-national comparative social research.
4. To promote, in general, cooperation, standardization of research techniques and the exchange of quantitative data at an international level among social scientists involved in survey research who are endeavoring to achieve comparable results with a view to their common evaluation.[45]

Included in the Multinational Project are two studies from the United States done by Converse and Robinson at the Survey Research Center of the University of Michigan. One study was conducted in Jackson, Michigan consisting of 778 respondents, and one study was using a national probability cross-section drawn from forty-four metropolitan areas. Both studies were conducted between November 1965 and April 1966.[46] The later study, referred to as the Forty-four Cities, U.S.A., was selected as the empirical base for the development of the simulation model and will be discussed in more detail.

Other time-budget studies include the family of activity studies undertaken primarily by the Center for Urban and Regional Studies at the University of North Carolina. Brail and Chapin report two national surveys from samples drawn from forty-three Standard Metropolitan Statistical Areas. The first, done in 1966, consisted of 1,467 households. The second, done in 1969, was a follow-up of 1,199 of the 1966 households. Since both studies were not centrally concerned with daily activity, but rather residential mobility, questions relating to activity had to be kept to a minimum. In both studies respondents were asked to reconstruct yesterday's nonpersonal activities from the time they got up until the time they retired.[47] Chapin reports a series of studies in Washington, D.C. beginning in 1968. The basic study had a primary focus on household use of medical care services and facilities, but obtained substantial activity information from 1,756 respondents. Two additional studies were done in 1969 among the inner-city black community and in 1971 among the transitional white community.[48]

The Forty-Four City study was selected as the basis for this project because of the generalizability of the national sample, and because of the richness of the data reported in the literature. The reports of the Brail and Chapin, and Chapin studies do not include the volume of data reported in the Forty-Four City study, or as titled by the Survey Research Center, the United States Time Use Survey. The Forty-Four City study is the only available time-budget data source that provides in any form the data necessary to estimate the probability distributions necessary for the development of the computer simulation model described in Chapter V.

United States Time Use Survey

The United States Time Use Survey conducted by the Survey Research Center of the University of Michigan had four major goals. The first was the collection and comparison of basic behavioral data across eleven nations as part of the Multinational Comparative Time-Budget Project. Second was the tabulation of general descriptive information about life in the United States. Third was the use of these data as bench-marks in the measurement and assessment of social change. Fourth and last was the investigation into the major activities and objects which bring gratification and satisfaction to individuals in different parts of society.[49]

The survey was conducted using the regular continuing national sample of the Survey Research Center chosen to represent the United States. A total of forty-four metropolitan areas are included in the sample designed to secure 1,500 respondents. Characteristics of the sample are shown in Table 2. Due to an unexpectedly high proportion of households without an eligible respondent, that is households where all respondents were over age 65, the total national sample came to 1,244 respondents.[50] For a more detailed description of the sample and the metropolitan areas refer to the Survey Research Center report.[51]

The interviewing procedure consisted of a recruitment personal interview leaving a diary for the respondent to record a single day's activities. A follow-up personal interview was then conducted at least one day later to help complete the diaries and to collect them. The first personal interview was short, about twenty to twenty-five minutes, and the second interview was somewhat longer lasting forty to fifty minutes. Diaries were distributed so that all days of the week would be represented. The field work was conducted in two waves. The first wave was conducted between November 15 and December 15, 1965, and yielded 936 usable nonfarm employed respondents. A second "clean-up" wave added 308 additional respondents and was conducted between March 1 and April 25, 1966. An overall completion rate for both waves of 81.5 percent was obtained.[52]

TABLE 2

SUMMARY CHARACTERISTICS OF THE NATIONAL TIME USE SURVEY SAMPLE

The final national urban sample contained:

(a) 543 men, 701 women

(b) 345 people under 30, 283 aged 30-39, 305 aged 40-49 and 304 aged 50 or over

(c) 357 housewives, 342 employed women, 519 employed men, 13 students and 13 nonworkers

(d) 40 unskilled, 365 (semi) skilled, 18 technical, 189 lower white-collar, 94 upper white-collar and 172 professional workers

(e) 203 workers were employed in manufacturing industries, 240 in trade and retail, 107 in technical public service, 81 in education, 52 in construction, 61 in administrative public service, and 136 in the remaining other branches of the economy

(f) 191 respondents had graduated from college, 647 from high school, 321 from primary school and 72 had not graduated from primary school

(g) 995 respondents were married, 127 single, 57 widowed and 62 divorced or separated

(h) 470 had no children in the household, 300 had children all over 4 years old, 460 had no child under 4 years old

(i) 922 lives in residential sections of cities, 55 in the industrial and business districts, 71 in small towns outside larger cities and 129 in isolated houses outside of Jackson city

(j) 1,101 respondents had an automobile belonging to the household

(k) 149 respondents earned over $10,000/year, 262 between $7,500 and 9,999, 494 between $5,000 and 7,499, 205 between $3,000 and 4,999 and 100 under $3,000 (note income is for the year 1965)

(l) 745 respondents considered themselves Protestant, 383 Catholic, 62 Jewish and 39 expressed no religious preference

SOURCE: Summary of United States Time Use Survey. Survey Research Center, Institute of Social Research, University of Michigan, Ann Arbor, Michigan, 1966.

Approximate calculation of F-ratios are shown between all the sociological groupings in the tables presented in the Survey Research Center report. Only overall "omnibus F-tests" are reported, and for more detailed comparisons the special range tests, either Tukey or Scheffé, are recommended as appropriate statistical procedures.[53]

Analytical Models of Time-Budget Data

Time-budget studies consist of large-scale sociological studies using survey research methodology to obtain estimates of the participation rate and the mean duration of daily activities for some population. Of critical importance to the analysis of time-budget data is the classification scheme applied to the various daily activities. The Multinational Comparative Time-Budget Project employed a two-digit 96 activity category scheme which was also used by the United States Time Use Survey. The 96 activity category scheme while accommodating most activity is somewhat difficult to analyze. A reduced categorization scheme of 37 activities partially alleviates the problem and is the standard activity categorization scheme employed in the Multinational Project.[54] Other activity classification schemes vary somewhat from the Multinational Project, Chapin, for example, reports a 225 activity classification scheme which is reduced to a 40 activity scheme and a 12 activity scheme, depending upon the situation.[55] The computer simulation model developed here relies on a further reduction of the 37 activity categorization scheme because the United States Time Use Survey is the source of the data. This is discussed in more detail in Chapter V.

Stone describes five types of analytical models appropriate to the analysis of time-budget data. The first of these is accounting for variance. This is the most commonly applied analytical model and conforms to the research strategy for time-budget studies described earlier. The goal is to describe either groups or motivations that produce certain patterns of activities, that is what factors account for more variance in the time-budget. The second analytical model is the Markov model. Markov chains are appropriate whenever a time sequence is involved and when one event is predicted by a preceding event. Although, as Stone points out, brief consideration of how time is allocated leads to the discounting of such a simplistic assumption as one event being determined by a preceding one. Stone concludes that Markov models cannot address the complexities of time-budget data. The third analytical model is economic elasticity. Elasticity models, such as those described here earlier, predict overall time allocations on the basis of tradeoffs, that is more time spent on one kind of activity implies less time for another. The fourth type of analytical model discussed by Stone is path analysis of causality. Path analysis involves the developing of coefficients for estimating the dependency of one variable on another, within a causal analysis framework. Such techniques are well suited to time-budget problems because they allow for a variety of causal dependencies other than precedence, including elasticity.[56]

The most sophisticated analytical model appropriate to time-budget data discussed by Stone is the process model. A process model attempts to represent the decision making that is involved in making time allocations. The sequence of a process model tends to have the natural representation in the steps of a computer program, especially by the "if" statement. Stone goes on to discuss the major limitation of process models, which is the large number of variables and relationships which must be specified to describe even a simple activity such as reading. Probably the only justification for developing models is in answering important social questions, rather than in merely being able to describe a process. An example might be in traffic and pollution. New plans could be designed as inducements to change travel habits to reduce congestion and pollution. The effects of such plans could then be anticipated by running them against the computer model.[57]

Stone's application of the process model is the application that makes the technique attractive to the urban planner. It is this attraction that has led to the development of any time-budget process or computer simulation literature that exists in the field of urban planning.

Urban Planning Time-Budget Computer Simulation Models

While a working time-budget simulation model has yet to be published, almost all of the literature suggesting the development of such a model is in urban planning. Chapin suggests a four-phased research and development effort focused on human activity systems in the metropolitan community as follows:

1. Description, that is, a study of patterned ways different sub-societal segments of the metropolitan community use the city, its facilities, and its services;
2. Explanation, that is, a study of the factors that appear to regulate patterns thus described;
3. Simulation, that is, the development of a model capable of reproducing activity patterns, incorporating these explanatory factors;
4. Evaluation, in which the simulation model is used to investigate the likely impacts on human activity of the implementation of various alternative plans and policies.[58]

It is this approach that makes the computer simulation of time-budget data an attractive tool in technological forecasting. The ability to evaluate the impact of a new technology using a simulation model can provide valuable information to both public and private sector planners. Although, as Hemmens points out, the development of such a model is "clearly an enormous task and, possibly, even a misguided one."[59]

Chapin cites only two simulation models extant in the urban planning literature, the Brail model in 1969 and the Tomlinson, Bullock, Dickens, Steadman and Taylor model in 1973.[60] Tomlinson et al. developed a quantitative model to predict the distribution of students in different activities and locations during a typical day, depending on the restrictions imposed by the spatial distribution of buildings and sites, and by administrative and social constraints on the timing of activities. They describe the model as an "entropy-maximizing type," and derived the mathematical relationships from two student time-budget studies. The model developed in England has two purposes, first as a research tool for examining particular types of university organization, and second to develop general methods of studying and modeling human spatial behavior.[61] The model is less than perfect, however, as the authors conclude "the model requires further development and refinement before it can be applied with confidence to the solution of actual planning problems."[62] Tomlinson et al., however, point out a serious problem in the development and utilization of such models, and that is the stability of time allocations under different physical conditions that may be imposed through the use of the model.[63]

The Brail microanalytical model exists only on block diagram form and has not been published in any further stage of development. The Brail model is the basis for the computer simulation model developed here and is discussed extensively in Chapter V.

CHAPTER IV--NOTES

[1]Wilbert E. Moore, Man, Time, and Society (New York: John Wiley & Sons, 1963), p. 7.

[2]Ibid., p. 8.

[3]Ibid., p. 19.

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CHAPTER V

THE SIMULATION MODEL

Microanalytic Approach

The computer simulation model developed to conduct the telecommunication experiments is called TIMMOD, named from its functional description as a time model. TIMMOD is a microanalytic model beginning with a single individual as the unit of analysis and building populations one individual at a time. This is contrasted with a macroanalytic model, which would begin with a group of individuals as the unit of analysis. The essential logic underlying TIMMOD is to develop a series of probability distributions which describe a single individual's decision-making regarding the allocation of time from real world decision processes. In this case data describing the real world decision processes are derived from the 1965 United States Time Use Survey. An individual's day is then constructed by the computer by drawing random deviates from the various empirically derived probability distributions. Populations are created by merely repeating the process for subsequent individuals. To experiment with the model it is only necessary to manipulate an appropriate probability distribution and run the model.

The fundamental operation of TIMMOD is borrowed from a micro-level activity system simulator designed by Brail.[1] Brail's model, while developed only to the extent of a generalized block diagram, demonstrates the logic of working with an individual decision-maker and developing aggregate measures by running a number of individuals through the same process as the first. Brail's model also points to a very important distinction between activity selection and activity duration.

Time, according to Hemmens, enters into the structure of daily activity patterns in two ways. First is the duration of the activity, and second is the time of occurrence of the activity.[2] The duration of an activity is simply the amount of time given to the activity and is of course of basic building block of any time allocation model. The time of day is equally important in that it affects directly the selection and sequencing of activities, as well as their duration. At a minimum, then, it is necessary to include activity selection probabilities that vary with the time of day in the allocation model. Ideally the activity duration probabilities would vary with the time of day as well, but this is not possible due to the limited sample sizes of available time-budget surveys. This problem will be discussed in more detail later.

The basic building blocks of a time allocation model are probability distributions which describe both the selection and duration of human activities. The logic of the Brail model is diagrammed in Figure 3. The model begins by determining a waking time for one individual from a continuous probability distribution. The individual then moves to an activity choice distribution which is divided into two subsets of in-home and out-of-home activities. Since the number of activities which can be chosen is finite, Brail suggests the use of a discrete probability distribution for activity choice. If the activity chosen is out-of-home, then a location must be determined by sampling another discrete probability distribution which would account for the present location of the individual as well as the location of the residence. The travel time necessary is determined by sampling a continuous probability distribution describing the appropriate travel time. In Brail's model activity choices are considered as discrete events and elapsed time as a continuous event.

After the activity has been selected, whether it be in-home or out-of-home, the duration of the activity is determined from a continuous probability distribution describing that particular activity.

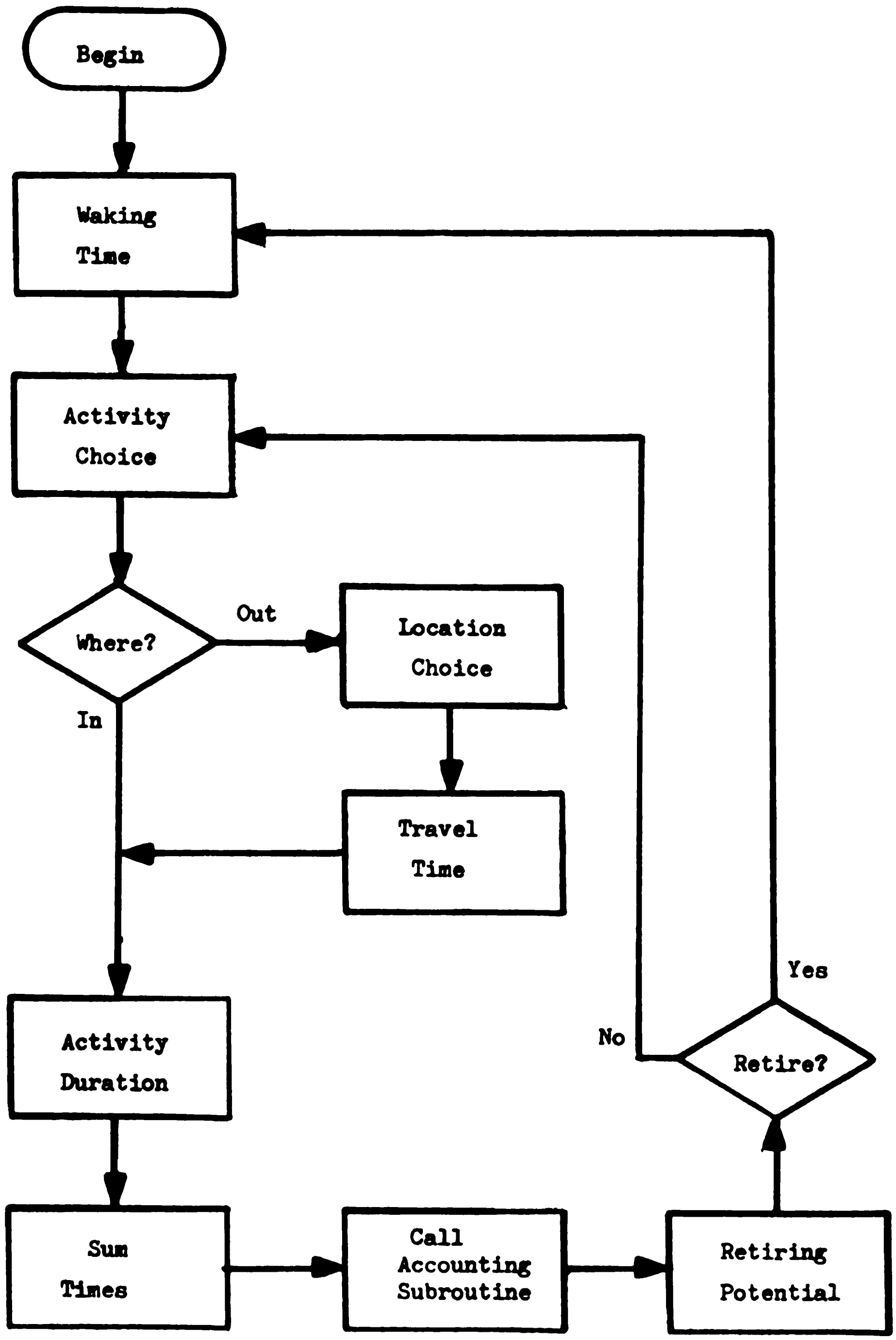

Fig. 3. Brail's Activity System Simulation Model

SOURCE: Richard K. Brail, "Activity System Investigations: Strategy for Model Design" (Ph.D. dissertation, University of North Carolina, 1969).

If any travel time was involved, it is added to the activity duration time. Brail's flow diagram now passes control to an accounting subroutine which keeps track of the current time of day, the activity choice and activity location as the day progresses. Upon return from this subroutine, the retiring potential for the individual is determined from a continuous probability distribution. This is followed by a retiring decision from a discrete probability distribution. If the individual is not retiring, then another activity is selected and the process is repeated. If the individual is retiring, then a "new" individual is started with the sampling of another waking time. The process is continued until the desired number of hypothetical individuals have been cycled through the model.

Brail suggests two general kinds of experimentation that would be appropriate with the micro-level activity system simulator. First is the study of changes in activity choice and structure. This includes both the substitution of one activity for another as well as the temporal patterning of the sequence of activity throughout the day. Second is the study of the changes in location choice.[3] It is the first kind of experimentation that is the primary focus of TIMMOD, that is the substitution of one activity for another. Examples of such experimentation in this BCN technology forecasting setting would include the substitution of telecommunication for transportation and the substitution of interactive television services for various face-to-face services such as shopping and marketing. The consideration of location is of much less importance here since electronic telecommunication is virtually independent of out-of-home distance.

Brail cites two basic problems with the micro-level activity system simulator that he has proposed. First is the very difficult problem of simulation model verification. Computer simulation models are by their very nature extremely complex models requiring verification of their ability to imitate real world systems before any confidence can be attached to their output. The verification problem not only involves the comprehension of the simulation model itself, but also basic issues in the philosophy of science. The problem of model verification will be discussed in more detail later in this chapter in the context of TIMMOD.

The second problem described by Brail is in the determination of the probability distributions required by the model. It would be difficult enough to develop the discrete probability distributions required for the activity and location choice decisions, according to Brail, without considering the need to alter the probabilities as they may change throughout the day.[4]

Determining the probability distributions would first require a large body of empirical data able to support the cross-classification necessary to provide statistically stable estimates of the probability of activity choice by hour of the day. The problem is further complicated when stable estimates of the duration of activities are also required by hour of day, as well as by location such as in-home and out-of-home. Unfortunately, none of the time-budget surveys described in Chapter IV are sufficient to develop the probability distributions required by Brail's model. They are simply too small.

Even if sufficient data were available, determining probability distributions would still represent a major problem. To begin with, it would have to be decided to use an empirically derived distribution taken directly from the data or a theoretical probability distribution, such as the normal distribution. Generally speaking, a theoretical probability distribution would be preferred to an empirically derived distribution because of computational convenience and simplicity. Assuming that a known theoretical probability distribution is adequate, then comes the problem of selecting the appropriate probability distribution. For example, if a discrete distribution were appropriate a Bernoulli or Poisson distribution could be selected, or if a continuous probability distribution were appropriate a uniform or beta distribution could be selected. There are literally dozens of families of theoretical probability distributions to choose from. Assuming that the appropriate theoretical probability distributions are selected, then comes the problem of establishing the various distribution parameters.

No doubt the major reason why Brail's model has not progressed beyond the block diagram stage is the barrier raised by the probability distribution problem. Even in TIMMOD the probability distribution problem has been only partially solved because of the limitations imposed by a less than adequate empirical base. Several compromises are necessary to develop a working computer model within the constraints of available data. A functional description of TIMMOD indicating some of the problems will precede a continued discussion of theoretical probability distributions.

A Description of TIMMOD

The computer simulation model, TIMMOD, is a working computer program designed specifically for the purpose of conducting the experiments designed to evaluate the potential impact of BCN technology. TIMMOD grew out of Brail's micro-level activity system simulator, and is itself a micro-level activity system simulator. TIMMOD is designed to simulate the activity of an average adult during an average day living in the

United States. The average adult is a composite of working men, working women, and housewives. The average day is a composite of weekdays, Saturdays and Sundays. TIMMOD does not include unemployed adult men or children, and also does not represent special holidays such as Christmas. TIMMOD is intended to represent the average day spent by the average American adult.

Two significant departures from Brail's micro-level activity system simulator are necessary to develop TIMMOD into a working computer model because of the constraints imposed by a limited empirical base. The first of these is the assumption that activity duration does not change with the hour of the day. This assumption means that the activity event of eating or watching television will be assumed to be the same duration during the morning hours, as during the afternoon hours, as during the evening hours. The probability of occurrence does change with the hour of the day; only the duration of the activity event remains constant. This means that the length of time eating breakfast during the eight o'clock in the morning hour is the same as eating dinner in the six o'clock in the evening hour, but the probability of eating breakfast at eight o'clock is not the same as eating dinner at six o'clock. The reason for this simplifying assumption is the lack of available data to generate activity duration statistics by hour of the day, requiring activity duration statistics to be compiled and used summed across the entire day.

A second departure is the lack of any logical connection between travel and in-home and out-of-home activities. TIMMOD considers travel to be the same as any other activity, and does not require the selection of an out-of-home activity requiring travel to be selected first. Again the reason for this change is the lack of available data describing the linkage between activity choice and physical location. It is simply not possible to adequately describe physical location using existing activity choice categories.

