MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET: A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIO[illegible]

by

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ABSTRACT

Two tier market describes a mechanism where customers purchase both a device and an additional product or service to gain benefit. An example is the compact disc (CD) player and the music CD's that go with them. What makes two tier markets interesting is the unique dynamics that are created by the unbundling of the product. These dynamics exhibit a particular structure and behavior that gives rise to compelling strategic issues. Each tier must confront synergies and conflicts that arise with the other tier while achieving growth and profitability. Mobile telephony is a timely and rich example of a two tier market. Equipment suppliers and service providers represent the tiers.

There are important interactions between the tiers and further interaction between each tier and the customer. Within these relationships, important issues arise. Equipment prices influence the market growth of the service. Service quality influences the customer satisfaction with the equipment. New technology becomes available to obsolete the installed base. These issues have strategic implications for each tier. Within the two tier market, what actions lead to market growth in the cellular industry? What actions must each tier take to achieve the highest profitability? System dynamics is used to evaluate the interactions, structure and behavior of a two tier market.

The model simulates the key management parameters associated with the two tier market. Parameters include customers, demand for devices and airtime, network and manufacturing capacity, costs, prices, revenues, profits and cash flows. The model determines market growth, equipment and service pricing, profitability and technology transitions during the simulation period of 1980 through 2012. Various management policy and technology strategy scenarios are developed and tested to determine maximum profitability.

From this analysis, the key strategic issues are price, cost, capacity and technology. Market growth is driven by the equipment price. The lower the price the faster the market grows. Subsidies and steep learning curves are key to lower prices. Service prices determine customer retention. Equipment capacity determines the rate the market can grow while service capacity determines how large the installed base can be. New generations of product technology, introduced at the right time, are required to keep the equipment suppliers in the market over the long term. With these guideline, the cellular communications two tier market can be very profitable for both tiers.

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MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET:
A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

TABLE OF CONTENTS

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET:
A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

TABLE OF FIGURES

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET:
A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

TABLE OF TABLES

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET: A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

CHAPTER 1: INTRODUCTION

1.0 TWO TIER MARKETS

Most people take two tier markets for granted. They may not even be aware they exist much less that they may participate in them almost every day. An example of a two tier market is the compact disc (CD) and a compact disc player. A player without the disc is useless and vice versa. Put them together and you get beautiful music. Think about what you went through when you wanted to buy your first compact disc player. Boy, these players are expensive. My turntable works fine. But the music sounds a lot better on a CD. Maybe, I will wait until the players are less expensive. Since then, you probably bought one and you may be buying new CDs, frequently or infrequently or somewhere in between. Nevertheless, by now, you probably spent more on CDs than on the CD player. Remember how important the cost of the CD player was in the original purchase decision. A two tier market describes a mechanism where a customer buys both a device and an additional product or service that together provide the benefit and value that the customer desires.

What makes two tier markets interesting is the unique dynamics that are created by the "unbundling" of the "product." These dynamics exhibit a particular structure and behavior that give rise to compelling strategic issues. Two tier markets must address the desire for market growth and profitability in the context of prices, costs, capacity and technology between different sets of players. Lets look at another example. Take personal computers, for instance. One tier is the computer itself. The other tier is the software, in particular, the application software. Somehow you bought a computer. It could have been because it ran the software you desired or because it was the right price. Nevertheless, the hardware folks are pushing hard to get prices down so more people will buy computers. Meanwhile, the software folks have applications that do almost anything. Over time, you add this software package and that software package. The prices of the software are sometimes cheap but other times pretty expensive. There comes a time when an owner of a computer no longer has the capability to run the latest software. If you buy the software then you have to buy another computer. Do you stop buying software? As you can see, the dynamics of a two tier market can be complicated.

Another simpler example is the video cassette recorder (VCR). Originally developed to allow for time shifting of broadcast television shows, the VCR is most frequently used to play rented movies. In this case, there is the player and the movie or content. There are several characteristics of a two tier market. There is typically a device and a complementary product or service. Many times, different companies are responsible for each. Often each is purchased through different channels. Finally, important technology intensive products and services exist in two tier markets. The interactions of the players and technology in a two tier market is worthy of a closer look

1.1 MOBILE TELEPHONY

Mobile telephony, more commonly called cellular telephone service in the U.S., is another example of a two tier market. Having been around for ten years now, it is both a rich and a timely example. The players are referred to as equipment suppliers and service providers. The equipment suppliers manufacture the device or handset. The service providers provide the wireless communication service. In the interest of simplicity, the distribution channels are not considered in this analysis. New customers buy a device from the equipment supplier (the first tier) and subscribe for the service from the service provider (the second tier). Figure 1 shows a simple representation of a two tier market.

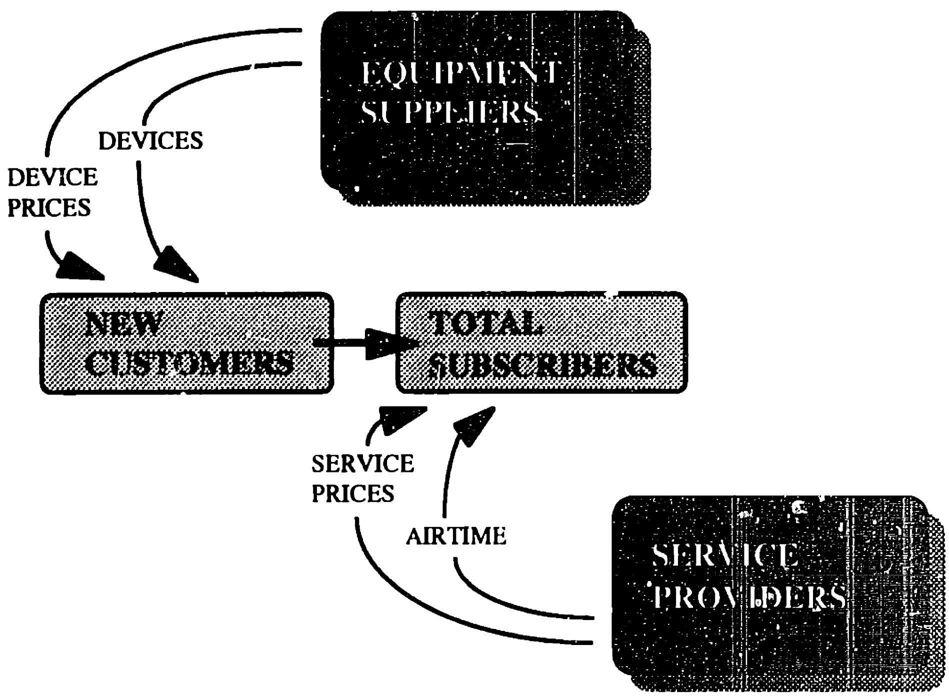

Figure 1: Simplified Cellular Industry Two Tier Market Model

Catching on faster than the first cars, and not far behind video recorders, cellular telephones may change the way society works as radically as either[1]. Originally perceived as a luxury item, cellular is moving into the mass market. Average equipment prices have fallen from $2,600 in 1986 to $390 at the end of 1992. Meanwhile, the monthly service cost per user has fallen from $197 in 1985 to less than $70 in 1992[2].

[1]The Economist Staff Writers, "Mobile Telephones: A Way of Life," The Economist, May 30, 1992, pg. 19.

[2]The Economist Staff Writers, "Telecommunications: A Softer Sell," The Economist, October 23, 1993, pg. SS8.

Today, 28,000 customers are signing up for cellular service each day[3]. Now, it is even possible to get a cellular phone for free. As Figure 2 shows, in 1992, there were approximately 9 million subscribers in the U.S. representing a penetration rate of 5% of the population[4].

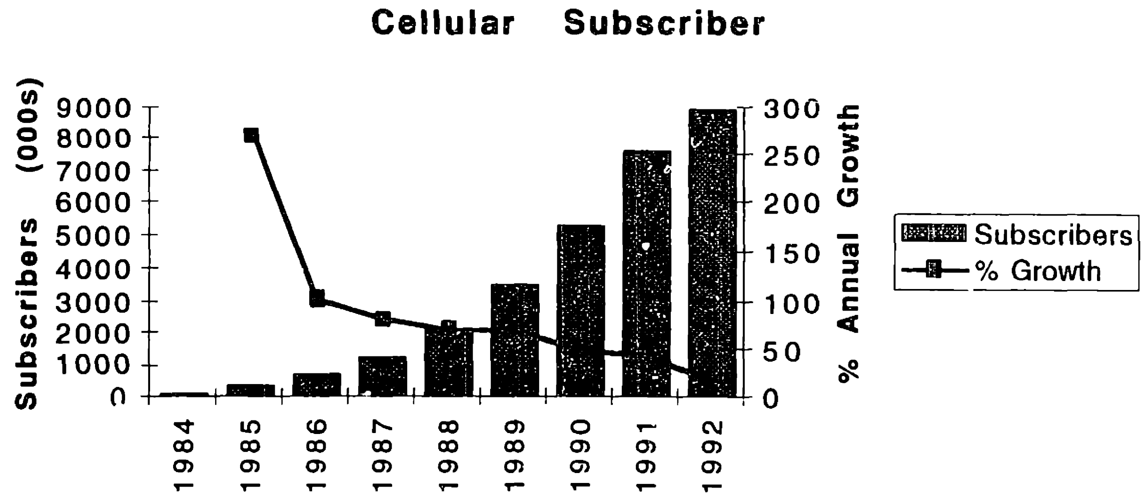

Figure 2: U.S. Cellular Subscriber History

Figure 3 forecasts the growth of wireless communications in the U.S. through the year 2000[5].

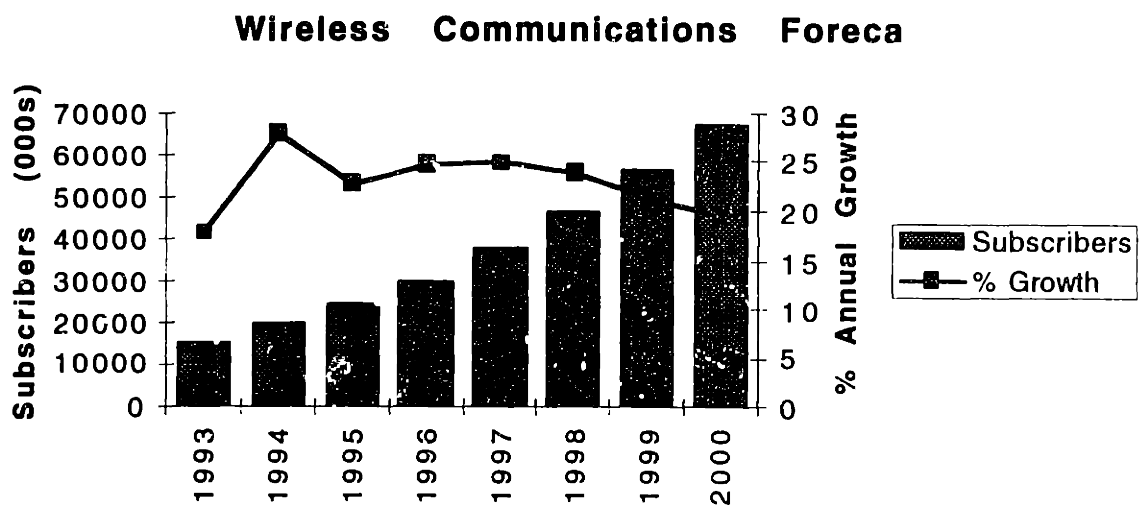

Figure 3: U.S. Wireless Communications Forecast

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[3] Cellular Telecommunications Industry Association, Washington, D.C., March 13, 1995.

[4] Huber, Kellog & Thorne, The Geodesic Network II, 1992, pg. 4.23.

[5] Leibowitz, D., E. Buck & J. Whittier, "The Wireless Communications Industry," Report for Donaldson, Lufkin & Jenrette Securities Corporation, Winter 1994, pg. 12.

There are important interactions between the entities in each tier to each other and further interaction between these tiers and the customer (end-user). Within these relationships, important issues arise. Equipment prices influence the market growth of the service. Service prices influence the customer satisfaction of equipment. New technology and interface standards can become available that obsolete the installed base. These issues have significant strategic implications for each player. Within the two tier market scenario, what actions lead to market growth for the cellular industry? What are the actions each entity must take for the highest profitability? This thesis answers these questions.

1.2 SYSTEM DYNAMICS

The interactions, structure and behaviors of a two tier market lend themselves to the system dynamics methodology. This research tool was selected for its ability to interpret the historical development of the market, establish a baseline for the future and test various management strategies. The model developed for this thesis is a simulation. A relatively simple system dynamics model has been developed which accurately represents the cellular telecommunications industry.

System dynamics provides three elements essential to effective corporate planning and policy design: an emphasis on understanding how behavior results from policies, a theory of behavior and the use of computer modeling to aid planning[6]. The understanding of the behaviors in the cellular market is the result of consultation with experts and personal experience. System dynamics modeling is well suited for the illuminating the behavior of this type of market and testing alternative technology and management strategies.

1.3 MODEL REPRESENTATION

All the service providers are simulated as a segment of the model and all the equipment suppliers are simulated as another segment of the model. In the integrated model, each segment interacts with the other and the market by way of the same mechanisms that exist in the actual market today. Another consideration is the impact of a new generation of equipment and/or service on each tier and on the industry as a whole. Two base cases are modeled. One assumes that a single technology exists for the duration of the simulation period. The other base case assumes a technology transition to another incompatible standard occurs during the simulation.

The model simulates the key management parameters associated with the two tier market. Parameters include customers, demand for devices and airtime, network and manufacturing capacity, costs, pricing, revenues, profits and cash flows. The model is used to determine market growth, cost reductions,

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[6]Lyneis, J.M., Corporate Planning and Policy Design: A System Dynamics Approach, Cambridge, MA Pugh-Roberts Associates, Inc., 1988, pg. 9.

profitability and technology transitions. The simulation period runs from 1980 to 2012. Validation of the model is based on the U.S. cellular telephone market history. Parameter estimation is designed to replicate the historical market development from its start to 1994.

This analysis served as the basis for the technology strategy framework development. Various management policy and technology strategy scenarios are developed and tested with the model to determine the maximum market and stakeholder benefit. The successful scenarios are the basis of the recommendations.

1.4 STRATEGIC CONCLUSIONS

The two tier market represents a particular structure and behavior that raise a set of challenging strategic issues. Understanding the dynamics of these issues is critical to the profitable participation of the players in a two tier market. These strategic issues are price, costs, capacity and technology.

Market growth is driven by device price. The lower the device price, the faster the market grows. Service providers should consider subsidizing the devices to assure the lowest price in the market. Lower prices are facilitated by lower costs. The equipment providers must follow steep learning curve cost reduction programs. On the other hand, lower service provider prices reduce churn in the installed base. Both the service provider and the equipment supplier need to aggressively add capacity as the market takes off. The equipment suppliers will exit unless there is a new technology standard introduced before market saturation by the initial technology standard.

Financially, the equipment supplier's U.S. market profitability will peak in the next couple of years unless the digital standard takes off. For the service providers, several more years are required before the massive network construction investments are paid back. In the meantime, high levels of profitability are just around the corner for most U.S. cellular service providers. Customers will continue to see lower device prices while service prices will remain the same for several more years.

1.5 DOCUMENT ORGANIZATION

This thesis follows a chronological format. The research is divided into three sections. In Chapter 2, the methodology and each of the key behaviors of the model are discussed. The model is described and validated in Chapter 3. In Chapter 4, a detailed understanding of the dynamics of the model is reached through scenario development and analysis for each of the proposed management of technology strategies. The recommendations are presented in Chapter 5.

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET: A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

CHAPTER 2: METHODOLOGY

2.0 PURPOSE

Before a system dynamics model can be developed, a critical and deep understanding of the behavior of both players in the market must be achieved. This has been accomplished through personal experience (gained through 15 years with Motorola), consultation with the several experts in the field, wide reading on the subject and testing of various concepts. This chapter discusses the behavior of each player in the industry and how they interact with each other and the customer. Several key concepts developed in this chapter follow.

- The driver of market growth is the price of the device. This is affected by the rate prices fall as volume rises and the amount of the device subsidies.
- Demand for devices follow a pattern that looks like a normal distribution. The number of subscribers or the installed base shows an S shaped pattern.
- Delivery delay and service quality effect cancellation rates for the device and the service. High cancellations are caused by shortages of capacity. Periods of excess capacity typically occur after a shortage of capacity. Excess capacity usually results in reduced profitability or even unprofitability.
- A technology transition to an incompatible standard causes the installed base to discard the current product for the next generation product. Significant additional capacity is required to meet total demand.

For purposes of clarity, a bottoms up approach to the market is presented. First the players are discussed in detail. Then the players are combined so that the market dynamics are easier to understand. The pieces are the equipment supplier segment, the service provider segment, the two tier market segment and the technology transition segment. Each segment represents a major element in the model. Much of the presentation that follows mirrors the construction of the model.

Several terms are used interchangeably throughout the thesis. Players refers to both the equipment supplier and the service provider. The term equipment supplier also means device manufacturer, terminal supplier and equipment manufacture. It specifically refers to the device end users purchase and use with the service. Portable, mobile and transportable phones are included in the category. Example equipment providers are Motorola and Nokia. The service provider term also means the cellular service provider or network operator. This is the collection of firms that own and operate the cellular networks in the U.S. Cellular One and NYNEX Mobile are examples of service providers. The term market refers to the U.S. cellular market or industry.

2.1 ANALYTICAL AGENDA

The two tier market offers almost infinite investigative possibilities. The focus of this project is the analysis of management of technology issues in the historical and future development of the cellular telecommunications market. It is expected that the recommendations developed for the cellular market will be applicable to other developing two tier markets. The emphasis is to gain an understanding of how a two tier market behaves and how various management of technology issues effect the successful development of the industry. This thesis focuses on the following business development issues: (1) market growth and (2) profitability of each entity.

Market Growth

How does device cost effect industry growth?

How does industry growth effect device cost?

How does service cost effect industry growth?

How does industry growth effect service cost?

How do shortages of the device or service effect market growth?

Profitability

What conditions produce optimal profit for each player?

How does a change in industry standards effect profitability?

What is the optimal time to implement a standards change?

These questions serve as the foundation for the work that follows.

2.2 EQUIPMENT SUPPLIER SEGMENT

The equipment supplier produces the device or terminal that is generally sold to the customer. The device only operates with a subscription from the service provider. The equipment supplier model considers all manufacturers in the aggregate. The competitive forces between firms are not explicitly considered in this model. However, the impact of any rivalry is considered in specific actions such as pricing and capacity. Within the model, there are a variety of relationships that shape the behavior of the equipment supplier.

The equipment supplier causal loop diagram is shown below in Figure 4.

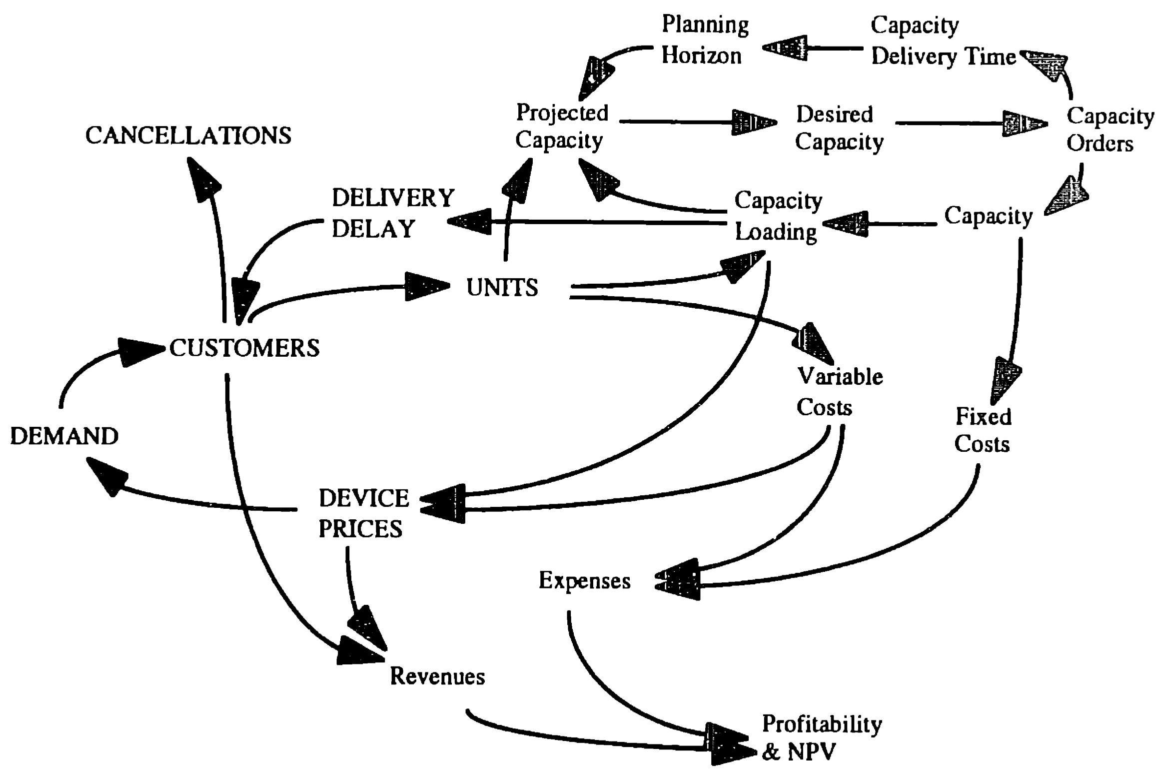


Figure 4: Equipment Supplier Causal Loop Diagram

There are a couple of causal loops that dominate the performance of the equipment supplier segment. The first is the loop that goes from prices to demand to customers to units to variable costs and back to prices. This produces the effect that lower prices cause more demand, more customers, more units, less cost and lower prices. The second loop is a balancing loop. It goes from units to capacity loading to delivery delay to customers and back to units. This loop illustrates that more units increase the capacity loading, increases the delivery delay, reduces the customers and reduces the units. The third important loop causes excess capacity. This reinforcing loop goes from capacity orders to capacity delivery to planning horizon to projected capacity to desired capacity and back to capacity orders. More orders cause longer delivery, longer planning horizon, mare projected capacity, more desired capacity and more orders for capacity. These three key loops describe the dominant behavior of the equipment supplier segment.

There are several concepts embedded in the model. Projected capacity is estimated using an extrapolation of demand forecast forward over the planning horizon. The capacity delivery time increases as the orders for capacity increase forcing a longer planning horizon. Desired capacity drives the orders for capacity. Capacity loading is calculated by dividing the demand into the available capacity. A high loading situation causes an increased projected need for capacity. If demand exceeds capacity, orders go into backlog and may be subject to cancellation. If capacity exceeds demand, capacity can be eliminated to reduce costs.

Variable costs are calculated based on the learning curve. Costs decline each time the cumulative volume doubles. Variable product cost multiplied by the desired margin produces a suggested price for the device. This price is then adjusted to reflect the capacity loading. Insufficient loading decreases prices while excess loading causes prices to increase. The price and units shipped produce revenues for the period. Expenses are calculated using a normal budgeting approach. This budgeting function models the engineering, marketing and administrative effort to develop, implement and educate the market on the device.

The equipment supplier model is essentially duplicated to represent a new standard or generation of product that might be introduced into the market. Therefore, two versions of equipment suppliers exist in the industry model. One represents the first generation and the second represents the second generation. The logic in each model operates identically, however, parameters are changed to represent the difference between the generations. For example, the initial price of each device generation can be and is different. The model operates with one or two generations of product.

To summarize, the key behaviors include cycles of capacity utilization that manifest themselves as periods of excess capacity and other periods of insufficient capacity. During capacity shortages, delivery delays occur which are unacceptable to customers causing product shortages and ultimately order cancellations. Product costs follow a learning curve pattern of cost reductions. The cost reduction results in price reductions that increase demand.

There are several key management inputs that are used to model management policy and strategy. These parameters that can be manipulated to tailor the model to specific markets and products include initial capacity, initial price and gross margin, learning curves, cost of capacity, expense ratios and profit targets. The primary units of measure in the equipment supplier segment are units (devices) and dollars. The model is intended to be both simple yet representative of the behavior of all equipment suppliers.

