System Dynamics based Modeling of the Global System of Mobile Communication (GSM) Market: A Comparative Study of Germany, Hong Kong and Vietnam

Claudia Loebbecke* and Tung Bui**

*University of Cologne
Wilh.-Backhaus-Str. 23
50931 Koeln, Germany
e-mail: claudia.loebbecke@uni-koeln.de

**The U.S. Naval Postgraduate School
Department on Systems Management
Monterey, Ca 93943-5000, USA
Tel.: 001-408-656-2630
e-mail: tbui@nps.navy.mil

March 1997

System Dynamics based Modeling of the Global System of Mobile Communication (GSM) Market: A Comparative Study of Germany, Hong Kong and Vietnam

ABSTRACT

The mobile telecommunication industry is becoming one of the most important industries in the world. In the spectrum of wireless communication technologies, digital cellular telecommunication using the Global System of Mobile Communication (GSM) standard has enjoyed the fastest growth rate. GSM has been adopted in more than one hundred countries, with spectacular national growths regardless of the country‘s economic and social structures. As GSM waves continue to cover the world, this paper attempts to examine GSM driving factors at the national levels and to extrapolate global trends. For this purpose, this paper uses system dynamics as a well-proven approach to capture the dynamics and the complexity of the GSM demand. Three national markets are studied: Germany, Hong Kong and Vietnam.

Keywords: Telecommunications, Global System of Mobile Communication (GSM), Long-range Planning, Demand Forecasting, System Dynamics

1. INTRODUCTION

Given the lack of historical data in highly dynamic, innovative telecommunication markets, simulation based approaches offer a valid option to capture the complexity and inherent feedback structures of such environments and to support telecom managers in their strategic decisions. In a simulation, all assumptions are required to be stated explicitly. They are translated into a set of equations to show the interdependence of the various assumptions and the resulting consequences. However, simulations can only show the consequences of the assumptions entered by the model users, regardless if these assumptions are correct or false (Forrester, 1972).

We propose Systems Dynamics (SD) as an approach to model the Global System for Mobile Communication (GSM) market. System dynamics has been successfully applied in a broad variety of economic and social settings, including market simulations. Due to its main characteristics and strengths, it has proven to be especially appropriate for modeling

- decision environments driven by a high degree of dynamic feedback loops between intervening forces (Homer, 1987; Morecroft, 1986; Bailles and Olivier 1993), and
- situations with a large amount of implicit expertise (usually at the best available in form of 'soft information' on the practitioners' side).

SD based systems provide a framework for understanding the dynamic interrelationships between system elements (Senge, 1990). Hence, system dynamics should be applied as a tool conducive to support thinking, group discussion and learning in management teams (Morecroft, 1992).

The system dynamics approach to design and implement simulation models emphasizes intuitive understanding of the mathematics underlying dynamic systems (Radzicki, 1993) by providing an integrated dynamic modelling approach that combines quantitative and qualitative aspects to simulate a phenomenon over time (Forrester, 1971; Lyneis, 1980). The methodology allows the representation of feedback loops and their underlying assumptions. Finally, system dynamics permits the integration of information cues that foster cognitive feedback (Bui, Loebbecke, 1996).

The main objective of this paper is to build a model capturing and forecasting national demand for GSM and to illustrate aggregated simulation results covering the number of GSM users, volume of GSM usage, and seven demand factors as driving forces for three example countries, Germany, Hong Kong, and Vietnam.

2. STUDY BACKGROUND

In 1982, the Global System of Mobile communication (GSM[1]) was established to initiate European telecommunication standards [EC, 1990]. Since 1992, it has been swiftly adopted by nations around the globe. Its growth is even faster than the already explosive telecommunication market which reached US$ 535 billion in 1992 [ITU, 1994]. GSM is already the largest segment within mobile communications and should further increase its share until the year 2005, as it becomes the most important telecommunication sector [Eutelis, 1993; Kirby,1992; Kruse, 1992].

As a new technology that provides obvious and immediate benefits for all users, regardless of the characteristics of the country of their residence, one can safely argue, at least for the short term, that GSM demand will continue to grow [EC, 1993].

---

1 The GSM acronym originally stood for the French expression 'Groupe Speciale Mobile'.

In the long run, however, the pattern of growth must certainly change as the forces that drive it change. Will GSM demand continue to grow indefinitely? What are the economic, social and technological factors that drive GSM national demands? How do these factors behave across countries with different economic, social and geographic profiles? Answers to these questions would help researchers in the telecommunications field, government or regulatory policy makers, handset manufacturers, network operators, and service providers to better understand the long term demand trends of a mobile telecommunication product that is enjoying unparallel success at a global level – any change in GSM consumption would significantly affect the entire telecommunication industry.

If one assumes that the extent of GSM impacts is a function of the quantity of GSM use, a first step toward a better understanding of its international impacts is to observe its demand characteristics for the various nations that have adopted GSM as a key technology for mobile communications. It would be ideal, indeed, to study the GSM demand for all countries and perform a thorough comparison across nations. To say the least, this task, although not impossible, is challenging and requires an enormous effort. We propose a more manageable approach by choosing three countries of distinct social, economic, and cultural profiles – Germany, Hong Kong and Vietnam. Each of the three is representative of a number of other countries to the extent that, if one understands their GSM demand behavior, one may gain enough insight to comprehend the dynamics of the GSM demand of the majority of the countries in the world. Despite differences, these countries share common characteristics with regard to GSM use. The entry of GSM is relatively new, with less than a year lag between the three countries (i.e., 1992 for Germany, 1993 for Hong Kong and 1994 for Vietnam), and the adoption has been overwhelming.

3. A SIMULATION MODEL FOR GSM NATIONAL DEMAND

3.1. THE DRIVING FACTORS OF GSM NATIONAL DEMAND

Based on previous research, we have identified seven factors that are known to influence the GSM demand [Altobelli, 1991; Loebbecke, 1995; Veldkamp 1994]. These are described below with the names of the variables used in the demand model given in parentheses for presentation and discussion purposes.

Cost: Invariably, the cost of GSM usage is the single most important demand driver [Eutelis, 1993; Romtech Systems Dynamics, 1993; Ross, 1992]. It is broken down into the monthly fee and the usage cost per minute. Telecommunication

analysts unanimously predict that the GSM usage fee will continue to decline due to economies of scale, maturation of the networks, and increased competition resulting from market liberalization. In the short term, however, the oligopolistic market structure allows network operators and service providers to apply a skimming price policy, that is, it permits them to keep the price high as long as there is a demand to absorb production and service capacity [Ross, 1992]. The cost element is represented by two variables: cost per minute (*MIN_COST*) and monthly cost (*MON_COST*).

Product quality (*PROD-QUAL*): Product quality remains a prevalent factor in affecting consumer‘s demand of information technology [Bacon, 1992]. It consists of network quality, service quality, and terminal or handset quality. GSM is still in the growth phase; as for any new product, its quality is a critical factor for consumers [von Weizsaecker, 1987]. Product quality probably helps boost the demand for GSM during the introductory phase, but the boost is likely to weaken over time. From a different perspective, it has been observed that GSM consumers are willing to tolerate poor quality service during the introduction of GSM. But their tolerance for low quality fades as the industry matures.

Information about GSM (*INFO_VOL*): This factor is known in the marketing literature as communicability of product benefits [Rogers, 1993]. It relates to the extent of which information about GSM promotes or harms GSM demand. Promotion of new telecommunication technology is often supported by advertising (including public relations), general publications introducing the new product and word-of-mouth [Kotler, 1977, Phillips, 1992]. As expected, advertising should convey a positive GSM image. However, this is not necessarily true for independent publications and information by word-of-mouth.

GSM impacts on private lifestyle (*PRIV_LIFE*): Reachability also affects GSM users in their private lives. GSM brings convenience to social interaction; at the same time, in certain situations, it can become disruptive and annoying [Dordick, 1989; Halal, 1992; Katz, 1988; Pelton, 1989]. This argument extends to the context of personal safety in which GSM can provide a person in need with a way to get immediate help [Keller, 1981]. Another factor that is often debated in the marketing literature is the social status consumers attach to the purchase and use of a new product; this in turn affects their decision whether or not to subscribe to GSM service [Gutenberg, 1973, Trommsdorff, 1975].