While these simplifications may lead to distortions in the output of the model, they do not negate the model's utility. Remembering that the simplifications are dictated by empirical necessity, it is possible to sufficiently limit experimental manipulation of the model so as to minimize the effect of any distortion. TIMMOD is not able to determine changes in the temporal sequencing of activities, and must be limited to aggregate activity times for the entire day. For example, eating as an activity is considered only as a total for the entire day as a sum of breakfast, lunch, dinner, and any snacks. This allows any differences in activity duration at different times of the day to average together and approach the overall activity duration used in the model. For example, if breakfast is always a little too long and dinner always a little too short, the total eating time will be the same. This still, however, does not rule out potential distortion in the activity selection process. An activity being too long or too short can change the probability of another activity being selected because the activity selection probabilities do change with the hour of the day. This effect is probably minimal for two reasons. First is that activity selection probabilities do not dramatically change from hour to hour except in only a few cases, and TIMMOD output would be interpreted only for relatively large numbers of hypothetical individuals causing the effect to average away across individuals.

TIMMOD is also unable to determine any changes in the physical location of various factors in the simulated environment. This limitation on the application of TIMMOD is not important to this experiment because of the focus on telecommunication rather than changes in physical distance. Travel time is considered in the same way as any other activity making it an ideal situation for experimental substitution. However, there is a potential for distortion because travel and activity requiring travel are not logically related. It is possible to distort the impact on other activity caused by a change in travel time. The only solution to this problem is care in the selection of experimental treatments and the consideration of only relatively large numbers of hypothetical individuals, assuming that the effect may average away.

It should also be pointed out that whatever distortions may exist in TIMMOD, they are held constant in both control and experimental treatment conditions. Assuming the worst case with the maximum distortion caused by the simplifying assumptions, then the experimental results would be interpreted as coming from a hypothetical world where all like activity events have the same duration throughout the day and travel is considered an independent activity in the same way as all other activity. No doubt this is not the case, but some caution should be employed in interpreting TIMMOD output knowing the underlying assumptions.

A number of computer simulation languages are available to write the computer program necessary to make a model like TIMMOD a working model. Several such special languages are available for general use at Michigan State University on the CDC 6500. Among the available simulation languages are SIMULA-67 which is based on ALGOL-60; SPURT (Simulation Package for University Research and Teaching) which is a package of FORTRAN subroutines providing stochastic generators, list processing capabilities, and scheduling functions for controlling discrete time simulations; and GASP II (General Activity Simulation Program) which is a collection of FORTRAN subroutines designed for discrete event simulation.[5]

TIMMOD while not written using all of the GASP II subroutines is written in Control Data Extended FORTRAN using the GASP II random variable generators and the GASP II approach.[6] GASP II, developed by Pritsker and Kiviat, is a set of FORTRAN programs and subroutines organized to provide seven specific functional capabilities required by every simulation:

1. Event control
2. Information storage and retrieval
3. System state initialization
4. System performance data collection
5. Program monitoring and event reporting
6. Statistical computations and report generation
7. Random variable generation[7]

To enhance program efficiency, the TIMMOD main program accomplishes the GASP II tasks of event control, system performance data collection, and program monitoring and event reporting. Since the information requirements of TIMMOD are relatively small because information is only stored in aggregate form, the information function is accomplished through the liberal use of common storage. A system state initialization subroutine called Setup and a statistical computation and report generation subroutine called Report have also been written to support the main program. Random numbers are provided through the use of GASP II routines used as external FORTRAN functions.

The TIMMOD program accommodates thirty-two different activity categories spread across twenty one-hour time periods beginning at five o'clock in the morning and extending past midnight. One TIMMOD run for a sample of 1,000 hypothetical individuals would require the generation of nearly 50,000 random numbers.

The TIMMOD main program as shown in Figure 4 begins with a call to the Setup subroutine which initializes all of the system variables. The operation of the Setup subroutine will be described later. TIMMOD's next task is to sample a random number for the waking time and then the retiring time for the first individual or cycle. Another random number is drawn to determine whether or not this individual will work at any time during the day. If the individual does not work, then the work-related activities are eliminated from the activity selection matrix, if the individual does work then the work-related activities are included along with all other activities. The waking time is converted to an integer value and the activity selection matrix is entered at that point. For example if the waking time were 6.75, the activity selection matrix would be entered at 6 which represents the six o'clock

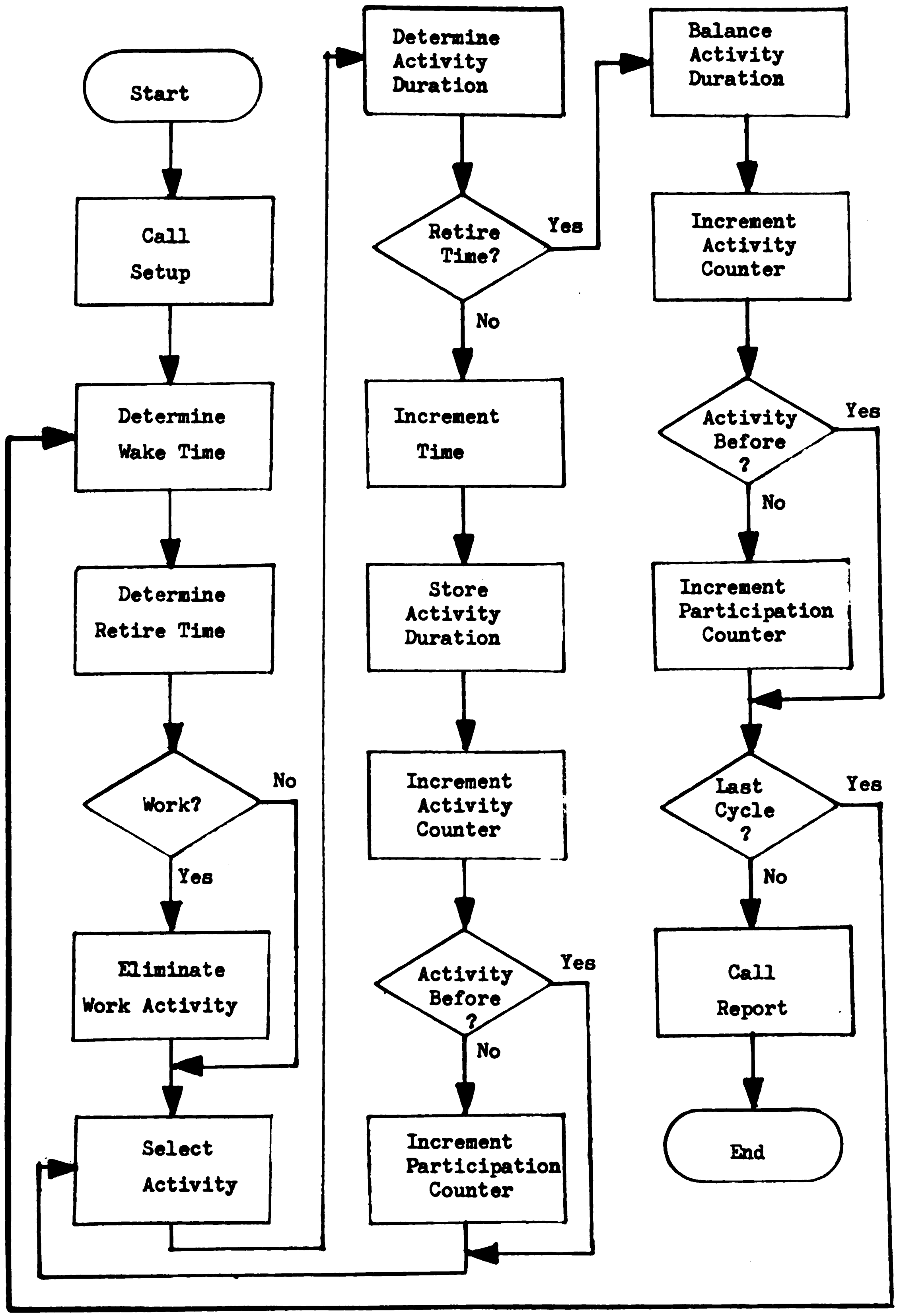

Fig. 4. TIMMOD Main Program Flow Diagram

hour. It should also be noted that the time and clock are maintained in hours and a decimal fraction to facilitate arithmetic within the program. The time of 6.75 would obviously be equal to 6:45.

An activity is selected randomly according to the appropriate hour. An activity duration is then determined from the duration probability distributions. If the current activity duration added to the current time, in this case the waking time, does not exceed the retiring time then the activity time is permanently added to the current time, thus incrementing the clock to account for the current activity. It should be noted that the clock is kept in decimal or floating-point form, and not in the integer form. The integer conversion is made each time it is necessary to enter the activity selection matrix. After the clock has been incremented, the activity duration is added to other of the same activity for this individual and stored. If this is the first occurrence of this particular activity for this individual then the participation counter is set to 1, if not this step is omitted. The current time is then converted to an integer value and the activity selection table is entered and a new activity is selected. This is followed by another activity duration selection, and through the rest of the process until the current time added to the current activity duration exceeds the retiring time.

When the retiring time is exceeded, the current activity duration is forced equal to the difference between the current time and the retiring time balancing out the day. This procedure is different from the one suggested by Brail that requires drawing two random numbers after each activity selection to determine retiring time. The simple balancing procedure used by TIMMOD is computationally simpler and faster, although it may lead to some distortion in the duration of the last activity before retiring for the night. This, however, should make little difference because the activity duration times are held constant throughout the day, and TIMMOD runs are for large numbers of hypothetical individuals which should average out the effect. After the activity duration has been balanced, then the activity counter is incremented for the last activity category. If this is the first occurrence of the particular activity, then the participation counter is set to 1, just as before. If it is not the first occurrence of the activity, then this step is omitted.

Since it is the last activity for the first individual, a decision is made based on an input parameter whether or not to continue with a new individual or cycle, or end the program. In both cases the generated data are stored in an array to be passed to the report generating subroutine. TIMMOD also has the capability to select one additional activity category apart from the overall tabulation and generate statistics for participants in that category only, such as individuals who go shopping or watch television.

If the last cycle or individual has been reached, then a call is issued to the Report subroutine which produces the output reports. If the last cycle has not been reached, then TIMMOD returns to the beginning and selects a new waking and retiring time and reinitializes all of the individual arrays. The current time is reset to the waking time. This process is repeated until the number of cycles is exhausted.

Figure 5 shows the flow diagram of the Setup subroutine which is called at the start of the TIMMOD run to initialize all of the system variables. Setup begins by dimensioning and initializing all of the system variables and arrays to zero. Setup then reads the run parameter card. The run parameter card specifies the random number seed, the number of parameters included in the activity duration parameter list, the number of parameters included in the activity selection parameter list, the number of cycles to be run, and the activity category to be separately tabulated. The run parameters are then set to the appropriate system variables.

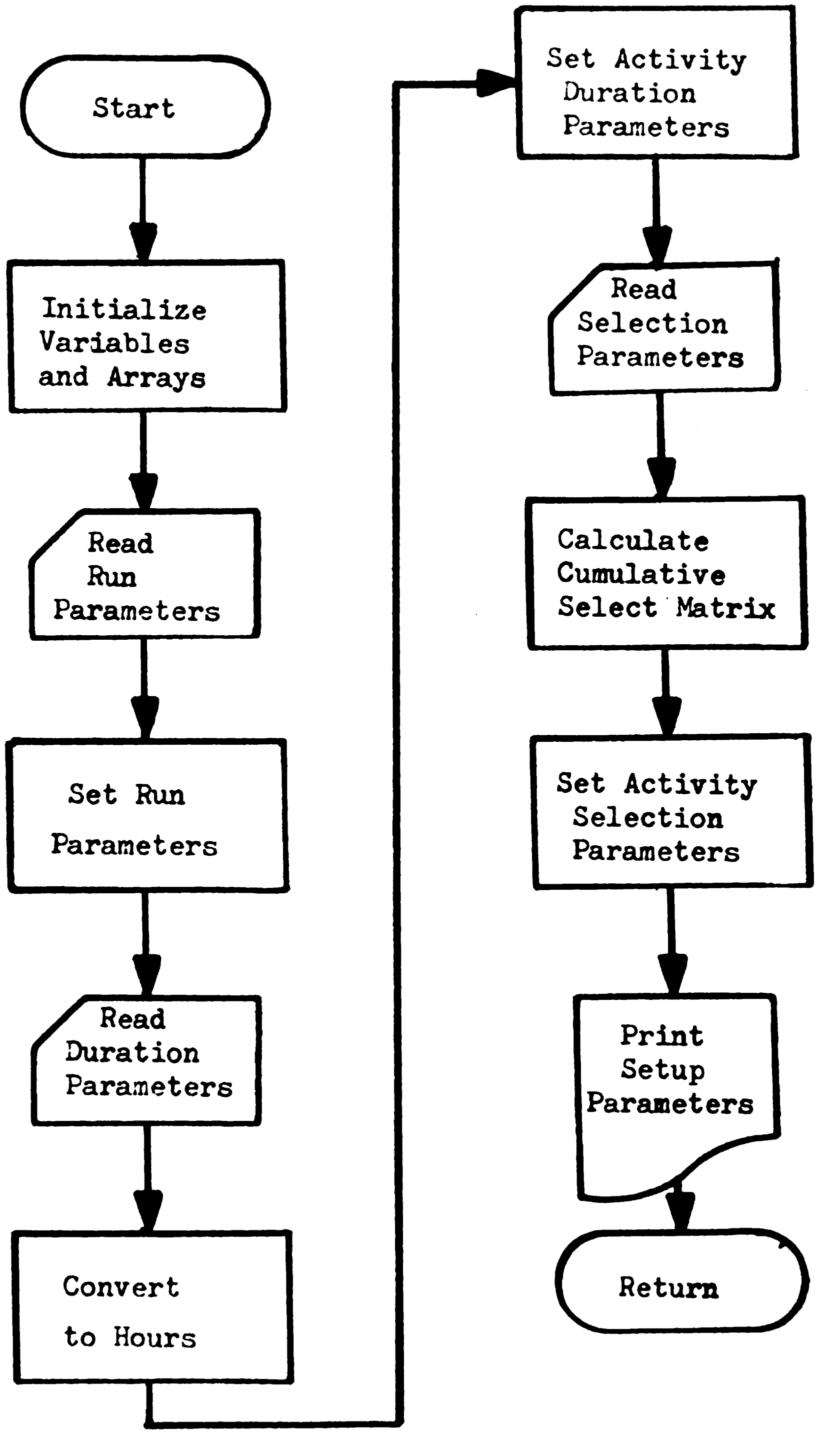

Fig. 5. TIMMOD Setup Subroutine Flow Diagram

The Setup subroutine then reads the activity duration parameters according to the run parameter card. The activity duration parameters include the theoretical probability distribution parameters, minimum and maximum values, and a weighting factor for each of the activity categories indicated by the run card. Since the activity duration parameters are entered into the TIMMOD program in minutes, it is necessary to convert all of the parameters in minutes to hours to facilitate computation in the running of the TIMMOD main program. The appropriate arrays are then set with the activity duration parameters.

The last cards read by the Setup subroutine are the activity selection parameters. These cards, again determined by the run parameter card contain the average frequency of occurrence of a particular activity by hour of the day. As will be described later, it is necessary to convert these frequencies to cumulative percentages by hour of the day. Setup performs all of the necessary calculations and then sets the appropriate array equal to the cumulative values. Setup then prints a listing of all of the input parameters, including the cumulative activity selection matrix, and returns control to the TIMMOD main program.

Figure 6 shows the flow diagram for the Report subroutine. Report is called by the TIMMOD main program

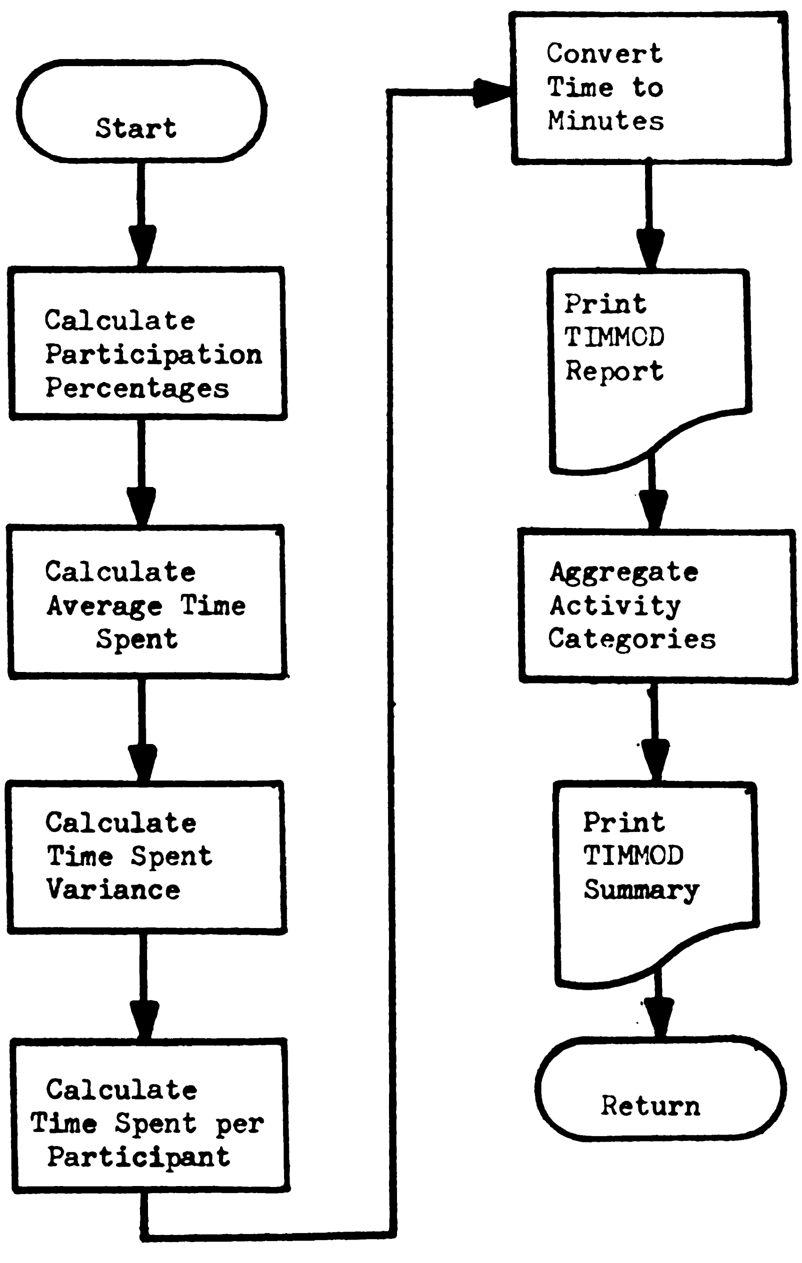

Fig. 6. TIMMOD Report Subroutine Flow Diagram

after the last cycle has been completed. Report begins by calculating the participation percentages from the total participation arrays passed to the subroutine from the main program. Then Report calculates the average time spent and the variance for the averages time spent for each activity category. The time spent per participant is then calculated by dividing the participation percentage into the average time spent per participant for each activity category. All time estimates are converted from hours back into minutes. The TIMMOD report is then printed for all participants and for participants in the single category specified on the run parameter card. The TIMMOD report includes the number of times each activity occurred for the entire group of participants, the average time spent and variance, the percentage participating, and the average time spent per participant. Samples of the TIMMOD report are included later in this chapter.

To simplify comparison with treatment and control conditions, a summary report is also included. This report is simply an aggregation of the activity categories shown in the TIMMOD report and a calculation of the average time spent and variance for the new categories. The TIMMOD summary is then printed. Report transfers control back to the main program which then ends the run. The FORTRAN source code for the TIMMOD main program, the Setup and Report subroutines, and the external random number functions is in the Appendix.

The functional description of TIMMOD at this point has ignored the critical problem of probability distributions. Each of the random numbers used in the operation of the model must come from either an empirically derived or theoretical probability distribution. The selection and use of probability distributions is crucial to the operation of TIMMOD, requiring the development of a rationale for the selection. What follows is a brief discussion of the common probability distributions that are available to TIMMOD.

Theoretical Probability Distributions

TIMMOD is a stochastic simulation which requires the construction of a probabilistic model of the time allocation process. This kind of simulation is often termed "Monte Carlo" simulation and was first employed by mathematicians to find solutions to deterministic problems whose answer is not easily obtainable using standard numerical methods. The classic examples of the application of stochastic simulation to solve such problems are in the evaluation of multiple integrals, solutions to high-order difference equations, complex queueing problems, and job-shop scheduling problems.

In general, Naylor, Balintfy, Burdick, and Chu describe stochastic simulation as involving the replacement of an actual statistical universe of elements by its theoretical counterpart, like the normal probability distribution, and then sampling by means of some type of random number generator from the theoretical probability distribution.[8] TIMMOD requires the sampling of random numbers from probability distributions representing the occurrence of activities throughout the day and the duration of each activity category. The problem is then to develop the appropriate probability distributions.

Probability is normally considered as the long-run relative frequency of occurrence for some event or experiment, such as the tossing of a fair coin. A formal mathematical definition of probability is offered by Hughes and Grawoig:

> If an outcome occurs f times out of n trials, its relative frequency is f/n; the value which is approached by f/n when n becomes infinite is called the limit of the relative frequency. The probability of an outcome O_i is defined as the limit of its relative frequency; that is:
>
> $$P(O_i) = \lim_{n \to \infty} f/n$$ [9]

The relative frequency of the occurrence of an event is then the ratio of the number of times the event occurred to the total number of events. If all possible events are grouped together, then a distribution of relative frequencies is obtained. It is then a simple matter to convert a distribution of relative frequencies into a distribution of probabilities.