2.3 SERVICE PROVIDER SEGMENT

The service provider provides the communication link between the customer device and the wireline network or another cellular customer. As with the equipment supplier segment, the service provider segment considers all service providers in the aggregate. This segment of the model represents the key behaviors of the service providers. Though similar in structure to the equipment supplier segment, major differences have been incorporated.

Figure 5 shows the causal loop diagram for the service provider segment.

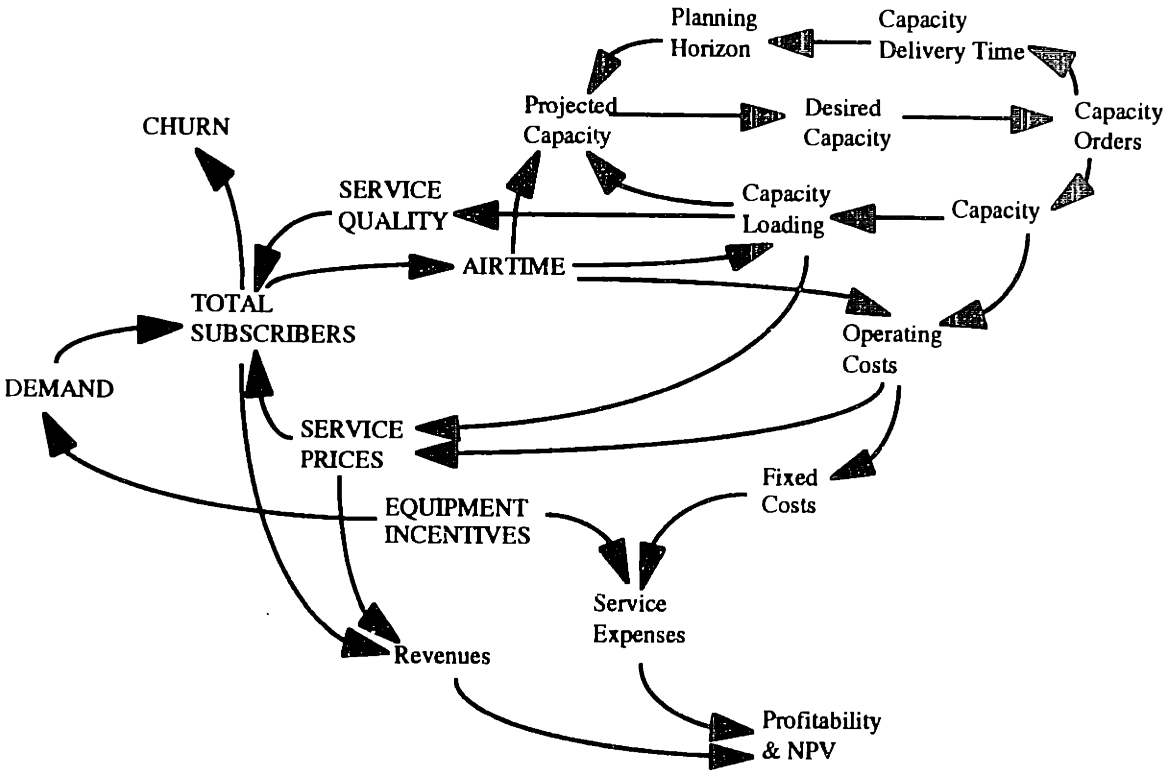


Figure 5: Service Provider Causal Loop Diagram

In the service provider segment, there are several important causal relationships. Networks become more beneficial as more customers join the network. To start the adoption of cellular services, equipment incentives in the form of subsidies are offered to lower the price of the device. The first important loop goes from price to subscribers to airtime to costs and back to prices. Lower prices cause more subscribers, more airtime, less cost, and lower prices. Very dominate in telecommunications is the loop that goes from airtime to loading to projected capacity to desired capacity to capacity orders to capacity loading and back to prices. In this loop, more airtime, higher capacity loading, higher projected capacity, higher desired capacity, more capacity orders, more capacity, lower capacity loading and lower prices. Lower prices caused by excess capacity leads to reduced profitability. The third important loop goes from airtime to capacity loading to service quality to subscribers and back to airtime. More airtime causes higher capacity loading, lower service quality, fewer customers, and less airtime.

There are several behaviors unique to the service provider segment. In the demand module, there is no provision for backlog. If capacity is exceeded, that excess demand is lost. Most networks have a target utilization level; for example, 80%. When that is exceeded, additional capacity is ordered. There are delays for adding new capacity. High network utilization typically lowers the service quality. Poor service quality causes customer dissatisfaction resulting in the loss of customers. As well, some customers may generate large cellular bills in the first month or two of service and decide to cancel their service. This is called churn in the industry. Another distinction of service providers is a two part pricing policy. Usually there is a subscription fee that is charged regardless of use. There is also a network use fee that is charged for the amount of network resource the customer uses. Pricing is determined by a margin over operating costs. Like the equipment providers, budgets for marketing, research and development and general and administrative are determined by a ratio to revenues.

There are several key behaviors exhibited by this segment of the model. Cycles of capacity utilization are modeled. These are characterized by periods of insufficient capacity during high growth periods and excess capacity when grow slows. As capacity utilization approaches 100%, service quality degrades resulting in dissatisfaction and churn. As the network gets larger, operating costs decline. With networks, the average usage of the network per subscriber declines as more subscribers join the network.

The key management inputs that shape the service provider behavior are initial capacity, target network utilization, pricing and device subsidies, cost ratios and learning curves, operating margin targets, capacity planning and profit and investment objectives. Careful selection of the appropriate parameters allows for the simulation of various proposed strategies.

2.4 TWO TIER MARKET MODEL

The two tier market model combines the equipment supplier segments and the service provider segment together with the market dynamics that influence the behaviors of both. As in the previous discussions, a rather simple model can demonstrate the behaviors that characterize the cellular industry.

The Bass diffusion model is implemented. This depicts the phenomenon that new capabilities diffuse slowly at first and then more quickly as more of the market becomes aware until saturation occurs. This is referred to as the S-curve because of its shape and represents the service provider subscriber base. To the equipment provider, unit shipments look more like the normal curve. The shipments start slowly build to a maximum and then start to decline, very quickly at first and then flattening out to the replacement rate. The replacement rate is the number of units in the installed base that require replacement because they are at the end of their product life.

As prices of the service and device fall, more demand is generated in terms of units and airtime. To accelerate the adoption process, the service providers have subsidized the device prices to lower entry cost barriers. These reinforcing loops are balanced by the service quality and cancellation loops. As the network exceeds target capacity, service quality suffers causing churn. Churn causes subscribers to exit the system, often after a significant amount of money was spent getting the customer to join the network. Likewise, as the manufactures reach maximum capacity, the delivery delay produces shortages that lead to increased order cancellations. Order cancellations deprive the service provider of new customers.

The causal loop diagram in Figure 6 illustrates the important relationships of the cellular market.

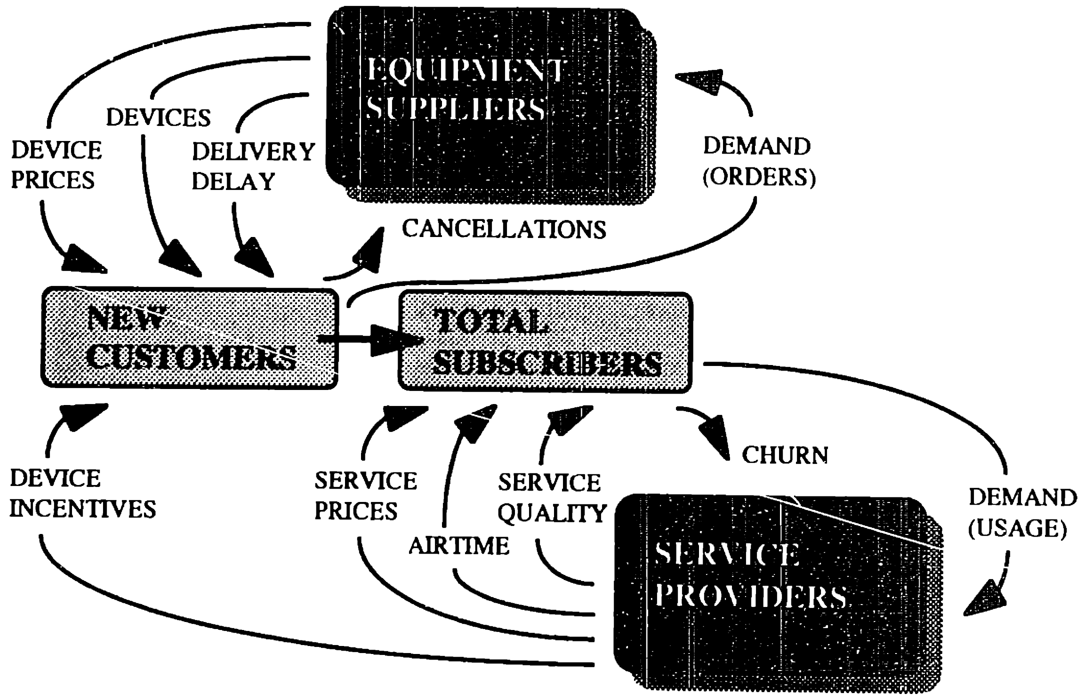


Figure 6: Cellular (Two Tier Market) Causal Loop Diagram

The two tier market model incorporates several key behaviors. The S-curve diffusion model for new technologies is the primary market adoption mechanism. Long delivery delays may result in order cancellations while poor service quality and high service prices can cause churn. Device prices can be reduced by subsidies on the part of the service provider. Replacement of worn out and damaged devices results in additional demand for the equipment provider. This replacement demand is the only business the equipment supplier can expect after the market saturates.

Key inputs that determine market behavior are the effect of price on the size of the market, the rate of diffusion, replacement rate, cancellation rate due to delivery delay and the big bill and service quality effect on churn. As with the other parts of the model, the parameters can be tailored to particular management policies and strategies.

2.5 TECHNOLOGY TRANSITION MODEL

In today's cellular systems, analog radio frequency (RF) modulation is the standard. A new digital (actually several) standard is available and is beginning implementation. The new digital devices provide backward compatibility to the analog standard by offering a capability called dual mode. Essentially, the new digital device is both analog and digital. However, it appears that cellular service providers will stop offering an analog service at some point in the future. This will force the conversion of the analog installed base to the new digital standard. It is like telling the owners of a black and white television set that they will no longer be able to receive a signal sometime at some time in the future.

The technology transition sector models the transition from one standard to another incompatible standard. Furthermore, the sector assumes that this transition must be completed within a given time frame. During this period installed manufacturing and network capacity will transition to the new standard. As well, new orders will move from the current standard to the new one. Concurrently, the installed base will also be upgraded from the old standard to the new standard. This transition is implemented exogenously in this model. Since the actual transition from analog to digital has only just begun in a couple of markets, it is not clear what mechanisms will actually cause the transition to occur. Further, to more effectively analyze the implications of a technology transition, a more predicable model is required.

The sector takes the ship date of the second generation device and the stop ship date of the first generation device and slowly at first, then more rapidly shifts demand from the old to the new. The cost to convert capacity from generation one to generation two is considered for both the manufacturer and the network. Different prices and different subsidies are possible for each generation of the device. Different cost structures are possible with both the equipment supplier and the service provider for each generation. The dates are also adjustable.

It is expected that some form of incentive, most likely from both the equipment supplier and the service provider are required to force the transition. Identifying these incentives is beyond the scope of this project. Instead, a simplifying assumption has been made regarding the model. An exogenous input to the model can be made to look similar to an S shaped diffusion curve. Considering the start and stop dates associated with the new and the old generations of product, technology transition can be simulated. With that being the case, assessments can be made regarding the management of technology scenarios that are developed.

Figure 7 shows the causal loop diagram that has been implemented in the model.

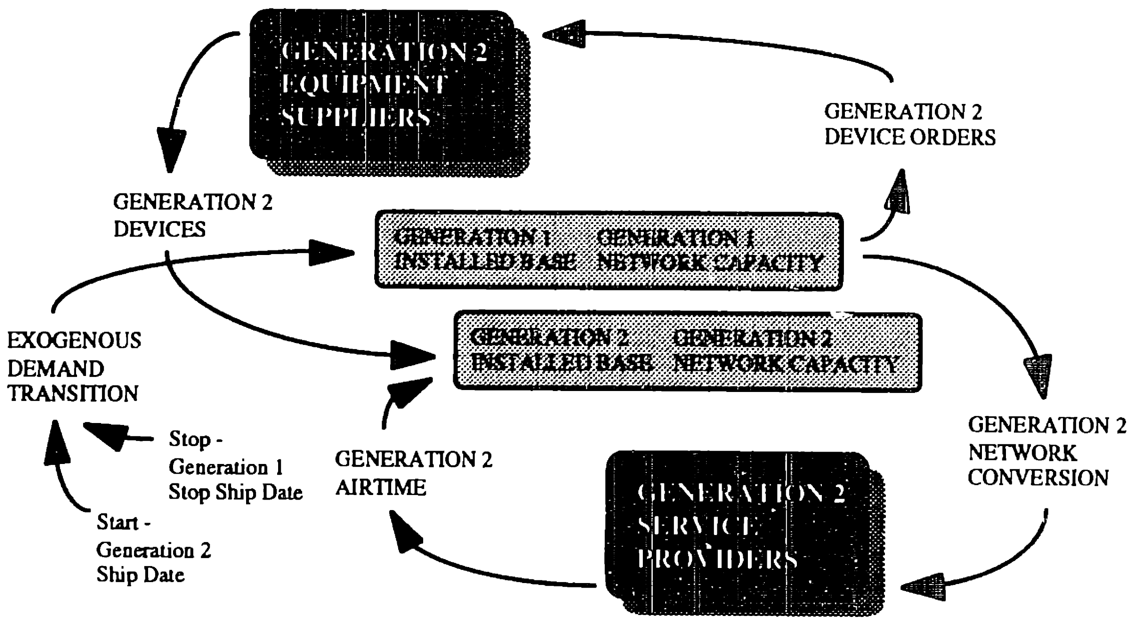


Figure 7: Exogenous Technology Transition Causal Loop Diagram

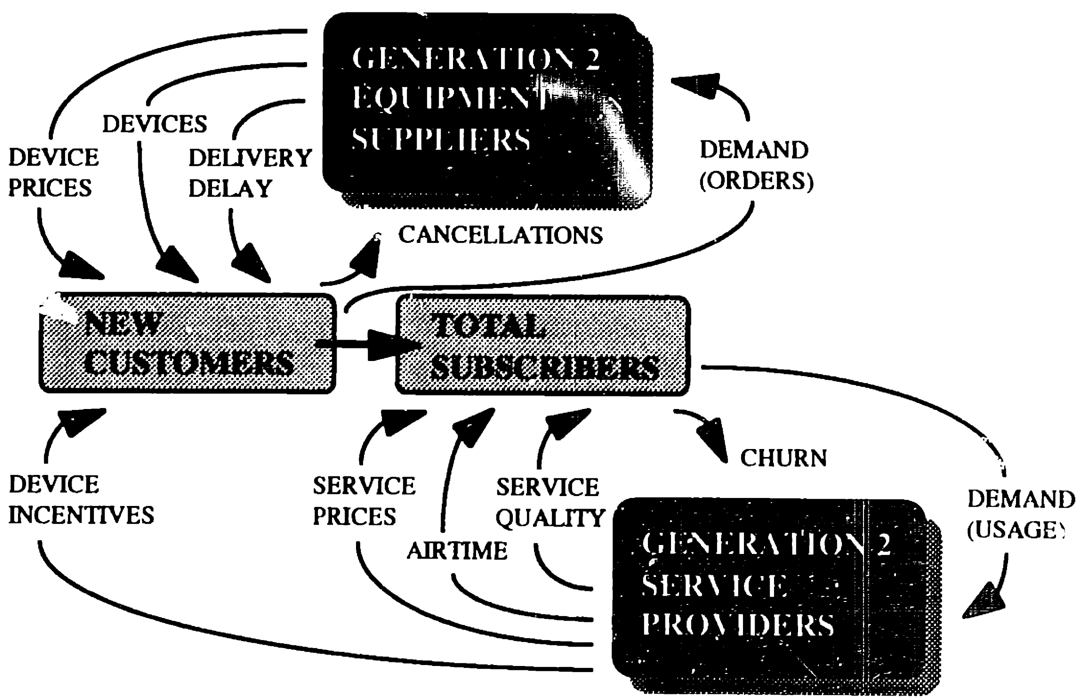


Figure 8: Second Generation Two Tier Market Causal Loop Diagram

After the transition begins, a portion of the new customers will select the second generation product over the first generation product. As well, a portion of the installed base will upgrade to the new standard. As more people try the new standard, more customers will adopt until the transition is completed. Figure 8 reflects the causal loop diagram for the second generation of product. Bear in mind that during the transition, Figures 6, 7 and 8 are all operating. At the beginning of the transition, Figure 6 is dominant. In the middle, all three are effecting each other. At the end of the transition, only the causal loops reflected in Figure 8 are in effect.

As in all the previous sectors, a rather simple structure can be used to simulate a very complex market situation. In the complete model, there is a technology transition sector, a two tier market sector, one service provider segment (for both generations of service) and two equipment suppliers (one for each generation of device). Key behaviors that the model exhibits are an S shaped diffusion curve (within the S shaped diffusion curve for the whole market) for the transition to the new generation of product and service and reduced short term profitability of both players due to conversion costs. Management policy parameters that can be manipulated are the dates new technology is introduced and the old technology is canceled, cost structure and pricing for each generation of technology, capacity planning targets and profitability goals.

2.6 MANAGEMENT OF TECHNOLOGY

There are many aspects to managing technology. These include defining research programs, selecting process technologies, capacity planning and cost reduction efforts. This thesis evaluates macro technology management policies to determine their effect on the performance of the players and market development. These policies include capacity deployment, price and cost relationships and technology diffusion and deployment. Policies that represent good management practice and only effect one of the entities are not discussed in any detail. The emphasis is on the policies of one player that affect the performance and financial success of the other player and the industry.

In this chapter, the basic behavior of each of the segment in the model is discussed. These behaviors are related to the structure and policies in the industry and individual firms. The importance of the device price to the growth of the industry is developed. As device volume increases, the price falls causing more demand. Increasing demand causes insufficient capacity that leads to shortages, increasing delivery delay and cancellations. The service provider can subsidize the device to lower the cost that results in more subscribers. More subscribers use more airtime that also reduces prices. More airtime causes capacity shortages that lower service quality and lead to service cancellations and churn. A technology transition results in the conversion of the installed service and device base from one generation to the next. Again, the threat of capacity shortages can influence the success of a transition program. The model is evaluated, tested, and validated in the next chapter.

CHAPTER 3: MODEL DISCUSSION AND VALIDATION

3.0 PURPOSE

The model of the cellular telecommunications industry is presented in this chapter. For this project, i•think from High Performance Systems Incorporated of Hanover, New Hampshire is the modeling tool. The model and its equations are contained in the Appendix. As in the previous discussions, the model is presented from the bottom up. The equipment supplier and service provider segments are discussed in detail. Then, the two tier market model that integrates the two segments is discussed. The feedback loops between the equipment providers and the service providers are connected. The changes in behavior from the stand alone to the integrated model are observed. Finally, the technology transition model is evaluated.

The key points developed in this chapter follow.

- Equipment suppliers require relatively small investments to participate in a two tier market. Profitability occurs in a relatively short time and then tapers off to a loss situation at market saturation.
- Service providers require significant investments. It takes a long time for profitability to occur and therefore positive investment returns. When profits finally are realized, they are very large.
- Key management of technology factors are capacity, cost reduction and pricing polices.
- The service providers control the customers and have a much stronger financial control over the industry than equipment suppliers. Over the simulation, the net present value of the service providers is twenty times greater than the equipment suppliers.
- A technology transition is very beneficial to the equipment suppliers. The financial returns are doubled in this situation. The benefit to the service providers is slightly negative.

This chapter establishes the reliability and validity of the model in its representation of cellular industry history. With this basis, the model is used to forecast likely future industry trends and performance. In addition, the degree to which certain parameters influence the performance of each of the players is established. This information is then used in Chapter 4 to address the questions of market growth and profitability.

The validation of the model follows a rigorous procedure. Each part of the model is tested individually for expected behavior. This testing assures that the behaviors discussed in Chapter 2 are present and function as discussed. Each segment is tested against a simulated market. This special case assures that the segment is evaluated against a known standard. This is called the test case. Both the equipment supplier and service provider segments are evaluated against the test case. Sensitivity testing is also performed against the base case. This procedure calls for the evaluation of all parameters in best and worse case scenarios to establish the degree to which they effect overall segment performance. Sensitive variables represent opportunities for further investigation.

When the segment testing is complete, the model is brought together to represent the industry. Feedback loops are connected between the segments and between the market and the segments. Testing to characterize and validate the expected behavior is conducted. At this point a base case is established. This is a reasonable approximation of the past and the future. From this base case, scenario testing is conducted to determine performance in relation to the base standard. Sensitivity testing is performed as described above. With the feedback loops connected, the sensitivity of parameters may change. Candidates with significant sensitivity are identified for further evaluation. Finally, the technology transition is tested and validated.

Extensive, systematic testing of the model has been performed. In all situations, the model performed as expected. These test results are not included in this work. However, the test cases are explained and the sensitivity tests are summarized. Two base cases are established to forecast the future. Base Case 1 assumes that there is only one generation of the product in the market during the simulation. Base Case 2 assumes that there are two generations of product, the second introduced into the market at a point after the present.

For comparative purposes, the net present value (NPV) of discounted cash flows financial measurement is used. This function is the preferred method for comparing different financial cash flows created by various scenarios with each other. It is also useful in comparing equipment suppliers to the service providers. The results can be added together resulting in the industry performance. The objective of a scenario is to calculate the net present value of the cash flows. Net present value rewards positive cash flows that occur early as opposed to later and vice versa. For evaluation purposes, a discount rate of 8% was used in the model. This represented the low rates available in the U.S. at the time this investigation began. Figure 9 shows the financial profile of the equipment supplier in the test case. The maximum investment is $310 million dollars and occurs in 1985, one year after the start of manufacturing. The investment is recovered by 1986 and assumes a maximum return of almost $6 billion 19?3. After that, the net present value declines due to the unprofitability of the equipment suppliers in the later years of the test case. Net present value appears in two types of graphs. The first is the comparative graph that Figure 9 and the second is the financial summary like Figure 12. In addition, the NPV is also presented in summary tables like Table 1.

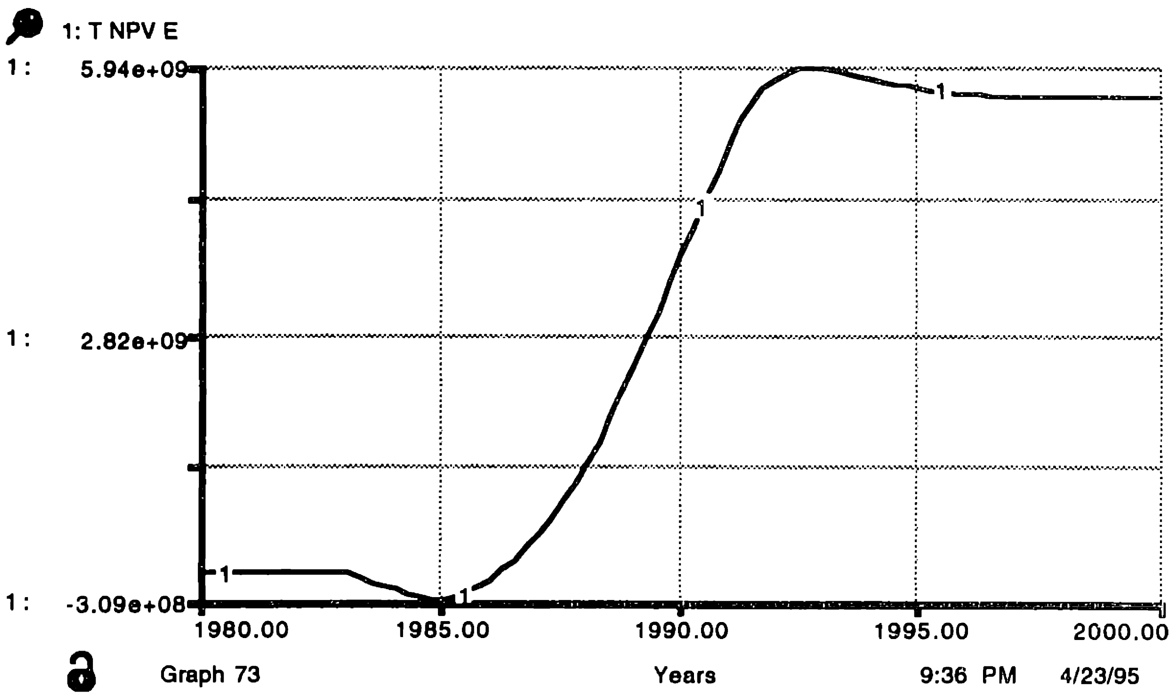


Figure 9: Test Case Equipment Supplier NPV

Table 1: Test Case Equipment Supplier NPV

Trace	1
Parameter	NPV
Minimum	-309M
Maximum	5940M

3.1 EQUIPMENT SUPPLIER SEGMENT

The equipment provider manufactures the device that new customers purchase to use on the network. The test case evaluates the equipment supplier segment against a simulated market. Sensitivity tests evaluate the effect of specific parameter values on overall simulation results.