GSM impacts on business practices (*BUS_LIFE*): The impact of cellular communication on business practices is in essence similar to that of the phone. GSM use is expected to have stronger and more positive externalities than other

telecommunication services. As the capacity of the network increases with new GSM subscribers, the utility for a GSM user will increase as he is able to communicate with more people [Bental, 1990]. With instant reachability, the most visible effect would be on continuous adaptation of work processes [Kerler, 1993; Malone, Rockart, 1993; Stoeber, 1992]. The new technology is expected to help foster business opportunities [Deloitte Touche Tohmatsu International, 1993], but to a much lesser extent when compared to the introduction of the wired phone. Conversely, the need to manage the adoption of new technology will discourage the diffusion of GSM use [Jagoda, Villepin, 1993]. This phenomenon will remain true until the organization is ready to integrate GSM into its business processes [Hiltz, Turoff, 1993; Porter, Millar, 1985].

Alternative technologies (*ALT_TECHNOS*): GSM is a newcomer in the communications industry. Depending on the country considered, it will be mainly supplemented by foreseeable integrated products and services (Germany) or it will have to compete with alternative fixed and mobile infrastructures (Hong Kong and Vietnam). Consequently, the GSM demand partially depends on the development of alternative technologies [Jarrat, Coates, 1990]. While GSM brings more flexibility, wired communication is cheaper and still more reliable, particularly for large data transfer.

Availability of a GSM evaluation framework (*EVAL_POSSI*): The cost-effectiveness of a new technology is difficult to estimate [Bacon, 1992]. Hence, an evaluation framework justifying the acquisition and use of GSM is often replaced by the user's belief in the benefits that he expects a new technology to bring to the organization. It is argued, however, that if a solid evaluation framework existed, this evaluation would be used to support argument for the GSM adoption [Jussawalla and Braunstein, 1990]. This factor is particularly relevant to corporate users.

Table 1 provides a synopsis of the seven demand factors and their relationships with variables affecting them, either positively or negatively. Although there is no assurance that the seven factors can entirely explain the behavior of the GSM national demand, the literature review as well as interviews with senior experts in the GSM market support these drivers as most significant.

The factors considered here show a unique departure from a large and traditional body of literature that models telecommunication demand according to price and income elasticities of telecommunication services [e.g., De Fontenay et al., 1990; Steele, 1994]. Our research rationale also differs from the marketing model that uses the adoption and diffusion approach to study the advent and use of new technology [Rogers, 1990]. Finally, research in the mobile phone sector has

exclusively been focused on the market supply [Eutelis,1993; BIS, 1993]. These studies focus on GSM growth factors such as size of country and population, GNP, liberalization policy, year of GSM introduction, etc., thus ignoring the fundamental aspects specific to market demand. Also, they offer little or no information about factors related to the comparability across political and cultural boundaries [Callmer, 1992; Lange, 1992; Ross, 1992].

- Cost Factor
  - Minute Cost
    - Users per population
    - Exogenous minute cost policy
  - Monthly Cost
    - Users per population
    - Exogenous monthly cost policy
- Product Quality Factor
  - Network quality
    - Time (+),
    - Users per population (+,-)
  - Service Quality
    - Time (+),
    - Users per population (+,-)
  - Terminal Quality
    - Time (+),
    - Users per population (+,-)
- Information Volume Factor
  - Advertising
    - Users per population (+,-)
    - Exogenous Advertising Policy (+)
  - Word of mouth
    - Users per population (+,-)
  - Publications
    - Users per population (+,-)
- Private Life Factor
  - Private reachability (+)
    - Private Mobility (+)
    - Desire to be left in peace (-)
  - Security needs (+)
    - Elderly-sick people per population (+)
    - Other security demand (+)
    - Rate of security needs decrease (-)
  - Image (+)
    - Users per population (+,-)
    - Rate of image saturation due to time (-)
- Business Life Factor
  - Work reorganisation (+)
    - Users per population (+)
    - Rate of work reorganisation decrease (-)
  - Business Process Redesign (BPR) (+)
    - Users per population (+)
    - Rate of BPR decrease (-)
  - New business opportunities (NBO) (+)
    - Users per population (+)
    - Rate of NBO decrease (-)
  - Efforts to manage GSM (-)
    - Necessity to manage GSM (+)
      - Users per Population
    - Difficulty to manage GSM (+)
    - Rate of facilitation to manage GSM (-)
- Alternative Technologies Factor
  - Fixed and mobile network integration (+)
  - Existing mobile technologies (+)
  - Future mobile technologies (+)
  - Fixed network stand alone quality (-)
    - Number of fixed network providers (+)
- Evaluation Possibility Factor
  - Research Level (+)
    - Users per population (+)
  - Cost benefit investment level (+)
    - Users per population (+)

Table 1: GSM Demand Factors and their Driving Variables

3.2. MODELING THE GSM MARKET USING SYSTEM DYNAMICS[2]

System dynamics provides a modeling framework for understanding the dynamic interrelationships between the elements of a system rather than the static snapshots of elements [Forrester, 1970; Roberts, 1978; Senge, 1990]. System dynamics was chosen for the GSM model for the following specific reasons. First, system dynamics has proven its effectiveness for long-range planning and simulation of modeling problems driven by a high degree of feedback loops between intervening forces [Baills, Olivier 1993; Homer, 1987; Morecroft, 1986]. It has been successfully applied to a broad variety of economic and social settings. As a new industry, there is not sufficient historical data about GSM to build a robust forecasting model using econometrics techniques. Even if data were available, such modeling would be difficult. In contrast, system dynamics offers an integrated dynamic modeling approach which combines quantitative and qualitative aspects to simulate a phenomenon over time, making it particularly relevant to our study [Forrester 1971; Lyneis, 1980].

Second, system dynamics emphasizes intuitive understanding of the mathematics underlying dynamic systems [Radzicki, 1993]. The behavior of a system is regarded as a consequence of the developments of integrated causal relations. Accordingly, while time can also be an independent variable for some factors, it is mainly a component of the simulation results. From that perspective, models are considered a tool conducive to support thinking, group discussion and learning in management teams [Morecroft, 1992].

We propose a simulation model for the GSM market demand covering a ten year period, i.e., until the year 2005. A ten-year time frame is typical in long range planning. Our primary goal is to analyze the dynamics of the factors that drive users over time; our secondary objective is to estimate the total number of GSM users. The model seeks to integrate and capture the seven factors described above to derive the number of users (*USERS*) over time on a quarterly basis. Central to our model is the dynamic feedback that is represented in a simple circular structure. The demand factors influence *USERS*, and in turn, *USERS* drives the factors.

As a modeling approach, system dynamics uses integration to compute the values of the variables ('stocks') of a problem based on inflows and outflows. To calculate the number of GSM users, the model distinguishes four categories of users: non-users, small users, average users, and large users measured by the number of

---

2 For an extensive description of the modeling approach, see Loebbecke, Bui, 1996; Loebbecke, 1996.

GSM minutes per month and seeks to compute the switchrates (or flowrates) among these groups.[3] As the market is divided into four user groups, twelve different switch rates are possible. Each group is connected with each other group for incoming as well as for outgoing switches (Figure 1). Rate '3', for example, describes how many non-users become average users in a certain amount of time. Rate '2', '4', '6' , refer to the number of people who switch back to the group of non-users.

For each of the switchrates, the seven interdependent demand factors described in this paper lead to an integrated change rate. The change rate describes a percentage of persons changing from one group to another. It is than translated into the switchrate describing the actual 'switch' of people. The switchrates is calculated by multiplying the number of non-users with the change rate. Since the seven main demand factors are considered interdependent, their values are multiplied to receive the change rate (see Figure 2).

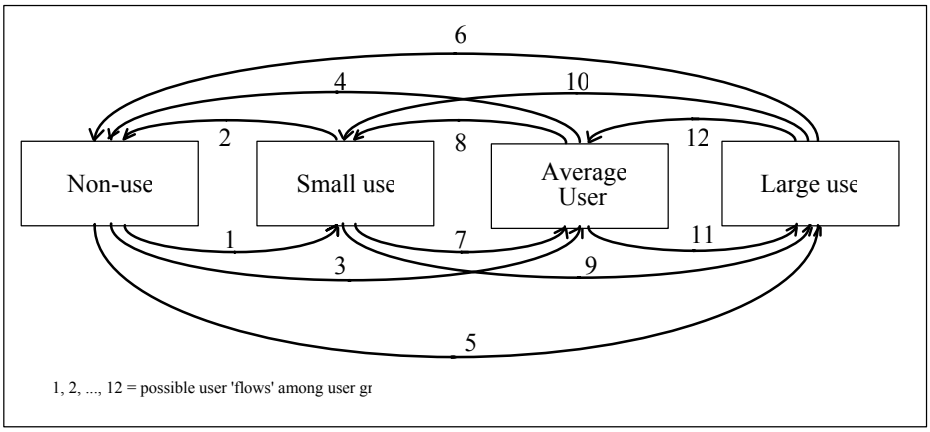

Figure 1: Four User Groups

[3] The allocation of GSM subscribers into the four groups depends on their average monthly GSM-usage expressed in minutes per card. It is important to note that the model considers actual GSM end-users and not decision makers, i.e., a single person (who uses his GSM handset extensively counts as one large user, while a company with 1,000 cards for its employees who use the network represents 1,000 small users. For example, for a company that decides to subscribe to GSM for its operations (say, 1,000 cards).