Probability distributions applied to computer simulation are of two general types, theoretical and empirically derived. Obviously the shape of a probability distribution can vary dramatically with the set of events or phenomenon it is supposed to represent. Theoretical probability distributions can be represented by a mathematical function or rule which allows the generation of the entire probability distribution. Empirical probability distributions cannot be adequately described by a mathematical function, and require enumeration of each event to generate the entire probability distribution. An empirical probability distribution is somewhat more awkward than a theoretical probability distribution from a computational viewpoint, especially if a large number of events is involved. An empirical probability distribution also assumes that the data are available to generate the distribution, which is not always the case.

Empirical probability distributions have to be ruled out for TIMMOD because of the data problem. A sample of just over 1,200 individuals simply cannot provide stable estimates of frequency distributions for thirty different activity categories across twenty hours of the day. Development of the required probability distributions using the available data necessitates the use of theoretical probability distributions.

Naylor et al. recommend always attempting to use theoretical probability distributions first, with empirical distributions used only as a last resort.[10]

Theoretical probability distributions divide into two major categories, discrete and continuous. Discrete probability distributions describe events or variables that can take only discrete, non-negative integer values. Discrete probability distributions generally are used to describe counting processes which can be either finite or infinite, but are limited to whole numbers. Tsokos defines a discrete one-dimensional random variable as follows:

> Let X be a random variable. If the number of elements in the range space, R_X, is finite or countably infinite, then X is called a one-dimensional discrete random variable.

A continuous random variable takes on uncountably infinite values, such as distance and time, and is limited only by the precision of the measuring instrument. Continuous random variables are considered in terms of intervals rather than discrete points. Tsokos defines a continuous one-dimensional random variable as follows:

> Let X be a random variable. If the range space, R_X, is an interval or the union of two or more non-overlapping intervals, then X is called a one-dimensional continuous random variable.[12]

To avoid the problem of working with an interval in performing calculations, continuous distributions are generally assigned values in a manner similar to the discrete case.

Theoretical probability distributions can be described in a number of ways. To begin with, probability distributions can be described in terms of their graphical representation and shape. Probability distributions can also be described algebraically using a mathematical probability function. Probability functions are rules for assigning the selection chances to the outcomes of a particular experiment. The probability function describes the mathematical behavior of a theoretical probability distribution.

Probability distributions are normally described in terms of $f(x_i)$ which represents the distribution of a random variable X. The distribution of $f(x_i)$ is also referred to as the mass or frequency density function. The general probability density function for a one-dimensional discrete random variable is expressed as:

$$\sum_{i=1}^{\infty} f(x_i) = 1$$

The general probability density function for a one-dimensional continuous random variable is expressed as:

$$\int_{-\infty}^{\infty} f(x)dx = 1$$

Probability density functions of these general forms then are used to describe the various theoretical probability distributions to be considered in this research.

In addition to the probability density function it is also useful to consider the long-run average result or expected value of the various probability distributions. Expected value, expressed as E(X), of the random variable X is synonymous with central tendency and is the single most representative value of the distribution. Expected value, however, really does not adequately describe a distribution because it gives no indication of the dispersion or range of values in the distribution around the expected value. Statistically, the variance is represented by the sum of the squared deviations around the mean divided by the total number of observations. The variance of random variable X is expressed as:

$$V(X) = \frac{\Sigma(X - \overline{X})^2}{n}$$

Variance can also be expressed in the form of a standard deviation, which is represented as the square root of the variance.

Theoretical probability distributions now can be characterized in a number of ways, distributional shape, probability density function along with any associated parameters, expected value, and variance.

To simplify the discussion of probability distributions, then, the above characteristics along with some applications for some common "families" of theoretical probability distributions will be only considered. Discussing probability distributions in terms of families that share certain characteristics is suggested by Zehna, and the families that follow are his catalog of common families.[13]

Discrete Probability Distributions

Discrete probability distribution families are those that describe various counting processes. The following five families are the most common.

Bernoulli Family

The Bernoulli or Point Binomial family of probability distributions is named after the Swiss mathematician Jacques Bernoulli and is the probability law for coin-tossing experiments. It can be applied to any dichotomous random experiment, such as the case of a piece of equipment which either succeeds or fails. The probability density function for the Bernoulli family is as follows:

$$f(x;p) = p^x q^{1-x}$$

The parameters include p, which is the probability of success for a given event, and must take a value between 0 and 1. The other parameter, q, is merely the probability of failure and is derived directly from p, $q = 1 - p$. The function generates values for X in the range of 0 to 1. The expected value and variance for the Bernoulli family are expressed as follows:

$$E(X) = p$$

$$V(X) = pq$$

<u>Binomial Family</u>

The binomial family is an algebraic generalization of the Bernoulli family adding the positive integer n to represent the number of trials. The application of the binomial family is similar to the Bernoulli family. The probability density function for the binomial family is as follows:

$$f(x;n,p) = \binom{n}{x} p^x q^{n-x}$$

The parameters are the same as those for the Bernoulli family. The function generates values for X in the range of 0 to n. The expected value and variance for the binomial family are expressed as follows:

$$E(X) = np$$

$$V(X) = npq$$

It should also be noted that for very large values of n, the binomial approaches the continuous normal distribution.

Geometric Family

The geometric family describes the distribution of the number of trials needed to achieve success. An example of the application of the distribution might be estimating the number of cycles a machine might operate before a failure. The probability density function for the geometric family is as follows:

$$f(x;p) = pq^{x-1}$$

The parameters are again the same as the Bernoulli family. The function generates values for X in the range of 1 to infinity. The expected value and variance for the geometric family are expressed as follows:

$$E(X) = \frac{1}{p}$$

$$V(X) = \frac{q}{p^2}$$

Negative Binomial Family

The negative binomial family describes the number of repetitions necessary to achieve r successes. An application of the distribution is in inventory management. The total demand for an item of a given type is normally assumed to be a random phenomenon. Especially in cases where the average demand is large and there is little past history the total number of units demanded is often assumed to be distributed according to the negative binomial distribution.[14] The probability density function for the negative binomial family is as follows:

$$f(x;r,p) = \binom{x + r - 1}{x} p^r q^x$$

The parameters remain the same, except for the addition of r which indicates the number of successes. The function generates values in the range from 0 to infinity. The expected value and variance for the geometric family are expressed as follows:

$$E(X) = \frac{rq}{p}$$

$$V(X) = \frac{rq}{p^2}$$

Poisson Family

The Poisson family, named after the French mathematician S. Poisson, is a limiting form of the binomial family. The parameter of the Poisson family is λ, which is the mean number of occurrences of an event per unit of time over a given number of trials. The distribution assumes different shapes depending on the value of λ. When λ is less than 1, the distribution is highly skewed to the right, and becomes more symmetrical as λ increases. The Poisson family describes situations when the concern is with the number of times an event occurs over some time interval. A large number of applications have been suggested for the Poisson family. Some examples are listed by Tsokos:

1. the frequency of certain peaks per minute at a telephone switchboard;
2. the number of misprints per page in a dictionary;
3. the number of traffic accidents which occur per day on a certain turnpike;
4. the number of alpha-particles emitted per hour by a radioactive source;
5. the number of babies born with heart defects in a large city during a one-year period;
6. the number of no-hitters pitched by a Hall of Famer during his baseball career;
7. the number of live viruses remaining after the production process of a certain vaccine.[15]

The probability density function for the Poisson family is as follows:

$$f(x;\lambda) = \frac{e^{-\lambda}\lambda^{x}}{x!}$$

The parameter λ is defined earlier. The function generates values for X in the range of 0 to infinity. The expected value and variance for the Poisson family is shown below:

$$E(X) = V(X) = \lambda$$

While other discrete probability distributions exist, such as the hypergeometric distribution, the families mentioned here represent the more commonly used distributions. Attention can now be turned to continuous probability distributions.

Continuous Probability Distributions

Five major continuous probability distribution families will be discussed in the same manner as the discrete probability distributions. Other continuous probability distributions will receive only brief mention.

Uniform Family

The simplest continuous probability distribution family is the uniform family. The uniform distribution applies in situations where all events are equally likely to occur. As a model for random experiments, Zehna describes the uniform family as being suitable for bounded random variables whose essential range coincides with the interval (α, β).[16] A uniform distribution is shown graphically in Figure 7. Its distributional shape is simply the representation of a horizontal line inside the range of its parameters. The probability density function for the uniform family is expressed as follows:

$$f(x;\alpha,\beta) = \frac{1}{\beta - \alpha}$$

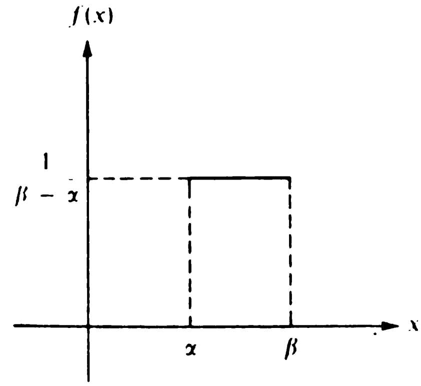

Fig. 7. The Uniform Distribution

The parameters α and β set the lower and upper boundary for the random variable X. The expected value and variance for the uniform family are expressed as follows:

$$E(X) = \frac{\alpha + \beta}{2}$$

$$V(X) = \frac{(\alpha - \beta)^2}{12}$$

<u>Exponential Family</u>

The exponential family provides density functions for non-negative random numbers. A classic application of the exponential is estimating the time to failure of a machine. Like the Poisson family, the exponential is well suited to describe the occurrence of an event across time intervals. According to Naylor et al., if the probability that an event will occur in a small time interval is small, and if the occurrence of the event is statistically independent of other events, then the time interval between the occurrence of events is exponentially distributed.[17] An exponential distribution is graphically shown in Figure 8. The λ is the parameter for the distribution like the Poisson distribution.

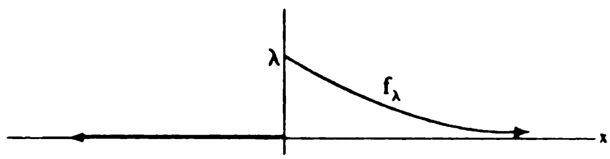

Fig. 8. The Exponential Distribution

The probability density function for the exponential family is expressed as follows:

$$f(x;\lambda) = \lambda e^{-\lambda x}$$

The λ parameter must be greater than 0. The function generates the random variable X in the range 0 to infinity. The expected value and variance for the exponential distribution are expressed as follows:

$$E(X) = \frac{1}{\lambda}$$

$$V(X) = \frac{1}{\lambda^2}$$

<u>Gamma Family</u>

The gamma family is a more general family of distributions for non-negative random variables. The gamma distribution has two parameters, α which is the number of successes per interval or unit space, and β which is the reciprocal of the average number of successes per interval $(\frac{1}{\lambda})$. The gamma distribution is related to both the Poisson and exponential distributions. The exponential is a special case of the gamma distribution when $\alpha = 1$. As α increases, the distribution becomes less skewed until it approaches the normal distribution. One of the most powerful properties of the gamma family is the ability to change shape from an extremely skewed exponential distribution to a very near normal distribution by changing only the α parameter. As Zehna points out, the gamma family is so extensive that it "is a fairly safe assumption to make as a model for an experiment described by almost any nonnegative random variable."[18] Letting $\alpha = n/2$, where n is a positive integer, and $\beta = 2$, the gamma distribution becomes a chi-square distribution with n representing degrees of freedom. Figure 9 shows the affect on the shape of the distribution by changes in the parameter α.

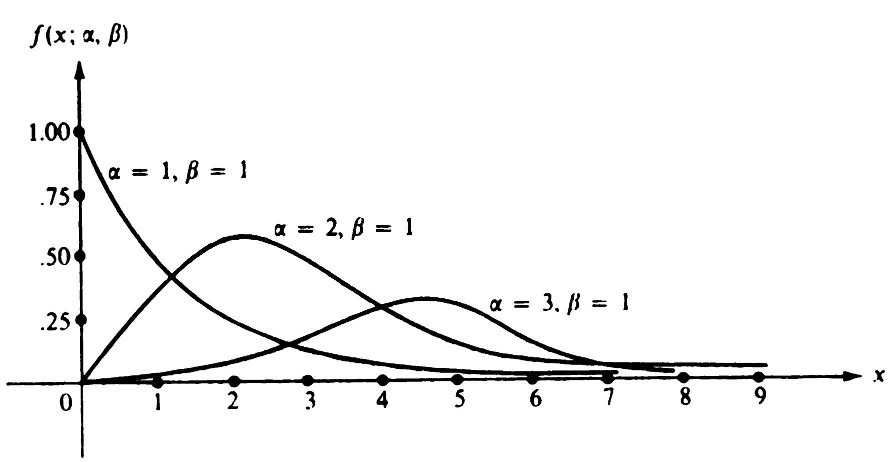

Fig. 9. The Gamma Distribution

The probability density function for the gamma distribution is expressed as follows:

$$f(x;\alpha,\beta) = \frac{x^{\alpha-1}e^{-x/\beta}}{b^{\alpha}\Gamma(\alpha)}$$

The α and β parameters have been described before, and they both must be greater than 0. The Γ notation indicates a one-parameter integral called the gamma function as shown below:

$$\Gamma(p) = \int_0^\infty x^{p-1}e^{-x}dx$$

In this function, p must be greater than 0. The gamma probability density function generates a random variable X in the range from 0 to infinity. The expected value and variance of the gamma family are expressed as follows:

$$E(X) = \alpha\beta$$

$$V(X) = \alpha\beta^2$$

<u>Beta Family</u>

The beta family makes possible structuring a model for a random variable in the range 0 to 1. It is a two parameter distribution like the gamma family, and is rich enough to take almost any shape. Also like the gamma, the beta family is related to a function called the beta function. However, a beta function can be expressed in terms of gamma functions. The beta family flexibility is illustrated in Figure 10 which shows differences in the value of α with a fixed β. The beta family probability density function is expressed as follows:

$$f(x;\alpha,\beta) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1 - x)^{\beta-1}$$

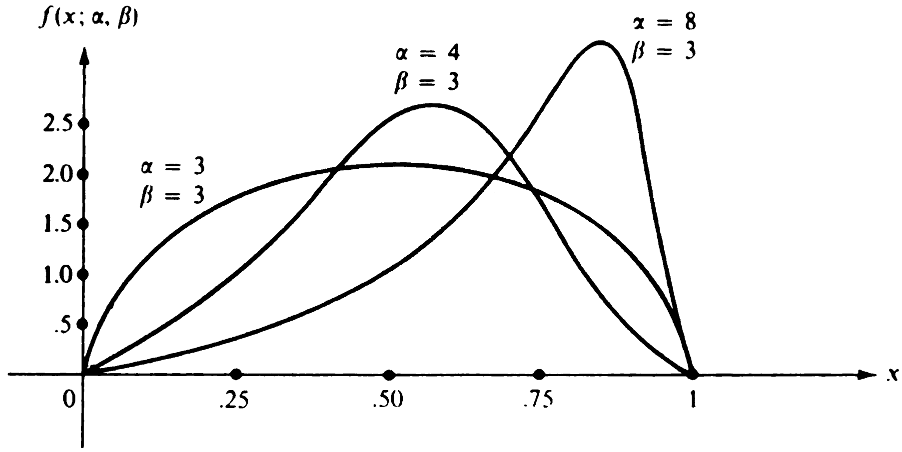

Fig. 10. The Beta Distribution

The affiliation of the beta family with the gamma family is apparent. The α and β parameters must be greater than 0. The function returns a random variable X in the range of 0 to 1. The expected value and variance of the beta family is expressed as follows:

$$E(X) = \frac{\alpha}{\alpha + \beta}$$

$$V(X) = \frac{\alpha\beta}{(\alpha + \beta)^2(\alpha + \beta + 1)}$$

Normal Family

The last continuous probability distribution family is probably the most important. Many continuous variables such as height, weight, and intelligence quotient are normally distributed. The normal family is the most important probability model is statistical analysis, and no doubt the most familiar. It is shown graphically in Figure 11 with three different values for the standard deviation, or σ. The mean μ is held constant at 0. The probability density function for the normal family is expressed as follows:

$$f(x;\mu,\sigma^2) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-1}{2\sigma^2}(x-\mu)^2}$$

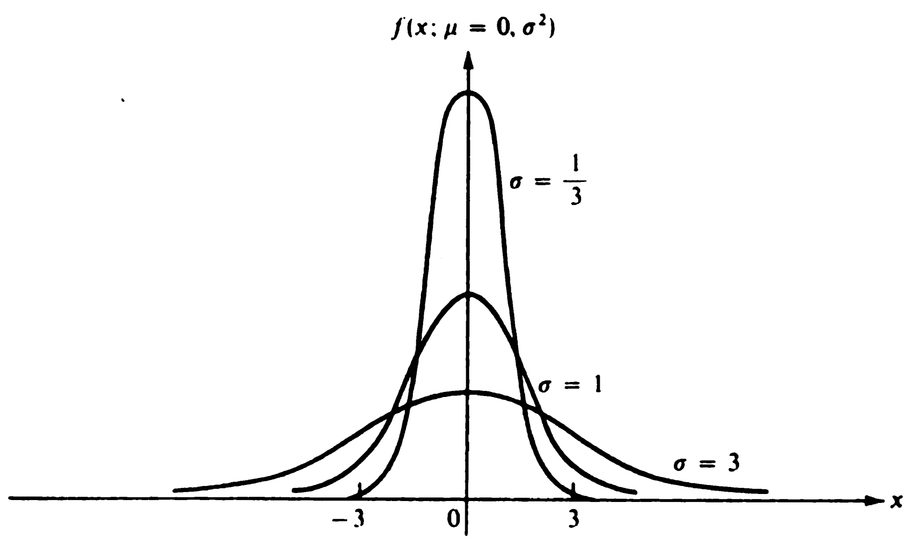

Fig. 11. The Normal Distribution

The normal of Gaussian family is a two-parameter family, with the familiar mean, μ, and variance, σ^2. The expected value and variance are obvious:

$$E(X) = \mu$$

$$V(X) = \sigma^2$$

A large number of other continuous probability distributions could also be used. Among these are the Cauchy distribution, the Laplace distribution, the log-normal distribution, the Weibull distribution, the Rayleigh distribution, Maxwell's distribution, extreme-value distribution, arc sine distribution, and Pareto's distribution. None of these have application to TIMMOD, so the discussion will be terminated. Additional discussion and description can be found in Tsokos.[19]

Applications to TIMMOD

There are two general approaches to the generation of random numbers in TIMMOD. The first is the use of a continuous uniform distribution to determine the activity choice. The second is the use of a gamma distribution to determine the duration of the activity.

The activity selection process is very similar to the media selection process used by the Simulmatics Model described in Chapter III. The activity selection frequencies are arranged in a two-dimensional matrix, activity by time of day. The activity selection frequencies are converted to cumulative percentages, beginning with the first hour of the day through the last for each activity category. A random number is then sampled from a uniform distribution bounded by 0.0 and 100.0. This number is then skipped through the cumulative percentages for the appropriate hour of the day as determined by the logic of the computer program. The activity selected is the activity category where the random number lies. While the essential nature of this selection process is discrete, it is computationally convenient to use the continuous probability distribution to compare percentages. A similar procedure is used to determine work activity.

The determination of activity duration directly involves sampling the continuous variable time. Activity durations are represented in a wide range of distributional shapes, from extremely skewed J-shaped distributions to a normal distribution. The range of activity duration can extend from 0 to 1,440 minutes or 24 hours. The appropriate theoretical distribution to describe activity duration is the gamma family. A gamma distribution can describe non-negative random processes from extremely skewed exponentially shaped distributions through a symmetrical approximately normal distribution. The versatility of the gamma family makes its application popular. Basic, for example, uses the gamma distribution to approximate demand for products in the metal service industry and then exploits the versatility of the gamma distribution family to serve as a guide for the management of inventory within the industry.[20]

To use a gamma distribution all that is required are the two parameters, α and β, which have been described previously. These parameters, with some effort, can be estimated from directly from an empirical data base. The calculation of gamma random variates, however, is reasonably complex and requires some discussion.

Computer Generated Random Numbers

There are essentially four methods of generating random numbers. The methods include manual methods, such as coin tossing and card shuffling, random number tables, the use of analog computers, and the use of digital computers. Since TIMMOD is programmed for a digital computer, only modes for generating random numbers using a digital computer will be considered.

Three alternative modes for generating random numbers are discussed by Naylor et al.[21] External provision of random numbers is possible by storing a random number table on a peripheral device, such as a magnetic tape or disk unit. This mode, however, is quite slow because of the time required to read the device. A second mode is the internal generation by a random physical process such as the use of the noise generated by some electronic process. The major problem with this mode is inability to reproduce the process so that calculations can be checked. The third, and most widely used mode, is the internal generation of random numbers through the use of a recurrence relation.