3.1.1 TEST CASE

There are four sectors in the equipment supplier segment. These are the unit demand, capacity, budgeting and financial sectors. Each is discussed in detail. The unit demand sector manages equipment orders. Orders are received by the sector and flow into backlog. Shipments occur only to the amount of capacity available in the current time period. Orders that do not ship remain in backlog. Delivery delay is calculated as the ratio of backlog to shipments. This ratio is applied to cancellation table that results in a portion of the orders in backlog being canceled. Figure 10 illustrates the behaviors of the unit demand sector. As orders exceed capacity, backlog develops. As backlog develops, cancellations rise until the time capacity exceeds orders. At that point cancellations fall to zero. Backlog may remain, however, delivery delay is within an acceptable range. It is very important to note that the market first grows very rapidly and then declines very rapidly. This is the boom bust cycle that is inherent to a manufacturer whose product follows an S shaped diffusion curve.

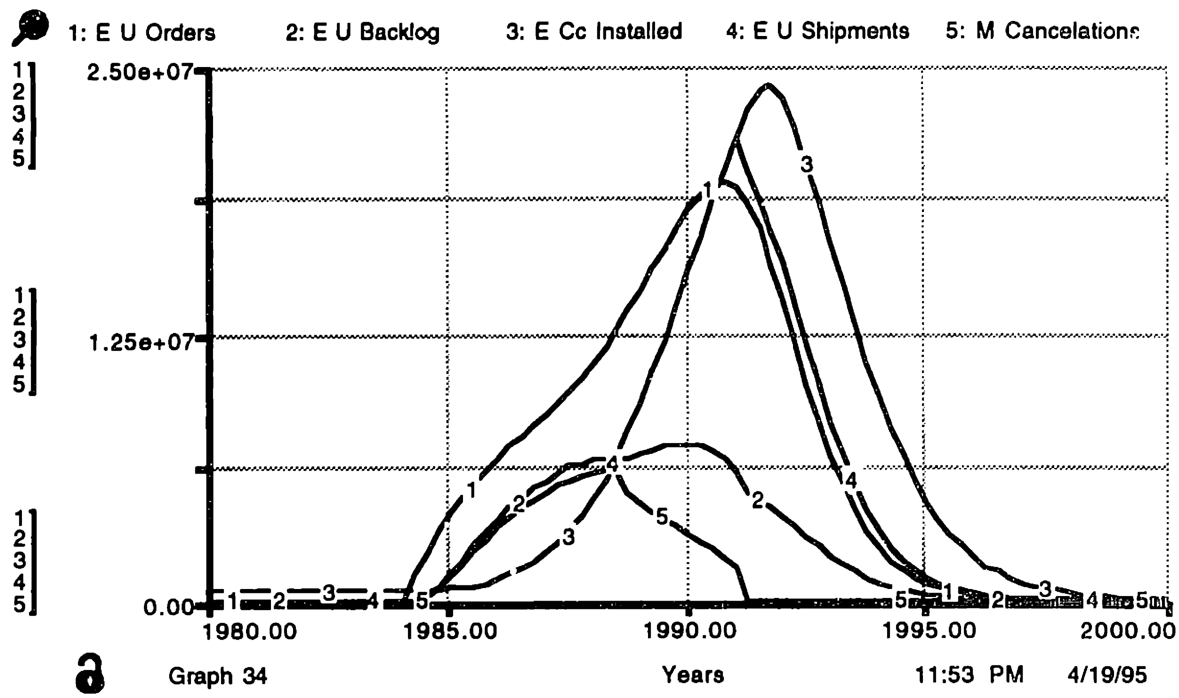


Figure 10: Test Case Total Unit Demand Equipment Suppliers

The second sector plans capacity. This sector determines the level of capacity required and attempts to have it in placc at the proper time. The order flow rate is first smoothed then applied to a trend function. The trend function growth rate is extrapolated forward over the planning horizon resulting in the projected capacity. This number is modified by a loading function that will be discussed in a moment. In many production settings, it is appropriate to have excess capacity during growth and this is provided for. The modified projected capacity is known as the desired capacity. If the desired capacity is more than the capacity on hand and on order, new orders for capacity are placed. Large orders for capacity are subject to delivery delay and this is reflected in the installation function. Once ordered capacity is installed, it is now available to manufacture units. Excess capacity is removed by the capacity reduction function. This occurs when demand falls to reduce fixed costs. The loading is the ratio of installed capacity to orders. High levels of capacity loading results in large orders for capacity that also causes an increase in the delivery delay of capacity as well as a longer planning horizon in the forecast. There is also a check to assure capacity can only be ordered when the profitability policy allows. When excess capacity occurs, it is eliminated as required. In the model, there is no cost for eliminating capacity.

The next sector is budgeting. Budgets for marketing, research and development and general and administrative activities are considered. These are handled as a percentage of revenues. There is also the ability to consider the research and development costs prior to the shipment of the product. These costs are accumulated in the time periods before shipment.

The last sector is the financials. The primary functions are to accumulate costs, report revenues and profits and to calculate a new price. As more units are produced, variable costs decline because of the learning curve. Typically in a manufacturing company, product pricing is determined by a desired gross margin times variable costs. As product costs fall, the price falls. Costs usually fall faster than prices in the first few years of product life. This can create high profitability for manufacturers. As the market matures, profitability is reduced. In a situation where the industry has insufficient capacity, prices may rise. As well, the opposite is also true. Production capacity costs are also subject to learning, though this is usually referred to as productivity improvements. These costs are added to the marketing, research and development (R&D) and general and administrative (G&A) costs and are called fixed costs. Revenue is generated by multiplying shipments by the price. Revenues minus the fixed and variable costs determine the profits. Revenues and profits are accumulated over the simulation. Profit margins are calculated for each time period and cumulatively. The net present value of the discounted profit is also calculated.

Figure 11 depicts the cost and price reductions as volume increases. Note that the fixed costs are not declining at the same rate as the unit price during the second half of the simulation resulting in unprofitability. This is caused by the much lower shipment level at the end of the S curve that can no longer support the fixed cost levels. Also note the variable costs stop declining due to the lower volumes.

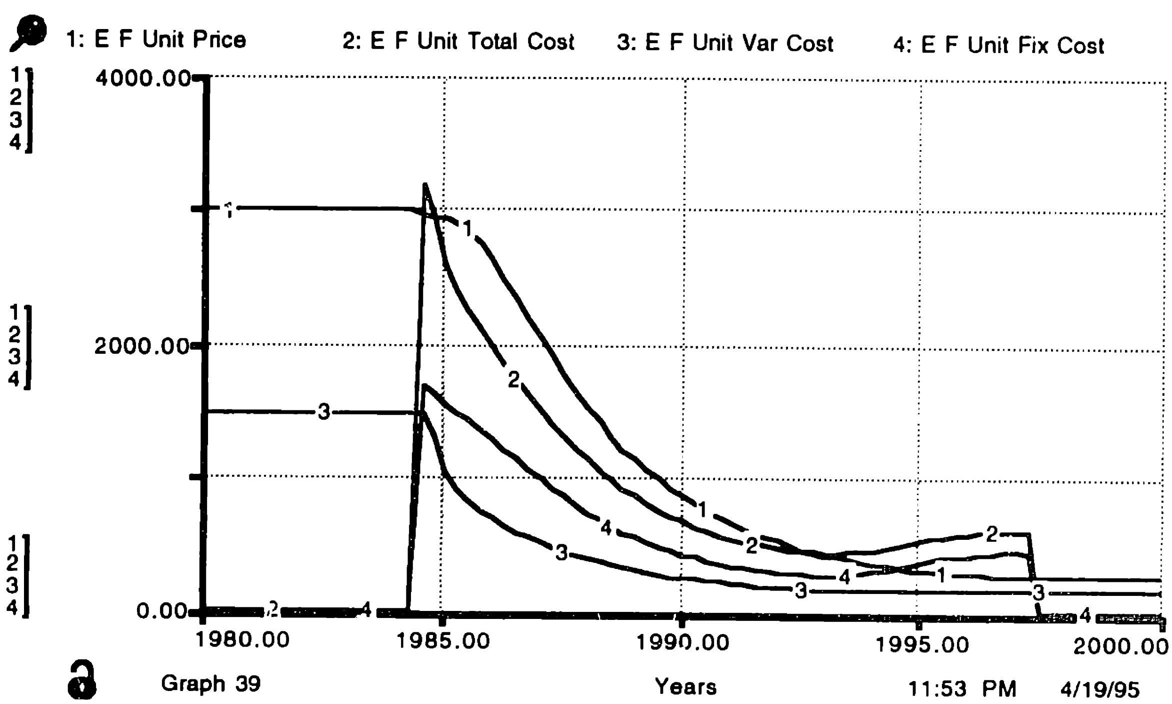


Figure 11: Test Case Per Unit Costs for Equipment Suppliers

Figure 12 and Table 2 are summaries of the financial performance of the equipment supplier sector. This graph shows the minimum and maximum values and the trends of several important measurements. The first trace is the net present value of the discounted cash flow. Note that it is identical to the trace previously presented in Figure 9. The second trace represents the profit margin. Profits begin in 1985 and approach 26% in one year before turning negative in 1993. The loses continue for the rest of the simulation period. Profit is shown by the third trace. Profits for all equipment suppliers peak at $3 billion. When demand dies, the manufacturers lose a total of $387 million. The fourth trace is revenue. Revenues peak at $14 billion in 1991 before falling off rapidly. Trace five is device shipments. The peak occurs when revenues peak at almost 22 million units for that year. This graph is used because it conveys much information quickly. Most importantly, the shape of each measurement is clearly visible over time. The table makes comparisons between different cases easy to perform.

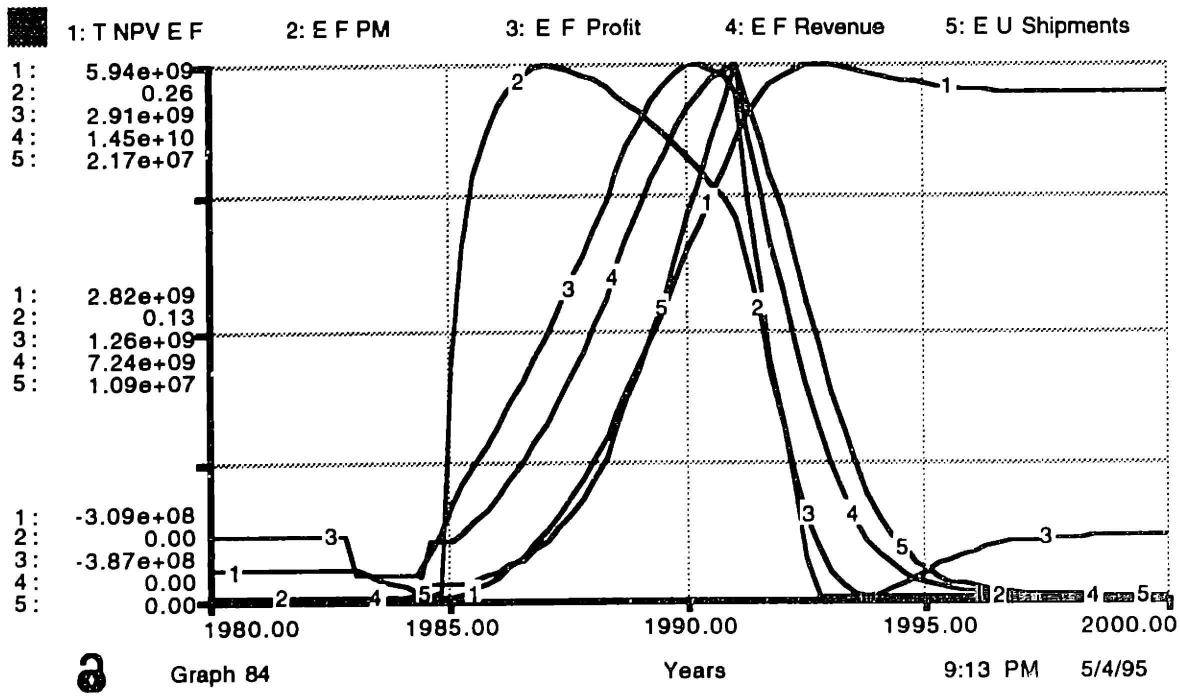


Figure 12: Test Case Equipment Supplier Financial Summary

Table 2: Test Case Equipment Supplier Financial Summary

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Shipments
Minimum	-309M	NA	-387M	0	0
Maximum	5940M	26%	2910M	1450M	21M

The equipment supplier segment demonstrates capacity cycles of insufficient and excess, shortages resulting in order cancellations, learning curve cost reductions and the boom and bust revenue cycle of many manufacturing firms.

3.1.2 SENSITIVITY ANALYSIS

A sensitivity analysis is performed on a system dynamics model to determine which parameters strongly influence the performance of the system. The sensitivity of every parameter in the equipment supplier segment is evaluated. Sensitivity is evaluated on its impact to net present value using the test case. For each parameter, three tests are run. The first test has a value much lower than the test case value, the second test uses the test case value and the third test uses a value much high than the test value. The results were evaluated for impact on net present value, the model behavior exhibited and the effect in the short term and in the long term. Short term is defined as the first five years of shipments and long term is defined as fifteen years after shipments began. A minor effect is defined as a change in net present values less than fifteen percent or $1 billion from the test case. A major effect is greater than that. Due to the amount of data generated during the sensitivity analysis, a summary of the results is appropriate. Table 3 summarizes the sensitivity analysis for the equipment supplier sector. The table shows how much of an impact each parameter has on the net present value of equipment suppliers, whether the behavior was expected, how the parameter influences the NPV and the relative short-term and long-term effects of the variable.

Table 3: Test Case Sensitivity Results for Equipment Suppliers

Parameter	Significance	Behavior	S/T Effect	L/T Effect
Word Of Mouth	Small	Expected, more is better	None	Minor
Marketing Effectiveness	Significant	Expected, more is better	Major	Major
Market Size	Significant	Expected, bigger is better	Minor	Major
Market Growth Time	Small	Expected, faster is better	Minor	Minor
Discard Rate	Small	Expected, higher is better	Minor	Minor
Initial R&D Investment	None	Expected		
R&D Budget Percent	Small	Expected, less is better	Minor	Minor
Initial Capacity	Significant	Expected, more is better	Major	Major
Capacity Growth	Significant	Expected, faster is better	Major	Major
Capacity Delivery Delay	Significant	Expected, shorter is better	Minor	Major
Demand Info Delay	Significant	Expected, less is better	Minor	Major
Initial Unit Price	Significant	Expected, higher is better	Major	Major
Time to Change Price	Significant	Expected, longer is better	Major	Major
Gross Margin	Significant	Expected, higher is better	Major	Major
Initial Unit Cost	Significant	Expected, lower is better	Major	Major
Cost Learning Curve	Significant	Expected, steeper is better	Major	Major

In the table above, the market parameters define the size and speed the market grows. Their influence is well understood. For this model a market size of 80 million was selected which is consistent with several forecasts. The market growth uses the same values as the base case. The important management of technology parameters strongly influences the equipment supplier financial performance as expected. All the capacity, cost and pricing parameters are used in later testing.

Following are a couple of examples of the data developed during the sensitivity analysis of the equipment supplier segment of the model. Figure 13 shows the effect of the initial capacity on the net present value of all equipment suppliers. Table 4 indicates the sensitivity values used in the test. Large amounts of capacity create large losses as the industry starts up. However, break-even occurs quickly because of the rapid growth of the market. Large amounts of capacity minimize the delivery delay and the resulting cancellations and provides for rapid shipment growth in line with demand.

Table 4: Test Case Initial Capacity Sensitivity Values

Trace	1	2	3
Initial Capacity (Units)	100,000	500,000	2,000,000

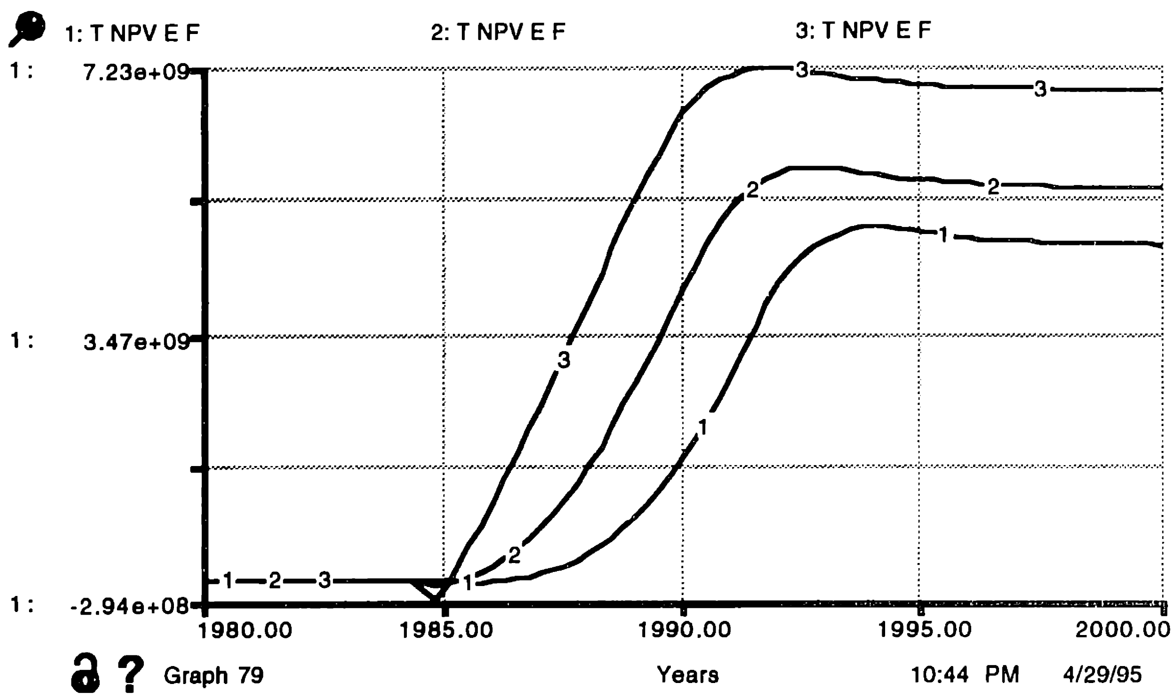


Figure 13: Test Case Initial Capacity Effect on Equipment Supplier NPV

Another example is illustrated by the cost learning curve. Learning curve theory specifies that the cost is reduced by a percentage every time the production volume doubles. The results show that a learning curve of .9 prevents the market from taking off, whereas, a value of .7 provides a slight advantage over .8. Many consumer electronic products have learning curves between .8 and .85. Table 5 shows the values tested. Figure 14 shows the impact of various learning curves on the NPV of the equipment supplier in the base case.

Table 5: **Test Case Product Cost Learning Curve Sensitivity Values**

Run	1	2	3
Learning Curve	.9	.8	.7

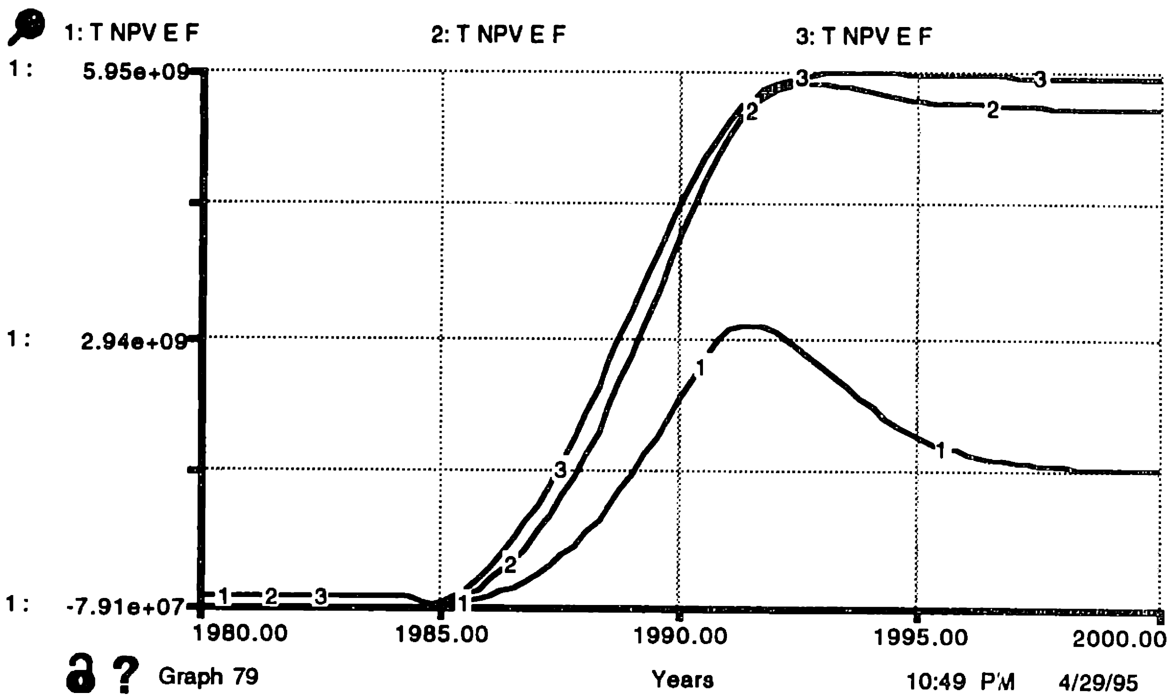


Figure 14: Test Case Learning Curve Effect on Equipment Supplier NPV

The sensitivity analysis for the equipment suppliers demonstrates that the segment is stable and behaves as expected. Table 6 summarizes the key parameters that can be adapted to various management policies and strategies to assess the impact of various scenarios on management of technology issues and financial performance. These parameters significantly impact the performance of equipment suppliers.

Table 6: Base Case Equipment Supplier Key Management Parameters

Parameter	Significance	Behavior	S/T Effect	L/T Effect
Initial Capacity	Significant	More is better	Major	Major
Capacity Growth	Significant	Faster is better	Major	Major
Capacity Delivery Delay	Significant	Shorter is better	Minor	Major
Demand Info Delay	Significant	Less is better	Minor	Major
Initial Unit Price	Significant	Higher is better	Major	Major
Time to Change Price	Significant	Longer is better	Major	Major
Gross Margin	Significant	Higher is better	Major	Major
Initial Unit Cost	Significant	Lower is better	Major	Major
Cost Learning Curve	Significant	Steeper is better	Major	Major

3.2 SERVICE PROVIDER SEGMENT

Service providers provide the communication services the customers use the device with. The test case uses a known stable market to evaluate the performance of the service providers. The sensitivity analysis identifies the key management of technology parameters.