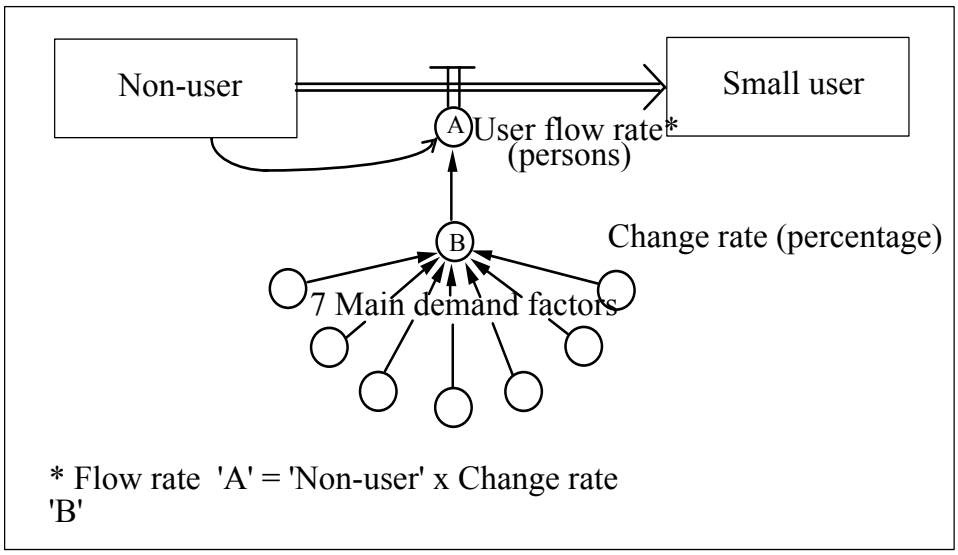

Figure 2: Modeling Principle

Out of the seven demand drivers described in this paper, 'Cost' is considered the most important one. The cost factor is expressed as the percentage of people changing from one user group to another. When the cost factor reaches the minimum 'zero' this means that nobody changes from one group to another. The cost factor's maximum value of 1 (=100%) would mean that in one calculation interval, everybody leaves their original user group and moves to the new one. The other six main demand factors are modeled as dimensionless parameters, their values fluctuate around '1'. Values less than '1' mean that the factor reduces the impact of the cost factor, while values greater than '1' mean that the factor increases the effect of the cost factor. Once the basic factors for the demand drivers have been determined, their weights are adjusted according to their importance regarding each specific change rate.

The goal of the proposed model is not to make precise quantitative predictions, but rather to uncover the trends of key interelated decisions. System dynamics has proved to be appropriate for this purpose (Veit, 1978).

3.3. DATA COLLECTION AND MODEL VALIDATION

The three models were developed based on statistical analyses and field interviews with local experts in telecommunication, wireless communication, and GSM. High-ranking senior executives of network operators, service providers, and industry analysts were interviewed at length in Germany, Hong Kong, and Vietnam. They provided historical data and marketing study results for all seven factors. More important, they provided opinions with regard to the trends of telecommunication policies, pricing, and market demand in general based on market surveys, discussions among GSM industry specialists, and personal experience. The extraction of

knowledge and expertise followed a two step approach (see Figure 3) that was supported by congnitive user feedback provided by the system during the modeling process [Bui, Loebbecke, 1996]. The models were built to depict future trends and their dynamic interrelationships. Many iterations, based on the experts' feedback and about 50% with direct involvement of experts in the modeling process, were required until the revised models provide satisfactory answers to experts.

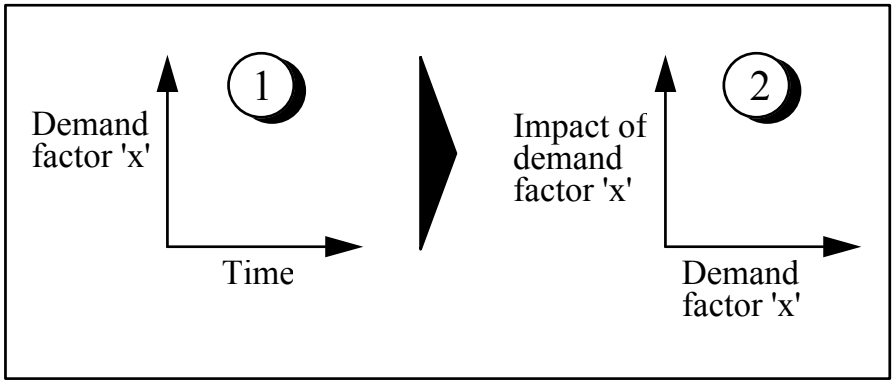

Figure 3 Two step data gathering and modelling

The purpose of system dynamics modeling is to uncover the behavior of the factors being studied. As such, model validation is the most tedious task, but has not been recognized by system dynamics specialists to be indispensible. Using the sensitivity analysis features built in the system dynamics software, we tested the structural validity as well as the face validity of the three models. Structural validity refers to the goodness of fit (the system prediciton fell within the 5% range of actual values). The actual data (i.e., 1992-96 for Germany, 1993-1996 for Hong Kong, and 1994-1996 for Vietnam) were compared to the estimated switch rates and number of users.

Face validity requires consistency between the system prediction and that of additional experts [Tavana, Lee, Joglekar, 1994]. Additional experts, both in telecommunications and system dynamics, were invited to comment on the system behavior and the output of the computerized models. Experts were asked to comment on the robustness of each individual demand factor. They were also asked to check the predicitve accuracy of the system given different scenarios. Simulation runs were performed both over time and over a range of values for the variables. With the computer visualization of the progress of the simulation, experts were asked to validate the model. Experts were satisfied with the results.

4. THE GSM MARKETS IN GERMANY, HONG KONG AND VIETNAM: BACKGROUND AND SIMULATION RESULTS

GSM was introduced to Germany, Hong Kong, and Vietnam in 1992, 1993, and 1994, respectively. For each of the three countries, a demand model was iteratively constructed, tested and used to simulate market trends. The national models are described below. They are preceded by a brief description of the data collection and model validation procedures.

4.1 COUNTRY-SPECIFIC RESULTS

4.1.1. Germany: Background and Simulation Results

Germany has a population of about 80 million. After the reunification of East and West Germany, massive investment projects were launched to build infrastructure in the East. After more than 35 years of cellular communication in Germany, GSM was introduced in Germany in July 1992 by two network operators, the German Telecom subsidiary 'DeTeMobil' and the privately-owned 'Mannesmann Mobilfunk GmbH', which had been the first non-public company in Germany to be granted a telecommunication license in 1989. In addition to the two above networks, in May 1994 a third operator called 'E-Plus' started to market its Personal Communication Network (PCN) which runs on 1800 MHz.

Figure 4 displays a typical output of a simulation model using system dynamics. Curves are plotted over time. In the case of Germany, the time axis starts in July 1992 (i.e., quarter 1) and extends to December 2005 (i.e., quarter 55). Prediction extends from January 1995 until December 2005. For each curve, three statistics are given on the y-axis: the maximum, the mid-point, and the minimum values. The simulation results shown in Figure 4 reflect a steady increase of GSM users in Germany, reaching a maximum of 19.4 million users in 2003. The upward trend is, however, not linear. Demand grows exponentially during the first years after the introduction of the technology. It then follows the cascaded shape of the cost curves. As a new technology, GSM is perceived as a complement to existing telecommunication infrastructures. This observation is further supported by scenario analyses revealing that consumers are more sensitive towards cost reductions than towards absolute cost levels (Figure 4).