The recurrence relation involves a mathematical transformation of a group of arbitrarily chosen numbers. Normally the starting number for the sequence is referred to as the seed. The selection procedure is a deterministic process. The same random number seed will generate the same sequence of numbers, although the next number in a sequence cannot be predicted. Because computer generated random numbers are drawn using a deterministic process, they are commonly referred to as pseudorandom numbers. However, the pseudorandom process must generate random numbers which provide sequences which must meet several stringent requirements. Nayor et al. enumerate five criteria for an acceptable method of generating random numbers including, uniform distribution, statistical independence, reproducibility, high speed, and low core memory requirements.[22] Random numbers for TIMMOD are selected using a congruential method for TIMMOD represented by the CDC FORTRAN function RANF.[23]

The functions for generating deviates of the uniform and gamma distributions are borrowed from

Pritsker and Kiviat.[24] The functions themselves are shown with the FORTRAN source code in the Appendix. Both functions employ the inverse-transformation method suggested by Naylor et al. to calculate the random deviates.[25]

The uniform distribution is handled in a straightforward manner and is quite simple. The gamma distribution, however, is different and requires additional discussion. As Naylor et al. point out, the cumulative distribution function for a gamma distribution cannot be formulated explicitly, requiring an alternate method.[26] Generally the approach is to limit the consideration of the gamma distribution to an Erlang distribution, which is a gamma distribution with an integer parameter. The a parameter then is limited only to integer values. Mathematically the Erlang distribution is a convolution of a exponential distributions. When $\alpha = 1$, the Erlang obviously becomes an exponential, as α increases in integer increments the Erlang approaches the normal distribution. A convenient computational formula is provided by Naylor et al., which is expressed below and used in the TIMMOD model:[27]

$$x = -\frac{1}{\beta}\left(\log \prod_{i=1}^{\alpha} r_i\right)$$

The random variate is x, α and β are the gamma parameters, and r is the pseudorandom number provided by RANF. The TIMMOD functions are appropriately named UNIFRM and ERLNG.

Preparation of TIMMOD Input Data

The input data for TIMMOD is estimated from the 1965 United States Time Use Survey described in Chapter IV. Data from this study are reported in two sources, *Summary of United States Time Use Survey*[28] and as part of the multinational comparative study described in *The Use of Time*.[29] The most useful tabulations for developing input for TIMMOD are found in the Statistical Appendix of the latter source.

Unfortunately these tabulations do not directly provide the data necessary for TIMMOD, namely mean and variance estimates for the duration of each activity event for the activity duration statistics and the frequency of occurrence for each activity by hour of the day for the activity selection matrix. All that is provided for activity duration statistics is the total time spent engaging in the activity for the entire sample, the percentage participating, and the average number of occurrences for participants. No variance estimates or frequency distributions are provided, except for a very few aggregate categories. Activity selection statistics are available only for aggregate categories, and not for the entire sample, only subgroups. In order to estimate the input parameters for the model it is necessary to perform a number of calculations on the available data. This transformation process will be described in detail.

The problem of variance estimates was quickly solved by contacting the Institute for Social Research at the University of Michigan which provided them for a large number of activity categories for the total time spent in that activity. All other data come from the Statistical Appendix of The Use of Time.

The next problem is to establish a consistent set of activity categories. The original United States Time Use Survey used ninety-six activity categories, but abridged this to a reduced thirty-seven activity categories for reporting the results. However, the reduced thirty-seven is still somewhat difficult to handle, and does not reflect all of the activities necessary to focus on marketing communication activity. The reduced thirty-seven activity categories require additional modification to arrive at the TIMMOD thirty-two activity categories. This last modification is shown in detail in Table 3.

Marketing, which as an activity category refers to shopping for everyday nondurable goods, and shopping and errands are separated from other activity and

TABLE 3

COMPARISON OF THE MULTINATIONAL COMPARATIVE STUDY AND TIMMOD ACTIVITY CATEGORIES

Multinational Comparative Time-Budget Project Reduced 37 Activity Categories	TIMMOD 32 Activity Categories
1. Main job	1. Main Job
2. Second job	2. Second Job
3. At work other	3. Work-Other
4. Travel to job	4. Travel to Job
Total work	
5. Cooking	7. Cooking
6. Home chores	8. Home Chores
7. Laundry	9. Laundry
8. Marketing	5. Marketing
Total Housework	
9. Garden, animal care	10. Pets and Garden
10. Errands, shopping	6. Shopping-Errands
11. Other house	11. Other House
Other household obligations	
12. Child care	
13. Other child	
Total child care	12. Child Care
14. Personal care	16. Personal Care
15. Eating	15. Eating
16. Sleep	32. Night Sleep (less day sleep)
Total personal needs	
17. Personal travel	13. Personal Travel
18. Leisure travel	14. Leisure Travel
Total non-work travel	
19. Study	
20. Religion	
21. Organization	
Study and participation	17. Study-Clubs
22. Radio	19. Radio
23. TV (home)	
24 TV (away)	18. Television (23 and 24 combined)
25 Read paper	20. Newspapers
26. Read magazine	21. Magazines
27. Read Books	22. Books
28. Movies	23. Movies
Total mass media	
29. Social (home)	
30. Social (away)	24. Social Activity (29 and 30 combined)
31. Conversation	25. Conversation
32. Active sports	26. Active Sports
33. Outdoors	27. Outdoors
34. Entertainment	28. Entertainment
35. Cultural events	29. Cultural Events
36. Resting	30. Resting-Naps (includes day sleep)
37. Other Leisure	31. Other Leisure
Total Leisure	

SOURCE: A. Szalai, ed., The Use of Time (The Hague: Mouton, 1972).

highlighted. The child care category is aggregated, as is study, religion and organization. Sleep is divided into night sleep, with day sleep being combined with resting. Television at home and away from home are combined in one category as is social activity. The other categories remain the same.

Given this set of thirty-two activity categories, the development of the necessary activity duration statistics and the activity selection matrix will be described in sequence.

Activity Duration Statistics

The estimation of the mean and variance of a single activity event requires a rather complex sequence of calculations. Starting with the means and variances of the reduced thirty-seven categories requires some initial aggregation. The means and variances for the total time spent per sample member are easily combined using the following equations:

$$M_t = M_1 + M_2 + \cdots + M_n$$

$$S_t^2 = S_1^2 + S_2^2 + \cdots + S_n^2$$

Each of these equations assumes that each of the categories is mutually exclusive. The total mean, M_t, is simply the sum of the means comprising it. The total variance, S_t^2, is the vector sum of the variances associated with the means in the total mean calculation.

With the new structure of thirty-two activity categories established, the preparation of the activity duration mean and variance estimates begins. Data describing the average time spent for the total sample engaged in primary activities are shown in Table 4. The total sample is used to make TIMMOD representative of the overall adult population, not just a specific sub-population such as employed men, employed women, or housewives. A distinction between primary and secondary activities is made throughout the multinational comparative study. A primary activity is the main activity recorded by the respondent, and the secondary or accompanying activity is then recorded in addition to the primary activity. The distinction between primary and secondary activity is left completely to the respondent. For example, watching television and eating, or eating and watching television, define different primary and secondary activities in each case. TIMMOD assumes only primary activities, which no doubt understate certain activities such as radio listening and conversation. Conversation as an activity category in TIMMOD is as a primary activity only.

TABLE 4

PROVIDED ACTIVITY SELECTION STATISTICS

Activity		Total Sample Time Spent			Percentage Participating	Mean Per Participant
		Mean	Standard Deviation	Variance		
1.	Main Job	225.0	236.1	55731.0	51.2	439.5
2.	Second Job	4.9	37.0	1369.0	2.4	204.2
3.	Work--Other	11.5	20.0	400.0	33.3	34.5
4.	Travel to Job	24.9	36.0	1296.0	50.7	49.1
5.	Marketing	14.0	31.0	961.0	34.4	40.7
6.	Shopping--Errands	17.9	42.1	1775.0	30.5	58.7
7.	Cooking	43.8	53.0	2809.0	60.6	72.3
8.	Home Chores	58.4	63.3	4013.0	60.9	95.9
9.	Laundry	25.5	53.2	2825.0	29.5	86.4
10.	Pets and Garden	3.3	13.0	169.0	12.2	27.0
11.	Other House	23.7	55.7	3097.0	37.7	62.9
12.	Child Care	32.6	58.1	3370.0	37.6	86.7
13.	Personal Travel	30.8	37.5	1410.0	63.5	48.5
14.	Leisure Travel	19.3	32.2	1036.3	42.9	45.0
15.	Eating	81.3	50.9	2589.0	98.5	82.5
16.	Personal Care	68.5	45.6	2081.0	98.2	69.8
17.	Study--Clubs	27.7	64.9	4214.0	20.3	136.5
18.	Television	91.6	99.0	9801.0	69.7	131.4
19.	Radio	3.6	18.0	324.0	8.2	43.9
20.	Newspapers	23.8	32.0	1024.0	48.6	49.0
21.	Magazines	6.4	21.0	441.0	11.3	56.6
22.	Books	5.3	24.0	576.0	7.1	74.6
23.	Movies	3.2	25.0	625.0	2.0	160.0
24.	Social Activity	63.0	95.1	9040.0	54.6	115.4
25.	Conversation	18.4	35.0	1225.0	41.2	44.7
26.	Active Sports	5.5	27.0	729.0	5.7	96.5
27.	Outdoors	2.4	18.6	345.0	3.1	77.4
28.	Entertainment	5.4	30.5	928.0	3.7	145.9
29.	Cultural Events	0.6	8.1	65.0	0.7	85.9
30.	Resting--Naps	19.4	45.4	2057.0	18.6	104.3
31.	Other Leisure	19.5	44.9	2015.0	25.7	59.7

SOURCE: A. Szalai, ed., The Use of Time (The Hague: Mouton, 1972), and Summary of United States Time Use Survey, Survey Research Center, University of Michigan, Ann Arbor, Michigan, 1966.

The mean total time spent statistics are obtained directly from the statistical appendix of The Use of Time using the data reported for the study designated forty-four cities, U.S.A.[30] The standard deviation and variance estimates supplied by the Institute for Social Research are also shown in Table 4. The percentage of the total sample engaging in a particular activity category is also taken directly from The Use of Time.[31] The percentage participating is also shown in Table 4.

The average or mean time spent per participant is then easily calculated using the following simple equation:

$$T_p = \frac{T_o}{P}$$

The average time spent per participant, T_p, is calculated by dividing the average time spent overall, T_o, by the percentage participating, P. This calculation is included in The Use of Time, but required recalculation because of the revised TIMMOD categories.[32]

Estimating the variance for participants is somewhat more complex. Using the computational formula for calculating variance, the following estimation equation is derived:

$$S_p^2 = \frac{P(S_o^2) + PT_o^2 - T_o^2}{P^2}$$

The variance for participants, S_p^2, is estimated from the proportion participating, P (expressed as a decimal fraction), the mean, T_o, and variance, S_o^2, for the time spent for the overall sample. The result of this calculation is shown in Table 5.

Now that the mean and variance for participants has been estimated, it is still necessary to reduce the estimates to the single activity level by taking into account the number of occurrences of a particular activity event per participant. These data are taken directly from the statistical appendix of The Use of Time and are shown in Table 5.[33] The mean and variance for a single activity event are then estimated using the following equations:

$$T_e = \frac{T_p}{k}$$

$$S_e^2 = \frac{S_p^2}{k}$$

The mean and variance for a single activity event are represented by T_e and S_e^2 respectively. The mean and variance for all participants is the same as in previous equations, T_p and S_p^2. The number of occurrences is represented by k and obviously can never have a value of less than one. The results of this calculation are shown in the last two columns of Table 5.

TABLE 5

ESTIMATED ACTIVITY DURATION STATISTICS

Activity		Percentage Participating		Occurrences Per Participant	Activity Duration	
		Mean	Variance		Mean	Variance
1.	Main Job	439.5	14614.5	4.0	109.9	3653.6
2.	Second Job	204.2	15833.3	1.5	136.1	10555.5
3.	Work--Other	34.5	446.8	2.1	16.4	212.8
4.	Travel to Job	49.1	1367.3	2.4	20.5	569.7
5.	Marketing	40.7	1711.9	1.3	31.3	1316.8
6.	Shopping--Errands	58.7	3426.9	1.5	39.1	2284.6
7.	Cooking	72.3	2579.0	2.7	26.8	955.2
8.	Home Chores	95.9	2993.0	3.2	30.0	935.3
9.	Laundry	86.4	4309.2	2.3	37.6	1873.6
10.	Pets and Garden	27.0	733.3	1.6	16.9	458.3
11.	Other House	62.9	5758.5	1.7	37.0	3387.4
12.	Child Care	86.7	4283.0	3.4	25.5	1259.7
13.	Personal Travel	48.5	1362.8	3.1	15.6	439.6
14.	Leisure Travel	45.0	1259.2	2.5	18.0	503.7
15.	Eating	82.5	2526.9	2.9	28.4	871.3
16.	Personal Care	69.8	2032.2	3.0	23.3	677.4
17.	Study--Clubs	136.5	5948.8	1.9	71.8	3130.9
18.	Television	131.4	8824.9	1.9	69.2	4644.7
19.	Radio	43.9	2189.6	1.3	33.8	1684.3
20.	Newspapers	49.0	875.4	1.3	37.7	673.4
21.	Magazines	56.6	1046.9	1.2	47.2	872.4
22.	Books	74.6	2960.0	1.3	57.4	2276.9
23.	Movies	160.0	6250.0	1.0	160.0	6250.0
24.	Social Activity	115.4	10516.4	1.7	67.9	6186.1
25.	Conversation	44.7	1797.6	1.7	26.3	1057.4
26.	Active Sports	96.5	4062.5	1.0	96.5	4062.5
27.	Outdoors	77.4	5100.0	1.2	64.5	4250.0
28.	Entertainment	145.9	4414.3	1.1	132.6	4013.0
29.	Cultural Events	85.7	2050.0	1.1	77.9	1863.6
30.	Resting--Naps	104.3	2202.3	1.2	86.9	1835.3
31.	Other Leisure	75.9	3565.2	1.5	50.6	2376.8

It is now possible to estimate the two parameters for the Erlang probability distributions used to describe the characteristics of the activity duration distributions used by TIMMOD. The parameters α and β can be estimated using the expected value and variance equations for the gamma family described earlier in this chapter. The only modification required in using these equations is in holding the α parameter to an integer value. This is accomplished by rounding to the nearest whole number. The TIMMOD activity duration parameter estimates derived as a result of this procedure are shown in Table 6.

Missing from Tables 4 through 6 has been category 32, night sleep. The reason for this omission is that night sleep is handled in a different manner in the logic of TIMMOD. As described before in this chapter, TIMMOD calculates both a waking and retiring time. The time for night sleep is then calculated from these times. The probability distributions for both waking and retiring times are Erlang distributions. The parameters from the distributions were estimated from the sleep category in the activity selection matrix which is described in the next section of this chapter. Both waking time and retiring time are highly skewed in the direction of sleep. Waking time is then generated from a highly skewed distribution toward the early morning hours. Retiring time

TABLE 6

ESTIMATED TIMMOD ACTIVITY DURATION PARAMETERS

Activity	Activity Duration		Erland Parameters	
	Mean	Variance	α	β
1. Main Job	109.9	3653.6	19	5.78
2. Second Job	136.1	10555.5	15	9.07
3. Work--Other	16.4	212.8	5	3.28
4. Travel to Job	20.5	569.7	4	5.13
5. Marketing	31.3	1316.8	5	6.26
6. Shopping--Errands	39.1	2284.6	5	7.82
7. Cooking	26.8	955.2	5	5.36
8. Home Chores	30.0	935.3	5	6.00
9. Laundry	37.6	1873.6	5	7.52
10. Pets and Garden	16.9	458.3	3	5.63
11. Other House	37.0	3387.4	4	9.25
12. Child Care	25.5	1259.7	4	6.38
13. Personal Travel	15.6	439.6	3	5.20
14. Leisure Travel	18.0	503.7	3	6.00
15. Eating	28.4	871.3	5	5.68
16. Personal Care	23.3	677.4	4	5.83
17. Study--Clubs	71.8	3130.9	11	6.53
18. Television	69.2	4644.7	8	8.65
19. Radio	33.8	1684.3	5	6.76
20. Newspapers	37.7	673.4	9	4.19
21. Magazines	47.2	872.4	11	4.29
22. Books	57.4	2276.9	9	6.38
23. Movies	160.0	6250.0	26	6.15
24. Social Activity	67.9	6186.1	7	9.70
25. Conversation	26.3	1057.4	4	6.56
26. Active Sports	96.5	4062.5	15	6.43
27. Outdoors	64.5	4250.0	8	8.06
28. Entertainment	132.6	4013.0	24	5.53
29. Cultural Events	77.9	1863.6	16	4.87
30. Resting--Naps	86.9	1835.3	19	4.57
31. Other Leisure	50.6	2376.8	7	7.23

is the opposite, skewed in the direction of the early morning hours, but from the opposite direction. Again the distribution is highly skewed, so the distribution is inverted, and subtracted from the last hour available in the activity selection matrix. It should also be mentioned again that while the activity duration statistics are described here in minutes, they are converted to hours with decimal fractions to facilitate computation.

Activity Selection Statistics

Estimating activity selection statistics and applying them is the simulation model presents one of the biggest problems for TIMMOD. To begin with activity selection data are simply not available in an ideal form. Data reported in The Use of Time are not aggregated for the total sample, but rather reported in three separate sub-classifications, employed men, employed women, and housewives. The activity categories are aggregated from the thirty-seven categories described before to eight. The eight categories include work, home and family (includes marketing and shopping), travel, eating, semi-leisure, television, other media, and other leisure. Unfortunately the aggregations for these tables do not coincide with the subtotals shown in the reduced thirty-seven activity code structure. In addition, the data are reported as the percentage doing a particular activity group, often with only one significant digit.[34]

It is simply not possible to estimate the selection statistics with the same precision as the activity duration statistics. The main reason for this, as discussed before, is the limitation imposed by the size of the sample in the United States Time Use Survey. A much larger study would be required to provide stable activity selection statistics.

The estimation procedure for activity selection statistics begins with the combination of the three sub-classifications into a total sample estimate. This is accomplished by converting the percentages in each of the three sub-classifications to frequencies by multiplying the total frequency by the appropriate percentage. The frequencies are then summed to provide total sample activity selection frequency estimates. Frequencies have been percented and are shown in Table 7.

To expand the aggregate category estimates to the thirty-two TIMMOD activity categories a straight line estimation procedure is used based upon the overall time spent doing an activity. The activity selection matrix then becomes a twenty-hour by thirty-two activity categories matrix instead of a twenty-hour by eight activity category matrix. It is the expanded activity selection frequency matrix that is input to TIMMOD.

Because of the loss of precision due to the lack of significant digits in the original selection matrices

TABLE 7

PERCENTAGE ENGAGED IN DIFFERENT ACTIVITIES BY HOUR OF THE DAY

	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12pm
Work	1.5	2.7	12.4	28.2	41.4	42.6	41.6	24.0	37.1	41.6	40.6	33.7	18.1	11.4	9.2	9.8	8.5	6.2	5.2	3.5
Home & Family	0.7	2.7	15.7	23.6	24.9	26.8	27.7	24.9	23.9	24.9	21.8	25.8	28.2	25.5	23.7	19.0	13.0	6.8	3.8	3.1
Travel	0.2	1.4	7.5	8.2	4.2	3.7	4.3	7.6	5.3	6.1	9.1	10.8	14.5	9.2	7.4	6.2	6.5	5.3	4.1	1.8
Eating	0.4	2.0	7.8	7.6	5.9	3.3	4.7	26.1	11.4	3.8	3.6	2.5	11.1	23.7	12.6	5.4	2.5	1.8	2.2	0.7
Semi-Leisure	1.4	5.1	12.5	10.3	8.1	9.7	8.8	6.4	7.0	4.7	6.6	6.2	5.2	7.2	8.7	8.7	10.0	12.4	9.8	4.1
Tele-vision	0.0	0.3	0.8	0.8	1.0	2.2	2.1	2.2	3.6	4.7	4.8	4.7	5.3	7.0	15.1	22.1	27.1	25.9	14.8	7.0
Other Media	0.1	0.5	2.0	1.6	4.3	3.1	3.4	3.6	4.6	5.1	5.8	6.1	7.3	7.5	11.6	13.3	11.5	10.6	7.2	3.6
Other Leisure	0.3	0.6	0.8	1.6	2.9	4.7	5.5	5.8	7.8	8.6	8.1	9.2	9.2	8.0	10.9	15.0	18.1	14.1	8.2	3.3

and the rather imprecise matrix expansion procedure outlined above, it is necessary to apply a differential weighting factor to the activity selection matrix. The weighting factor is simply multiplied by all of the frequency estimates for all hours of a particular activity category. Additional distortion in the activity selection matrix is caused by the logical connection of the four work-related activities. The weighting procedure helps correct for this. It should be noted that the weighting procedure applies only to the activity selection statistics and not to the activity duration statistics. The weighting is necessary because the required data are simply not available.

Sample TIMMOD Output

The TIMMOD output described here is the baseline run which will be used as the control condition in the simulation experiments which will follow in Chapter VI. The run shown is also the source of the TIMMOD output discussed in the model validation section of this chapter.