3.2.1 TEST CASE

In the service provider segment, there are also four sectors. They are airtime demand, capacity, budgeting and financial. Air time demand is calculated by multiplying the total number of subscribers by the airtime per subscriber. Airtime per subscriber is calculated using a learning curve function. This is supported by the fact that use per subscriber declines as more subscribers join the network. The amount of airtime provided cannot exceed the capacity. For the airtime in excess of capacity, this demand is lost. This sector also performs a service quality assessment. When the network starts up, service quality is low due to coverage issues. Over time, this improves until the demand exceeds the target capacity utilization. This causes a degradation in service quality. Poor service quality results in customer dissatisfaction. Figure 15 shows the airtime demand. Note the over capacity situation resulting in lost airtime. Also note the excess capacity when demand levels off. For the test case, desired capacity utilization is set at 75%.

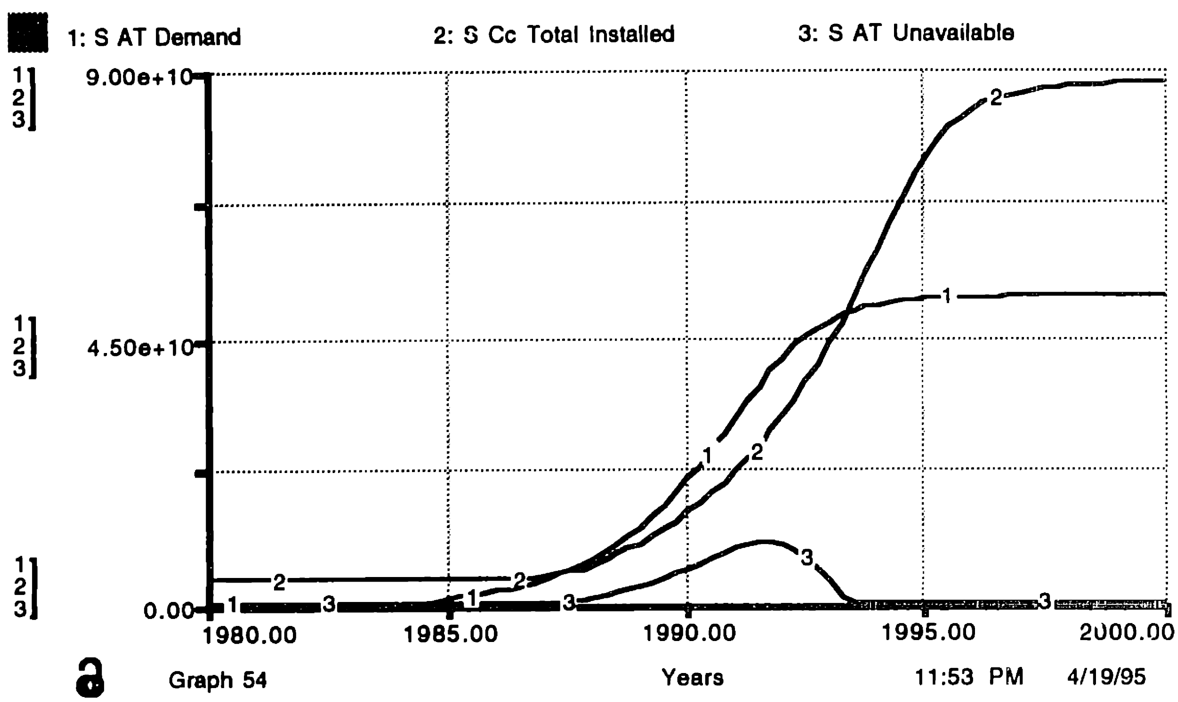


Figure 15: Test Case Total Airtime Demand for Service Providers

The quality index is shown Figure 16. Quality (Trace 1) starts out poorly and improves until capacity is exceeded. Note the delay in the behavior since quality is based on perceptions that take time to form. Also note that loading (Trace 2) is maximized at 1.33 which is the reciprocal of .75.

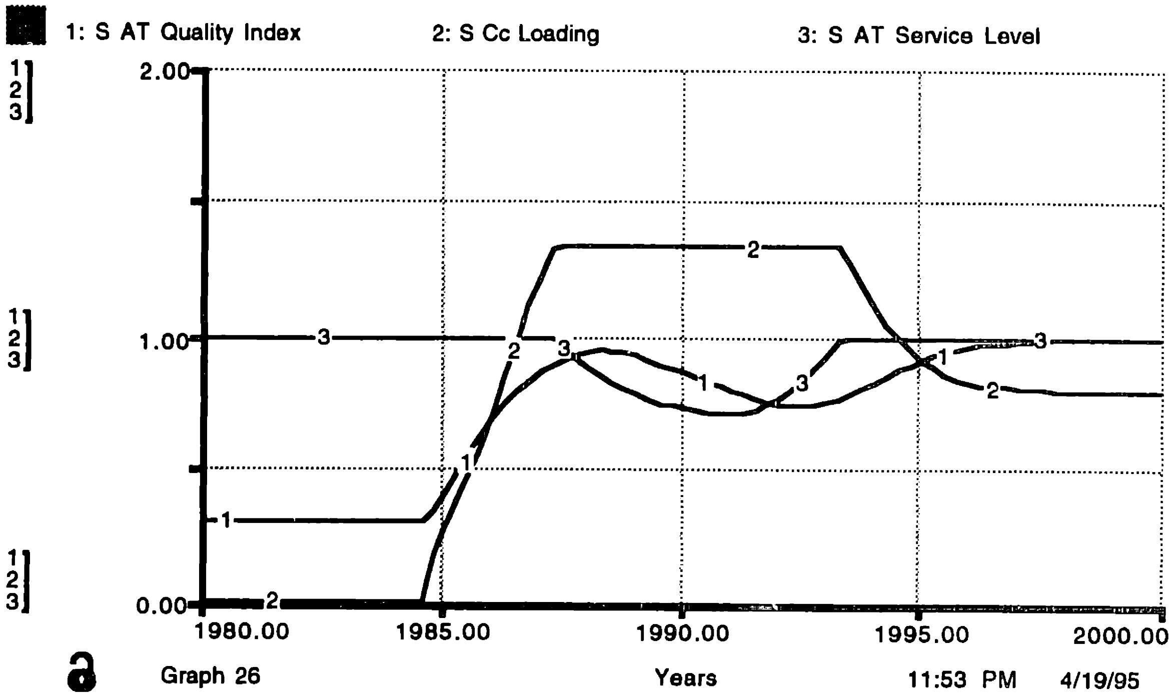


Figure 16: Test Case Quality Index for Service Providers

The capacity sector works like the equipment provider segment with one exception. Capacity on a network is based on planned network utilization. Needed capacity is determined by dividing demand by the target utilization. Certain parameters have been changed so that this sector can handle the several orders of magnitude greater expansion requirements in a network where capacity is based on call minutes. The capacity planning function tries to maintain excess capacity. Orders for capacity are created until adequate capacity, including the excess, is provided.

The budgeting sector for service providers is very similar to that of equipment providers. Typically, the difference is usually in the ratios of expenditure to revenue for each of the functional areas. There is one key difference for the service provider. As part of the marketing expenses, subsidies to lower the price of the device are required. The expenditures for marketing, R&D and G&A and the subsidies are calculated every period.

The financial sector determines airtime prices, revenues, costs and profitability. Unlike a manufacturer where prices are determined as a margin over variable costs, networks are priced as a margin over operating costs. Operating costs are defined as variable costs plus the capacity costs of the network. Low network loading lowers the price when excess capacity exists. Another difference in networks is the subscription fee. This is paid by subscribers regardless of network usage. Revenues are the sum of airtime charges and subscription fees. Costs are the sum of operating and fixed costs. Profitability is then calculated. One other element of this sector is the conversion ot capacity from one generation of service to the next as required in the technology transition model. As the operating costs (the sum of variable and capacity costs) fall, airtime prices will fall. In Figure 17, high network utilization prevents price reductions until the planned excess capacity is available. Note that this additional capacity raises operating costs in the later time periods.

Table 7: Legend for Figure 17

Trace	1	2	3	4	5
Parameter (Per minute of airtime)	Airtime Price	Operating Costs	Variable Costs	Network Capacity Costs	Fixed Costs

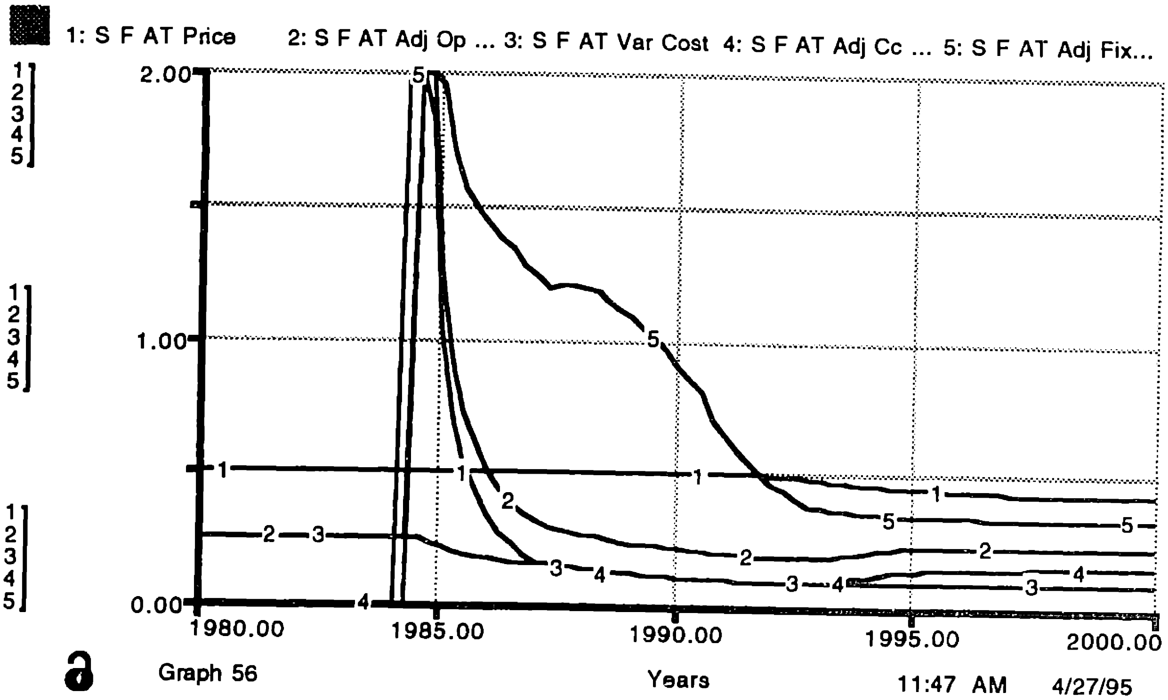


Figure 17: Test Case Per Minute of Airtime Costs for Service Providers

Figure 18 shows the service provider financial summary. Table 8 provides the same information in a tabular form. The net present value trace illustrates just how much patience and money are required to participate in the service side of the cellular business.

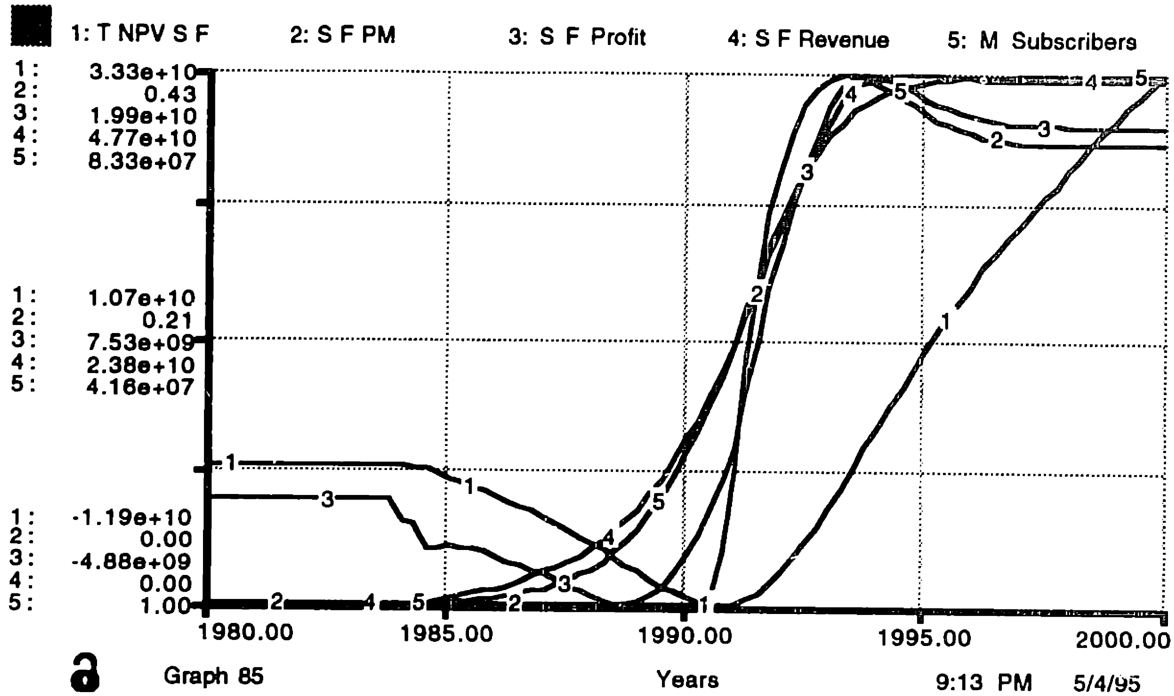


Figure 18: Test Case Service Provider Financial Summary

Table 8: Test Case Service Provider Financial Summary

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Subscribers
Minimum	-11.9B	NA	-4.8B	0	0
Maximum	33.3B	43%	19.9B	47B	83M

The service provider segment demonstrates cycles of capacity utilization, cost and price reductions and service quality fluctuations that are common to the service industry. The magnitude of the investment and the long payback period is an important characteristic of this industry.

3.2.2 SENSITIVITY ANALYSIS

A sensitivity analysis is also performed on the service provider segment. This analysis is used to evaluate the model for predicted behaviors and parameter variation on model output. Each parameter in the segment is evaluated for its impact on service provider net present value. As in the equipment supplier sensitivity analysis, Table 9 summarizes the results of the sensitivity analysis. The table shows how much of an impact each parameter has on the net present value of equipment suppliers, whether the behavior was expected, how the parameter influences the NPV and the relative short-term and long-term effects of the variable.

Table 9: Test Case Sensitivity Results for Service Providers

Parameter	Significance	Behavior	S/T Effect	L/T Effect
Word Of Mouth	Small	Expected, more is better	None	Minor
Marketing Effectiveness	Significant	Unexpected, more is better but too much is bad	Major	Major
Market Size	Significant	Expected, bigger is better but at a huge investment	Major	Major
Market Growth Time	Small	Expected, faster is better but at a bigger investment	Minor	Minor
Discard Rate	Small	Expected, less is better	Minor	Minor
Initial R&D Investment	Small	Expected, less is better	Minor	Minor
Marketing Budget Percent	Significant	Expected, less is better	Major	Major
Initial Capacity	Significant	Expected, more is better but too much is a killer	Major	Major
Capacity Growth	Small	Expected, faster is better	Minor	Minor
Capacity Delivery Delay	Significant	Expected, shorter is better	Minor	Major
Capacity Excess	Small	Expected, test case is best	Minor	Minor
Demand Info Delay	Small	Expected, less is better	Minor	Minor
Initial Airtime Price	Significant	Expected, higher is better	Major	Major
Service Fee	Significant	Expected, more is better	Major	Major
Time to Change Price	None	Expected, longer is better	Minor	Minor
Operating Margin	Significant	Expected, higher is better	Minor	Major
Initial Network Cost	Significant	Expected, lower is better	Major	Major
Cost Learning Curve	Significant	Expected, steeper is better	Major	Major

The market parameters have a significant effect on the performance of the service providers. Key management of technology parameters are initial capacity, capacity delivery and the cost structure, particularly at the outset. These variable are investigated further.

The key to high net present value for the service providers is to manage the growth rate. If the market grows too fast, profitability is hurt by shortages of capacity resulting in churn. An example of the sensitivity analysis is provided by initial network capacity. As Figure 19 shows, too much capacity is a disaster while too little capacity is okay early on but less profitable than having the appropriate capacity. The parameter values are shown in Table 10.

Table 10: Test Case Initial Capacity Sensitivity Values

Run	1	2	3
Initial Capacity (M Call Minutes)	400	4,000	40,000

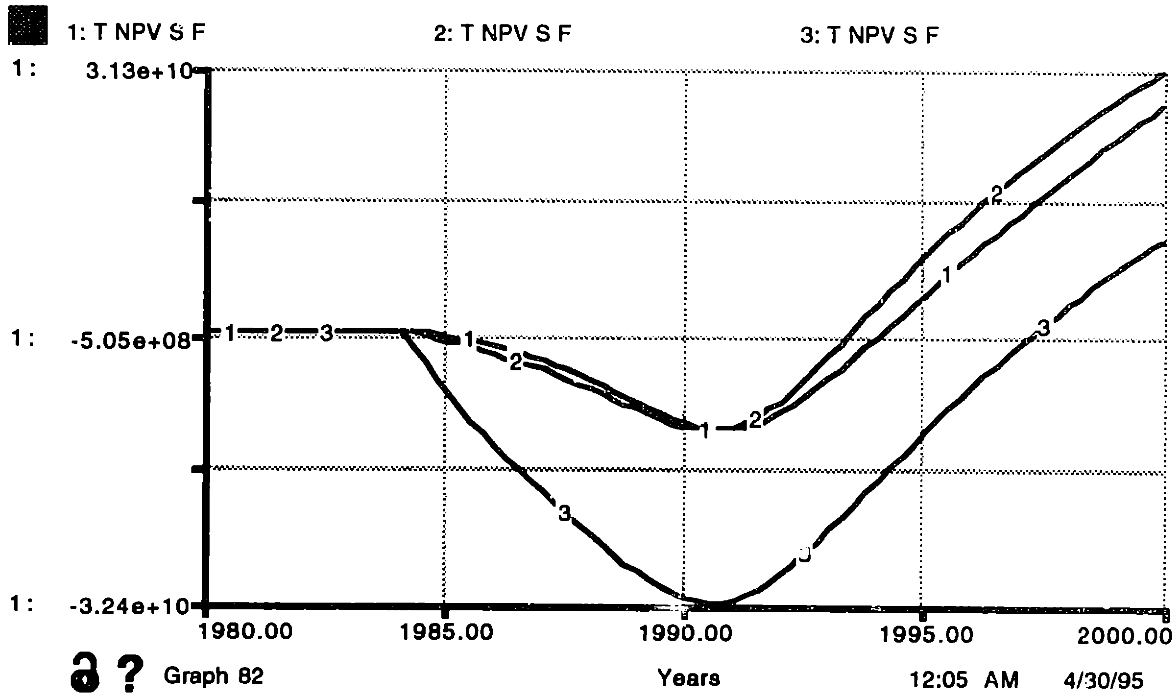


Figure 19: Test Case Initial Capacity Effect on Servicc Provider NPV

Another parameter evaluated is the learning curve on the cost of providing a call minute. The sensitivity values are shown in Table 11. Figure 20 shows that a shallow learning curve really hurts the financial performance of the service provider. However, there is a point of diminishing returns. The net present value at .8 is only marginally better than .9 suggesting that other costs, such as fixed costs, may require improvement at the same rate as the operating costs.

Table 11: Test Case Operating Cost Learning Curve Sensitivity Values

Run	1	2	3
Operating Cost Learning Curve	.8	.9	.95

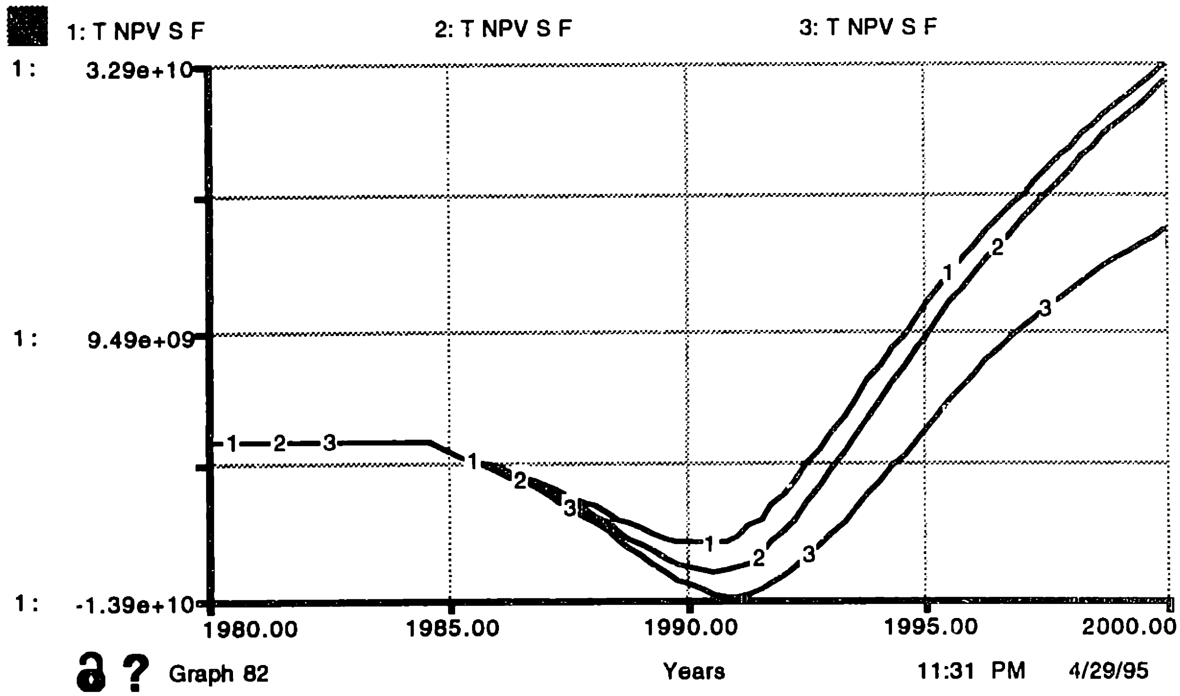


Figure 20: Test Case Operating Cost Learning Curve Effect on Service Provider NPV

The sensitivity analysis for service providers shows that the segment is stable and behaves as expected. Key variables like capacity and learning curve are evaluated in the next section for their impact on the two tier market. Table 12 summarizes the key management variables that influence the performance of the service provider segment.

Table 12: Test Case Service Provider Key Management Parameters

Parameter	Significance	Behavior	S/T Effect	L/T Effect
Marketing Budget Percent	Significant	Less is better	Major	Major
Initial Capacity	Significant	More is better but too much is a killer	Major	Major
Capacity Delivery Delay	Significant	Shorter is better	Minor	Major
Initial Airtime Price	Significant	Higher is better	Major	Major
Service Fee	Significant	More is better	Major	Major
Operating Margin	Significant	Higher is better	Minor	Major
Initial Network Cost	Significant	Lower is better	Major	Major
Cost Learning Curve	Significant	Steeper is better	Major	Major

3.3 TWO TIER MARKET MODEL

The two tier market model connects or wires together the equipment supplier and service provider segments with the market. For example, the price of the device now effects the size of the market. A base case is established which represents the history of the cellular market. A reasonable forecast of the future is established and this is called Base Case 1. A sensitivity analysis is performed and the results are summarized.

3.3.1 BASE CASE 1

The two tier market combines the equipment supplier segment and the service provider segments with a market sector. The initial cost to the subscriber is calculated as the device price minus the device subsidy. The size of the market is defined by this initial cost. It is known the higher the price, the fewer potential customers the product is attractive to. Potential customers become aware of the product through marketing activities and positive word of mouth from current customers. This creates demand for equipment that become orders for the equipment suppliers. Cancellations occur when the delivery delay becomes unacceptable. Customers that cancel do not become subscribers then but may later. When customers receive their devices via shipments they become subscribers. When the capacity of the network is exceeded, poor service quality results. Churn is defined as those subscribers that leave the service because of poor service quality or unacceptably large cellular bills. Subscribers that leave the service may return later.