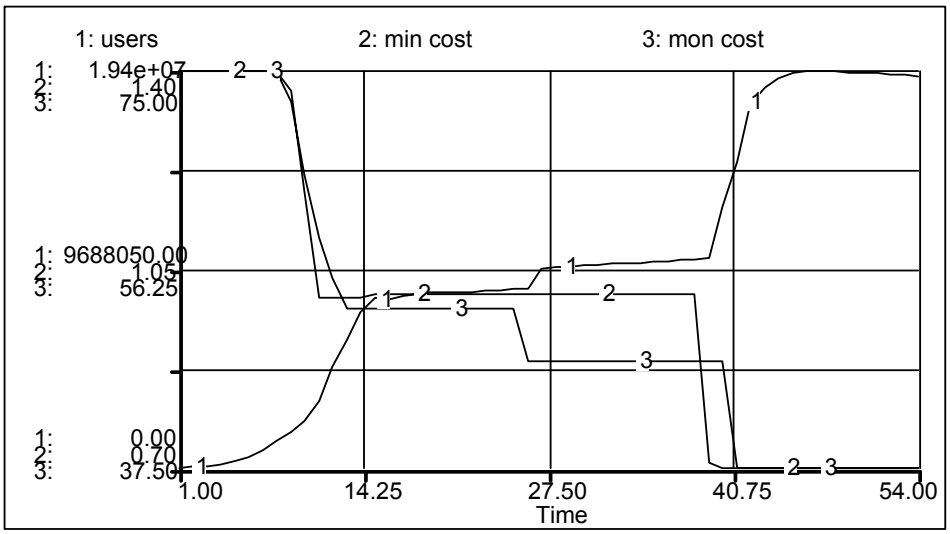

Figure 4: GSM Users and Cost from 1992 to 2005 for Germany

The improvement in product and service quality is the leading factor for GSM demand besides costs (Curve 1 in Figure 5). The increase in *PROD_QUAL* during the first quarters in Germany refers mainly to the improvement of future value-added services. Within the first two years, coverage has reached over 90%. One year later, two out of three operators will have achieved the targeted coverage of 98% of the population and more than 95% of the area. As the quality improves over time, its impact is apparent. An increasing number of service providers enlarges the range of services and of pricing schemes offered [Kirby, 1992].

The diffusion of information about GSM should have helped push the market until 1996 and then decline in its impact (Curve 2 in Figure 5). During the first three years after the launch, the amount of available information increased quickly due to three components, namely, advertising, word-of-mouth, and publications. There was hardly any daily, weekly or monthly publication that did not print some article on GSM. Furthermore, all three network operators have spent large amounts of money on advertising. In the medium and long run, however, the impact of *INFO_VOL* is expected to decrease drastically for three main reasons: (i) advertisements will shift its target away from product announcement campaigns to advertising for a familiar commodity, (ii) word-of-mouth will lose its impact as most people will be aware of the technology, and (iii) the frequency of publications, in parallel with the public‘s decreasing interest, will also drop. Additionally, it is realistic to expect that unfavorable news will appear, reducing the positive impact of the *INFO_VOL*.

GSM is expected to have a tremendous impact on the private lives of both business and non-business people. This impact is expected to rise quickly and then, in spite of a minor decline, remain rather high. Especially, reachability and the need to

feel secure, as intrinsic human characteristics, will continue to drive the popularity of GSM (Curve 3 in Figure 5). The latter mainly refers to elderly and sick people who will adopt GSM as part of their communication requirements. The increase to be expected from the two factors 'reachability' and 'security' will be counterbalanced by a desire to be left in peace (refering mainly to the private life of business people) and a decreasing image.

Shortly after GSM introduction, the *BUS_LIFE* factor played a major role in GSM growth, driven by the perpetual needs of top executives to improve existing business activities and to search for new business opportunities (Curve 1 in Figure 6). In spite of a sharp drop, mainly caused by some dissatisfaction with the data communication possibilities, the impact of business life on GSM demand in Germany is expected to stay at a rather constant level of average importance.

The behaviors of the *PRIV_LIFE* and *BUS_LIFE* are in essence similar. However, the market for non-business users, due to its larger size, will provide larger potential for market growth.

Interestingly, the German market sees alternative technologies as a complementary product to GSM. *ALT_TECHNOS* (Curve 2 in Figure 6) are expected to be complementary in Germany for three main reasons. Most new technologies will integrate various forms of mobile communication (e.g., IRIDIUM[4], Universal Mobile Telecommunication Services (UMTS)) [Buitenwerf, 1994; Iridium**,** 1994**;** Johnson, 1993]**.** The number of digital cellular licenses is predicted to be rather limited until 2005 thus keeping the direct competition from within digital wireless technology low. From the users' perspective, the distinction between fixed and mobile networks will be reduced within the coming years by features like integrated billing and card phones in the fixed network [Vardy, 1992; Harper, 1993].

The impact of *EVAL_POSSI* (Curve 3 in Figure 6) is closely related to that of *BUS_LIFE*. Companies that consider GSM as a technological means to support their (innovative) business procedures try to perform cost-benefit analyses to find the most promising infrastructure investment. Due to the vast amount of ongoing studies on GSM, it is to be expected that the quality of GSM-related cost benefit tools will increase steadily. Altogether, however, this factor will play a minor role for the market development.

---

4 IRIDIUM is a satellite based system dedicated for individual communication with international roaming capacity. It is expected to be in operation by 1988.

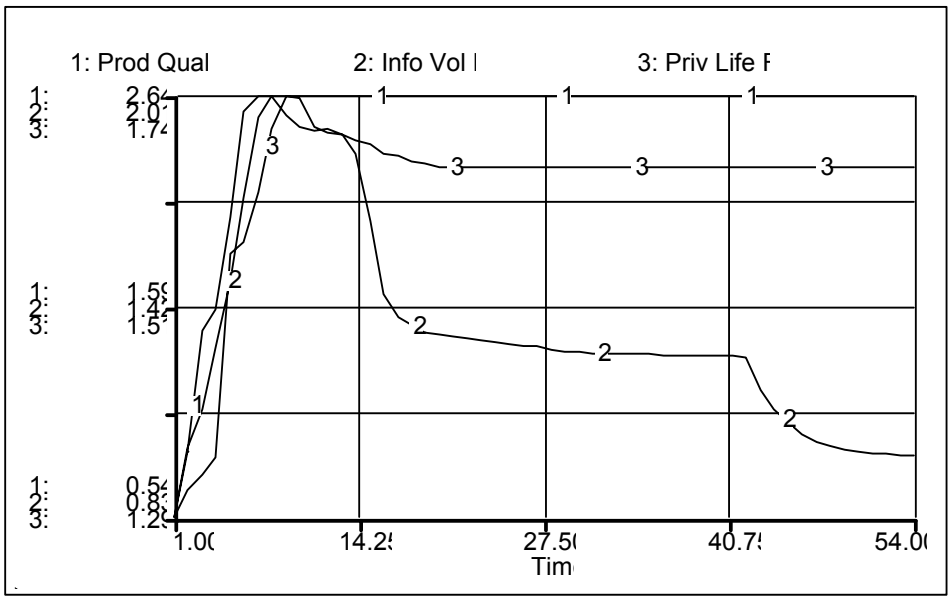

Figure 5: Evolution of GSM Demand Drivers from 1992 to 2005 for Germany (1)

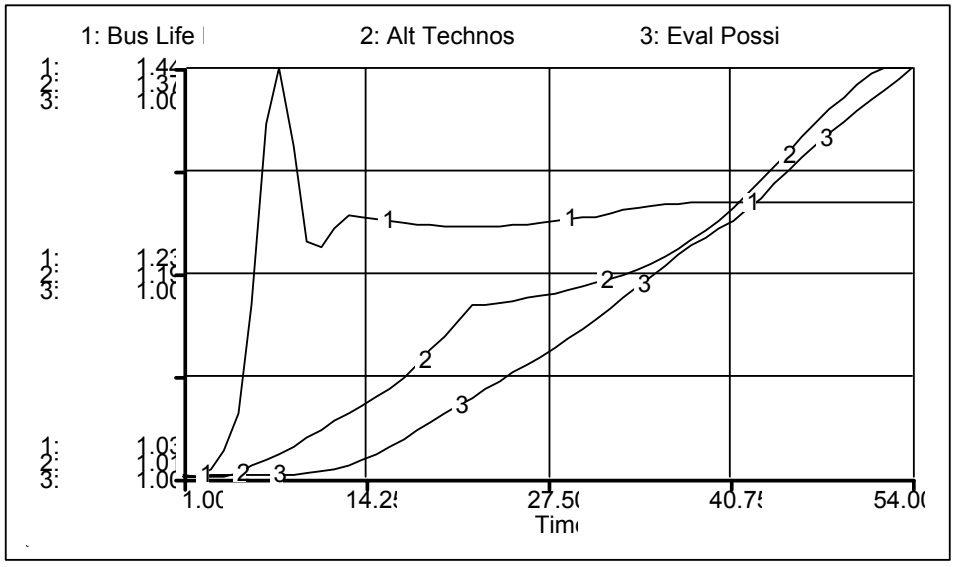

Figure 6: Evolution of GSM Demand Drivers from 1992 to 2005 for Germany (2)

4.1.2. Hong Kong: Background and Simulation Results

Hong Kong has a population and perhaps the most dynamic mobile communication market in the world, it is renowned for its attraction to new gadgets, services and technologies. Hong Kong‘s mobile phone network, which ranks among the most competitive in the world, is growing extremely fast with 10,000 new users each month.