TIMMOD output consists of a detailed printout including the number of occurrences, the average time spent, the variance for time spent, the percentage participating, and the time for those doing the activity for the thirty-two TIMMOD activity categories. This is shown in Table 8. An additional page of output is generated like the one for all participants for

TABLE 8

TIMMOD REPORT

		No. of Times	Time Spent	Variance	Percentage Doing	Time for Those Doing
1.	Main Job	2057.00	219.87	107499.49	49.50	444.18
2.	Second Job	43.00	5.78	868.26	4.20	137.60
3.	Work--Other	705.00	11.66	515.24	36.60	31.85
4.	Travel to Job	1089.00	22.53	1684.63	43.40	51.91
5.	Marketing	434.00	13.70	759.03	33.90	40.42
6.	Shopping--Errands	546.00	20.86	1422.87	41.80	49.90
7.	Cooking	1660.00	43.56	3665.94	73.80	59.02
8.	Home Chores	1988.00	58.79	6043.81	81.70	71.96
9.	Laundry	653.00	24.28	1778.22	46.20	52.55
10.	Pets and Garden	193.00	3.02	73.18	17.50	17.24
11.	Other House	680.00	25.29	1812.58	48.10	52.58
12.	Child Care	1405.00	36.35	2623.94	73.50	49.45
13.	Personal Travel	2070.00	31.91	1873.58	82.70	38.59
14.	Leisure Travel	1034.00	18.92	880.14	61.60	30.72
15.	Eating	2992.00	84.13	10837.95	91.20	92.25
16.	Personal Care	3039.00	70.49	7853.89	90.50	77.89
17.	Study--Clubs	414.00	28.85	3104.81	33.70	85.60
18.	Television	1451.00	88.50	14360.05	75.90	116.60
19.	Radio	108.00	3.14	112.64	10.30	30.46
20.	Newspapers	672.00	24.63	1710.69	47.50	51.85
21.	Magazines	167.00	7.40	419.24	15.70	47.11
22.	Books	93.00	5.06	352.45	8.90	56.84
23.	Movies	31.00	4.32	675.41	3.00	143.95
24.	Social Activity	1064.00	67.28	9559.97	64.60	104.15
25.	Conversation	668.00	16.52	807.35	47.80	34.57
26.	Active Sports	65.00	5.83	624.47	6.20	94.04
27.	Outdoors	39.00	2.28	149.78	3.90	58.46
28.	Entertainment	50.00	5.77	802.09	5.00	115.45
29.	Cultural Events	12.00	.90	73.67	1.20	74.68
30.	Resting--Naps	239.00	19.88	2085.44	21.50	92.44
31.	Other Leisure	428.00	20.30	1590.85	33.70	60.24
32.	Night Sleep	1000.00	448.22	.00	100.00	448.22

participants in the single category specified on the run parameter card. A sample of the TIMMOD report for all participants is shown in Table 8.

A TIMMOD summary report showing nine aggregate categories follows to simplify comparison with the experimental runs. Only the average time spent and the associated variance are shown in the summary. A sample of the TIMMOD summary is shown in Table 9.

Model Validation

As discussed in Chapter III, one of the most difficult problems with computer simulation is in validating the computer model once it is developed. Ideally, the multistage verification procedure recommended by Naylor et al. should be employed with TIMMOD. At the heart of the multistage verification procedure outlined in Chapter III is the model's ability to predict the behavior of the system under study. Not only must TIMMOD replicate the sample statistics described by the United States Time Use Survey, but it is also required to demonstrate the ability to adequately predict changes in the allocation of time based upon changes in the structural composition of the environment, such as the addition of television or BCN technology. To completely verify TIMMOD, it must demonstrate the ability to handle changes through either historical verification or accurate forecasting.

TABLE 9

TIMMOD SUMMARY

	For All Individuals	
	Time Spent	Variance
Work Related	259.83	110567.61
Shopping	34.56	2181.90
Home and Family	191.28	15997.67
Nonwork Travel	50.84	2753.73
Eating	84.13	10837.95
Semi-Leisure	99.34	10958.71
Television	88.50	14360.05
Other Mass Media	44.54	3270.43
Leisure	138.76	15693.62

Unfortunately the only validation possible with TIMMOD is in the model's ability to replicate the original data. It is not possible to verify the model through any historical exercise. TIMMOD might be verified by comparison with the 1935 time-budgets of Sorokin and Berger. It would seem simple to remove television from TIMMOD, which it is, but television is not the only difference between 1935 and 1965. For example, there have been tremendous changes in the transportation system indicated by improved highways and automobiles, not to mention the population growth, the move to the suburbs and shopping centers. The differences between 1935 and 1965 are simply too complex to describe in terms of changes in a few global activity categories. The same is true for a cross-national comparison.

The only validation that is possible for TIMMOD is the demonstration of the model's ability to reproduce the original data. Remember that TIMMOD has reduced the original data to a series of theoretical probability distributions and stochastic processes. If the model can replicate the original data, then there is some basis for an argument that the mathematical manipulations employed by the model are indeed valid.

Three important kinds of data generated by TIMMOD are considered here. First is the total number of occurrences of a particular activity for the number of cycles run using the model. In this case there are 1,000 cycles or simulated individuals. The original data number of occurrences per 1,000 individuals is calculated by multiplying the percentage participating in a particular activity by the number of occurrences per participant by 1,000. This comparison is shown in the first two columns of numbers in Table 10. A Pearson product-moment correlation is then calculated as an index of how well the simulation output matches the original data. In this case, r = .998. This high correlation should be expected, however, because of the weighting scheme employed on the activity selection statistics.

The most critical comparison is in the average time spent for the total sample. This measure is critical because it is the criterion variable to be used in the simulation experiments in Chapter VI. For the thirty-one mean times spent shown in the third and fourth columns of Table 10, the r = .999.

Another comparison is shown between the percentage participating in the original data, and the TIMMOD output. It should be mentioned that there is no logical connection between the various activity categories, except the work-related activities. For the percentages represented in the fifth and sixth columns of Table 10, the

TABLE 10

COMPARISON OF THE ORIGINAL DATA AND TIMMOD OUTPUT

Activity	Occurrences per 1000 Individuals		Overall Average Time Spent		Percentage Participation	
	Study	TIMMOD	Study	TIMMOD	Study	TIMMOD
1. Main Job	2048	2057	225.0	219.9	51.2	49.5
2. Second Job	36	43	4.9	5.8	2.4	4.2
3. Work--Other	699	705	11.5	11.7	33.3	36.6
4. Travel to Job	1217	1089	24.9	22.5	50.7	43.4
5. Marketing	447	434	14.0	13.7	34.4	33.9
6. Shopping-Errands	457	546	17.9	20.9	30.5	41.8
7. Cooking	1636	1660	43.8	43.6	60.6	73.8
8. Home Chores	1949	1988	58.4	58.8	60.9	81.7
9. Laundry	678	653	25.5	24.3	29.5	46.2
10. Pets and Garden	195	193	3.3	3.0	12.2	17.5
11. Other House	641	680	23.7	25.3	37.7	48.1
12. Child Care	1278	1405	32.6	36.4	37.6	73.5
13. Personal Travel	1969	2070	30.8	31.9	63.5	82.7
14. Leisure Travel	1073	1034	19.3	18.9	42.9	61.6
15. Eating	2857	2992	81.3	84.1	98.5	91.2
16. Personal Care	2946	3039	68.5	70.5	98.2	90.5
17. Study--Clubs	386	414	27.7	28.9	20.3	33.7
18. Television	1324	1451	91.6	88.5	69.7	75.9
19. Radio	107	108	3.6	3.1	8.2	10.3
20. Newspapers	632	672	23.8	24.6	48.6	47.5
21. Magazines	136	167	6.4	7.4	11.3	15.7
22. Books	92	93	5.3	5.1	7.1	8.9
23. Movies	20	31	3.2	4.3	2.0	3.0
24. Social Activity	928	1064	63.0	67.3	54.6	64.6
25. Conversation	700	668	18.4	16.5	41.2	47.8
26. Active Sports	57	65	5.5	5.8	5.7	6.2
27. Outdoors	37	39	2.4	2.3	3.1	3.9
28. Entertainment	41	50	5.4	5.8	3.7	5.0
29. Cultural Events	8	12	0.6	0.9	0.7	1.2
30. Resting--Naps	223	239	19.4	19.9	18.6	21.5
31. Other Leisure	386	428	19.5	20.3	25.7	33.7

r = .946. Needless to say all of these correlations (with n=31) are statistically significant.

While TIMMOD demonstrates validity with no experimental manipulation, any generalization of TIMMOD to experimental conditions should be done only with extreme caution. TIMMOD is limited by design to be a forecasting tool. It is intended only to estimate changes in the allocation of time based upon the manipulation of a few hypothetical environmental conditions, such as capability of BCN technology. It is not intended to become a general model for the human allocation of time. It is rather a forecasting tool allowing vicarious experimentation which is meant only to improve on the armchair scenario.

CHAPTER V--NOTES

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CHAPTER VI

THE SIMULATION EXPERIMENT

Experimental Paradigm

Experimentation with TIMMOD involves the manipulation of various probability distribution input parameters as independent variables with the concomitant variation in the allocation of time to various activity categories as the dependent variable. TIMMOD has been designed to provide a means of performing the vicarious experimentation discussed in Chapter III which may be appropriate to the assessment of the future impact of structural changes in the environment, such as new communication technology. The experiment outlined here is intended to provide insight into the future impact of BCN technology in a forecasting sense. The experiment is not addressed to specific hypotheses designed to test any marketing communication theory, but rather is suggested as a potential methodology for technological forecasting.

The experimental design employed in TIMMOD experiments is a simple before and after design comparing the allocation of time to various activity categories before and after experimental manipulation. A control condition is not necessary for reasons which will be discussed later. To simplify analysis the dependent variable is restricted to nine major categories of daily human activity as described in Chapter V. The major categories represented are work-related, shopping, home and family, nonwork travel, eating, semi-leisure, television, other mass media, and leisure. These nine categories represent an aggregation of the thirty-two categories described as the basic TIMMOD output to simplify the process of comparison. Work-related activities are an aggregation of main job, second job, at work other, and travel to job. Shopping consists of marketing, and shopping and errands. Home and family consists of cooking, home chores, laundry, pets and garden, other house and child care. Nonwork travel consists of personal travel, which includes travel for both marketing and shopping, and leisure travel. Eating category is the same. Semi-leisure includes personal care, and educational and organizational activity. Television category is the same. Other mass media includes radio, newspapers, magazines, books, and movies. Leisure activities include social activity, conversation as a primary activity, active sports, outdoor activities, entertainment and amusements, cultural events, resting and naps, and other leisure. Marketing is used here to describe shopping behavior for everyday nondurable goods, and is the term adopted by the United States Time Use Survey. Shopping in the original thirty-two categories means only shopping for durable consumer goods. In the aggregated shopping category, shopping means shopping for all consumer goods. Later in this chapter the distinction is made between the term "shopping," which refers to shopping for only durable consumer goods, and all shopping which combines both shopping for durable goods and marketing, or shopping for nondurable goods.

The dependent variable then becomes the allocation of minutes for the average employed adult to the nine activity categories. The independent variables center around the theoretical probability distribution described in Chapter V. Three parameters can be manipulated, the α parameter of the Erlang distribution which describes the number of minutes per interval or the skewness of the distribution, the β parameter which is the reciprocal of the average number of minutes per interval, and the weighting factor necessary to adjust the activity selection statistics discussed in Chapter V. Manipulating the α parameter would have the effect of making the activity duration distribution more or less skewed; manipulating the β parameter would have the effect of making the activity duration distribution being longer or shorter per unit interval, that is a longer or shorter average duration, and manipulating the weighting factor would have the effect of making the activity being selected either more or less often throughout the entire day.

The α parameter is not manipulated here, that is the shape of the activity duration distributions, because there is not sufficient evidence to build any case for this type of impact. The shapes of the activity distributions are then assumed to be the same. The weighting factor is also not manipulated, nor are any of the basic activity selection statistics, because the empirical base for these statistics is sufficiently weak to generate some lack of confidence in their ability to represent activity selection throughout the day. Because of this lack of confidence in the activity selection statistics, they are held constant.

The only parameter that has been manipulated as an independent variable is the β parameter which has the effect of lengthening and shortening the average duration of a particular activity event. All experimental manipulations using TIMMOD that are described here involve changes in the β parameter. It should be pointed out that the dependent variable is the result of the interaction of both the activity selection process and the activity duration process. The activity duration parameters describe only the duration of a single activity event, and the dependent variable describes the total time devoted to the particular activity category for the entire day. The specific treatment conditions and their translation to the β parameter are described later in this chapter.

Experimental and Statistical Problems in Using TIMMOD

Experimentation with computer simulation models, such as TIMMOD, involves making alterations either one at a time or in combinations in the model and noting the effects of these alterations. While at first glance this may appear relatively simple, statistical techniques which are traditionally applied in such experimental situations are no longer sufficient in the computer simulation situation. As Jacoby and Harrison point out, because computer simulation models possess special characteristics, it is often necessary to extend and modify the classical techniques.[1]

One of the first problems to be considered with most simulation models is the size of the model as discussed in Chapter III. Often computer simulation models grow to a very large size, with large numbers of both input and output variables making it extremely difficult to design manageable experiments using the model. However, this is not a critical problem with TIMMOD because the model is relatively small and simple by comparison to other simulation models. Essentially there are only three possible input variables and only one output variable. The output variable has been somewhat simplified by aggregating the original thirty-two categories to the nine categories described earlier in this chapter. While other output is possible, such as frequency of occurrence or participation rate, this analysis will concentrate on the total time allocated to various activities. While TIMMOD avoids most of the experimental problems caused by size, it can be argued that it looses isomorphism with the real world because of oversimplification. This problem will be discussed again later.

Jacoby and Harrison describe two special features of simulation models. The first is that a simulation model can be considered a closed system, and the second is that the random number sequences are strictly determined.[2] A closed system should contain no surprises or unknowns that might be expected in an open real-world system. In some circumstances this might be highly desirable experimentally, but in technological forecasting it is somewhat disturbing. Technology is commonly not viewed as a closed system because of the unexpected discovery such as the laser as described in Chapter III. However, a closed system limits the range of potential outcomes the system can have. The implications for

TIMMOD experiments involve assumptions that future activities will be selected in approximately the same manner as the present and that new factors which could play a role in the selection and duration of human activities would not be introduced.

The fact that random number sequences are strictly determined in computer simulation through the use of psuedo-random number generators as discussed in Chapter V makes the control of error variance possible. Error is known precisely. It is possible to manipulate error variance through the use of what Jacoby and Harrison term the Monte Carlo swindle.[3] If each experimental run is started with the same random number seed, then the sequences will be the same, generating an artificial correlation between the runs, which would have the effect of suppressing error variance. This obviously must be taken into account in designing simulation experiments. The TIMMOD experiments all begin with the same random number seed, thus taking advantage of the swindle. Fishman describes a related problem in generating time series from computer simulation experiments in terms of autocorrelation.[4] Because of the way random numbers are generated in computer simulation experiments, special consideration must be given to assumptions about statistical independence in experimental designs.

Another problem involves the stability of the activity selection and duration statistics over varying treatment conditions. This problem was discussed in Chapter IV. It is possible, as Tomlinson, Bullock, Dickens, Steadman, and Taylor point out, that time allocations may well change under different physical conditions within the environment, enough, to seriously limit the generalizability of a model based on a single set of time allocation data.[5] This caveat should be kept in mind when interpreting TIMMOD results.

Analysis Method

The basic comparison made in the TIMMOD experimental runs is the difference in time allocated to various activity categories in minutes. The comparison can be for any single activity category, such as consumption of mass media, or for all activity categories considered as a whole. The consideration of impact of BCN technology is in terms of apparent differences in this time allocation process. For example, if mass media had fewer minutes allocated to it for the entire day, then the implication would be that this is evidence of the impact the particular experimental treatment. In this case, experimental treatments are assumed to reasonable estimates of the result of the introduction of a BCN system.

The selection of a statistical technique to evaluate the differences in time allocation must begin with careful consideration of the time allocation data.

First is the problem already discussed of the before and after conditions not being statistically independent. This requires the use of a correlated measures design to reap the full benefits of the lack of independence. The use of an independent measures design would not take full advantage of the correlation, and thus would tend to overstate the error, making the procedure substantially less sensitive to any change in time allocation.

A second problem involves the manner in which time is allocated to the various activity categories. The waking and retiring times are determined independently of other activities which creates a standard length day to fill with various activities. Since the length of the day remains constant within sampling error tolerances, the sum of the days' activities always remains approximately the same regardless of any change in the distribution of activities. In other words, the activity categories are not independent. This presents a problem in applying traditional analysis of variance techniques because the difference across runs would always be the same, that is within the sampling error of the length of the day.

Development of statistical techniques to accommodate these problems is beyond the scope of this dissertation. Also, the intent is to demonstrate a methodology applicable to technological forecasting rather than to develop theory. The statistical analysis used in reference to differences in time allocations will be both simple and straightforward. The reason for employing any statistical measures at all is to provide a means of comparing the magnitude of differences across the various treatment conditions.

The difference between the average time allocated to a particular activity across the TIMMOD runs is shown as both the raw difference in minutes and as a standard score. The difference measure is standardized by using a simple comparison of different means equation as follows:

$$z = \frac{\bar{X}_b - \bar{X}_e}{\sqrt{S_b^2/1000 + S_e^2/1000}}$$

The mean time allocated to the particular activity without the experimental treatment is shown as X_b and the mean time allocated with the experimental treatment is X_e. The variances for the two groups are S_b^2 and S_e^2 respectively. Both groups are for 1,000 simulated individuals. This standard score then provides an index to evaluate the magnitude of the difference in time allocation in a given single category. The standard score estimate is conservative because it does not take into account any correlation between the two groups. The raw data are not readily available to calculate the necessary correlations from the TIMMOD runs. The use of the standard score here is intended only as an estimate of the magnitude of the difference between the two means as compared to what might be expected if chance were allowed to operate. It is not sufficient to describe the difference in terms of minutes alone. For example, a five-minute difference in shopping would indicate a greater degree of impact than would a five-minute difference in work-related activity. The reason is the relative magnitudes of the two activity categories, shopping requiring approximately 35 minutes per day and work-related activity accounting for nearly 260 minutes per day. The use of the standard scores here is limited to an index of difference between single pairs of activities. No attempt is made to ascribe statistical significance to any pair of activity categories.

While the standard scores can be used to describe the relative magnitude of difference between any set of single pairs of activity categories, it is not possible to describe the overall change for all the activity categories in this manner. Remembering that the sum of all of the activities for each experimental run is approximately the same, the comparison of interest is in the difference in shape of the two distributions. This suggests that minutes allocated to a particular activity category can be represented as a frequency and that a chi-square goodness-of-fit test can be applied. The use of the chi-square is suggested by Tomlinson et al.[6] McNemar describes the goodness-of-fit test as follows:

> If we wish to check on whether it is reasonable to believe that a given frequency distribution is, within the limits of chance sampling, of the normal or some other specified type, a frequency curve having the same basic constants as those computed from the observed frequency distribution can be fitted to the data.[7]

In this case, the no-treatment TIMMOD run becomes the theoretical probability distribution, and the experimental run becomes the observed frequency distribution being fitted. The goodness-of-fit statistic is calculated as follows:

$$\chi^2 = \Sigma \frac{(M_b - M_e)^2}{M_e}$$

The chi-square statistic is calculated from the number of minutes in each nontreatment activity category, M_b, and the number of minutes in each treatment activity category, M_e.

The goodness-of-fit chi-square is used in much the same way as the standard scores for each individual pair. This statistic serves as an index for the overall impact of the treatment condition across all of the activity categories. Again, statistical significance is not important.

Each TIMMOD run is based upon a simulated sample of 1,000 individuals. This sample size was selected primarily because of computational convenience. A larger sample size or number of cycles was not selected because it would contribute to misleading precision. The original United States Time Use Survey consisted of only 1,244 individuals. The sample selected was not smaller to minimize the problem of stochastic convergence discussed in Chapter III.

Experimental Conditions

The experimental conditions used to represent the features of a BCN system include transportation related to shopping, television viewing, and the time spent shopping. Each of the conditions are represented in terms of an increase or reduction of the β parameter of the appropriate Erlang distribution as previously discussed. The increases and decreases are represented as a low and a high value to simplify the analysis. Each low value is represented by a 10 percent increase or decrease in the β parameter while each high value is represented by a 50 percent increase or decrease.

Transportation

Transportation is the amount of time saved in making shopping trips as a result of having a BCN system. The reduction in the β parameter is in the personal transportation category, which includes other transportation such as travel to accompany children, travel necessary to purchase goods and services, and travel necessary for personal needs. Shopping and marketing related travel accounts for about 60 percent of all of the travel time in the category.[8] The β parameter for this distribution is 5.2 minutes and the α parameter is 3. In the nontreatment condition this provides a mean of 15.6 minutes and a variance of 81.1 minutes. In the low transportation treatment, representing a 10 percent reduction in the β parameter, the β parameter is decreased to 4.7 minutes providing a mean of 14.0 minutes and a variance of 65.7 minutes. In the high transportation treatment, the β parameter is decreased 50 percent providing a β parameter of 2.6 minutes and a mean personal travel time of 7.8 minutes and a variance of 20.2 minutes. Additional discussion of transportation as a key variable is assessing the impact of BCN technology is found in Chapter II.

Television

Television is the amount of time spent viewing television as a result of having the BCN system which would make viewing television more attractive because of the addition of interactive programming and a broader program offering. In this treatment, the β parameter is increased to represent an increase in viewing time to accommodate the more attractive program offering. In the low television treatment, there is a 10 percent increase in the β parameter. This increase is also discussed in Chapter II. In the nontreatment television Erlang distribution the β parameter is 8.7 minutes and the α parameter is 8. This provides a mean viewing time per television viewing event of 69.2 minutes and a variance of 598.6 minutes. In the low television treatment the β parameter is increased to 9.5 minutes providing a mean of 76.1 minutes and a variance of 723.5 minutes. In the high television treatment, which is a 50 percent increase in the β parameter, the β parameter is increased to 13.0 minutes, providing a mean of 103.8 minutes and a variance of 1,347.8 minutes.

Marketing

The marketing category includes the time allocated to shopping for nondurable or everyday goods on a per event basis. The β parameter for this Erlang distribution is 6.3 minutes and the α parameter is 5. The nontreatment β parameter for marketing is 31.3 minutes with a variance of 195.8 minutes. Following Bucklin's reasoning as described in Chapter II, as shopping becomes less expensive, the time allocated to it should increase since consumers have a tendency to shop more. The low marketing treatment, then, is represented by a 10 percent increase in the β parameter. The low marketing treatment β parameter is then 6.9 minutes providing a mean of 34.5 minutes and a variance of 237.2 minutes. The high marketing treatment is represented by a 50 percent increase in the β parameter giving a β parameter of 9.4 minutes. This provides a mean of 47.0 minutes and a variance of 440.9 minutes.