Base Case 1 is defined as the cellular telecommunications industry in the U.S. The data generated by the base case of the model is intended to represent this industry from its start in 1984 through 1994. The comparison of the model data to the historical data is contained in Section 3.5. Base Case 1 assumes that there is one technology standard during the entire simulation period 1980 through 2012.

The initial price for a mobile phone in 1984 was almost $3000. This resulted in a very small initial cellular market. Figure 21 shows that as the price declined, the potential market becomes much larger. Note that the market starts to take off when the price falls below $1000.

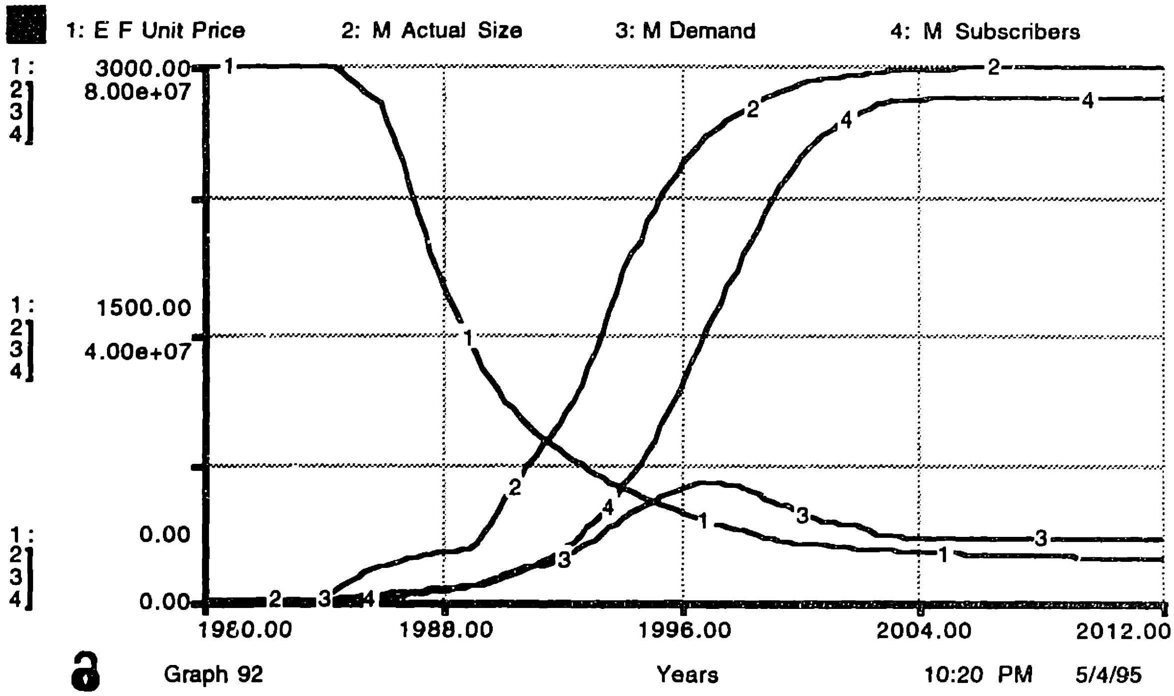


Figure 21: Base Case 1 Market Growth for Cellular Industry

Figure 22 shows the unit demand for Base Case 1. Note that orders stabilize at the replacement rate. The replacement rate is set at 10% which equates to an average product life of ten years. During the growth phase, capacity lags demand which results in some cancellations.

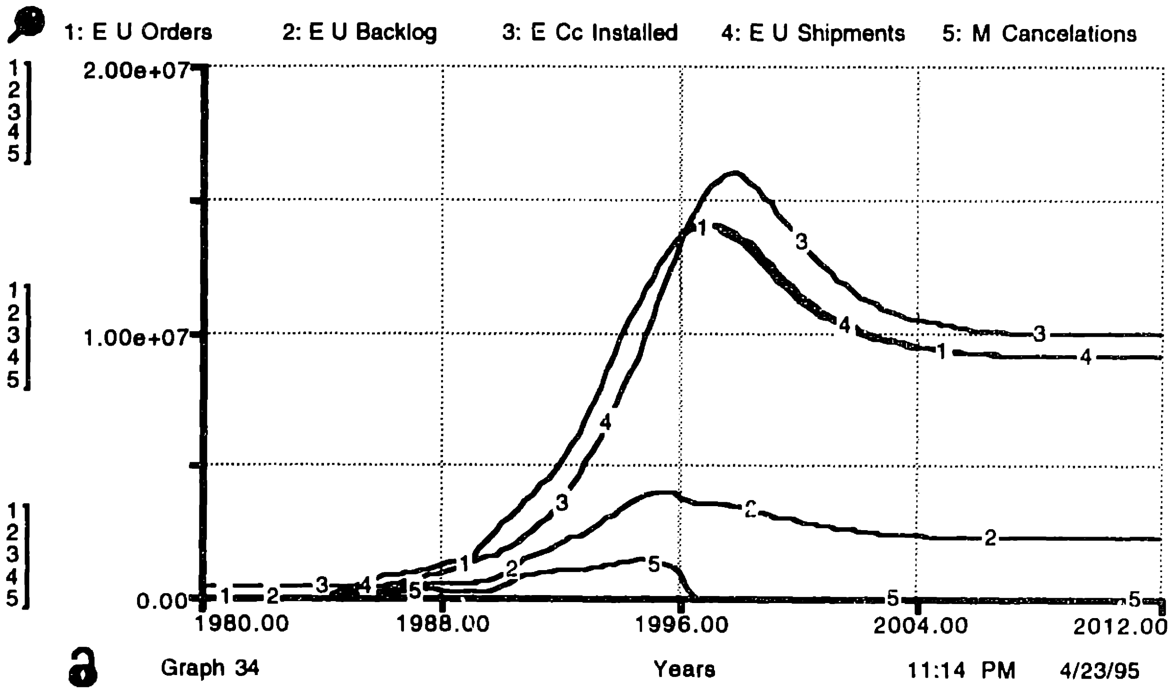


Figure 22: Base Case 1 Unit Demand for Equipment Providers

The service provider sees the airtime demand as Figure 23 shows. During rapid growth, capacity falls behind the demand requirements that leads to an inability to satisfy all demand. In the later time periods, capacity achieves the level required by the target utilization.

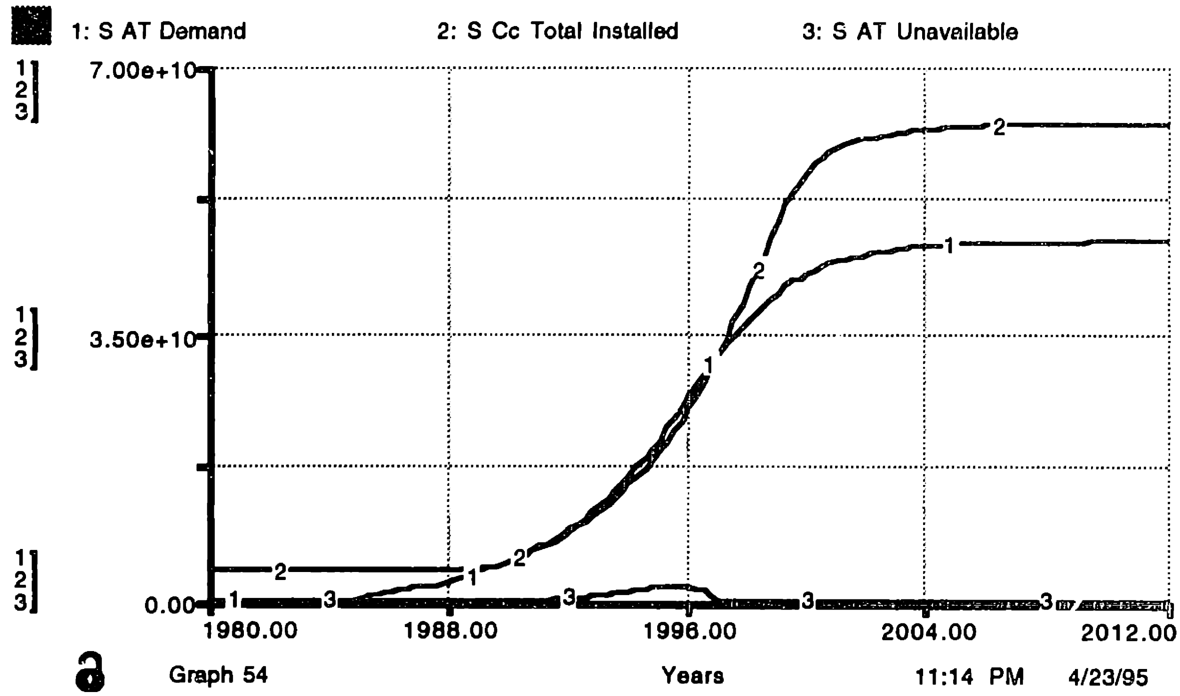


Figure 23: Base Case 1 Airtime Demand for Service Providers

Financials for the equipment provider in Figure 24 and Table 13. Notice the early profitability followed by rapidly declining profitability and finally sustained losses after 1997, when demand peaks.

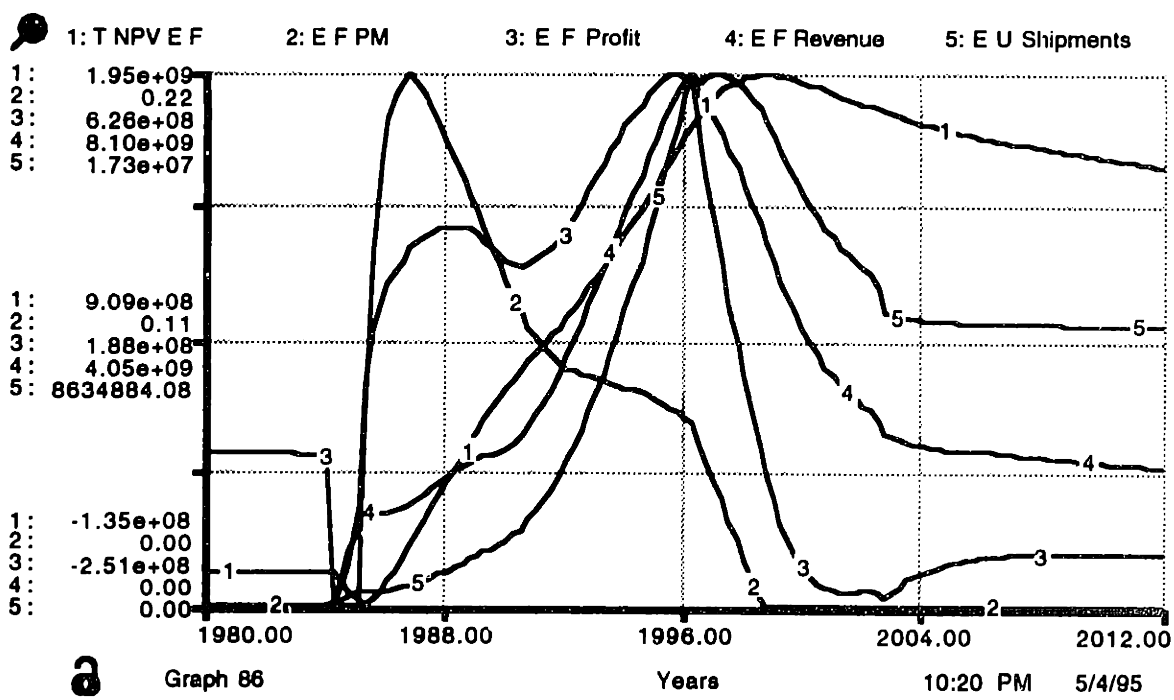


Figure 24: Base Case 1 Equipment Supplier Financial Summary

Table 13: Base Case 1 Equipment Supplier Financial Summary

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Shipments
Minimum	-135M	NA	-251M	0	0
Maximum	1950M	22%	626M	8100M	17M

Figure 25 and Table 14 show the financials for the service provider. At the time the net present value of the equipment provider has peaked, the service provider is just breaking even on their investment. The service provider also enjoys increasing rates of return even after the market has saturated as the next graph shows. It is these returns that have attracted so much money to the cellular industry. Why else would AT&T pay $12 billion for McCaw, a company that has never turned a profit?

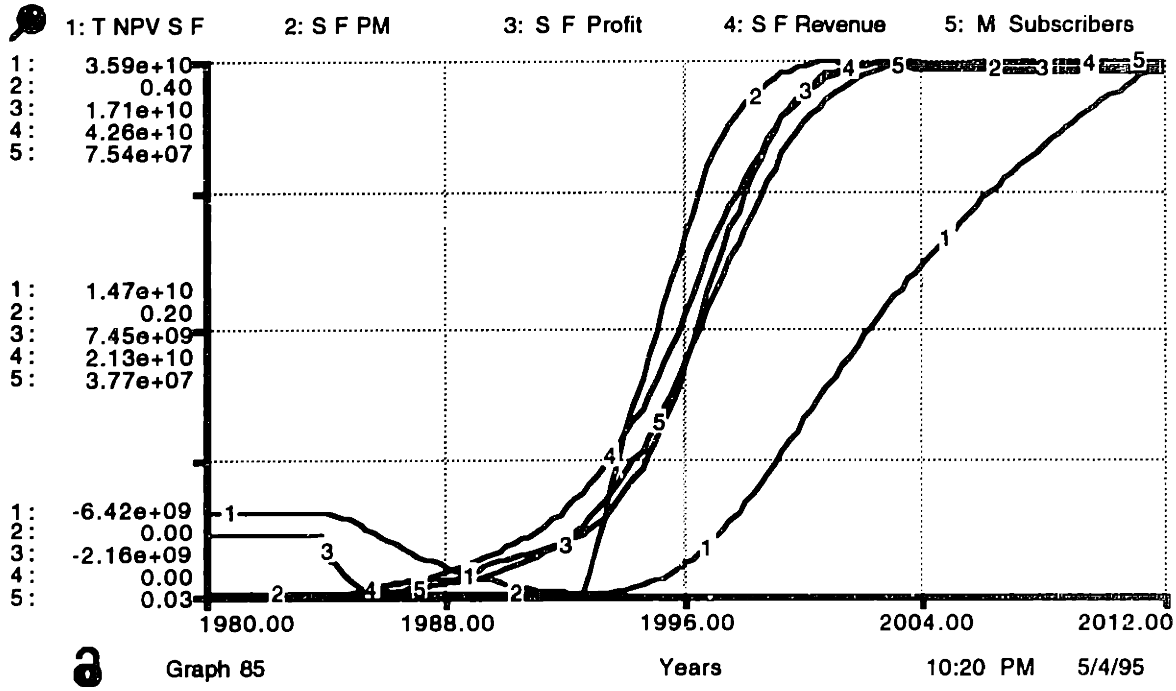


Figure 25: Base Case 1 Service Provider Financial Summary

Table 14: Base Case 1 Service Provider Financial Summary

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Subscribers
Minimum	-6.4B	NA	-2.2B	0	0
Maximum	35.9B	40%	17.1B	42.6B	75M

The financials for the industry are shown in Figure 26 and Table 15. In the twenty-eight years of the simulation, a total of 75 million subscribers went through an average of four phones creating an industry with annual revenues of almost $45 billion and profits of almost $17 billion.

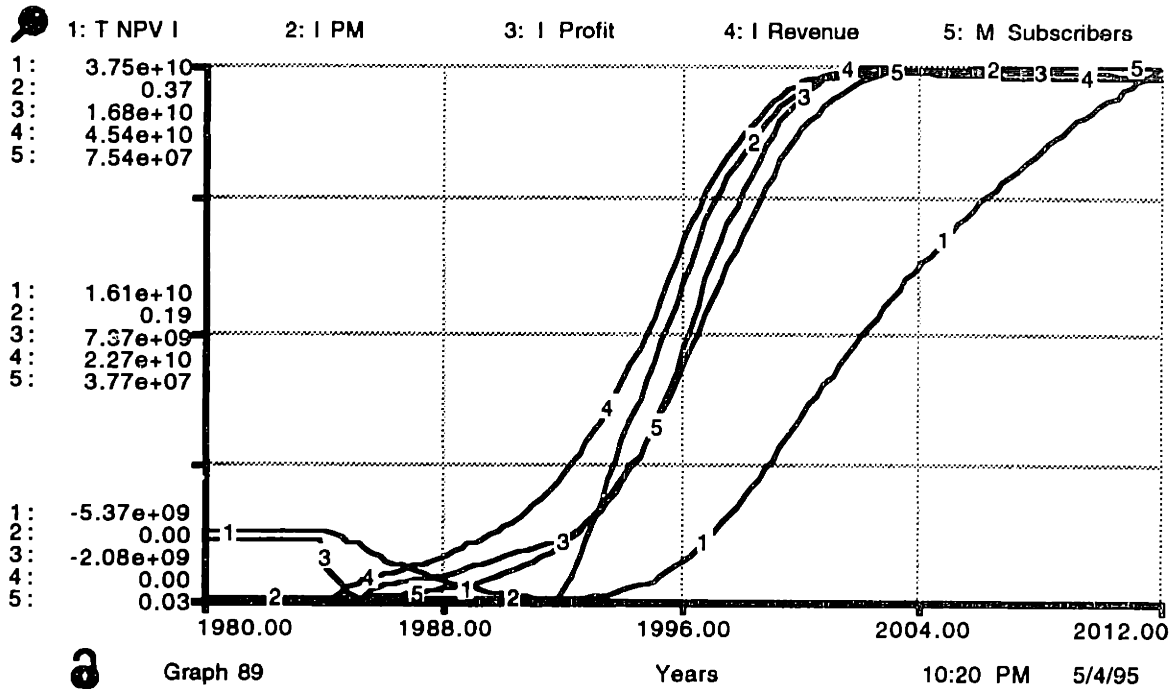


Figure 26: Base Case 1 Cellular Industry Financial Summary

Table 15: Base Case 1 Cellular Industry Financial Summary

Trace	**1**	**2**	**3**	**4**	**5**
Parameter	NPV	Profit Margin	Profit	Revenue	Subscribers
Minimum	-5.3B	NA	-2.0B	0	0
Maximum	37.5B	37%	16.8B	45B	75M

The two tier market operates as expected. The comparison of Base Case 1 and the history of the cellular market is discussed in Section 3.5 The market is currently enjoying very rapid growth, however, that will be short lived for the equipment suppliers. The bust cycle is just around the corner. Meanwhile, the service providers are seeing positive cash flows and are approaching break-even on their investments.

3.3.2 SENSITIVITY ANALYSIS

A complete sensitivity analysis was conducted on Base Case 1. In some cases, the effect of a parameter is in the same direction (i.e., the net present value of both parties increases). In other cases, it is in the opposite direction. Please note, the service provider performance strongly influences the industry performance. Therefore, a very large change in the equipment supplier performance is required to make a measurable impact to the industry. Table 16 summarizes the sensitivity tests conducted on the two tier market Base Case 1. The table shows how much of an impact each parameter has on the net present value the industry, whether the behavior was expected, how the parameter influences the NPV and the effects of the parameter on service providers and equipment suppliers.

Table 16: Base Case 1 Sensitivity Results for the Cellular Industry

Parameter	Industry Significance	Industry Behavior	SP Effect	ES Effect
Word Of Mouth	Small	Expected, more is better	Minor	Major
Marketing Effectiveness	Significant	Expected, more is better	Major	Major
Market Size	Significant	Expected, bigger is better but at a bigger investment	Major	Major
Market Growth Time	Small	Expected, faster is better	Minor	Minor
Discard Rate	Small	Expected, less is better	Minor	Major, opposite
Network Quality	Small	Expected, higher is better	Minor	None
Big Bills	Small	Expected, lower is better	Minor	None
Discount Rate	Significant	Expected, lower is better	Major	Major
Equipment Subsidies	Significant	Expected, higher is better	Major	Major
Initial Capacity - Service Provider	Significant	Expected, not enough is bad but too much is a killer	Major	Minor
Initial Capacity - Equipment Supplier	Small	Expected, more is better but too much is bad	Minor	Major
Capacity Growth - Service Provider	Small	Expected, faster is better	Minor	Minor, opposite
Capacity Growth - Equipment Supplier	Small	Expected, faster is better	Minor	Major
Capacity Delivery Delay - Service Provider	Small	Expected, shorter is better	Minor	Minor, opposite
Capacity Delivery Delay - Equipment Supplier	Significant	Expected, shorter is better	Major	Major
Capacity Excess - Service Provider	Significant	Expected, test case is best but too small is a killer	Major	Minor, opposite
Demand Info Delay - Service Provider	Small	Unexpected, almost no effect but too little is bad	Minor	Minor, opposite
Demand Info Delay - Equipment Supplier	Small	Expected, less is better	Minor	Major
Initial Airtime Price	Significant	Expected, higher is better	Major	None
Service Fee	Significant	Expected, higher is better	Major	None
Initial Device Price	Significant	Expected, lower is better	Major	Major, opposite
Time to Change Price - Equipment Supplier	Significant	Expected, shorter is better	Minor	Major, opposite
Cost Learning Curve - Service Provider	Significant	Expected, too little and too much are bad	Major	None
Cost Learning Curve - Equipment Supplier	Significant	Expected, steeper is better, too little, market dies	Major	Major

Several of the parameters that were significant to a segment in the test cases are insignificant in the base case. An example is the initial device price. For the equipment supplier, higher is better. However in the market, lower is better. On the other hand, the capacity delivery delay is significant to the service provider segment, but in the market is minor. These resulted are evaluated as scenarios in Chapter 4.

A couple of examples demonstrates the power of a sensitivity analysis. In the first example, the learning curve for the equipment is highlighted. The values for the parameters are shown in Table 17. In the sensitivity evaluation of the equipment supplier segment by itself, a learning curve of 90% produced a net present value of over $1 billion. In the two tier market, the market fails to take off resulting in losses for both the equipment supplier and the service provider. A 70% learning curve provides significantly improved profitability for the industry when compared to the 80% learning curve. Figure 27 shows the effect of the learning curve on the subscriber base .

Table 17: Base Case 1 Device Learning Curve Sensitivity Values

Run	1	2	3
Device (Product Cost) Learning Curve	.7	.8	.9

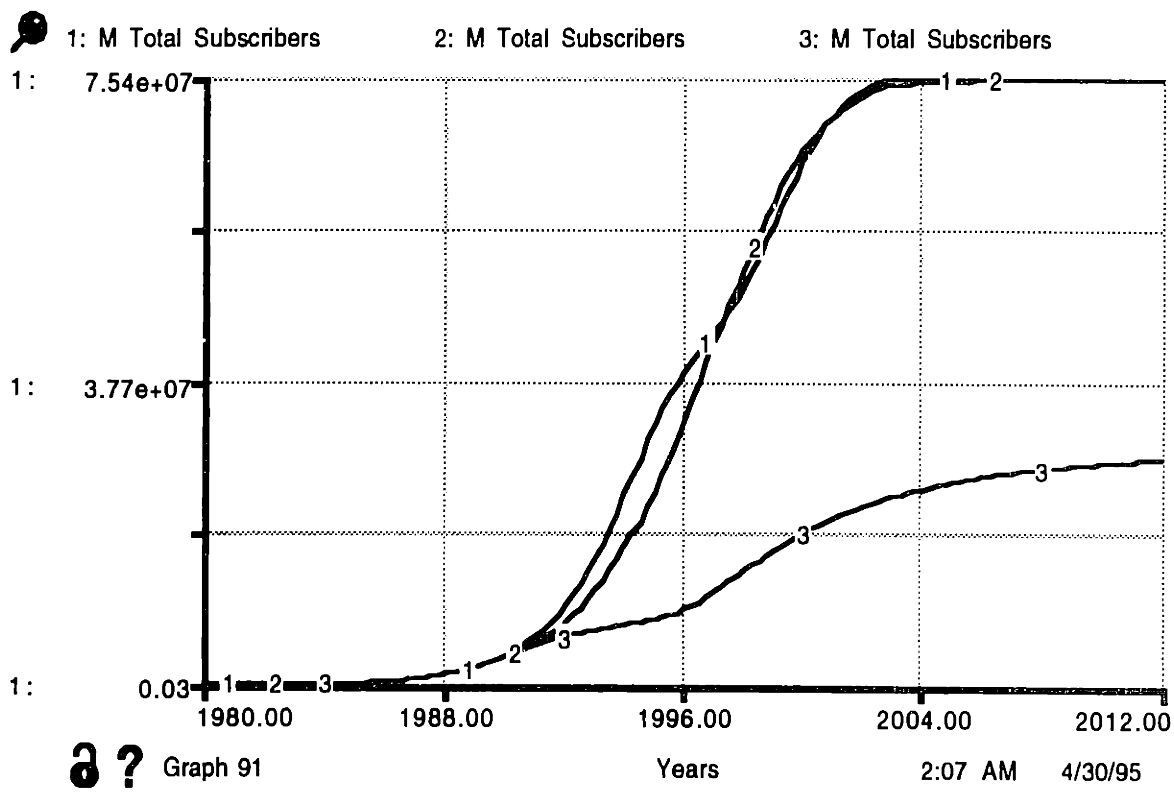


Figure 27: Base Case 1 Device Learning Curve Effect on Subscriber Base

Figure 28 shows the financial performance of the equipment suppliers for the three values of the cost learning curve parameter.