For Hong Kong, and likewise for Vietnam, the time horizon starts from January 1994 till December 2005, with prediction starting in January 1996. The Hong Kong GSM market is best characterized by (i) its high penetration rate, (ii) an increasing competition due to market liberalization, and (iii) better quality of service as the GSM services start to stabilize. These elements are further strengthened by the growth opportunities in neighboring South China. Hong Kong uses more office equipment per capita, such as copiers, faxes, and computer networking products, than any other place in the world. The mobile phone is perceived by 'the demand' as a 'natural' extension of the existing communication platform.

While overall cost reductions are also the main driver for the growth of the user number in Hong Kong, the *USERS* increase does not follow the shape of the cost factor as closely as in the case of Germany. Figure 7 suggests that consumers are looking more at the absolute cost level than at cost changes.

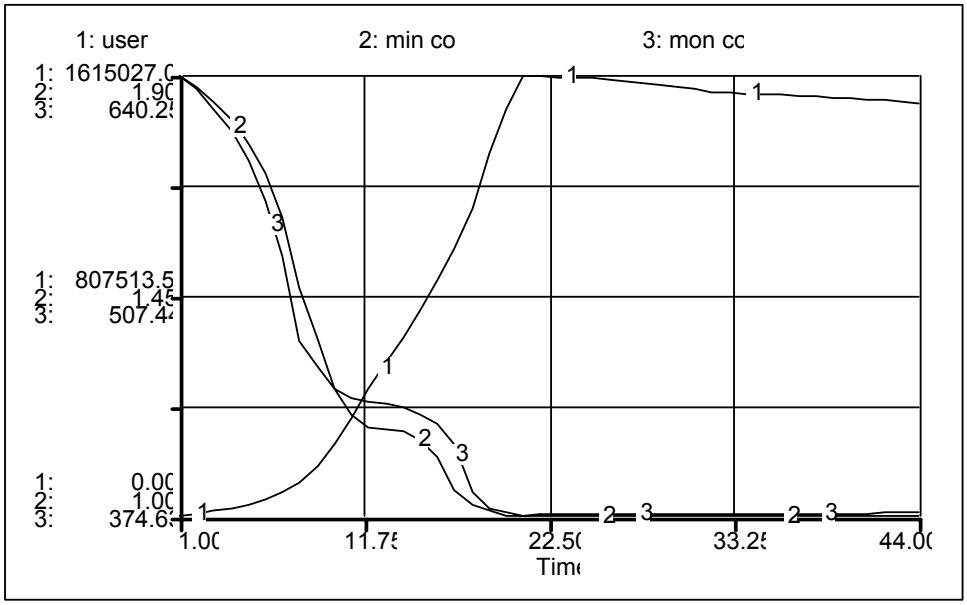

Figure 7: GSM Users and Cost from 1995 to 2005 for Hong Kong

The evolution of *PROD_QUAL* over time is shown in Curve 1 in Figure 8. The high product quality attained in 1994 convinced an increasing number of inhabitants to adopt GSM. As completed outdoor coverage had been ensured for the entire territory, expectation on quality shifted to in-building communication [Haug, 1994]. The improvement and extension of indoor cellular communication possibilities will give GSM a competitive edge over comparable technologies (e.g., analog systems, Code Division Multiple Access (CDMA)) while value-added services have played and are expected to continue to play a minor role in demand development.

INFO_VOL, mainly consisting of word-of-mouth and advertising, should cause a sharp increase in GSM use in the near future. According to informed GSM users in Hong Kong, people — many of whom had used analog cellular networks before — still need to be made aware about the additional features provided by digital technology. Once this education effort will have reached the vast majority of potential customers, it will provide a steady high-pressure push for GSM demand (Curve 2 in Figure 8).

In spite of the high penetration rate of cellular phones in Hong Kong, the segment of private users is still rather small. However, the technology is now considered to be mature and cost-efficient enough to tackle the private market. Telecommunication executives are convinced that the private segment promises the largest growth, leading to a significantly higher overall penetration rate in a very mobile society (Curve 3 in Figure 8). As the GSM penetration in the business sector comes close to saturation, *BUS_LIFE* plays a minor role for further growth in Hong Kong since most businesses are already equipped with cellular technology (Curve 4 in Figure 8). With the high number of established and foreseeable licenses, the competition in Hong Kong from other cellular networks is predicted to be sharp (Curve 5 in Figure 8).

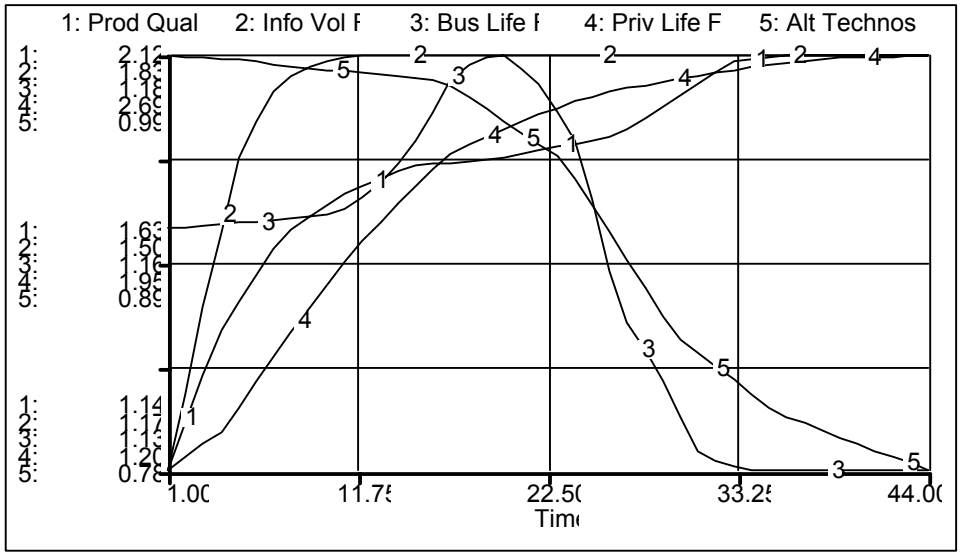

Figure 8: Evolution of GSM Demand Drivers from 1995 to 2005 for Hong Kong

4.1.3. Vietnam: Background and Simulation Results

Due to a number of difficulties related to the post-war recovery process, Vietnam has one of the lowest teledensities among lower-income countries of the Asia-Pacific region. However, an intensive investment program launched by the

government, with the assistance of international funds, has made significant progress in modernizing and expanding the existing telecommunications network. In 1994, with a population of 70.6 million inhabitants, Vietnam launched its first cellular phone network in Saigon, called Callink. In May 1994, the Vietnam Postal and Telecom Services (VNPT) adopted GSM as the standard for future and nation-wide cellular telecommunications.

Most of the existing infrastructure and services in Vietnam are provided in urban centers. By 1994, only 1,600 of Vietnam's 10,000 villages had some kind of phone service. The basic rationale that discouraged initiatives to provide rural telephony in the past argued that rural population is generally scarce, lives scattered in extended geographical areas, and has a much lower income than its counterpart settled in urban centers. In Vietnam, however, most of these characteristics are not true [Petrazzini, Bui, 1995].

The convergence of new low cost technology, a new outlook on the economics of rural networks, and the peculiar characteristics of Vietnam's rural population (income, density, and relative importance in proportion to overall population) makes rural telecommunications a segment of the market with significant potential.