Shopping

The shopping category includes the time allocated to shopping for durable consumer goods, and is manipulated in much the same way as is the marketing category. The nontreatment shopping β parameter is 7.8 minutes and the α parameter is 5. This provides a nontreatment mean of 39.1 minutes and a variance of 305.6 minutes. The low shopping treatment, again represented by a 10 percent increase in the β parameter, yields a β parameter of 8.6 minutes. This provides a low shopping treatment mean of 43.0 minutes and a variance of 369.6 minutes. The high shopping treatment is a 50 percent increase in the β parameter, or a β parameter of 11.7 minutes. The high shopping treatment yields a pershopping event mean of 58.7 minutes and a variance of 688.0 minutes.

The all shopping treatment is represented by the combination of both the marketing and shopping treatments. Combinations of the various treatments are shown later in this chapter.

Limitations

There are a number of limitations which should be considered when interpreting the results of TIMMOD experiments. All the limitations are related either to simplifying assumptions made in the early stages of the model development, to the lack of a broad empirical data base, or to the very difficult problem of model verification.

TIMMOD assumes that the cable penetration will be 100 percent of all households, or at least all households represented in the United States Time Use Survey. No attempt was made to assess the varying impact due to different levels of penetration, which could be done by multiplying the penetration percentage by the results shown here. Also, it is assumed that a BCN subscriber would be demographically the same as the average American, which is probably not the case.

As discussed earlier, an adequate data base is not available to develop all of the probability distributions for all activities for each hour of the day. It is also not possible to develop the probability distributions for very many different population segments, such as employed men, employed women, housewives and children. A study which would provide adequate data would be extremely large and very expensive. The weakest data input into the model here is the activity selection statistics. This problem is discussed in more detail in Chapter V. Also, the activity duration statistics remain constant throughout the day.

Related to the data problem is the fact that there is no logical connection between various activity categories, except working. The reason for this is insufficient data to describe the logical connections. A priori "commonsense" logical connections were considered, but could easily create more distortion than no logical connections at all. The only relationship between activity categories is the time-of-day probability of occurrence. It is felt that odd combinations of activities which may result in a single individual's activity allocations will average out across a large number of individuals or cycles. No attempt is made to make any statement about a single individual's time allocations.

Better specification of treatment conditions is also desirable, but again there is simply not sufficient evidence to justify it. More than just the β parameter can be experimentally manipulated using TIMMOD. However, studies do not exist which describe shapes of distributions and time-of-day allocations of various activities under the conditions which can be anticipated with the application of BCN technology. No doubt the various demonstration projects using BCN technology will provide some of the necessary estimates.

Perhaps the most serious limitation of the TIMMOD experiments is the difficulty encountered in verifying the TIMMOD model itself. Since TIMMOD is intended as a technological forecasting tool, its ultimate verification is in its ability to forecast the future impact of BCN technology. This problem is discussed in both Chapter III and Chapter V, and a satisfactory solution to the problem is simply not possible.

Another problem, described by Fishman, is the lack of analytical models developed to handle the special circumstances involved in computer simulation experiments.[9] The statistical techniques necessary for the analysis of this kind of data will begin to appear in the literature.

Impact of Transportation

The results of the low and high transportation treatment experimental runs are shown in Table 11 and Table 12. In the low transportation condition, the overall reduction in nonwork travel is only 2.8 minutes. This means that while each trip is shorter, more trips are made. The average adult still spends 48.0 minutes per day engaging in nonwork travel. The overall impact of the low reduction in personal travel is virtually nil. The chi-square for the low transportation experiment is .87, which translates to a nonchance probability of less than .005 at eight degrees of freedom.

TABLE 11

TIMMOD RESULTS SHOWING LOW TRANSPORTATION IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	269.1	117590.9	9.3	.6157
Shopping	34.6	2181.9	33.2	2078.5	-1.4	-.6783
Home and Family	191.3	15997.7	189.8	15716.6	-1.5	-.2664
Nonwork Travel	50.8	2753.7	48.0	2442.8	-2.8	-1.2283
Eating	84.1	10838.0	84.1	10497.4	.0	.0000
Semi-Leisure	99.3	10958.7	99.3	10996.9	.0	.0000
Television	88.5	14360.0	84.6	12745.6	-3.9	-.7491
Mass Media	44.5	3270.4	46.8	3479.7	2.3	.8853
Leisure	138.8	15693.6	137.0	15627.3	-1.8	-.3216

TABLE 12

TIMMOD RESULTS SHOWING HIGH TRANSPORTATION IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	263.6	115253.0	3.8	.2529
Shopping	34.6	2181.9	31.9	1939.7	-2.7	-1.3299
Home and Family	191.3	15997.7	197.7	17009.7	6.4	1.1140
Nonwork Travel	50.8	2753.7	35.1	1341.0	-15.7	-7.7587
Eating	84.1	10838.0	84.9	10781.5	.8	.1721
Semi-Leisure	99.3	10958.7	98.8	10587.2	-.5	-.1077
Television	88.5	14360.0	85.5	13416.0	-3.0	-.5692
Mass Media	44.5	3270.4	43.3	3083.0	-1.2	-.4761
Leisure	138.8	15693.6	140.7	16063.1	1.9	.3372

The high transportation reduction is more interesting. In Table 12 there is a 15.7 minute reduction in nonwork travel to an average of 35.1 minutes. The resulting redistribution of time allocation indicates a 2.7 minute decrease in shopping, and a 6.4 minute increase in home and family activity. The overall chi-square is 5.50 which translates to a nonchance probability of slightly more than .25. While the overall impact of a reduction in shopping related transportation is by no means startling, there is a slight tendency to decrease shopping and increase home and family activity when the reduction in such transportation is relatively large. Overall, the impact of transportation is quite small when considered alone, and a large reduction in the travel time is necessary to observe even the smallest impact.

Impact of Television

The low and high increases in television viewing time considered in isolation are shown in Table 13 and Table 14. Again, the low condition resulted only in a small increase in overall television viewing time. An increase of only 1.9 minutes to a daily total of 90.4 minutes. The chi-square for the low television experiment shown in Table 13 was .43. This converts to a nonchance probability of less than .005. A small increase in the attractiveness of television by itself, then, has no impact on the overall allocation of time.

TABLE 13

TIMMOD RESULTS SHOWING LOW TELEVISION IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	260.1	110987.3	.3	.0202
Shopping	34.6	2181.9	32.9	1981.7	-1.7	-.8331
Home and Family	191.3	15997.7	188.1	15655.7	-3.2	-.5688
Nonwork Travel	50.8	2753.7	51.6	2845.0	.8	.3381
Eating	84.1	10838.0	80.2	9760.0	-3.9	-.8593
Semi-Leisure	99.3	10958.7	98.0	10687.6	-1.3	-.2794
Television	88.5	14360.0	90.4	15274.5	1.9	.3490
Mass Media	44.5	3270.4	44.1	3095.0	-.4	-.1585
Leisure	138.8	15693.6	141.1	15924.2	2.3	.4090

TABLE 14

TIMMOD RESULTS SHOWING HIGH TELEVISION IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	257.0	109870.6	-2.8	-.1886
Shopping	34.6	2181.9	33.0	2147.2	-1.6	-.7690
Home and Family	191.3	15997.7	182.0	15115.7	-9.3	-1.6673
Nonwork Travel	50.8	2753.7	48.7	2526.6	-2.1	-.9139
Eating	84.1	10838.0	79.7	9937.3	-4.4	-.9653
Semi-Leisure	99.3	10958.7	94.6	9910.8	-4.7	-1.0288
Television	88.5	14360.0	114.6	23194.2	26.1	4.2590
Mass Media	44.5	3270.4	39.6	2799.5	-4.9	-1.9889
Leisure	138.8	15693.6	128.1	14517.2	-10.7	-1.9467

The high television condition is a different situation. The high television treatment provides a 26.1 minute increase in television viewing time for a total of 114.6 minutes per day. The chi-square for the high television experiment is 10.12 which translates to a nonchance probability of nearly .75. The greatest impacts are in the reduction of 10.7 minutes from the leisure activity category, a reduction of 4.9 minutes in the other mass media category, and a reduction of 9.3 minutes in the home and family category. Also, there are small reductions in nonwork travel, eating and semi-leisure. The high television condition appears to have greater impact than does the high transportation condition. Television alone, then, appears to have the greatest impact on other mass media and leisure in general, with a somewhat smaller impact on home and family activity. Television time is a very important dimension of the overall impact of BCN technology.

Impact of Shopping

Because of the division of shopping into two categories, marketing or shopping for nondurable goods, and shopping for durable goods, the consideration of the impact of shopping is somewhat more complex. Marketing, shopping, and all shopping will be considered in turn.

The low marketing condition results in an overall decrease in marketing activity of .8 of a minute.

This is because a small increase in marketing event time apparently causes a reduction in the number of shopping events occurring during the day. The chi-square for the low marketing condition shown in Table 15 is 1.01, which translates to a nonchance probability of less than .005. While the low marketing condition seems to show a reduction of 6.4 minutes in eating, overall it has virtually no impact. The high marketing condition is very similar. As shown in Table 16, the high marketing condition increases the overall shopping time per day 5.1 minutes to a total of 39.7 minutes. The chi-square for the high marketing condition is 1.03, translating again to a nonchance probability of less than .005. An increase in the attractiveness of shopping for nondurable goods, then, appears to have little impact on the allocation of time to other activities during the day.

Low and high durable good shopping are shown in Table 17 and Table 18. The low shopping condition results in a 1.0 minutes decrease in overall shopping to 34.6 minutes per day. The chi-square for the low shopping condition is 1.20, which is also translated to a nonchance probability of less than .005. At least in the low shopping condition, like marketing or nondurable shopping, there is virtually no impact whatsoever.

In the high shopping condition, however, a very slight trend begins to emerge. The high shopping

TABLE 15

TIMMOD RESULTS SHOWING LOW MARKETING* IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	268.5	116074.7	8.7	.5779
Shopping	34.6	2181.9	33.8	2121.4	-.8	-.3856
Home and Family	191.3	15997.7	189.8	15646.5	-1.5	-.2667
Nonwork Travel	50.8	2753.7	51.4	2720.4	.6	.2564
Eating	84.1	10838.0	77.7	9275.6	-6.4	-1.4270
Semi-Leisure	99.3	10958.7	98.4	10672.0	-.9	-.1935
Television	88.5	14360.0	84.7	13487.2	-3.8	-.7201
Mass Media	44.5	3270.4	45.5	3287.1	1.0	.3905
Leisure	138.8	15693.6	139.0	15867.0	.2	.0356

*Shopping for nondurable consumer goods

TABLE 16

TIMMOD RESULTS SHOWING HIGH MARKETING* IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	256.1	109109.2	-3.7	-.2496
Shopping	34.6	2181.9	39.7	2793.2	5.1	2.2865
Home and Family	191.3	15997.7	190.2	16149.2	-1.1	-.1940
Nonwork Travel	50.8	2753.7	51.7	2727.3	.9	.3844
Eating	84.1	10838.0	82.8	10785.2	-1.3	-.2796
Semi-Leisure	99.3	10958.7	102.1	11640.9	2.8	.5890
Television	88.5	14360.0	86.3	13569.9	-2.2	-.4163
Mass Media	44.5	3270.4	43.6	3075.6	-.9	-.3573
Leisure	138.8	15693.6	136.6	15820.4	-2.2	-.3919

*Sho-ping for nondurable consumer goods

TABLE 17

TIMMOD RESULTS SHOWING LOW SHOPPING* IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	274.0	116720.3	14.2	.9419
Shopping	34.6	2181.9	33.6	2209.8	-1.0	-.4772
Home and Family	191.3	15997.7	189.1	15993.8	-2.2	-.3890
Nonwork Travel	50.8	2753.7	51.4	2731.7	.6	.2562
Eating	84.1	10838.0	80.6	10076.1	-3.5	-.7653
Semi-Leisure	99.3	10958.7	95.6	10258.2	-3.7	-.8033
Television	88.5	14360.0	86.2	13323.9	-2.3	-.4371
Mass Media	44.5	3270.4	45.5	3262.6	1.0	.3912
Leisure	138.8	15693.6	138.9	16093.2	.1	.0177

*Shopping for durable consumer goods

TABLE 18

TIMMOD RESULTS SHOWING HIGH SHOPPING* IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	249.2	105419.1	-10.6	-.7213
Shopping	34.6	2181.9	43.6	3751.1	9.0	3.6949
Home and Family	191.3	15997.7	191.5	15884.0	.2	.0354
Nonwork Travel	50.8	2753.7	50.4	2662.2	-.4	-.1719
Eating	84.1	10838.0	85.4	11193.2	1.3	.2770
Semi-Leisure	99.3	10958.7	94.7	10339.2	-4.6	-.9968
Television	88.5	14360.0	89.5	14218.6	1.0	.1871
Mass Media	44.5	3270.4	45.2	3273.8	.7	.2736
Leisure	138.8	15693.6	135.8	15102.6	-3.0	-.5406

*Shopping for durable consumer goods

condition demonstrates a 9.0 minute increase in shopping to 43.6 minutes per day. The chi-square for this experiment is 3.10 which translates to a nonchance probability of less than .10. There is a very slight indication that semi-leisure activity is the most vulnerable to this increase, with an overall reduction of 4.6 minutes. The balance of the time is spread across the other activity categories.

Combining the nondurable and durable shopping categories provides more interesting results. Shown in Table 19 are the combined results of low marketing and low shopping conditions. This results in a 1.1 minute reduction in shopping time, but interestingly a disturbance in the overall allocation of time showing a 5.0 minute reduction again in semi-leisure time. The chi-square for this experiment is 1.25, and again translates to a nonchance probability of less than .005. So far there has not been any demonstrable impact of the overall allocation of time as a result of any change in shopping behavior.

The combined high marketing and high shopping begin to show some impact as shown in Table 20. The high all shopping condition provides a 13.6 minute increase in shopping for a daily total of 48.2 minutes. The chi-square here is 9.79 which is converted to a nonchance probability of less than .75. The trend of

TABLE 19

TIMMOD RESULTS SHOWING LOW ALL SHOPPING IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	270.3	116047.3	10.5	.6975
Shopping	34.6	2181.9	35.7	2339.2	1.1	.5173
Home and Family	191.3	15997.7	187.2	15830.1	-4.1	-.7267
Nonwork Travel	50.8	2753.7	51.4	2675.2	.6	.2575
Eating	84.1	10838.0	81.4	10293.8	-2.7	-.5873
Semi-Leisure	99.3	10958.7	94.3	10339.2	-5.0	-1.0834
Television	88.5	14360.0	83.3	12910.6	-5.2	-.9958
Mass Media	44.5	3270.4	43.0	3087.8	-1.5	-.5949
Leisure	138.8	15693.6	138.3	16441.3	-.5	-.0882

TABLE 20

TIMMOD RESULTS SHOWING HIGH ALL SHOPPING IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	280.5	120767.0	20.7	1.3610
Shopping	34.6	2181.9	48.2	4371.9	13.6	5.3124
Home and Family	191.3	15997.7	186.2	15121.8	-5.1	-.9142
Nonwork Travel	50.8	2753.7	48.8	2587.3	-2.0	-.8654
Eating	84.1	10838.0	77.4	9475.1	-6.7	-1.4866
Semi-Leisure	99.3	10958.7	90.3	9263.4	-9.0	-2.0014
Television	88.5	14360.0	82.8	12780.2	-5.7	-1.0941
Mass Media	44.5	3270.4	42.9	3077.1	-1.6	-.6351
Leisure	138.8	15693.6	128.2	13909.4	-10.6	-1.9482

a reduction in semi-leisure activity becomes much stronger with a decrease of 9.0 minutes for a total of 90.3 minutes per day. Other changes indicated are a reduction in leisure activity of 10.6 minutes to a total of 128.2 minutes per day. Other changes appear in a reduction of eating time, a slight reduction in television time, and interestingly an increase in the amount of work-related time of 20.7 minutes to a total of 280.5 minutes. It appears that for shopping to show any impact, it is necessary for the activity event to be at least 50 percent longer. The primary impact at this high level seems to be in the reduction of semi-leisure and leisure activity, with an increase in the amount of work-related time.

Impact of Combined Experimental Conditions

The strategy for the combined experimental conditions is much the same as for the various experimental conditions considered singly. The combined experiments represent the most realistic view of the potential impact of BCN technology because it is most reasonable to assume that the technology would impact in all of the experimental areas. The first of the combined experiments is a combination of all of the low treatment conditions, representing an estimate of the minimal overall impact of BCN technology on marketing.

The combined low treatment conditions for transportation, television, and all shopping are shown in Table 21. The chi-square for this experiment is 1.26, again with a nonchance probability of less than .005. While there is a 1.6 minute increase in shopping to 36.0 minutes, and 2.2 minute decrease in nonwork travel, and a 2.9 minute increase in television viewing to 91.4 minutes, overall there is very little impact, except for a very slight reduction in semi-leisure activity of 6.8 minutes. At the low treatment level, the main effect seems to be to trade off decreases in nonwork travel time with increases in shopping and television time.

The combined high treatment conditions shown in Table 22 exhibit by far the greatest impact of any of the experiments. This experiment has a chi-square of 17.14, which translates to a nonchance probability of nearly .975. Shopping time is increased 11.3 minutes to a daily total of 45.9 minutes, television viewing time is increased 23.5 minutes for a daily total of 112.0 minutes, and nonwork travel is reduced a total of 18.3 minutes for a daily total of 32.5 minutes. It is extremely interesting to note that only slight changes exist in any other category, including a 5.9 minute reduction in leisure and a 5.5 minute reduction in home and family activity. It appears

TABLE 21

TIMMOD RESULTS SHOWING LOW TRANSPORTATION, LOW TELEVISION AND LOW ALL SHOPPING IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	268.0	114787.4	8.2	.5462
Shopping	34.6	2181.9	36.0	2454.7	1.4	.6502
Home and Family	191.3	15997.7	192.2	16064.2	.9	.1589
Nonwork Travel	50.8	2753.7	48.6	2496.3	-2.2	-.9602
Eating	84.1	10838.0	81.2	10087.1	-2.9	-.6340
Semi-Leisure	99.3	10958.7	92.5	9733.9	-6.8	-1.4949
Television	88.5	14360.0	91.4	15181.1	2.9	.5336
Mass Media	44.5	3279.4	43.7	3193.0	-.8	-.3147
Leisure	138.8	15693.6	134.0	15699.4	-4.8	-.8567

TABLE 22

TIMMOD RESULTS SHOWING HIGH TRANSPORTATION, HIGH TELEVISION AND HIGH ALL SHOPPING IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	261.1	112173.6	1.3	.0871
Shopping	34.6	2181.9	45.9	3976.5	11.3	4.5535
Home and Family	191.3	15997.7	185.8	15177.7	-5.5	-.9850
Nonwork Travel	50.8	2753.7	32.5	1174.0	-18.3	-9.2338
Eating	84.1	10838.0	81.1	10157.7	-3.0	-.6547
Semi-Leisure	99.3	10958.7	96.3	10614.7	-3.0	-.6459
Television	88.5	14360.0	112.0	23103.9	23.5	3.8394
Mass Media	44.5	3270.4	44.7	3380.7	.2	.0776
Leisure	138.8	15693.6	132.9	15302.9	-5.9	-1.0597

that if all of the effects suggested in Chapter II are included in the experiment, that there is a tendency for them to cancel each other out. The main impact of BCN technology then appears to be the trade off of nonwork travel for shopping and television viewing time, with little impact on other activities.

The single most important factor here seems to be television, which is partly due to the length of time, relatively speaking, and the time of day, primarily the evening hours, that the activity is engaged in. Table 23 and Table 24 show experiments holding the other treatments at the high level, transportation and all shopping, but manipulating the television condition. Table 23 shows an experiment with transportation and all shopping at the high level, and television at the nontreatment level. The chi-square for this experiment is 12.62, which converts to a nonchance probability of nearly .90. The increase in television viewing time drops dramatically, showing only a 2.2 minute increase. This experiment still shows large changes in shopping with a 15.8 minute increase, and in nonwork travel with a 15.7 minute decrease. The only other change of interest is a slight 5.2 minute decrease in leisure time.

Table 24 shows the same experiment as shown in Table 23, except television viewing time is reduced to the low treatment condition. The chi-square here is

TABLE 23

TIMMOD RESULTS SHOWING HIGH TRANSPORTATION, NO TELEVISION AND HIGH ALL SHOPPING IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	261.4	112494.0	1.6	.1071
Shopping	34.6	2181.9	50.4	4669.3	15.8	6.0363
Home and Family	191.3	15997.7	191.4	16193.8	.1	.0176
Nonwork Travel	50.8	2753.7	35.1	1357.2	-15.7	-7.7434
Eating	84.1	10838.0	80.9	9920.0	-3.2	-.7024
Semi-Leisure	99.3	10958.7	100.3	11236.8	1.0	.2123
Television	88.5	14360.0	90.7	14262.9	2.2	.4112
Mass Media	44.5	3270.4	45.7	3376.8	1.2	.4654
Leisure	138.8	15693.6	133.6	15118.5	-5.2	-.9368

TABLE 24

TIMMOD RESULTS SHOWING HIGH TRANSPORTATION, LOW TELEVISION AND HIGH ALL SHOPPING IMPACT

Activity Category	Control Run		Experimental Run		Difference	Z-score
	Time Spent	Variance	Time Spent	Variance		
Work Related	259.8	110567.6	273.5	117766.6	13.7	.9066
Shopping	34.6	2181.9	48.2	4179.4	13.6	5.3922
Home and Family	191.3	15997.7	187.0	15517.4	-4.3	-.7660
Nonwork Travel	50.8	2753.7	34.5	1291.4	-16.3	-8.1044
Eating	84.1	10838.0	80.0	9744.8	-4.1	-.9037
Semi-Leisure	99.3	10958.7	93.3	9970.8	-6.0	-1.3115
Television	88.5	14360.0	93.0	15896.4	4.5	.8181
Mass Media	44.5	3270.4	44.1	3281.3	-.4	-.1563
Leisure	138.8	15693.6	131.1	14419.7	-7.7	-1.4032

12.49, again nearly a .90 nonchance probability. This experiment shows results similar to the previous experiment with a 13.6 minute increase in shopping time, and 16.3 minute decrease in nonwork travel time. The other changes, although representing only slight trends, include reductions in semi-leisure activity of 6.0 minutes and leisure activity of 7.7 minutes. This indicates that while shopping and nonwork travel seem to balance each other, television has some capability to compete with other activities such as semi-leisure and leisure.