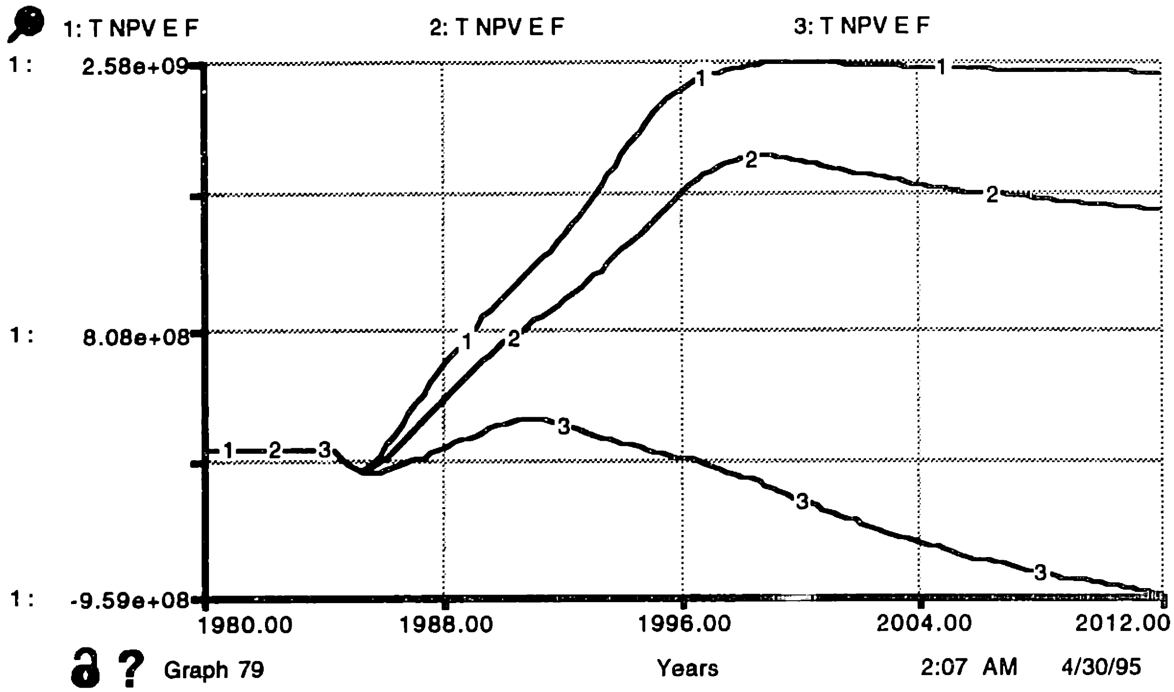


Figure 28: Base Case 1 Device Learning Curve Effect on Equipment Suppliers

Figure 29 shows the financial performance of the service providers.

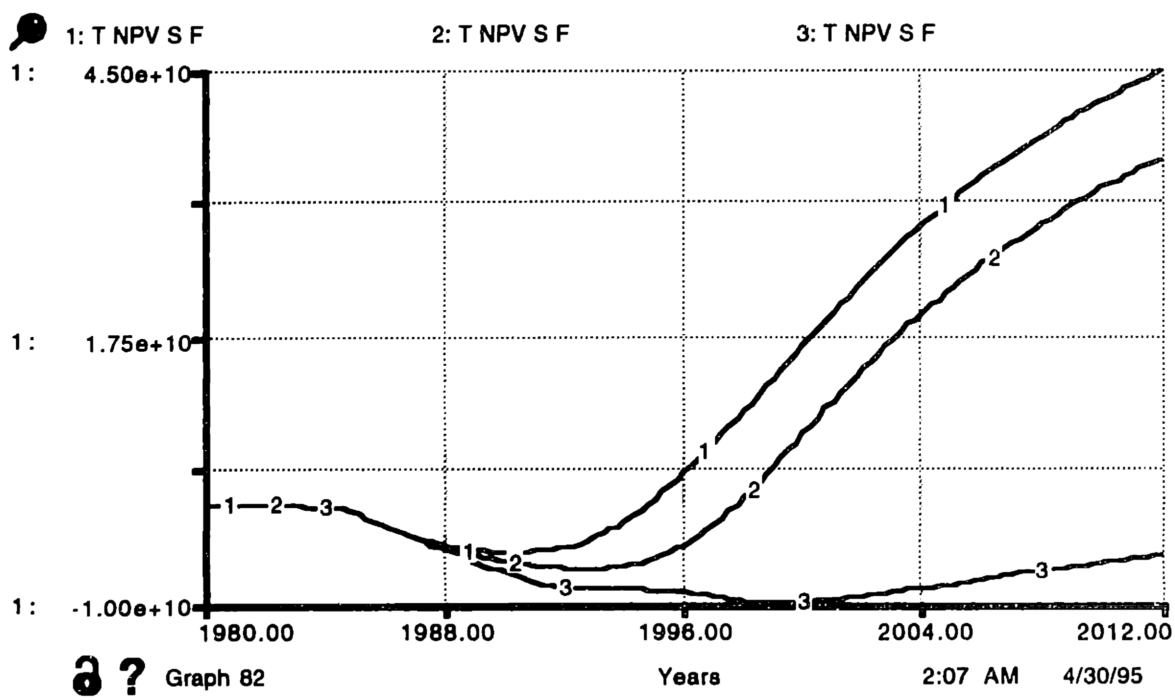


Figure 29: Base Case 1 Device Learning Curve Effect on Service Providers

The second sensitivity example tests the effect of subsidies on the device provided by the service providers. Table 18 contains the test values. The subsidies reduce the price of entry and cause the market to develop much faster than it would have without the subsidies as in the previous example, both parties profit. The following graphs show the development of the market and the financial performance of the service provider, equipment supplier and the industry. Figure 30 shows the development of the market for subscribers.

Table 18: Base Case 1 Device Subsidy Sensitivity Values

Run	1	2	3
Device (Equipment) Subsidy ($)	0	300	600

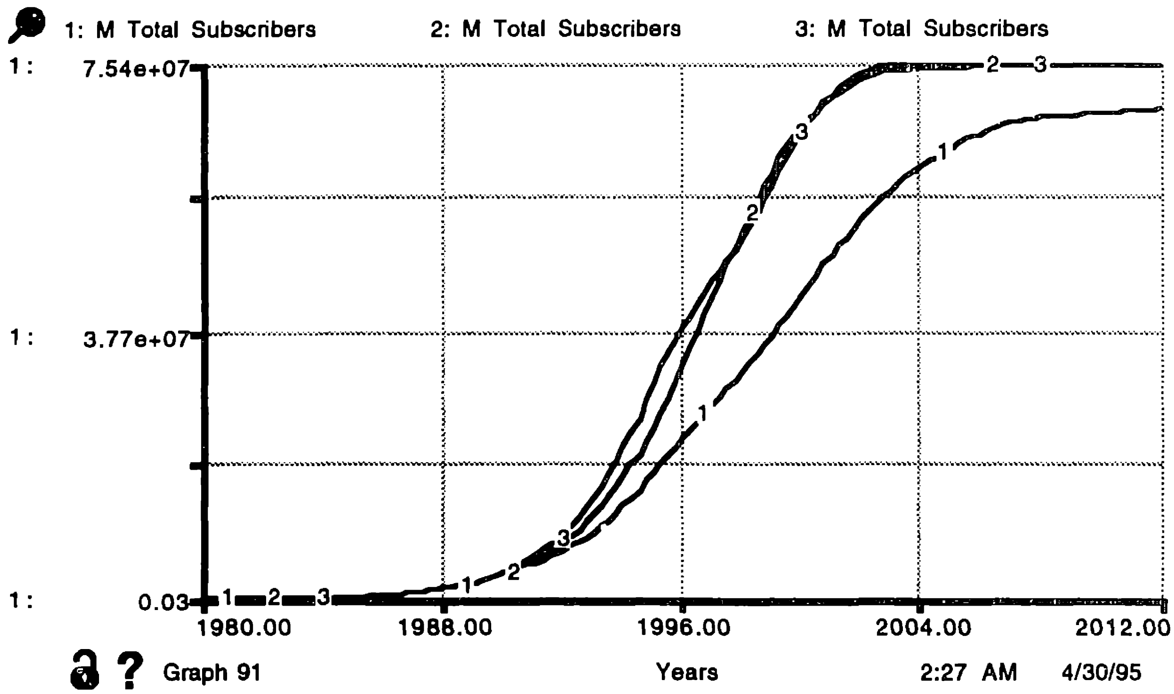


Figure 30: Base Case 1 Device Subsidy Effect on Subscriber Base

Figure 31 shows the dramatic change in financial performance of the equipment suppliers. The subsidy causes the market to grow much faster.

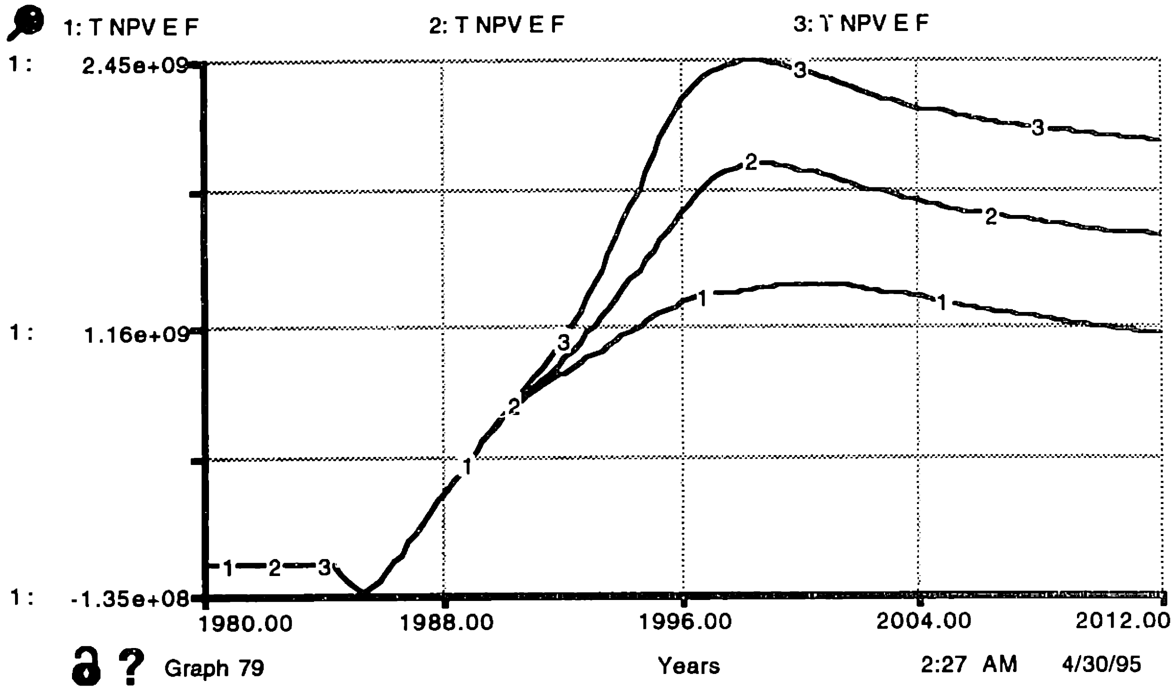


Figure 31: Base Case 1 Device Subsidy Effect on Equipment Suppliers

Figure 32 shows the financial performance of the service providers.

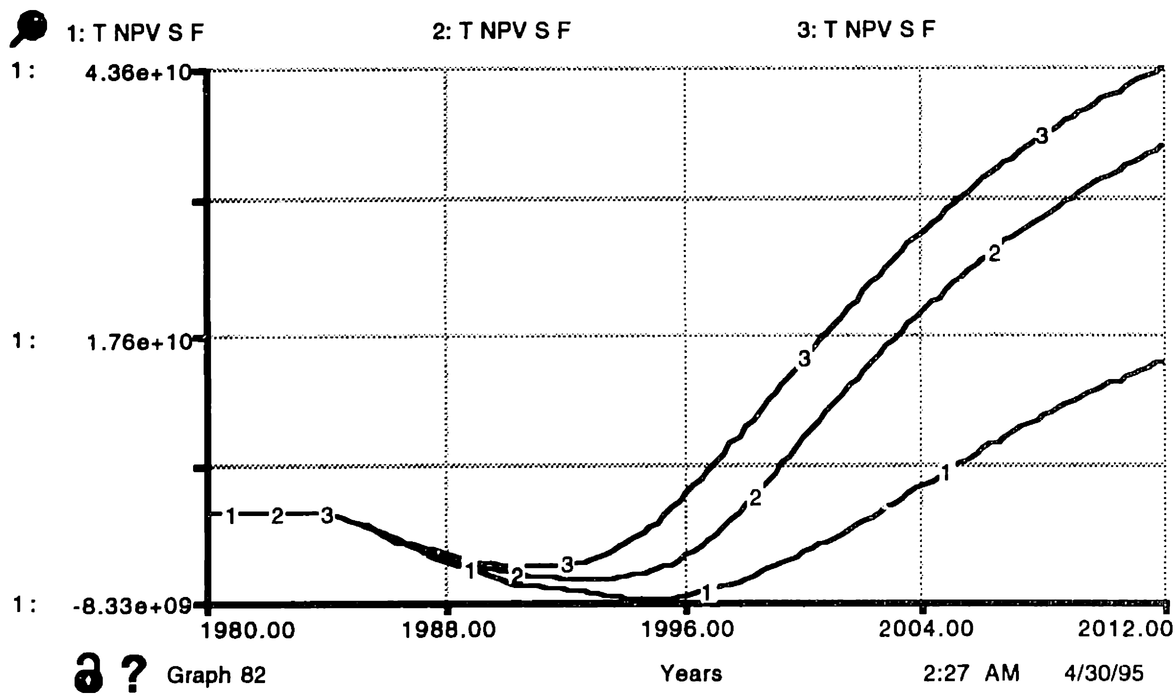


Figure 32: Base Case Device Subsidy Effect on Service Providers

One of the most important parameters is the discount rate. Figure 33 shows the effect of the discount rate on the equipment provider for Base Case 1. Table 19 shows the values tested.

Table 19: Base Case 1 Discount Rate Sensitivity Values

Run	1	2	3
Discount Rate (%)	8	12	20

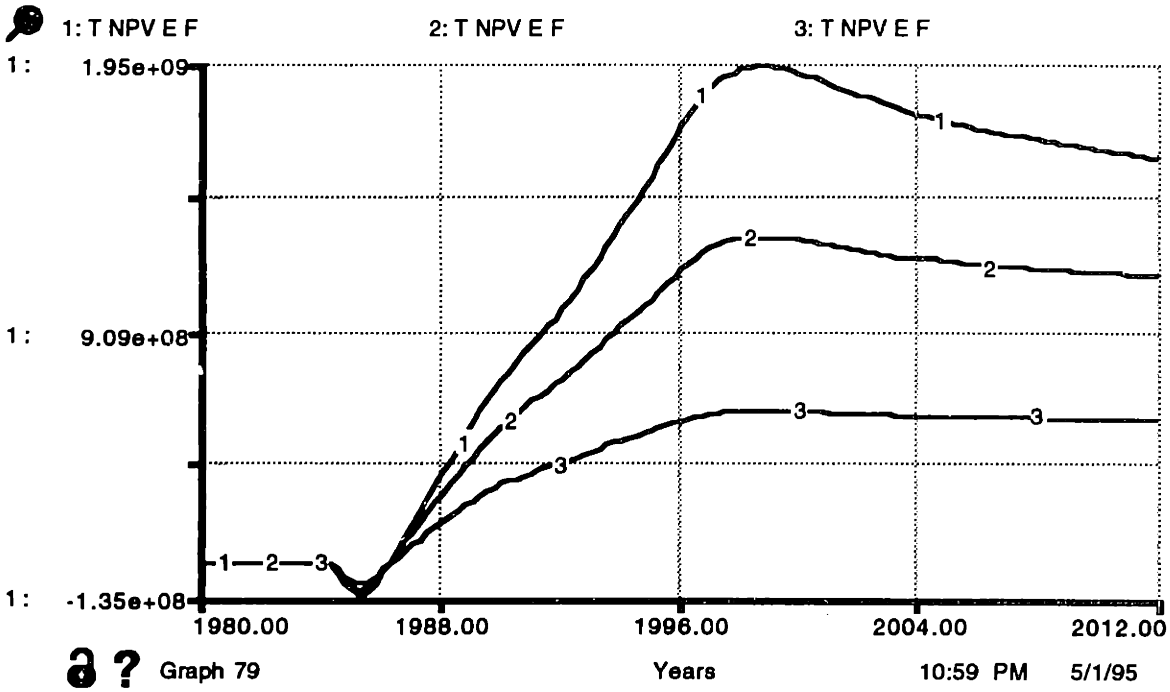


Figure 33: Base Case 1 Discount Rate Effect on Equipment Suppliers

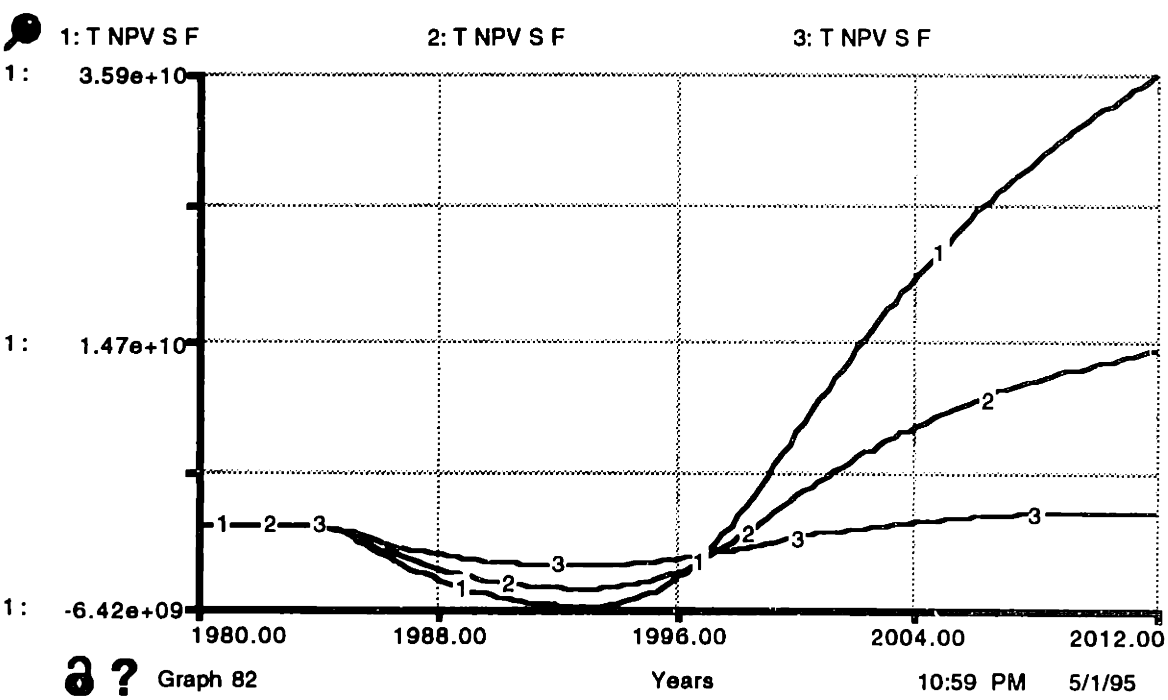


Figure 34: Base Case 1 Discount Rate Effect on Service Providers

Figure 34 shows the effect of the discount rate on the service providers.

Though the discount rate significantly effects the returns, they are satisfactory to the equipment suppliers at the rates evaluated. However, the business case becomes suspect for the service providers at a discount rate of 20%.

Table 20 compares the results of the test cases and the base case. The changes in behavior for the service providers occurred with capacity. In the real market (Base Case 1), setting the excess capacity to the right number became more important than the capacity delivery delay. For the equipment suppliers, two factors became important but in a direction that disadvantaged the service providers. Equipment providers favor a high discard rate and slower price reductions.

Table 20: Base Case 1 and Test Case Sensitivity Comparison

Parameter	SP Effect Base Case 1	SP Effect Test Case	ES Effect Base Case 1	ES Effect Test Case
Discard Rate	Minor	N/A	Major, opposite	Minor
Network Quality	Minor	N/A	None	N/A
Big Bills	Minor	N/A	None	N/A
Equipment Subsidies	Major	N/A	Major	N/A
Initial Capacity - Service Provider	Major	Major	Minor	N/A
Initial Capacity - Equipment Supplier	Minor	N/A	Major	Major
Capacity Growth - Service Provider	Minor	Minor	Minor, opposite	N/A
Capacity Growth - Equipment Supplier	Minor	N/A	Major	Major
Capacity Delivery Delay - Service Provider	Minor	Major	Minor, opposite	N/A
Capacity Delivery Delay - Equipment Supplier	Major	N/A	Major	Major
Capacity Excess - Service Provider	Major	Minor	Minor, opposite	N/A
Demand Info Delay - Service Provider	Minor	Minor	Minor, opposite	N/A
Demand Info Delay - Equipment Supplier	Minor	N/A	Major	Major
Initial Airtime Price	Major	Major	None	N/A
Service Fee	Major	Major	None	N/A
Initial Device Price	Major	N/A	Major, opposite	Major
Time to Change Price - Equipment Supplier	Minor	N/A	Major, opposite	Minor
Cost Learning Curve - Service Provider	Major	Major	None	N/A
Cost Learning Curve - Equipment Supplier	Major	N/A	Major	Major

The parameters that do not effect the other party are eliminated from further evaluation. For example, the cost structure of the service providers has a big impact on service providers and the industry but little impact on equipment suppliers. This is because the subscribers have already bought the device and lower service prices usually mean more usage and not more devices.

The sensitivity tests of the two tier market base case demonstrate model stability, robustness and predictability. The key market and model interactions are also verified. The basis for management policy and strategy analysis is now available. The key parameters are summarized in Table 21. The table lists the parameter, its significance to industry performance, industry behavior and how it effects the service provider and the equipment supplier. These parameters are investigated further in Chapter 4.