As illustrated in Figure 9, Curve 1 shows that the number of users should increase continuously until it reaches its maximum (6 million users) in the 31st quarter (July 2002) when a slight decline will begin. Although cost is the key driver in Vietnam similar to Germany and Hong Kong, the shape of the curve representing the number of users does not follow the shape of the cost curve. While the cost per minute of consumption is predicted to reach its minimum in the 17th quarter (i.e., in October 1999), the monthly cost would reach its minimum only in the 30th quarter (i.e., n April 2002). The cascaded shape of both cost curves can be explained by the cost policy of the network operator (VNPT) which declared it would lower the prices according to infrastructure availability and marketing reasons. *MIN_COST* should fall from a maximum of US$0.18 to a minimum of US$0.09 over the ten-year time span.

USERS increase represents approximately a cellular phone density of 6% assuming that the Vietnam population will reach 100 million inhabitants by 2002. The number of users shows, however, little direct correlation with the GSM cost. This means that the cost does not play as dominant a role for GSM demand in Vietnam as has been observed and predicted in other countries. Because demand will remain higher than the ability of the VNPT to offer new services, users whose business needs critically depend on telecommunications, are willing to pay more to subscribe to the

service. Consequently, demand drivers other than cost are important for the increase of GSM demand.

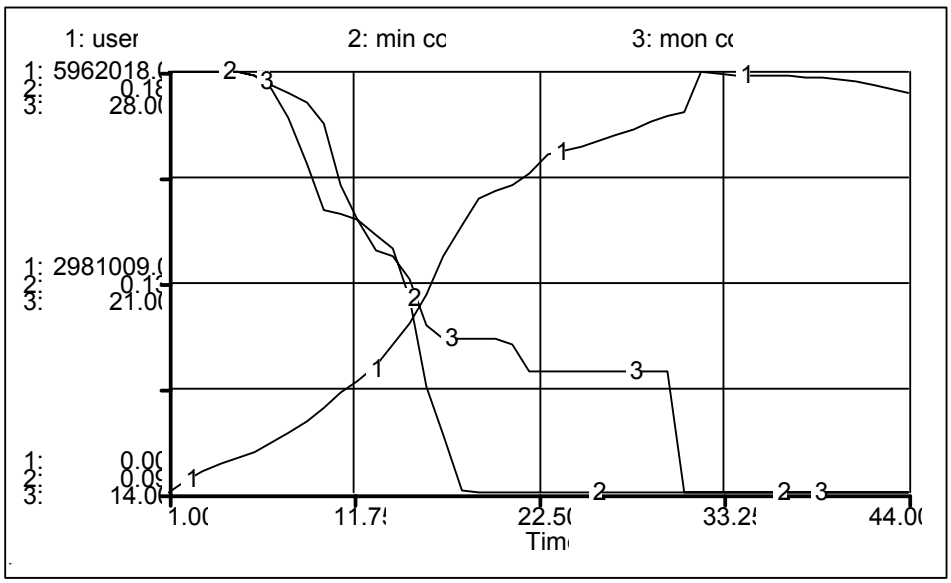

Figure 9: GSM Users and Cost from 1995 to 2005 for Vietnam

PROD_QUAL in Vietnam mainly covers the increase in nation-wide coverage as quality handsets are imported from overseas. Until the end of 1994, GSM was only offered in the two main cities (Hanoi and Saigon). However, an extension of coverage into medium- and small-size cities as well as into the rural areas has provided unprecedented communication opportunities to these areas while the fixed network availability remained limited (Curve 1, Figure 10). The impact of *PROD_QUAL* should increase steadily over time, mainly reflecting the improved national coverage of the GSM network.

As the second most important demand driver, *INFO_VOL*, mainly consisting of advertising and word-of-mouth, shows a sharp increase in the early years, and then stabilizes in 2005 (Curve 2 in Figure 10). Vietnam has been investing heavily in GSM television and radio commercials, which has rapidly increased general awareness of the new technology. At its maximum, the impact of *INFO_VOL* in Vietnam reaches the same value as in Germany, both being slightly higher than in Hong Kong. Vietnam reaches the maximum of information impact later than the other two countries since it will take longer to spread the word into the less inhabited areas and since the general understanding of telecommunication infrastructures and possibilities is lower than in Germany or Hong Kong. Although the impact of information should also decrease slightly in Vietnam, after having reached its maximum it should continue to stay at a rather high level until 2005. Over time, the impact of advertisements can be expected to increasingly replace word-of-mouth because (i) the

number of users who spread the word will increase, and (ii) advertisements for high-technology products have proven to be most effective during the early years after a product launch.

The positive impact that GSM has on *BUS_LIFE* should also continuously push the demand (Curve 3 in Figure 10). Since GSM is currently the most convenient way to provide communication services, many companies, private and public alike, are willing to pay almost any price to subscribe to this service. GSM represents virtually the only opportunity to communicate in real time outside the company building.

Remarkable also is Curve 4 in Figure 10 representing the impact of *ALT_TECHNOS, DEPICTING A DOWNWARD SLOPE.* In Vietnam, these technologies are predicted to compete with GSM. While the government policy in Vietnam will keep the number of licenses limited, the steady improvement of the fixed network will certainly be an increasing competition for GSM. As modeled in the system, the closer the value of the curve is to 1.00, the smaller the impacts that alternative technologies have on the demand. Conversely, as the value drops to 0.50 in the year 2005, *ALT_TECHNOS* will affect negatively the demand. As a business tool, mobile phones seem to serve a role for a few years and are then integrated back into the core (wired communication infrastructure) [Ross, 1992].

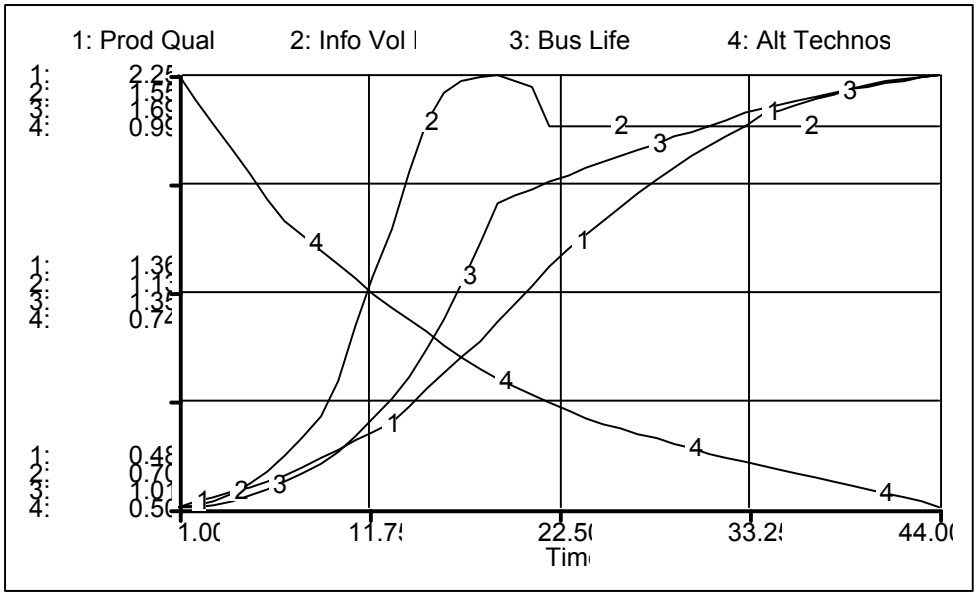

Figure 10: Evolution of GSM Demand Drivers from 1995 to 2005 for Vietnam

4.2. GSM MARKET DEMANDS: NATIONAL DISCREPANCIES AND GLOBAL TRENDS

Our study provides some insights into the discrepancies in the way demand drivers impact the national GSM market demand and vice-versa. Also, it highlights the global trends of market demand.

4.2.1. National Discrepancies

Given the fundamental differences between the three nations, the national results can be expected to differ from one country to the next. This is the case for the *ALT_TECHNOS* factor, which shows drastical differences. While *ALT_TECHNOS* compete with GSM in Hong Kong, they are mainly considered supplementary in Germany.

More challenging is the search for national differences when the consumption trends exhibit the same pattern. The evolution of GSM users have the same pattern in three countries. However, besides costs, that represent the key demand factor for all three countries, the relative importance of the other factors is different. As can be seen in Table 2, *PROD_QUAL* is perceived crucial for Germany (i.e., competition with existing and reliable telecommunication technologies) and Vietnam (i.e., mobile phone is currently the only means of telecommunication in many areas of the country). For Hong Kong, however, with one of the highest penetrations of wireless communication in the world, *PRIV_LIFE* and *ALT_TECHNOS* are more prevalent than *PROD_QUAL*.