CHAPTER VI--NOTES

[1]Joan E. Jacoby and Stephen Harrison, "Multi-Variable Experimentation and Simulation Models," in Computer Simulation of Human Behavior, eds. J. Dutton and W. Starbuck (New York: John Wiley & Sons, 1971), p. 627.

[2]Ibid.

[3]Ibid.

[4]George S. Fishman, "Problems in the Statistical Analysis of Simulation Experiments: The Comparison of Means and the Length of Sample Records," in Computer Simulation of Human Behavior, eds. J. Dutton and W. Starbuck (New York: John Wiley & Sons, 1971), p. 659.

[5]Janet Tomlinson, N. Bullock, P. Dickens, P. Steadman, and E. Taylor, "A Model of Students' Daily Activity Patterns," Environment and Planning 5 (1973): 265.

[6]Ibid.

[7]Quinn McNemar, Psychological Statistics, 3rd ed. (New York: John Wiley & Sons, 1962), p. 220.

[8]Summary of United States Time Use Survey, Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, Michigan, 1966.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

The basic purpose of this dissertation is to assess the potential impact of broadband communication network technology on consumer marketing communication using a computer simulation model of human time allocations. BCN technology represents the combination of interactive cable television, computer and information processing technology, and communication satellites. The computer simulation model is used in an experimental mode to determine the impact of a hypothetical BCN system on the allocation of time to daily human activity. An analogy can be drawn in the assessment of television from a 1935 perspective in describing the approximately ninety minutes per day the average adult spends watching television in 1965. The goal is to estimate the impact of BCN technology on consumer marketing communication in a similar manner.

Marketing communication can be described in terms of a number of traditional marketing activities, including personal selling, advertising, packaging, point-of-purchase, direct mail, product sampling, publicity, and public relations. Each of the traditional marketing communication situations can be described in terms of communication situations, such as face-to-face in the situation of personal selling and mediated in the situation of advertising. Traditional consumer marketing communication activity can be organized in terms of a diagrammatic communication model with a source, message, channel, receiver, and feedback. A typology of marketing communication methods is suggested using the elements of such diagrammatic communication models. The first type of marketing communication is advertising and promotion which involves the passive consumption of messages by large numbers of consumer receivers through the mass media. This type of marketing communication for the most part does not involve any immediate feedback. The second type of marketing communication is retailing and selling which involves the active participation of both the source or seller and the consumer receiver. The communication situation is often face-to-face and usually implies transportation in order to accomplish the communication. The third type of marketing communication is marketing research which is described as the feedback mechanism from the consumer receiver to the marketer source. The problem with market research as a channel for feedback communication to marketers is that the communication is primarily controlled by the marketer which may eliminate some of the communication by focusing on material of interest to the marketer rather than of interest to the consumer.

The impact of BCN technology can be considered on each type of marketing communication. The impact of BCN technology on advertising would center around the addition of response capability and the addition of considerably more program material. The result would most likely be a more attractive program offering which would command a larger share of the viewer's daily time. Such an increase is indicated among traditional cable television subscribers.

The impact of BCN technology on retailing and selling involves two dimensions. The first dimension is the direct trade-off by consumers of communication time for transportation time that is implied in the offering of in-home shopping services. The second dimension is an increase in the amount of time shopping which may result from the reduction of the overall cost of shopping because of in-home shopping services. This latter impact is suggested by a study of shopping behavior where retail outlets are in geographic proximity and where they are not. Another important consideration of the impact of BCN technology is the suggestion that the better educated and more affluent consumer would make better use of the technology, possibly serving to widen the gap between the affluent and less affluent consumer. Evidence for this is apparent in the studies of convenience-oriented and in-home shoppers who tend to be both more affluent and better educated.

The impact of BCN technology on marketing research is more difficult to describe in terms of changes in the life-styles of consumers. BCN technology has the capacity to revolutionize data collection techniques in marketing research by using the response generated by an in-home terminal. While it can be argued that improved research techniques can result in better products and services for consumers, it is difficult to describe any direct effect on the life-styles of consumers.

The means of describing these impacts more fully is found in the methodology of technological forecasting. Technological forecasting is a relatively recent development among the tools of scientists and social planners. Technological forecasting originates primarily from the administration of military research and development and is divided into four methodological groups.

Dialectical methods are founded on the notion that both the future and past history are the result of a sequence of conflicts. The dialectical method itself is divided into two major approaches, the scenario and the Delphi Method. The scenario is perhaps the most common approach in technological forecasting and involves the expert consultation of a large volume of relevant material and literature, and then the application of intuitive judgment to describe the future. The scenario approach is much the same as that of the historian.

The Delphi Method is a unique method of eliciting and refining group judgment. The salient features of the method are anonymity, controlled feedback, and group response. The basic theory behind the Delphi Method is that with repeated measurement the range of expert responses will decrease and converge toward a midrange, and that the total group response will successively move toward the true or correct prediction.

Teleological methods explicitly recognize the interaction between the forecasts made and the future itself. In other words, the forecast itself plays a role in the determination of future events because the forecast becomes a goal. An example of a teleological forecast is the normative backcast or PERT analysis. In PERT, a sequential network of activities is constructed with time estimates for completion of the necessary activities.

Experimental and empirical methods are data oriented technological forecasting methods. The most common example of this method of technological forecasting is time series analysis. Time series analysis allows accumulated past experience to guide future expectation through the numerical representation of some set of empirical observations. The fundamental process involves the extrapolation of trends from a mathematically described series of historical points, such as linear regression.

Analytical methods involve the model oriented approach to technological forecasting. Analytical methods are generally theoretically based models trying to describe the interrelationships between variables. The distinction between empirical models and analytical models is often unclear, but is generally defined in terms of the starting point of the forecaster, whether it be in data or in a subjective view of some relationships that can be converted into a model. Analytical models themselves can be divided into two types, deterministic models which are generally mathematically sophisticated models which offer unique solutions, and stochastic models which make use of random processes and offer specific case results rather than unique solutions. Normally stochastic models are thought of in terms of computer simulation models.

The technological forecasting model developed here is a computer simulation model based upon human time allocation data. The model, named TIMMOD, allows for the vicarious experimentation with various aspects of human time allocation to daily activities, including hypothesized impacts of the result of the installation of a BCN system. Empirically the allocation of time to various activity categories is determined through the use of the time-budget study. The time-budget study, through the utilization of survey research techniques, measures the duration, frequency, and sequential order of human activities throughout the day. Generally the time-budget data are considered as dependent variables, with other socio-economic and motivational factors as the independent variables.

The empirical basis for TIMMOD is the United States Time Use Survey conducted by the Survey Research Center of the University of Michigan in 1965. The survey, consisting of a national sample drawn from forty-four metropolitan areas, was part of the Multinational Comparative Time-Budget Project. The study describes the average daily activity patterns for a sample of 1,244 employed adults.

The suggestion for the development of a simulation model based upon time-budget data, such as TIMMOD, comes from urban planning. This kind of simulation model would allow the study of changes in activity choice and structure in an urban environment without having to make changes in the physical world. Also suggested as an application of this kind of simulation model is the study of changes in location choice.

TIMMOD constructs time allocations to various daily activity categories from the selection of random deviates from two basic theoretical probability distributions. The first probability distribution describes the activity selection behavior of the hypothetical population, and the second probability distribution describes the duration of the selected activity. Both probability distributions are estimated from the data published in the United States Time Use Survey. The simulation begins with a single individual, who has a randomly selected waking time and retiring time. According to the appropriate hour of the day, an activity is selected, followed by the computation of the appropriate activity duration. The process continues until the entire day is exhausted. When the first individual has retired, then the process starts again with a new individual. The activity selection distribution consists of a matrix of cumulative percentages by activity category and hour of the day. Uniform random numbers are drawn and compared to this matrix to select a particular activity. The activity duration is determined from a family of Erlang distributions with different parameters to describe different shaped distributions for different activity categories.

While the total time allocated to various activity categories is the TIMMOD output, the input can be one of three possible variables. The first is an activity selection weight which can increase or decrease the probability of the selection of a particular activity. The second is the constant parameter associated with the Erlang distribution that determines the shape of the distribution from an extremely skewed exponential distribution to a nearly symmetrical normal distribution. The third is the other Erlang distribution parameter which determines the length of the activity for the particular distributional shape.

Experimentation with TIMMOD then involves the manipulation of some combination of these input parameters with the associated comparison of the output time allocations. The experiments described here involve only the manipulation of the length of the activity parameter. The other parameters are held constant.

The experimental conditions include the manipulation of the parameter to reduce the amount of time spent in personal travel, which represents the communication for transportation trade-off aspect of the application of a BCN system. Another experimental condition involves the lengthening of the time spent viewing television, accommodating the assumed increased attractiveness of the medium as a result of a BCN system. Also considered is the lengthening of the time spent shopping for both nondurable or everyday goods and the time spent shopping for durable consumer goods. The experimental conditions are appropriately named transportation trade-off, television viewing, marketing (or shopping) for nondurable goods, shopping for durable goods, and all shopping which encompasses all shopping behavior, i.e. for nondurable and durable goods. These experimental conditions are considered separately and in various combinations. Two levels of each experimental condition are considered to simplify the number of possible simulation runs. There is the low experimental treatment level which represents a 10 percent increase or decrease in the appropriate category, and the high level which represents a 50 percent increase or decrease in the appropriate category.

In general, each of the experimental conditions demonstrated almost no impact whatsoever with the low treatment level. Transportation trade-off time exhibited only a very slight trend to decrease time allocated to shopping activity and increase time in home and family activity when the personal transportation time spent per trip is decreased at the high treatment level.

The high television viewing time treatment has somewhat more impact than does the high transportation trade-off time treatment when considered alone. With the high level increase in television viewing time, there is a trend toward a decrease in other mass media time and in leisure time. There is also a small decrease in time allocated to home and family activity. Overall, television viewing time appears to be the single most important of the experimental treatment conditions considered.

Shopping represents a more complex situation. In the low and high level treatment conditions for non-durable goods shopping or marketing there is almost no change in the allocation of time to other activities. In the case of the high level durable goods shopping condition there is a very slight decrease in semi-leisure activity time which includes such activity as personal care, study, religious and organizational activities. Combining both nondurable and durable good shopping into an all shopping category, a stronger trend toward a decrease in semi-leisure time is apparent in the high level all shopping treatment condition. Other changes include a reduction in general leisure time, eating time, a slight reduction in television viewing time, and of most interest an increase in work-related time.

The combined experimental condition of low transportation trade-off time, low television viewing time, and low all shopping time shows almost no overall change in the time allocated to other activities. If there is any effect, it is a trade-off of the decrease in travel time with increases in shopping and television time. The same pattern, although far more apparent in the high level transportation trade-off time, high level television viewing time and high level all shopping time experimental conditions, is apparent. In this all high combined experimental condition all of the major changes appear in the manipulated activity categories, that is nonwork travel, television viewing time, and all shopping time. The effect of the three experimental conditions seem to be cancelling each other out. There are only a few other noticeable changes, including a small reduction in the time allocated to leisure activity and home and family activity.

Of the three experimental conditions, television viewing time appears to have the greatest impact. Holding transportation trade-off time and all shopping time experimental conditions at the high levels, and moving television viewing time from the low experimental level to no experimental manipulation at all demonstrates television's ability to compete with other activity such as semi-leisure and leisure activity which fill the void left by television time.

Conclusions

The conclusions which can be drawn from this research fall into two general categories. The first category deals with the application of the computer simulation model to the technological forecasting problem. The second category deals with estimation of the potential impact of BCN technology on consumer marketing communication. The methodological conclusions are considered first.

The TIMMOD experiments demonstrated impact on the human allocation of time to daily activity categories. The amount of time allocated to particular activity categories changed in response to an experimental manipulation of various treatment variables. Examining the relative changes caused by a particular experimental condition alone makes a case for the validity of TIMMOD. Reducing the amount of time spent in shopping related travel, for example, reduces the amount of time spent shopping and increases the amount of time spent in home and family activities. Increasing the amount of time spent viewing television reduces the amount of time spent participating in other mass media consumption and reduces the amount of overall leisure time. Increasing the amount of shopping time, that is making shopping a less expensive activity, reduces semi-leisure time, that is time spent in personal care, study, religious and organizational activity, and reduces overall leisure time. Most interesting, however, is that increasing shopping time also causes an increase in the amount of work-related time. Increased shopping time is the only experimental condition to demonstrate a concomitant increase in work-related activity. TIMMOD results appear to have validity in terms of the relative changes in time allocations. However, the magnitude of the changes may be another question.

It is interesting that TIMMOD does not demonstrate much change as a result of small or low level change in treatment conditions. For example, the low treatment of transportation trade-off time involves a 1.6 minute reduction in the average time spent in shopping related travel per trip, the low television treatment involves an increase of 6.9 minutes in viewing time per time watching television, the nondurable good shopping and durable good shopping trip times are increased 3.2 minutes and 3.9 minutes respectively. At these relatively low levels, TIMMOD demonstrates little or no change in the allocation of time to activity categories. At the high treatment levels, indicated by a 3.9 minute reduction in the average shopping trip, a 34.6 minute increase in the average time spent watching television, a 15.7 minute increase in the time spent shopping for non-durable goods per shopping trip, and a 19.6 minute increase in the time spent shopping for durable consumer goods, there is a marked impact on the time allocations. In other words, TIMMOD does not appear to be sensitive to small changes, requiring relatively large changes in the experimental conditions to make obvious the relative impact of the experimental condition. TIMMOD does, however, demonstrate the ability to show differing impacts by activity category not necessarily in proportion to the amount of time increased or decreased in the experimental condition. This is due largely to the fact that TIMMOD makes use of an activity selection probability matrix that changes with hour of the day, and allows for different shaped probability distributions to describe the various activity durations.

Overall, TIMMOD appears to have potential as a useful tool in future planning. Given the limitations set forth for the application of the model, the experiments conducted using TIMMOD were successful. Within the limits imposed by the available information sources, that is time-budget study data and data describing various aspects of the marketing communication process such as shopping, TIMMOD provided a successful demonstration of an analytical technological forecasting model.

Turning to conclusions about the potential impact of BCN technology on consumer marketing communications, it appears, relatively speaking, that BCN technology will not have an impact in the same order of magnitude that broadcast television has had. Assuming that BCN technology would result in a combination of benefits, including a reduction in the amount of time spent traveling, increased attractiveness of television due to increased program material diversity and the added interactive capability, and an overall reduction in the cost of shopping, there appears to be no impact on other human activities except on these three. In other words, decreases in shopping travel time are offset by increases in television viewing time and shopping time, with little apparent effect on any other activity category. Unlike television which was able to attract its average of ninety minutes per day in viewing time from other activities, BCN technology appears to have little effect on other categories. However, semi-leisure and leisure activities appear to be the most vulnerable if there is any impact on other activity categories at all.

BCN technology does not represent a new mass medium in the same sense as did television in 1935. Time allocated to the other mass media and other activity categories would remain much the same today. There is, however, the potential for the redistribution of time among the shopping related categories already discussed, including transportation trade-off time, television viewing time and shopping time. An obvious impact is the reduction of travel time in the range of five to thirty-five minutes per day depending upon the volume of shopping services available on a BCN system. This travel time reduction could be translated into dollar savings, which should become more important as the price of fuel increases. There is a physical distribution problem which has not been considered here, that is moving the physical goods from the retail outlet to the home. The majority of this physical distribution currently is accomplished by using the family automobile. A BCN shopping service implies some form of home delivery service, which presumably would be more efficient than the use of individual automobiles.

Another impact of a BCN system on shopping is the rather intangible result of increased shopping time. Consumers who spend more time shopping might be expected to become more expert in making purchase decisions, and thus become more efficient shoppers. A consumer presumably would examine more purchase alternatives. Add increased efficiency to the improved product and service offering resulting from improved marketing research techniques, and it is possible to forecast improvements in the quality of life as a result of the introduction of BCN system services. A more cynical view would be that the increased shopping time would result in consumers buying more products and services that they really do not need.

In the short run, BCN technology offers a reduction in shopping related travel, which most consumers probably do not consider particularly important, an intangible benefit of increased shopping time, and perhaps a more entertaining form of television. The consumer benefits of a BCN system may be seen as either relatively unimportant or obscure to the consumer. This lack of obvious consumer benefit may be a contributing factor in the retarded growth of BCN systems. This does not mean, however, that the benefits of such a system always will remain obscure or unimportant.

Suggestions for Future Research

It is a simple matter to suggest the further refinement of computer simulation experiment methodology, and point out that related statistical analysis techniques are needed to improve the ability of such methodology to serve as a technological forecasting methodology. However, this type of inquiry would provide only improvement in the efficiency of the computer simulation model, such as TIMMOD, without solving the fundamental problem of specifying experiment treatment conditions necessary to conduct vicarious experimentation. Similarly, it would be simple to point to the lack of time-budget data needed to develop more precise activity selection statistics and activity duration statistics for different hours of the day. Also, activity selection and duration statistics could be calculated for different sub-groups within the population, such as housewives and children. While such data would be of enormous value in refining TIMMOD, it would be very expensive to collect because it would require large national surveys. While such data would be useful, the resources necessary to obtain them could better be directed toward research that would solve the more immediate need of better description and specification of the experimental conditions.

As is apparent from the difficulty discussed throughout this work, the most critical need for additional research is in both the description of the fundamental processes that may be involved in the application of BCN technology, and in the demonstration of the capability of the BCN technology to modify these fundamental processes. Examples of such processes include seemingly elementary behavior such as shopping and viewing television. As mentioned before, there is a need to understand better in precise terms the role played by the family automobile in the physical distribution of goods. A personal automobile utilization study would be relatively easy to undertake using standard survey and diary techniques. The result of lower shopping costs also could be more precisely specified. For example, the relationship between reduced shopping costs and the time allocated to shopping needs description. Also the difference, if any, of product category on shopping time needs to be understood. In terms of its activity characteristics, shopping is not particularly well described in the research literature. A study of cable and noncable television subscribers should be considered to get a better understanding of the relationship between program offering and television participation. A demonstration project applying a two-way digital return system would be helpful in understanding the dimensions of any increased viewing time that may result.

In addition to studies which would better describe the fundamental processes involved, it is mandatory to develop commercially oriented demonstration projects of the BCN technology. Only through such studies will the parameters surrounding the impact of BCN technology on consumer marketing communication be understood with any degree of certainty. When these parameters are better understood and the range of treatment in terms of input conditions better specified to TIMMOD, then any number of experiments can be conducted to estimate the potential impact of BCN technology on the life-style of users of the system as indicated by the way they allocate their time.