Table 21: Base Case 1 Cellular Industry Key Management Parameters

Parameter	Industry Significance	Industry Behavior	SP Effect	ES Effect
Discard Rate	Small	Less is better	Minor	Major, opposite
Equipment Subsidies	Significant	Higher is better	Major	Major
Initial Capacity - Service Provider	Significant	Not enough is bad but too much is a killer	Major	Minor
Initial Capacity - Equipment Supplier	Small	More is better but too much is bad	Minor	Major
Capacity Growth - Equipment Supplier	Small	Faster is better	Minor	Major
Capacity Delivery Delay - Equipment Supplier	Significant	Shorter is better	Major	Major
Capacity Excess - Service Provider	Significant	Test case is best but too small is a killer	Major	Minor, opposite
Demand Info Delay - Equipment Supplier	Small	Less is better	Minor	Major
Initial Device Price	Significant	Lower is better	Major	Major, opposite
Time to Change Price - Equipment Supplier	Significant	Shorter is better	Minor	Major, opposite
Cost Learning Curve - Equipment Supplier	Significant	Steeper is better, too little, market dies	Major	Major

3.4 TECHNOLOGY TRANSITION MODEL

The technology transition model assumes a second generation of product and service is introduced to the market sometime in the future. The new product may be compatible with the previous generation, however, the previous generation is incompatible with the new generation of product and service. As well, the previous generation is obsoleted later in the simulation. This case replicates the history of the cellular telecommunications market but uses a two generations of product and service as the premise of the future forecast. This is referred to as Base Case 2

3.4.1 BASE CASE 2

The technology transition model assumes that cellular converts from analog technology to digital technology during the simulation. The assumptions for Base Case 2 are investments begin in 1990 and shipments begin in 1994. Further, the analog products and services are no longer available in 2002. Therefore, over an eight year period, the entire installed base of devices and service is upgraded to the new standard. Market growth is very similar to Base Case 1 however there is additional growth in subscribers around the year 2000 due to lower subscriber bills. This adds about 2 million more subscribers. Figure 35 shows the shipments for each generation of product.

Table 22: Legend for Figure 35

Trace	1	2	3	4	5
Parameter	Installed Base of Gen. 1	Installed Base of Gen. 2	Device Shipments	Subscribers	Cumulative Device Shipments

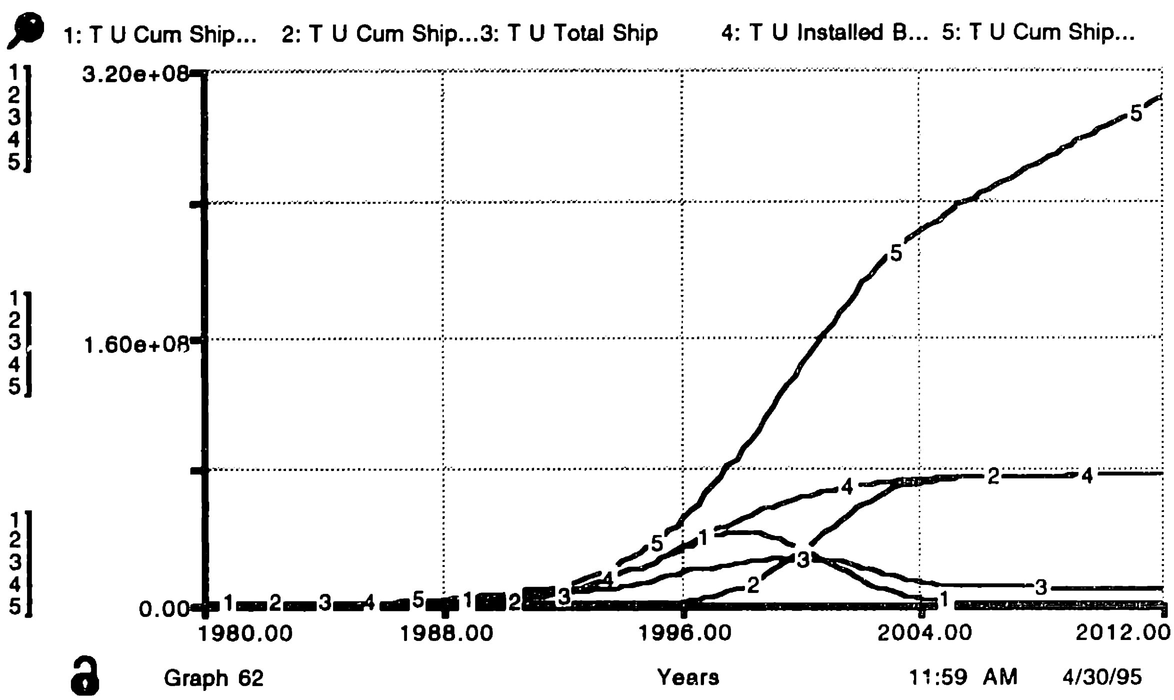


Figure 35: Base Case 2 Technology Transition Shipment Profile

Looking at the financial summary for the first generation device shows that the profitability looks the same as the single generation scenario up to the year 2000. Because the product is phased out, a higher level of profitability is achieved by the equipment manufacturers of this generation. The second generation device supplier achieves profitability very rapidly and at a high level. After demand is saturated, minimal profitability exists. However, the unprofitability over the last ten years of the single generation market is avoided. Tables 23, 24 ,25 and 26 summarize the financial results of each situation. Figure 36 shows the aggregated financial performance of combining generations 1 and 2.

Table 23: Base Case 1 Equipment Supplier Financial Summary (Table 12 Reproduced)

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Shipments
Minimum	-135M	NA	-251M	0	0
Maximum	1950M	22%	626M	8100M	17M

Table 24: Base Case 2 Generation 1 Equipment Supplier Financial Summary

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Shipments
Minimum	-135M	NA	-273M	0	0
Maximum	1910M	22%	626M	7970M	16.8M

Table 25: Base Case 2 Generation 2 Equipment Supplier Financial Summary

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Shipments
Minimum	-21M	NA	-42M	0	0
Maximum	1450M	38%	1400M	3940B	19.9M

Table 26: Base Case 2 Generation 1 and 2 Equipment Supplier Financial Summary

Trace	1	2	3	4	5
Parameter	NPV	Profit Margin	Profit	Revenue	Shipments
Minimum	-135M	NA	-251M	0	0
Maximum	3170M	22%	1410M	9790M	26.2M

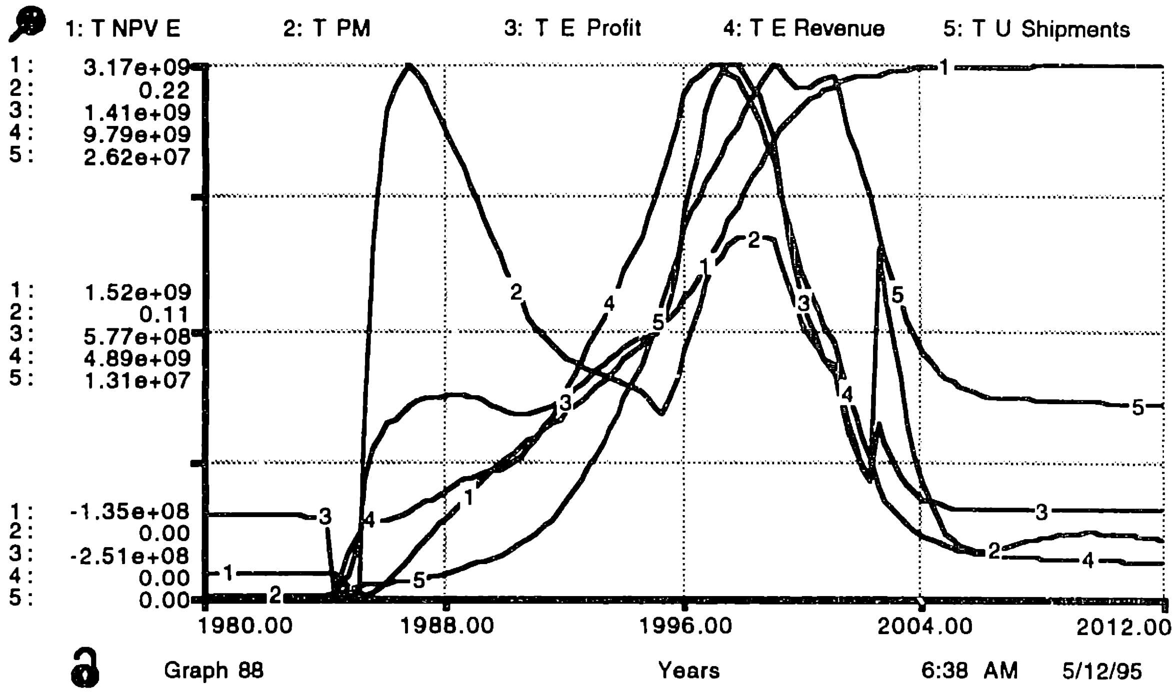


Figure 36: Base Case 2 Generations 1 and 2 Equipment Supplier Financial Summary

From the service provider perspective, there are more subscribers, profits and revenues as well as increased margins. This is due to the lower costs and higher capacity of a digital network. Figure 37 summarizes the financial performance of the service providers in a two generation market. For the industry , there are higher margins, profits, revenues and subscribers as expected. Only a small effect on the subscriber base is apparent during the transition. In the real world, there may be a much greater effect depending on if or what incentives are applied.

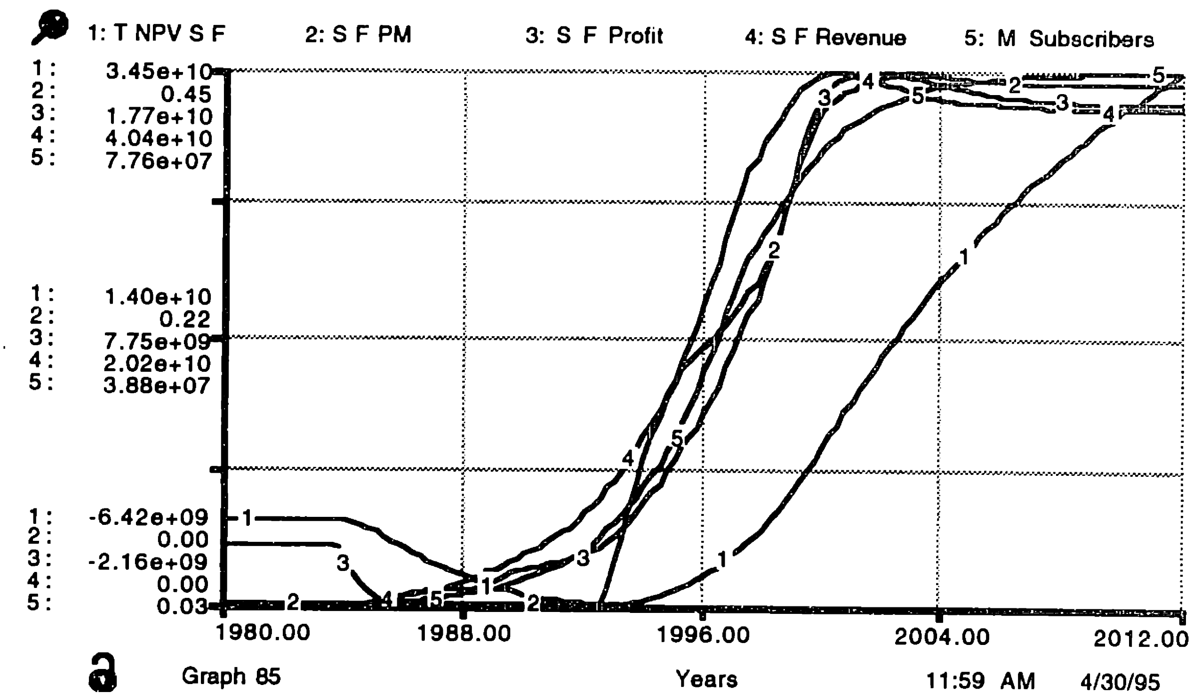


Figure 37: Base Case 2 Service Provider Financial Summary

Table 27 summarizes the cases in Figure 38. Figure 38 shows the dramatic improvement in financial performance for the equipment suppliers when a second generation product is introduced into the market.

Table 27: Base Case 1 and 2 Comparison

Trace	1	2
Parameter	One Generation of Device (Base Case 1)	Two Generations Of Device (Base Case 2)

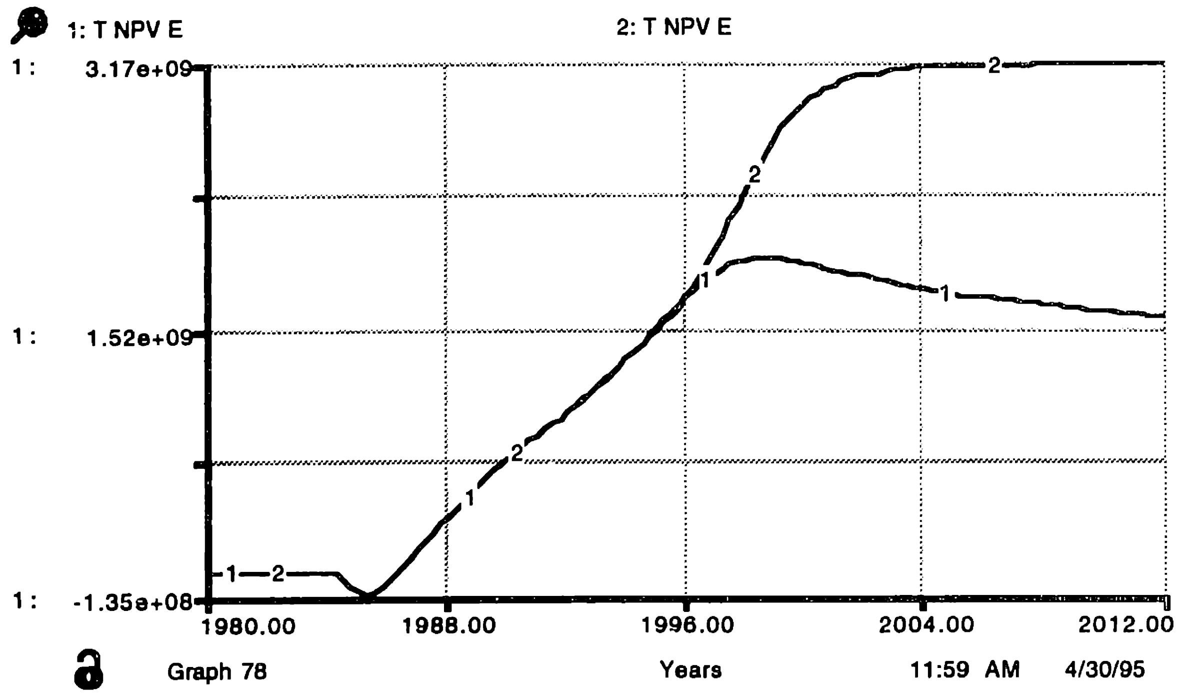


Figure 38: Base Cases 1 and 2 Effect on Equipment Supplier NPV

However, for the service providers, the net present value changes slightly to a less favorable situation. For the industry, net present value improves slightly in the two generation market. The improvement in financial performance of the equipment suppliers is large enough to overcome the degradation in the financial performance of the service providers. In summary, a technology transition results in higher subscribers, profits and revenues. Two generations create big wins for the equipment suppliers. The financial advantages of two generation of service are slightly less favorable to service providers in the Base Case 2 with the current model assumptions.

3.4.2 SENSITIVITY ANALYSIS

As in the normal procedure, Base Case 2 is tested for sensitivity. Table 28 summarizes the significant behaviors.

Table 28: Base Case 2 Sensitivity Results for the Cellular Industry

Parameter	Industry Significance	Industry Behavior	SP Effect	ES Effect
Word Of Mouth	Significant	Expected, more is better	Major	Major
Marketing Effectiveness	Significant	Expected, more is better	Major	Major
Market Size	Significant	Expected, bigger is better but at a bigger investment	Major	Major
Discard Rate	Small	Expected, less is better	Minor	Major, opposite
Discount Rate	Significant	Expected, lower is better	Major	Major
Equipment Subsidies - Generation 1	Significant	Expected, higher is better	Major	Major
Equipment Subsidies - Generation 2	Small	Expected, higher is better	Minor	None
Initial Capacity - Service Provider	Significant	Expected, not enough is bad but too much is a killer	Major	Minor
Initial Capacity - Equipment Supplier	Small	Expected, more is better and excess is bad	Minor	Major
Capacity Growth - Equipment Supplier	Small	Expected, faster is better	Minor	Major
Capacity Delivery Delay - Equipment Supplier	Significant	Expected, shorter is better	Major	Major
Capacity Excess - Service Provider	Significant	Expected, test case is best but too small is a killer	Major	Minor, opposite
Initial Airtime Price	Significant	Expected, higher is better	Major	None
Service Fee	Significant	Expected, higher is better	Major	None
Initial Device Price - Generation 1	Significant	Expected, lower is better	Major	Major, opposite
Initial Device Price - Generation 2	Small	Expected, lower is better	Minor	Major, opposite
Time to Change Price - Gen. 1 Equipment Supplier	Small	Expected, shorter is better	Minor	Major, opposite
Time to Change Price - Gen. 2 Equipment Supplier	Small	Expected, shorter is better	Minor	Major, opposite
Initial Unit Cost - Gen. 1 Equipment Provider	Small	Expected, lower is better	None	Major
Initial Unit Cost - Gen. 2 Equipment Provider	Small	Expected, lower is better	None	Major
Cost Learning Curve - Gen. 1 Equipment Supplier	Significant	Expected, steeper is better, too little, market dies	Major	Major
Cost Learning Curve - Gen. 2 Equipment Supplier	Significant	Expected, steeper is better, too little, market dies	Major	Major
Cost Improvement Factor Gen. 2 Service Provider	Small	Expected, lower is better, same is bad	Minor	None
Conversion Cost Gen. 2 Service Provider	Small	Expected, very high is bad	Minor	None
Upgrade Timing	Small	Unexpected, timing doesn't matter	None	Major
Upgrade Time Frame	Small	Unexpected, longer is better	Minor	Major, opposite

Very similar results were obtained during sensitivity testing of Base Case 2 as were found with Base Case 1. The biggest difference involved those parameters specific to Base Case 2.

The upgrade period is significant to the equipment suppliers. In the example that follows, this period is varied from four to twelve years. Table 29 shows the upgrade time frames under evaluation. Figure 39 shows that the equipment suppliers perform much better when the period is shorter. A long time frame eliminates the benefits of a technology transition.

Table 29: Base Case 2 Upgrade Time Sensitivity Values

Run	1	2	3
Upgrade Time (Years)	4	8	12

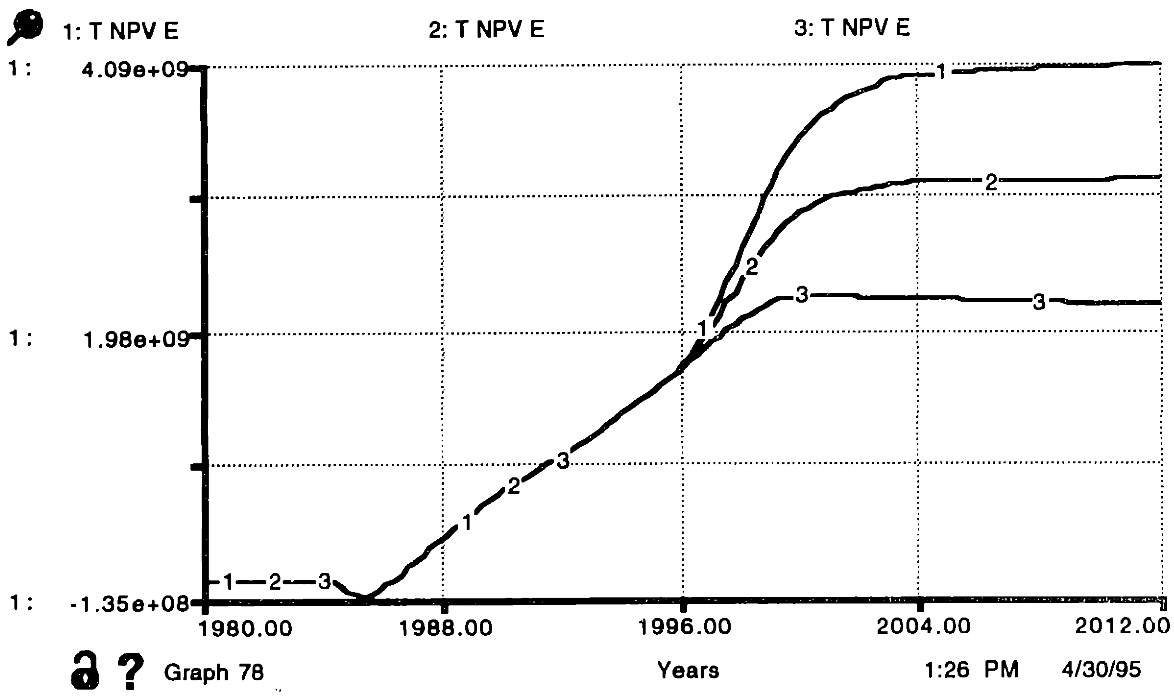


Figure 39: Base Case 2 Upgrade Time Effect on Equipment Supplier NPV

On the other hand, service providers favor a longer transition period as Figure 40 shows. This is caused by the lower profitability of the digital service. Management policy can turn this into a win. The price of the digital service is addressed in Chapter 4. Note that the difference between each test is $2 Billion of NPV discounted cash flow.

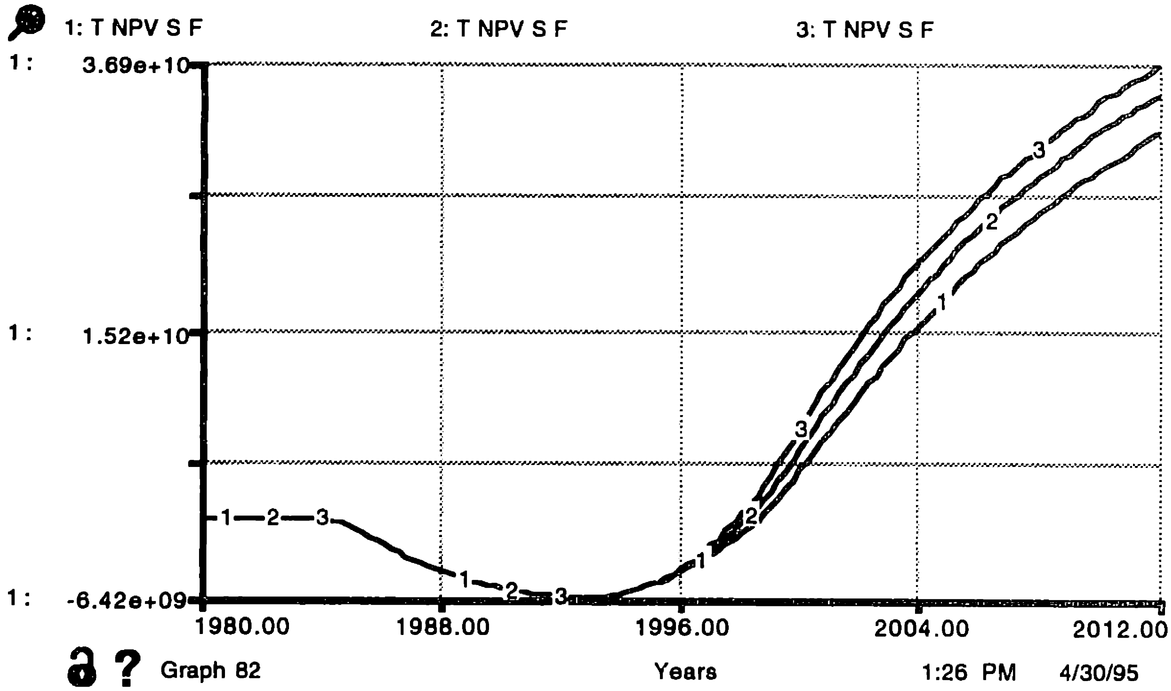


Figure 40: Base Case 2 Upgrade Time Effect on Service Provider NPV

As is typical, the industry prefe ence mirrors the service provider preference.

The next example shows the effect of the learning curve on the second generation of device. Table 24 shows the values tested. As the Figure 41 shows, a learning curve that is not aggressive enough slows the development of the market. The highest return is indicated by a learning curve of .8 rather than .7 for the equipment suppliers.