	Germany			**Hong Kong**			**Vietnam**		
	short	medium	long	short	medium	long	short	medium	long
PROD_QUAL	1	1	1	3	2	2	1	2	1
INFO_VOL	2	4	2	4	3	3	2	3	4
PRIVATE_LIFE	6	2	3	2	1	1	-	-	-
BUS_LIFE	4	3	4	5	4	5	1	1	2
ALT_ TECHNOS	5	5	5	1	5	4	4	4	3
EVAL_POSSI	6	6	6	-	-	-	-	-	-

Legend
1: Strongest Impact
6: Weakest Impact

Table 2. The Importance of the Demand Factors over Time per Country

Likewise, the reasons for the slowdown in demand differ substantially between the three countries. The decline in Germany seems to be driven by the perceived utility that GSM can offer to the users as far as their private life is concerned. The decline is, however, insignificant: as long as the cost moves

downward, demand will be sustained. Hong Kong‘s decline is grounded in the fierce competition from alternative technologies. This reflects the intention of the Hong Kong government to further liberalize the market by issuing more licenses and more powerful technologies for a densely populated territory. The GSM market may eventually lose some of its share to other cellular networks. Finally, the small decline of the GSM market in Vietnam can best be explained by the steady improvement in the country infrastructure. As the fixed network will attain a high level of coverage, like in Germany and Hong Kong, some of the communication traffic will be taken away from GSM by the newly established fixed network.

Perhaps the discrepancy in GSM demands can be explained by the countries economic development phases. In Hong Kong and Germany, highly competitive markets for telecommunication products and services put a growing pressure on the reduction of user time costs and monthly subscription fees. For Vietnam, with little infrastructure, the need for the Vietnamese GSM network operator and service provider to push for lower costs is less urgent, at least in the short term.

4.3.2. Global Trends

In our simulation of three GSM markets, four broader trends seem to have emerged, which have also been noted earlier by many studies, e.g., [Romtech System Dynamics, 1993; Deloitte Touche Tohmatsu International, 1993].

- First, the dynamics of globalization arise largely from the rapid technological advance of digital cellular communication with a standard already adopted by more than 100 countries world wide. In a circular loop fashion, the underlying rationale is that progress in GSM technology pushes the global demand, and in turn the demand increase drives the technology to a new level due to economies of scale. These dynamics are apparent in all three countries. The implementation of GSM technology is complementary to existing communication systems in Germany and Hong Kong. It is a new and predominant technology for Vietnam due to infrastructure deficiencies.

- Technology, with its global expansion, not only affects the growth but also the decline of GSM demand. In all three countries the GSM demand should decline around the year 2002 or 2003. Although the accuracy of long-term prediction is not guaranteed, the convergence of the three trends in our model is striking.

- The liberalization and deregulation of telecommunication services constitute another critical ingredient of the global trends. Except for Hong Kong, which pushes privatization toward a strong competition, Germany and Vietnam seek

to alleviate the problem associated with the monopoly market, but refuse to have more than two or three network operators. Nonetheless, market liberalization has a prevailing impact on the global GSM demand. Our national models suggest universal decline of the user time costs *(MIN_COST)* and the monthly subscription charge *(MON_COST)*. Although, the time frame for cost reduction differs slightly from one country to another, national pricing policies tend to converge toward an international cost level as GSM technology will be universally installed in many countries [ITU, 1994; Mirfin, 1993; Petrazzini, Bui, 1995].

- Another similarity across countries is the interdependence between the number of users, the GSM operational costs, and the decision to adopt GSM based on business and/or private needs. The adoption and use of GSM is still primarily considered as a business investment. Once business needs are satisfied, potential users can be found in the 'private' sector. This trend is clearly visible in comparing *PRIV_LIFE* and *BUS_LIFE* for the three countries (Table 2). In Vietnam, our study reveals that GSM demand is driven only by business communication needs. For Germany, the business market for GSM is not yet saturated and still exhibits potential for growth. This phenomenon seems to be caused by the fact that GSM costs are still perceived as too high. As an important communication tool for business, GSM use is considered more like a business expense or investment. Yet, *PRIV_LIFE* is perceived to be very important in the not-so-distant future. Consumers still react strongly to the price. Given this price elasticity, with the predicted reduction in *MIN_COST* and *MON_COST*, it is expected that the GSM market for private users will soon become more important than the market serving business needs.

4.3. SUMMARY OF FINDINGS

Although GSM is only one of the pieces in the cluster of current and future telecommunication networks, its ability to provide 'anytime-anywhere communication', boosted by a steady decrease in production and operational costs, will continue to push demand higher. In response to this new and booming technology, the world-wide market is growing rapidly, with no saturation expected in the short term. However, our model suggests that the impact of mobile telecommunication will dynamically alter the demand in the long run. Increasing GSM use will certainly influence many people's professional and personal lives. In turn, these changes will alter the development and usage of GSM.

A major finding of this study is that GSM demand should grow rapidly in all three countries in the short term. The demand growth follows an S-shape curve with a sharp increase at the beginning of the time period. This finding is consistent with most recent publications on the future of telecommunication. However, our finding stands out from others in that it estimates a slight decline of GSM demand in the long run.

This comparative research also contributes to the understanding of the relative importance of the demand factors. Our simulation shows the pronounced effect of cost on GSM demand. It also confirms the prevailing impression that the quality of the GSM network, the handsets, and the value-added services are important to sustaining demand over time. As a new and promising technology, GSM demand should not be much affected by alternative technologies. Interestingly enough, the lack (e.g., the case of Vietnam) and the maturity (e.g., the cases of Germany and Hong Kong) of alternative technologies both contribute to the growth of GSM demand.

GSM constitutes a prime case of product success on an international scale. The world-wide growth is induced by technological advances, market liberalization and international competition. Our model captures the intrensic dynamics of technological progress in that telecommunication alternatives are both complementary and substitutive throughout their life cyles. Global competition plays a significant role in pushing prices towards comparable levels, despite national differences.

5. SYSTEM-DYNAMICS BASED MODELING: LESSONS LEARNT AND FUTURE RESEARCH

The model developed in this paper not only allows interesting insights in the simulation outcomes, i.e., the GSM patterns of three (purposefully) very different countries. It also serves as a knowledge extraction and learning engine for those who prefer to appreciate the consequences of their own assumptions built into the system. This proved to be most valuable in order to attract managers and experts to participate in the modeling and simulation exercise and to actually apply the model in the context of several strategic decision processes along the way. Thus, the managers' and experts' motivation ceratinly also heavily contributed to thorough and validated model inputs.

The lack of data is an inherent problem of long term forecasting for a new technology. As discussed earlier and demonstrated elsewhere [e.g. Homer, 1987; Bui, Loebbecke, 1996], the use of system dynamics has proven to be an appropriate approach to forecasting and analysis. Since the proposed model focuses on demand rather than on supply, the basic elements of the market structure and the demand

forces are more stable, making it easier to apply the model to other countries. After many iterations and feedback analyses with managers, additional experts and modelers, the three models seem to provide stable and sensible results. Nonetheless, additional historical data will undoubtedly enhance the quality in analyzing the dynamics of the various factors and their growth pattern over time. The simulation model is being tested on a regular basis as more data are made available.

Further research will include simulating the GSM demand in other countries and applying the basic model structure to different technologies and infrastructures. New demand patterns could emerge and, in turn, enhance the conceptual model. Also, investigations of additional nations and technologies would support a better understanding of the international convergence and divergence of demand factors. In any case, it is believed that the basic elements of the GSM model studied in this research would remain structurally solid.

6. REFERENCES

Altobelli, C., *Die Diffusion neuer Kommunikationstechniken in der Bundesrepublik Deutschland - Erklaerung, Prognose und marketingpolitische Implikationen*, Ph.D. Thesis, University of Tuebingen, 1991.

Bacon, J., 'The Use of Decision Criteria in Selecting Information Systems / Technology Investments', *Management Information Systems Quarterly*, Vol. 16, No. 3, 1992, 35-360.

Bental, B., 'Consumption Externalities in Telecommunication Services', in: de Fontenay, A. et al. (eds.), *Telecommunication Demand Modeling*, Amsterdam - New York - Oxford - Tokyo 1990.

Baills, G., Olivier, C., *MIRZA: Un Modèle Dynamique du Marché de l'Automobile*, Presentation to the Congrès AFCET (Association Française pour la Cybernitique Economique et Technique), 1993.

BIS Strategic Information Systems, *Cellular User Survey Market Report*, Luton, December 1993.

Bui, T:; Loebbecke, C.,'Supporting Cognitive Feedback Using System Dynamics: A Demand Model of the Global System of Mobile Communication', *Decision Support Systems*, 17, pp. 83 - 98, 1996.