APPENDIX

```
      PROGRAM TIMMOD(INPUT,OUTPUT)
      COMMON PARAM(34,5),ISEED,NRUNS,NTIMES,NPRMS,NSTOT
      COMMON NACT,AMATRIX(20,32),TMAT(3,32),TTOT(3,32),STOT(3,32)
      COMMON TSQ(32),SSQ(32),PMATRIX(20,32)
      NTEST=0
      CALL SETUP
  100 WAKE=4.0 + ERLNG(1)
      SLEEP=25.0 - ERLNG(2)
      TNOW=WAKE
      NIGHT=0
      IWORK=0
      WORK=UNFRM(0.0,100.0)
      IF (WORK.GT.51.0) IWORK=1
  110 ITIME=(TNOW - 4.0)
      IF (ITIME.GE.20) ITIME=20
      IF (ITIME.LT.1) ITIME=1
  115 RNUM=UNFRM(0.0,100.0)
      IF (RNUM.GT.AMATRIX(ITIME,31)) GO TO 115
      IF (IWORK.NE.1) GO TO 116
      IF (RNUM.LE.AMATRIX(ITIME,4)) GO TO 115
  116 DO 120 IT=1,NACT
      IF (RNUM.LE.AMATRIX(ITIME,IT)) GO TO 140
  120 CONTINUE
  140 IACT=IT + 2
      IF (IACT.GT.NPRMS) IACT=NPRMS
      DURATE=ERLNG(IACT)
      STEST=TNOW + DURATE
      IF (STEST.LE.SLEEP) GO TO 150
  195 DURATE=SLEEP-TNOW
      NIGHT=1
  150 TMAT(1,IT)=TMAT(1,IT) + 1.0
      TMAT(2,IT)=TMAT(2,IT) + DURATE
      IF (TMAT(3,IT).EQ.0.0) TMAT(3,IT)=1.0
      TNOW=TNOW + DURATE
  200 IF (NIGHT.EQ.1) GO TO 250
      GO TO 110
  250 DO 260 J=1,NACT
      DO 265 I=1,3
      TTOT(I,J)=TTOT(I,J) + TMAT(I,J)
  265 CONTINUE
      TSQ(J)=TSQ(J) + ((TMAT(2,J)*60.0)**2)
  260 CONTINUE
      IF (TMAT(3,NSTOT).EQ.1.0) GO TO 270
  300 NTEST=NTEST + 1
      DO 280 J=1,NACT
      DO 285 I=1,3
      TMAT(I,J)=0.0
  285 CONTINUE
  280 CONTINUE
      IF (NTEST.LT.NTIMES) GO TO 100
      GO TO 310
  270 DO 275 J=1,NACT
      DO 274 I=1,3
      STOT(I,J)=STOT(I,J) + TMAT(I,J)
  274 CONTINUE
      SSQ(J)=SSQ(J) + ((TMAT(2,J)*60.0)**2)
  275 CONTINUE
      GO TO 300
  310 CALL REPORT
      CALL EXIT
      END
```

SUBROUTINE SETUP

```
      SUBROUTINE SETUP
      COMMON PARAM(34,5),ISEED,NRUNS,NTIMES,NPRMS,NSTOT
      COMMON NACT,AMATRIX(20,32),TMAT(3,32),TTOT(3,32),STOT(3,32)
      COMMON TSQ(32),SSQ(32),PMATRIX(20,32)
      DIMENSION AINPUT(20,32),ASUM(20),PDATA(34,5)
      DIMENSION PPCT(32)
      DATA PPCT/32*0.0/
      DATA ASUM/20*0.0/
      XSUM=0.0
   10 FORMAT (6I10)
   11 FORMAT (5F10.4)
   12 FORMAT (10F6.1)
      READ 10,NRUNS,NTIMES,NPRMS,JSEED,NACT,NSTOT
      DO 20 I=1,NPRMS
      READ 11,(PDATA(I,K),K=1,5)
   20 CONTINUE
      DO 25 I=1,NPRMS
      PARAM(I,1)=PDATA(I,1)/60.0
      PARAM(I,2)=PDATA(I,2)/60.0
      PARAM(I,3)=PDATA(I,3)/60.0
      PARAM(I,4)=PDATA (I,4)
      PARAM(I,5)=PDATA(I,5)
   25 CONTINUE
      DO 30 I=1,NACT
      READ 12,(AINPUT(K,I),K=1,10)
      READ 12,(AINPUT(K,I),K=11,20)
   30 CONTINUE
      DO 31 K=1,NACT
      DO 32 J=1,20
      AINPUT(J,K)=AINPUT(J,K)*PARAM(K+2,5)
   32 CONTINUE
   31 CONTINUE
      DO 35 I=1,20
      DO 34 J=1,NACT
      ASUM(I)=ASUM(I) + AINPUT(I,J)
   34 CONTINUE
   35 CONTINUE
      DO 38 I=1,20
      DO 37 J=1,NACT
      PMATRIX(I,J)=AINPUT(I,J)/ASUM(T)
      AMATRIX(I,J)=PMATRIX(I,J)
      PMATRIX(I,J)=PMATRIX(I,J)*100.0
      XSUM=XSUM + AMATRIX(I,J)
      AMATRIX(I,J)=XSUM*100.0
   37 CONTINUE
      XSUM=0.0
   38 CONTINUE
      DO 39 I=1,20
      AMATRIX(I,NACT+1)=100.0
   39 CONTINUE
      DO 40 I=1,3
      DO 45 J=1,NACT
      TMAT(I,J)=0.0
      TTOT(I,J)=0.0
      STOT(I,J)=0.0
   45 CONTINUE
   40 CONTINUE
      DO 70 I=1,32
      TSQ(I)=0.0
      SSQ(I)=0.0
   70 CONTINUE
      DO 80 I=1,NACT
      DO 85 J=1,20
      PPCT(I)=PPCT(I)+PMATRIX(J,T)
   85 CONTINUE
      PPCT(I)=PPCT(I)/20.0
   80 CONTINUE
  200 FORMAT (1H1,*SETUP INPUT PARAMETERS*/)
  201 FORMAT (1X,*NRUNS=*,I5,5X,*NTIMES=*,I5,5X,*NPRMS=*,I5,5X,*NACT=*,
     -I5,5X,*NSTOT=*,I5,5X,*ISEED=*,I5/)
  202 FORMAT (1X,*ACTIVITY DURATION PROBABILITY DISTRIBUTION*,
     -* PARAMETERS*/)
  203 FORMAT (11X,I2,5X,5(F10.4,5X))
  204 FORMAT (1H1,1X,*ACTIVITY SELECTION MATRIX*/)
  205 FORMAT (1H1,1X,*ACTIVITY SELECTION INPUT MATRIX*/)
  206 FORMAT (1H1,*NONCUMULATIVE ACTIVITY SLECTION MATRIX*/)
  207 FORMAT (1X/,1X,8(I2,*--*,F6.2,5X))
  300 FORMAT (6X,I2,5X,10(F6.1,4X))
```

SUBROUTINE SETUP

```
  301 FORMAT (6X,I2,5X,10(F7.3,3X))
  302 FORMAT (1X)
      PRINT 200
      PRINT 201,NRUNS,NTIMES,NPRMS,NACT,NSTOT,JSEED
      PRINT 202
      DO 50 I=1,NPRMS
      PRINT 203,I,(PARAM(I,J),J=1,5)
   50 CONTINUE
      PRINT 205
      DO 55 I=1,NACT
      PRINT 300,I,(AINPUT(J,I),J=1,10)
   55 CONTINUE
      PRINT 302
      DO 56 I=1,NACT
      PRINT 300,I,(AINPUT(J,I),J=11,20)
   56 CONTINUE
      PRINT 204
      DO 60 I=1,NACT
      PRINT 301,I,(AMATRIX(J,I),J=1,10)
   60 CONTINUE
      PRINT 302
      DO 61 I=1,NACT
      PRINT 301,I,(AMATRIX(J,I),J=11,20)
   61 CONTINUE
      PRINT 206
      DO 100 I=1,NACT
      PRINT 301,I,(PMATRIX(J,I),J=1,10)
  100 CONTINUE
      PRINT 302
      DO 110 I=1,NACT
      PRINT 301,I,(PMATRIX(J,I),J=11,20)
  110 CONTINUE
      PRINT 207,(K,PPCT(K),K=1,8)
      PRINT 207,(K,PPCT(K),K=9,16)
      PRINT 207,(K,PPCT(K),K=17,24)
      PRINT 207,(K,PPCT(K),K=25,31)
      ISEED=JSEED
      RETURN
      END
```

SUBROUTINE REPORT

```
      SUBROUTINE REPORT
      COMMON PARAM(34,5),ISEED,NRUNS,NTIMES,NPRMS,NSTOT
      COMMON NACT,AMATRIX(20,32),TMAT(3,32),TTOT(3,32),STOT(3,32)
      COMMON TSQ(32),SSQ(32),PMATRIX(20,32)
      DIMENSION TVAR(32),SVAR(32)
      DIMENSION TPCT(32),SPCT(32),TPD(32),SPD(32),LABEL(2,32)
      DIMENSION STAB(9,4),SLAB(2,9)
      DATA TVAR,SVAR/64*0.0/
      DATA STAB/36*0.0/
      DATA ((SLAB(I,J),I=1,2),J=1,9)/10H WORK RELA,10HTED          ,
     110H SHOPPING ,10H          ,10H HOME AND ,10HFAMILY    ,
     210H NON-WORK ,10HTRAVEL    ,10H EATING   ,10H          ,
     310H SEMI-LEIS,10HURE       ,10H TELEVISIO,10HN         ,
     410H OTHER MAS,10HS MEDIA   ,10H LEISURE  ,10H          /
      DATA((LABEL(I,J),I=1,2),J=1,32)/10H1. MAIN JO,10HB              ,
     110H2. SECOND ,10HJOB       ,10H3. WORK-OT,10HHER       ,
     210H4. TRAVEL ,10HTO JOB    ,10H5. MARKETI,10HNG        ,
     310H6. SHOPPIN,10HG-ERRANDS ,10H7. COOKING,10H          ,
     410H8. HOME CH,10HORES      ,10H9. LAUNDRY,10H          ,
     510H10. PETS A,10HND GARDEN ,10H11. OTHER ,10HHOUSE     ,
     610H12. CHILD ,10HCARE      ,10H13. PERSON,10HAL TRAVEL ,
     710H14. LEISUR,10HE TRAVEL  ,10H15. EATING,10H          ,
     810H16. PERSON,10HAL CARE   ,10H17. STUDY-,10HCLUBS     ,
     910H18. TELEVI,10HSION      ,10H19. RADIO ,10H          ,
     -10H20. NEWSPA,10HPERS      ,10H21. MAGAZI,10HNES       ,
     110H22. BOOKS ,10H          ,10H23. MOVIES,10H          ,
     210H24. SOCIAL,10H ACTIVITY ,10H25. CONVER,10HSATION    ,
     310H26. ACTIVE,10H SPORTS   ,10H27. OUTDOO,10HRS        ,
     410H28. ENTERT,10HAINMENT   ,10H29. CULTUR,10HAL EVENTS ,
     510H30. RESTIN,10HG-NAPS    ,10H31. OTHER ,10HLEISURE   ,
     610H32. NIGHT ,10HSLEEP     /
  500 FORMAT (1X,*REPORT*)
  200 FORMAT (1H1,* TIMMOD REPORT*/)
  201 FORMAT (1X,* FOR*,I10,*  STMULATED INDIVIDUALS*//)
  202 FORMAT (31X,*NO. OF*,4X,*TIME *,16X,*PERCENT*,3X,*TIME FOR*)
  203 FORMAT (31X,*TIMES*,5X,*SPENT*,6X,*VARIANCE*,2X,*DOING*,5X,
     - *THOSE DOING*//)
  204 FORMAT (6X,2A10,5X,2(F7.2,3X),F9.2,1X,2(F7.2,3X)/)
  400 FORMAT (1X,*TOTAL FOR ALL PARTICIPANTS*//)
  401 FORMAT (1H1,*PARTICIPANTS IN NSTOT CATEGORY NUMBER*,I5//)
  402 FORMAT (1H1,* TIMMOD SUMMARY*/)
  403 FORMAT (31X,* FOR ALL INDIVDUALS*,11X,*FOR NSTOT CATEGORY*,I5/)
  404 FORMAT (31X,2(*TIME SPENT*,5X,*VARIANCE*,7X)/)
  405 FORMAT (4X,2A10,4(F15.2)/)
      DO 50 I=1,32
      TPCT(I)=0.0
      SPCT(I)=0.0
      TPD(I)=0.0
      SPD(I)=0.0
   50 CONTINUE
      X1=X2=0.0
      XTIMES=NTIMES
      STIMES=STOT(3,NSTOT)
      IF (STIMES.EQ.0.0) STIMES=XTIMES
      DO 100 I=1,NACT
      X1=X1+TTOT(2,I)
      X2=X2+STOT(2,I)
  100 CONTINUE
      TTOT(2,NACT+1)=(24.0*XTIMES)-X1
      STOT(2,NACT+1)=(24.0*STIMES)-X2
      TTOT(1,NACT+1)=XTIMES
      TTOT(3,NACT+1)=XTIMES
      STOT(1,NACT+1)=STIMES
      STOT(3,NACT+1)=STIMES
      DO 110 I=1,32
      TPCT(I)=TTOT(3,I)/XTIMES
      SPCT(I)=STOT(3,I)/STIMES
  110 CONTINUE
      DO 111 I=1,32
      IF (TPCT(I).EQ.0.0) GO TO 111
      TPD(I)=TTOT(2,I)/TPCT(I)
      IF (SPCT(I).EQ.0.0) GO TO 111
      SPD(I)=STOT(2,I)/SPCT(I)
  111 CONTINUE
      DO 112 I=1,32
      TPCT(I)=TPCT(I)*100.0
      SPCT(I)=SPCT(I)*100.0
      TTOT(2,I)=TTOT(2,I)*60.0/XTIMES
```

SUBROUTINE REPORT

```
      STOT(2,I)=STOT(2,I)*60.0/STIMES
      TPD(I)=TPD(I)*60.0/XTIMES
      SPD(I)=SPD(I)*60.0/STIMES
  112 CONTINUE
      DO 113 I=1,NACT
      IF (TTOT(2,I).EQ.0.0) GO TO 113
      TVAR(I)=((XTIMES*TSQ(I))-(TTOT(2,I)**2))/(XTIMES**2)
      IF (STOT(2,I).EQ.0.0) GO TO 113
      SVAR(I)=((STIMES*SSQ(I))-(STOT(2,I)**2))/(STIMES**2)
  113 CONTINUE
      PRINT 200
      PRINT 201,NTIMES
      PRINT 400
      PRINT 202
      PRINT 203
      DO 120 I=1,32
      PRINT 204,(LABEL(K,I),K=1,2),TTOT(1,I),TTOT(2,I),TVAR(I),TPCT(I),
     - TPD(I)
  120 CONTINUE
      PRINT 401,NSTOT
      PRINT 202
      PRINT 203
      DO 130 I=1,32
      PRINT 204,(LABEL(K,I),K=1,2),STOT(1,I),STOT(2,I),SVAR(I),SPCT(I),
     - SPD(I)
  130 CONTINUE
      DO 140 K=1,4
      STAB(1,1)=STAB(1,1) + TTOT(2,K)
      STAB(1,2)=STAB(1,2) + TVAR(K)
      STAB(1,3)=STAB(1,3) + STOT(2,K)
      STAB(1,4)=STAB(1,4) + SVAR(K)
  140 CONTINUE
      DO 141 K=5,6
      STAB(2,1)=STAB(2,1) + TTOT(2,K)
      STAB(2,2)=STAB(2,2) + TVAR(K)
      STAB(2,3)=STAB(2,3) + STOT(2,K)
      STAB(2,4)=STAB(2,4) + SVAR(K)
  141 CONTINUE
      DO 142 K=7,12
      STAB(3,1)=STAB(3,1) + TTOT(2,K)
      STAB(3,2)=STAB(3,2) + TVAR(K)
      STAB(3,3)=STAB(3,3) + STOT(2,K)
      STAB(3,4)=STAB(3,4) + SVAR(K)
  142 CONTINUE
      DO 143 K=13,14
      STAB(4,1)=STAB(4,1) + TTOT(2,K)
      STAB(4,2)=STAB(4,2) + TVAR(K)
      STAB(4,3)=STAB(4,3) + STOT(2,K)
      STAB(4,4)=STAB(4,4) + SVAR(K)
  143 CONTINUE
      STAB(5,1)=TTOT(2,15)
      STAB(5,2)=TVAR(15)
      STAB(5,3)=STOT(2,15)
      STAB(5,4)=SVAR(15)
      DO 144 K=16,17
      STAB(6,1)=STAB(6,1) + TTOT(2,K)
      STAB(6,2)=STAB(6,2) + TVAR(K)
      STAB(6,3)=STAB(6,3) + STOT(2,K)
      STAB(6,4)=STAB(6,4) + SVAR(K)
  144 CONTINUE
      STAB(7,1)=TTOT(2,18)
      STAB(7,2)=TVAR(18)
      STAB(7,3)=STOT(2,18)
      STAB(7,4)=SVAR(18)
      DO 145 K=19,23
      STAB(8,1)=STAB(8,1) + TTOT(2,K)
      STAB(8,2)=STAB(8,2) + TVAR(K)
      STAB(8,3)=STAB(8,3) + STOT(2,K)
      STAB(8,4)=STAB(8,4) + SVAR(K)
  145 CONTINUE
      DO 146 K=24,31
      STAB(9,1)=STAB(9,1) + TTOT(2,K)
      STAB(9,2)=STAB(9,2) + TVAR(K)
      STAB(9,3)=STAB(9,3) + STOT(2,K)
      STAB(9,4)=STAB(9,4) + SVAR(K)
  146 CONTINUE
      PRINT 402
      PRINT 403,NSTOT
```



```
      PRINT 404
      DO 150 K=1,9
      PRINT 405,(SLAB(I,K),I=1,2),(STAB(K,I),I=1,4)
  150 CONTINUE
      RETURN
      END
```

SUBROUTINE REPORT

```
      STOT(2,I)=STOT(2,I)*60.0/STIMES
      TPD(I)=TPD(I)*60.0/XTIMES
      SPD(I)=SPD(I)*60.0/STIMES
  112 CONTINUE
      DO 113 I=1,NACT
      IF (TTOT(2,I).EQ.0.0) GO TO 113
      TVAR(I)=((XTIMES*TSQ(I))-(TTOT(2,I)**2))/(XTIMES**2)
      IF (STOT(2,I).EQ.0.0) GO TO 113
      SVAR(I)=((STIMES*SSQ(I))-(STOT(2,I)**2))/(STIMES**2)
  113 CONTINUE
      PRINT 200
      PRINT 201,NTIMES
      PRINT 400
      PRINT 202
      PRINT 203
      DO 120 I=1,32
      PRINT 204,(LABEL(K,I),K=1,2),TTOT(1,I),TTOT(2,I),TVAR(I),TPCT(I),
     - TPD(I)
  120 CONTINUE
      PRINT 401,NSTOT
      PRINT 202
      PRINT 203
      DO 130 I=1,32
      PRINT 204,(LABEL(K,I),K=1,2),STOT(1,I),STOT(2,I),SVAR(I),SPCT(I),
     - SPD(I)
  130 CONTINUE
      DO 140 K=1,4
      STAB(1,1)=STAB(1,1) + TTOT(2,K)
      STAB(1,2)=STAB(1,2) + TVAR(K)
      STAB(1,3)=STAB(1,3) + STOT(2,K)
      STAB(1,4)=STAB(1,4) + SVAR(K)
  140 CONTINUE
      DO 141 K=5,6
      STAB(2,1)=STAB(2,1) + TTOT(2,K)
      STAB(2,2)=STAB(2,2) + TVAR(K)
      STAB(2,3)=STAB(2,3) + STOT(2,K)
      STAB(2,4)=STAB(2,4) + SVAR(K)
  141 CONTINUE
      DO 142 K=7,12
      STAB(3,1)=STAB(3,1) + TTOT(2,K)
      STAB(3,2)=STAB(3,2) + TVAR(K)
      STAB(3,3)=STAB(3,3) + STOT(2,K)
      STAB(3,4)=STAB(3,4) + SVAR(K)
  142 CONTINUE
      DO 143 K=13,14
      STAB(4,1)=STAB(4,1) + TTOT(2,K)
      STAB(4,2)=STAB(4,2) + TVAR(K)
      STAB(4,3)=STAB(4,3) + STOT(2,K)
      STAB(4,4)=STAB(4,4) + SVAR(K)
  143 CONTINUE
      STAB(5,1)=TTOT(2,15)
      STAB(5,2)=TVAR(15)
      STAB(5,3)=STOT(2,15)
      STAB(5,4)=SVAR(15)
      DO 144 K=16,17
      STAB(6,1)=STAB(6,1) + TTOT(2,K)
      STAB(6,2)=STAB(6,2) + TVAR(K)
      STAB(6,3)=STAB(6,3) + STOT(2,K)
      STAB(6,4)=STAB(6,4) + SVAR(K)
  144 CONTINUE
      STAB(7,1)=TTOT(2,18)
      STAB(7,2)=TVAR(18)
      STAB(7,3)=STOT(2,18)
      STAB(7,4)=SVAR(18)
      DO 145 K=19,23
      STAB(8,1)=STAB(8,1) + TTOT(2,K)
      STAB(8,2)=STAB(8,2) + TVAR(K)
      STAB(8,3)=STAB(8,3) + STOT(2,K)
      STAB(8,4)=STAB(8,4) + SVAR(K)
  145 CONTINUE
      DO 146 K=24,31
      STAB(9,1)=STAB(9,1) + TTOT(2,K)
      STAB(9,2)=STAB(9,2) + TVAR(K)
      STAB(9,3)=STAB(9,3) + STOT(2,K)
      STAB(9,4)=STAB(9,4) + SVAR(K)
  146 CONTINUE
      PRINT 402
      PRINT 403,NSTOT
```

SUBROUTINE REPORT

```
      PRINT 404
      DO 150 K=1,9
      PRINT 405,(SLAB(I,K),I=1,2),(STAB(K,I),I=1,4)
  150 CONTINUE
      RETURN
      END
```

FUNCTION DRAND

```
      FUNCTION DRAND(ISEED)
      DRAND=RANF(ISEED)
      RETURN
      END
```

FUNCTION UNFRM

```
      FUNCTION UNFRM(A,B)
      COMMON PARAM(34,5),ISEED,NRUNS,NTIMES,NPRMS,NSTOT
      COMMON NACT,AMATRIX(20,32),TMAT(3,32),TTOT(3,32),STOT(3,32)
      COMMON TSQ(32),SSQ(32),PMATRIX(20,32)
      RNUM=DRAND(ISEED)
      UNFRM=A+(B-A)*RNUM
      RETURN
      END
```

FUNCTION ERLNG

```
      FUNCTION ERLNG(J)
      COMMON PARAM(34,5),ISEED,NRUNS,NTIMES,NPRMS,NSTOT
      COMMON NACT,AMATRIX(20,32),TMAT(3,32),TTOT(3,32),STOT(3,32)
      COMMON TSQ(32),SSQ(32),PMATRIX(20,32)
      K=PARAM(J,4)
      IF (K-1) 8,10,10
    8 PRINT 20,J
   20 FORMAT (/16H K=0 FOR ERLNG   ,I7)
      RETURN
   10 R=1
      DO 2 I=1,K
      RNUM=DRAND(ISEED)
    2 R=R*RNUM
      ERLNG=-PARAM(J,1)*ALOG(R)
      IF (ERLNG - PARAM(J,2)) 7,5,6
    7 ERLNG = PARAM(J,2)
    5 RETURN
    6 IF (ERLNG - PARAM(J,3)) 5,5,4
    4 ERLNG = PARAM(J,3)
      RETURN
      END
```

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