Buitenwerf, E., 'Third Generation Mobile Telecommunication Systems', *Mobile Communications International*, No. 18, Summer 1994, 72-75.

Callmer, C., 'The Diffusion of Cellular Telephonie in Western and Eastern Europe, Projection of Demand and Pricing', *Europa Telecom '92, Part 3, Economic Symposium*, Budapest, 14.-16. October 1992, 195-198.

Deloitte Touche Tohmatsu International, Mobile Products Europe*, The Impact of Wireless Communications on Business in the 90s*, Chobham, Surrey, UK 1993.

Dordick, H., 'The Social Uses of the Telephone', in: Forschungsgruppe Telekommunikation (ed.), *Telefon und Gesellschaft*, Vol. 1, Berlin 1989, 221-238.

De Fontenay, A. et al. (eds.), *Telecommunication Demand Modelling*, Amsterdam - New York - Oxford - Tokyo 1990.

Forrester, J., *Urban Dynamics*, 3. ed., Cambridge, Massachussetts 1970.

Gutenberg, E., *Grundlagen der Betriebswirtschaftslehre, Vol. II, Der Absatz*, 14. ed., Berlin - Heidelberg - New York 1973.

Halal, W., 'The Information Technology Revolution', *The Futurist*, July-August 1992, 10-15.

Harper, A., 'PCN Tariffs and their Implications*', CommEd Conference on UK, European and International Tariffs*, London, 08.07.1993.

Haug, T., 'The Development of GSM outside Europe - Will GSM become a World Standard?', in: FIBA (ed.), *Mobile Communications, Europaeischer Mobilfunk Kongreß*, Muenchen, 28.2.-02.03.1994.

Hiltz, S., Turoff, M., *The Network Nation, Human Communication via Computer*, improved edition, Cambridge, Massachussetts - London 1993.

Homer, J., 'A Diffusion Model with Application to Evolving Medical Technologies', *Technological Forecasting and Social Change*, Vol. 31, 1987, 197-218.

Iridium, *Fact Sheet*, Washington, D.C. 1994.

Jagoda, A.; de Villepin, M., *Mobile Communications*, Chichester - New York - Brisbane - Toronto - Singapur 1993.

Jarratt, J.; Coates, J., 'Future use of cellular technology - Some social implications', *Telecommunications Policy*, February 1990, 78-84.

Johnson, C., 'Das Kommunikationsnetz Iridium', in: Johnson, C. (ed.), *Satellitenkommunikation - Das Handbuch der satellitengestuetzen Kommunikationsnetze*, Ulm, May 1993, Section 8.3.

Jussawalla, M.; Braunstein, Y., 'Information Theory and Telecommunications: A Non-Specialist's Primer', *International Telecommunications Society (ITS), 8th International Conference,* Venedig, 18.-21. March 1990.

Katz, J. , 'US Telecommunications Privacy Policy', *Telecommunications Policy*, December 1988, 353-368.

Keller, S., 'The Telephone in New (and Old) Communities', in: Pool, I. (ed*.), The Social Impact of the Telephone*, Massachussetts, 1981, 281-298.

Kerler, H., 'Mobilfunk-Trends - Schwerpunkte, Dienste und Maerkte in der Entwicklung', *telekom praxis*, No.7, 1993, 10-13.

Kirby, G., 'The market transition to GSM', in: FIBA (ed.), *Europaeischer Mobilfunk*, 4. Annual Conference, Duesseldorf, 28./29. January 1992.

Kotler, P., *Marketing Management, Analyse, Planung und Kontrolle*, Stuttgart 1977.

Kruse, J., ' Oekonomische Strukturen im Mobilfunk', in: Kruse, J. (ed.), *Zellularer Mobilfunk*, Heidelberg 1992, 1-16.

Lange, K., 'Some Concerns about the Future of Mobile Communications in Residential Markets', *Communications Policy Research (CPR) '92 Conference*, Soro Storko, Denmark, October 1992, 215-228.

Loebbecke, C., *Evolution innovativer Informationstechnolgie-Infrastrukturen - Dynamische Simulation des deutschen Mobilfunkmarktes*, Schaeffer-Poeschel-Verlag, Stuttgart 1996.

Loebbecke, C.; Bui, T., 'Designing and Implementing DSS with System Dynamics: Lessons Learned from Modeling a Global System of Mobile Communication (GSM) Market', in: P.Humphreys et al. (eds.) 'Implementing Systems for Supporting Management Decisions: Concepts, Methods, and Experiences', Chapman & Hall, July 1996.

Lyneis, J., *Corporate Planning and Policy Design: A System Dynamics Approach*, Massachussetts 1980.

Malone, T., Rockart, J., 'How will information technology reshape organizations? Computers as coordination technology', in: Bradley, S. et al. (eds.), '*Globalization technology and competition: the fusion of computers and telecommunication in the 1990s*', Harvard Business School, 1993.

Mirfin, A., 'The Distribution of Mobile Telephone Services by Service Providers', in: in: *IDATE (ed.), 15th International Conference*, Montpellier, 24.-26. November 1993.

Morecroft, J., 'The dynamics of a fledging high-technology growth market: Understanding and managing growth cycles', *System Dynamics Review*, Vol. 2, No. 1, Winter 1986, 36-61.

Morecroft, J., 'Executive Knowledge, Models and Learning', *European Journal of Operational Research*, Vol. 59, 1992, 9-27.

Pelton, J., 'Telepower, The Emerging Global Brain', *The Futurist*, September-October 1989, 9-14.

Petrazzini, B., Bui, T., 'Vietnam: Rapid Growth and Cautious Reform', *Telecommunications Journal*, April 1995, 93-101.

Phillips, S., '7 years of service providing in the UK - chances and risks', in: FIBA (ed.), *Europaeischer Mobilfunk*, 4. Annual Congress, Duesseldorf, 28./29. January 1992.

Porter, M., Millar, V., 'How Information Gives You a Competitive Advantage', *Harvard Business Review*, July-August 1985, 149-160.

Radzicki, M., 'Dyadic processes, tempestuous relationships, and system dynamics', *System Dynamics Review*, Vol. 9, No. 1, Winter 1993, 79-94.

Roberts, E. (ed.), *Managerial Applications of System Dynamics*, Cambridge, Mass. - London 1978.

Rogers, E., *Diffusion of Innovations*, 3.ed., London 1983.

Romtech System Dynamics, *Public Mobile Telecommunications in Europe, Special Report*, Maidenhead, Bershire, UK, June 1993.

Ross, M., 'Prospects for Mobile Communications Markets - The European Market: The Effect of Economics, Policy and Regulation', *World Mobile Communications, Financial Times Conference*, London, 12./13. February 1992.

Senge, P., *The Fifth Discipline, The Art and Practice of the Learning Organization*, New York - London - Toronto - Sidney - Auckland 1990.

Steele, R., 'The Evolution of Personal Communications', *IEEE Personal Communications*, Second Quarter 1994, 6-11.

Stoeber, H., 'Netzausbau und Marktstrategie bei Mannesmann Mobilfunk', in: Kruse, J. (ed.), *Zellularer Mobilfunk - Neue Maerkte mit neuen Netzen fuer das Funktelefon*, Heidelberg 1992, 96-111.

Tavana, M., Lee, P., Joglevar, P., 'The Devlopment and Validation of a Campus Recruiting System Expert System Using Expert Opinions and Historical Data', *Expert Sytems With Applications*, Vol. 7, No. 2, pp. 305-321, 1994.

Trommsdorff, V., *Die Messung von Produktimages fuer das Marketing, Grundlagen und Operationalisierung*, Koeln - Berlin - Bonn - Muenchen 1975.

Vardy, T., 'Developing within the Fixed-Link Network', *in World Mobile Communications, Financial Times Conference*, London, 12./13. Februar 1992.

Veit, K., 'System Dynamics and Corporate Long Range Planning', in: Roberts, E. B. (ed.), *Managerial Applications of System Dynamics*, Cambridge, Massachussetts - London 1978, 537-541.

Veldkamp, G., *Kurzfassung zum durchgefuehrten Forschungsvorhaben 'Auswirkung und Gestaltung informationstechnologischer Netzwerke im Hinblick auf die Handlungsfaehigkeit des Menschen in komplexen Problemloeseprozessen*, Handout HDZ/IMA, RWTH Aachen 1994.

Weizsaecker, C. von, *The Economics of Value Added Network Services*, Koeln, Germany, 1987.