Table 30: Base Case 2 Generation 2 Learning Curve Sensitivity Values

Run	1	2	3
Gen. 2 Product Cost Learning Curve	.9	.8	.7

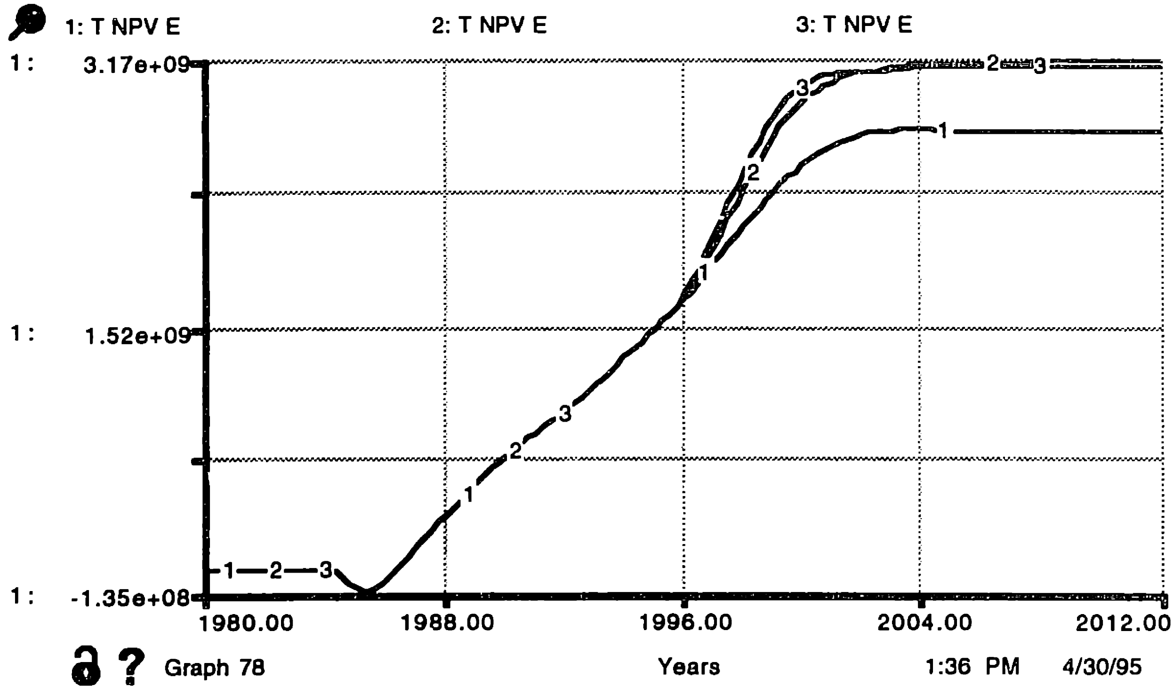


Figure 41: Base Case 2 Generation 2 Learning Curve Effect on Equipment Supplier NPV

The service providers favor the more aggressive cost reduction strategy because it means the lowest device prices as shown in Figure 42. The industry also favors the 70% learning curve.

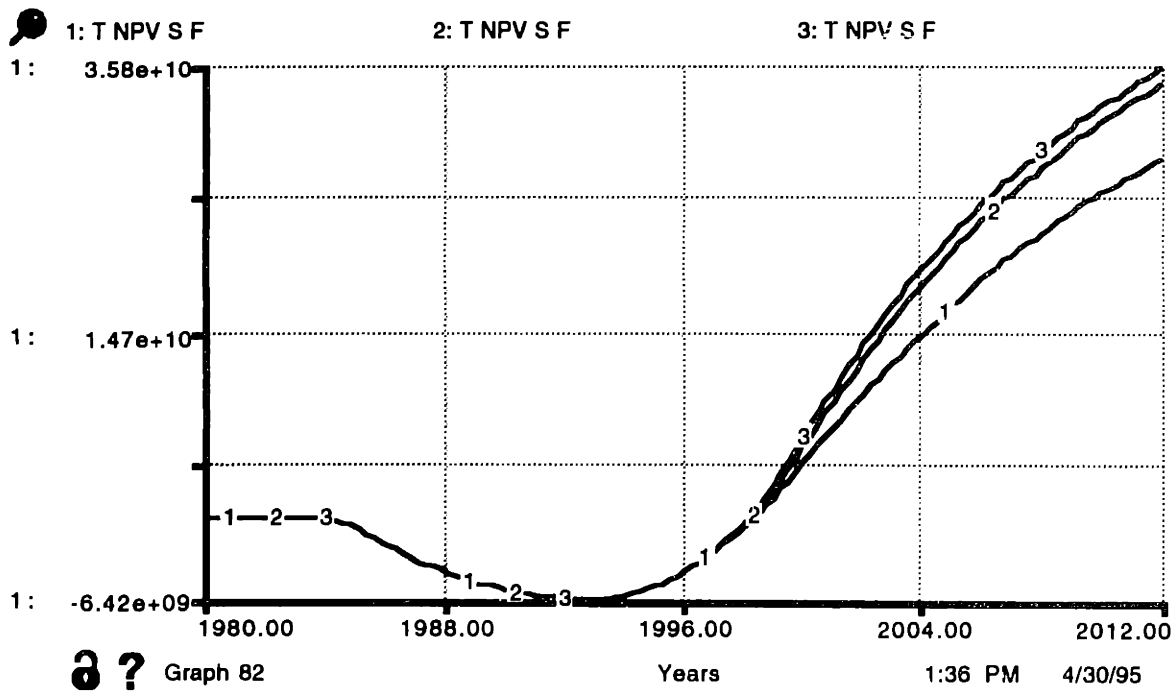


Figure 42: Base Case 2 Generation 2 Learning Curve Effect on Service Provider NPV

The sensitivity tests confirm the technology transition model represented by Base Case 2 is stable, predictable and reliable. The clear conclusion is that a technology transition is great for the equipment suppliers. It does have benefits for the service providers, however, they are not as significant. Eliminating parameters that only effect one of the players, Table 31 lists the key management of technology parameters identified in Base Case 2.

Table 31: Base Case 2 Cellular Industry Key Management Parameters

Parameter	Industry Significance	Industry Behavior	SP Effect	ES Effect
* Discard Rate	Small	Less is better	Minor	Major, opposite
* Equipment Subsidies - Generation 1	Significant	Higher is better	Major	Major
* Initial Capacity - Service Provider	Significant	Not enough is bad but too much is a killer	Major	Minor
* Initial Capacity - Equipment Supplier	Small	More is better and excess is bad	Minor	Major
* Capacity Growth - Equipment Supplier	Small	Expected, faster is better	Minor	Major
* Capacity Delivery Delay - Equipment Supplier	Significant	Expected, shorter is better	Major	Major
* Capacity Excess - Service Provider	Significant	Test case is best but too small is a killer	Major	Minor, opposite
* Initial Device Price - Generation 1	Significant	Lower is better	Major	Major, opposite
Initial Device Price - Generation 2	Small	Lower is better	Minor	Major, opposite
* Time to Change Price - Gen. 1 Equipment Supplier	Small	Shorter is better	Minor	Major, opposite
Time to Change Price - Gen. 2 Equipment Supplier	Small	Shorter is better	Minor	Major, opposite
* Cost Learning Curve - Gen. 1 Equipment Supplier	Significant	Steeper is better, too little, market dies	Major	Major
Cost Learning Curve - Gen. 2 Equipment Supplier	Significant	Steeper is better, too little, market dies	Major	Major
Upgrade Time Frame	Small	Longer is better	Minor	Major, opposite

*** Key Management Parameter Identified in Base Case 1.**

3.5 CELLULAR INDUSTRY

There are three levels of validity for a system dynamics model. Only the first level of validation is required for this model. That means that the model behavior approximates history, usually with an error of 10 to 15 percent. As the following data shows, the model of the two tier cellular telecommunications market fits well within this range.

The model performance was compared to the actual history of the cellular telecommunications industry. For the service provider portion of the industry, good data is available from the Cellular Telecommunications Industry Association. The key parameters evaluated were total cellular subscribers at each year end, revenues per year and the average cellular bill per subscriber. For the equipment supplier side, no similar data base exists. Estimates and extrapolations were made from the sketchy data presented in Chapter 1.

The key driver in the cellular industry is the subscribers base. By using the initial device price minus the subsidy, a very close approximation of the actual adoption rate is achieved by the model as reflected by Figure 43. The actual data values for all parameters are contained within the model documentation that is included in the Appendix.

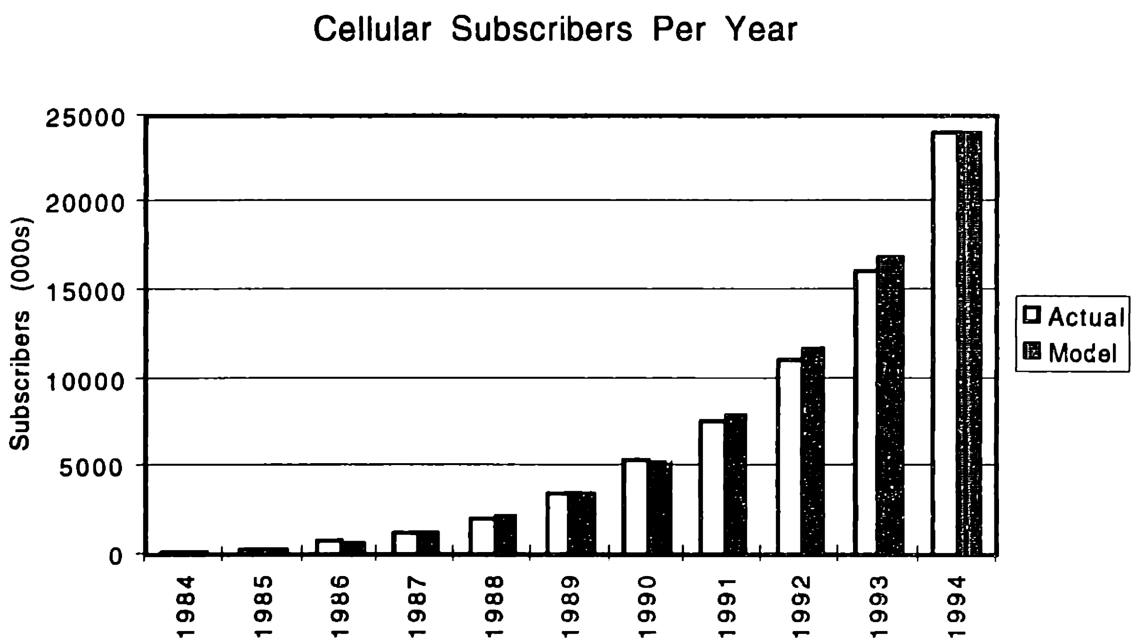


Figure 43: Annual Year End Cellular Subscribers

The average cellular bill is calculated by taking the learning curve of installed base times the initial airtime multiplied by the price of airtime that the model generates and adding the subscription fee. Again a very close approximation is produced by the model as reflected in Figure 44.

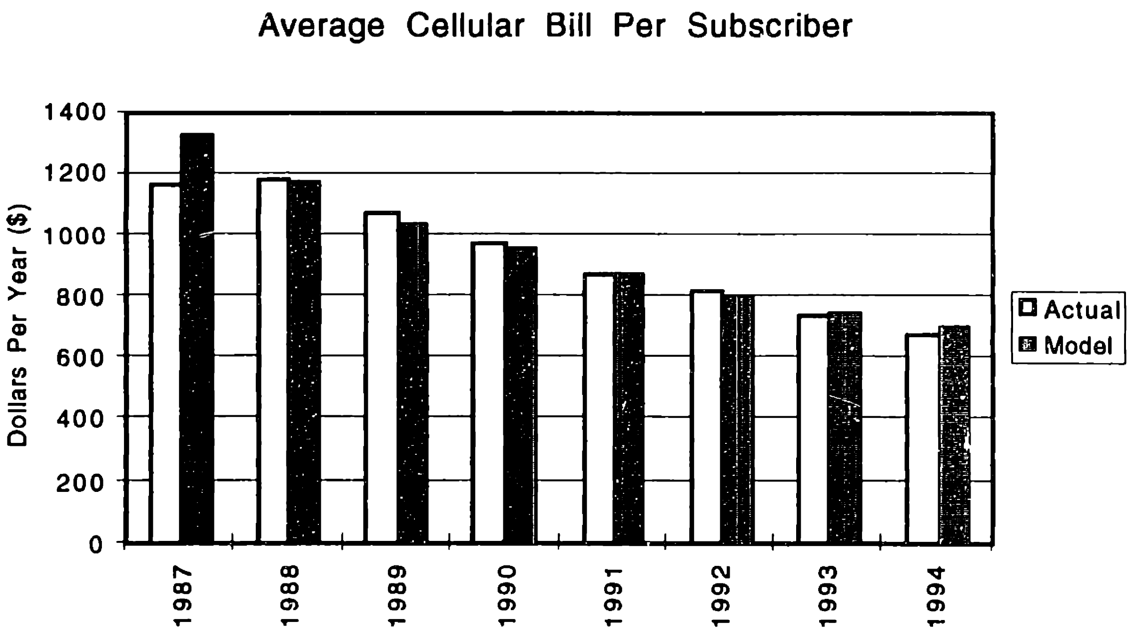


Figure 44: Annual Average Cellular Bill per Subscriber

Annual cellular revenues are generated by multiplying the number of subscribers times the average cellular bill. Figure 45 shows a relatively close approximation of the actual industry experience to that predicated by the model.

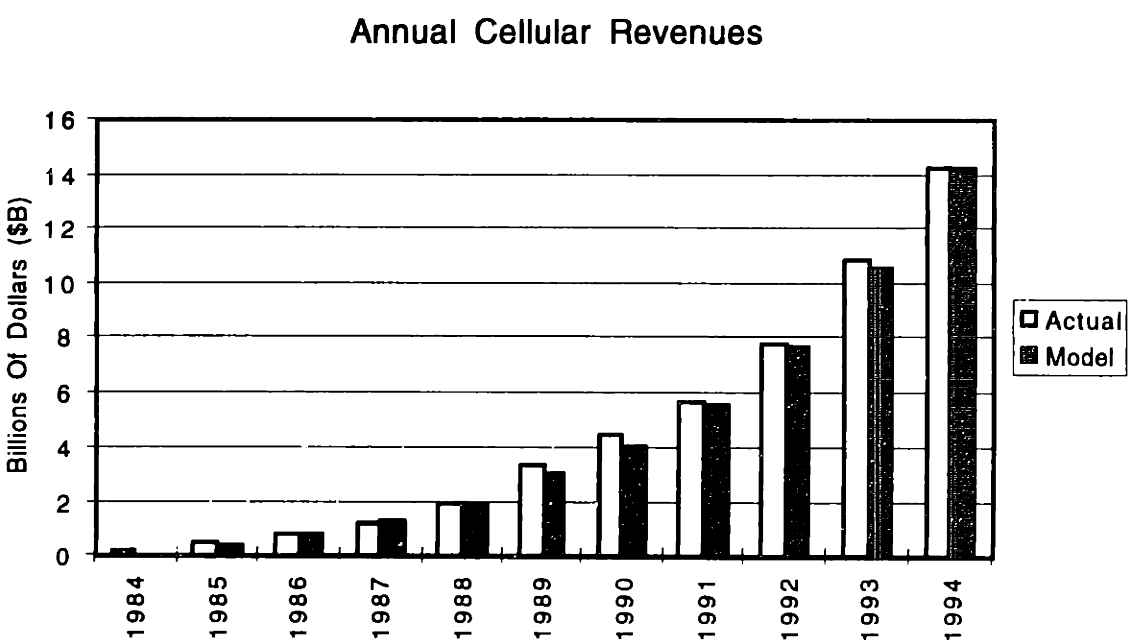


Figure 45: Annual Cellular Revenues

Extensive testing and interviews with experts suggest the model behaves in a manner that is very similar to the history of the cellular telecommunications market. Base Case 1 and Base Case 2 represent two possible forecasts for the future cellular market. Each case is explored in more detail in Chapter 4. In summary, the proposed model reliably reflects the behaviors of and simulates closely the historical performance of the cellular telecommunications industry. The key management of technology parameters are identified in Tables 21 and 31. The next chapter explores the power of these parameters in more detail.

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET:
A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

CHAPTER 4: SCENARIO DEVELOPMENT AND ANALYSIS

4.0 PURPOSE

The system dynamics model developed for the cellular telecommunications industry can now be used to assess various management policies and technology strategies. Consistent with the analytical agenda, various scenarios are developed and analyzed. These results are compared and in some cases combined to form the most desirable performance from the perspective of each entity. The key findings in this chapter follow.

- Low device prices cause the market to grow. This makes device price reductions essential for the equipment suppliers. The more aggressive the price reductions, the faster the market grows and the higher the profitability.
- As prices fall, aggressive capacity growth of both equipment suppliers and service providers is essential. Shortages significantly impact market growth and profitability.
- A second generation of product and service is very beneficial to the equipment providers. Service provider benefits are more speculative.

Each of these findings is explored in detail. Other less significant findings are also developed. Together they paint a very interesting picture of how to make money in a two tier market.

4.1 MARKET GROWTH

Using the model, it is important to identify what causes the market to grow from the perspective of each segment. As well, it is also important to understand how market growth effects each segment. This section answers these questions for the cellular telecommunications industry. Industry growth is measured by the number of subscribers at a given time.

4.1.1 EFFECT OF DEVICE PRICE ON INDUSTRY GROWTH

The device price is the driver for industry growth in the model. In many consumer electronic markets, limited market potential exists when the price of the product is more than $1000. The market becomes larger as the price falls and many products take off as the price falls below $500. As discussed earlier, most cellular providers evaluate their market performance with penetration rather than market share. For this analysis, the total population is 250 million people. Penetration is defined as the percentage of subscribers divided by the total population. The maximum penetration for cellular is projected to be 32% for the U.S. market. In this analysis, industry growth will be assessed by the degree to which the target market adopts the service. For this experiment, device price is an exogenous input. Industry growth is determined as a result of the price effect. All other interactions have been turned off. Table 32 summarizes the total number of subscribers for each price point. The price is held constant for each simulation.

Table 32: Device Price Effect on the Subscriber Base

Device Price	$2000	$1000	$750	$500	$250	$0
Subscribers	8M	25M	30M	44M	74M	80M
Penetration (%)	3.2	10.0	12.0	17.6	29.6	32.0

Consumer electronic devices usually exhibit price reductions over the product life cycle. Figure 46 shows various price curves based on percentage of price reductions over the life of a the product. In all cases, the price starts at $3000. Table 33 shows the percentage price reductions used in this analysis. Note the differences in the size of the market and the time it takes for the market to develop.

Table 33: Device Price Reduction Values

Run	1	2	3	4
Percentage Price Reduction Per Year (%)	0	5	10	20

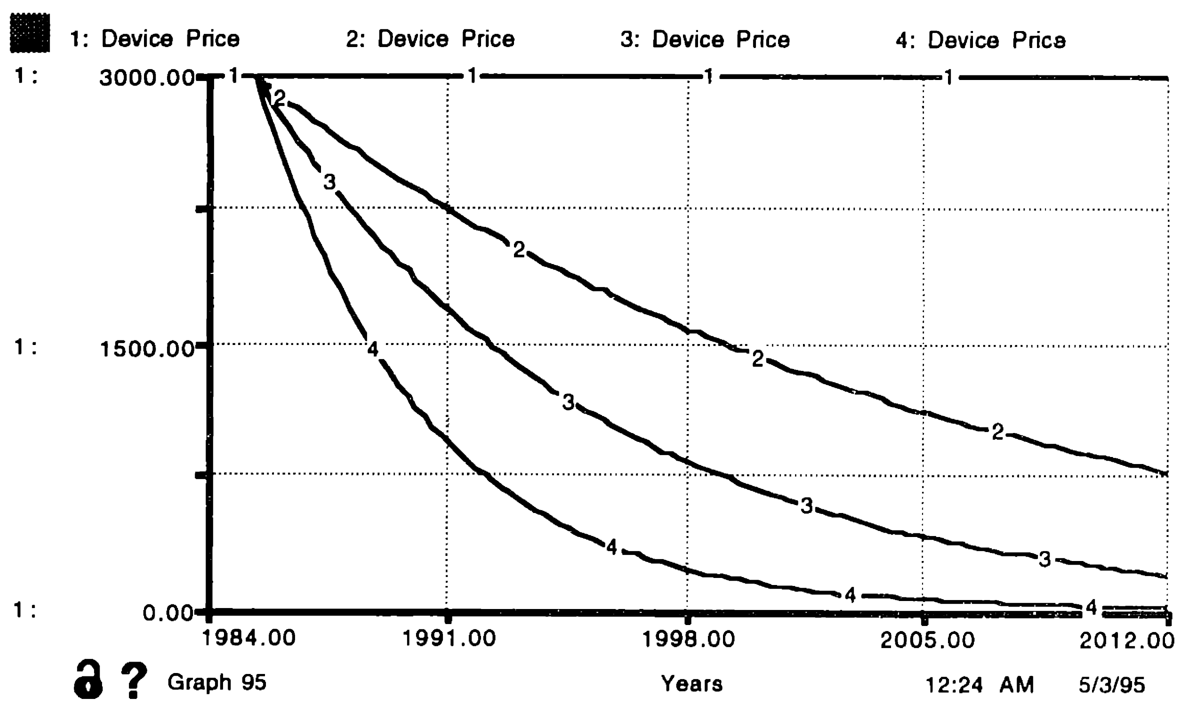


Figure 46: Percent Price Reduction Effect On Price

The effect of price on industry growth is shown in Figure 47. The graph depicts the number of subscribers in the market at various price points.

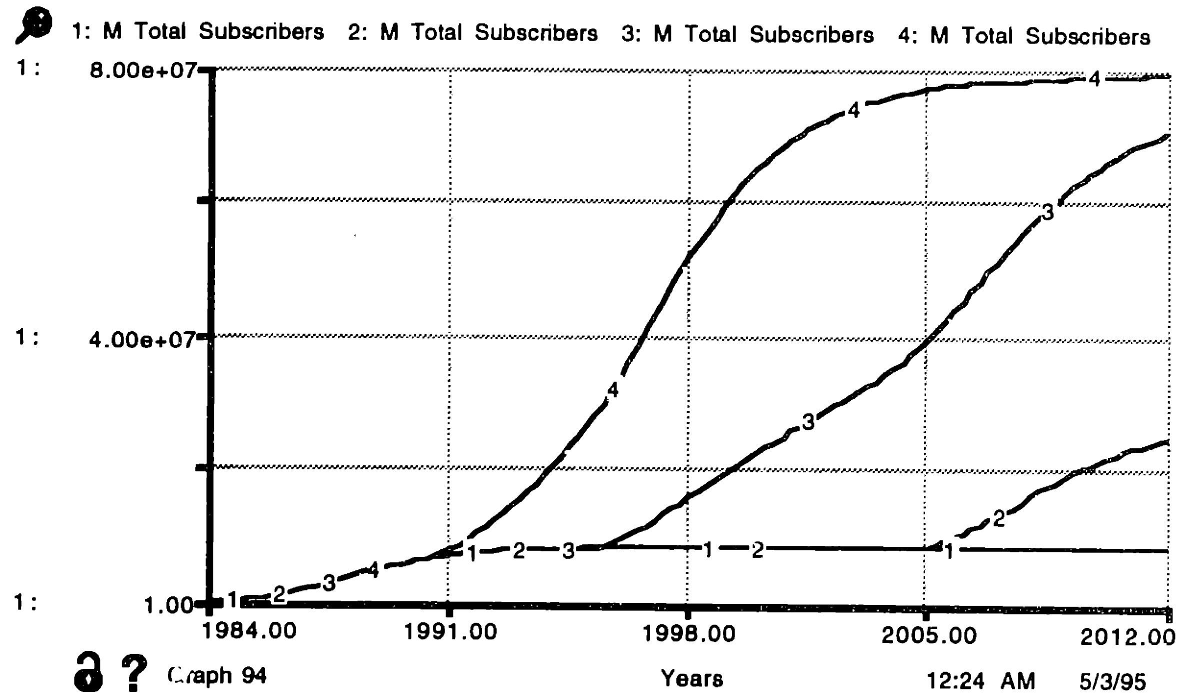


Figure 47: Device Price Reduction Effect on Industry Growth

From these graphs, it is easy to see the effect of price on the size of the market. The model shows that starting with a high price will attract some customers, however, the real market power resides in how quickly prices fall over time. In summary, the lower the price, the larger the market and installed base. The key management of technology issue is providing the lowest price possible to the market.

4.1.2 EFFECT OF INDUSTRY GROWTH ON DEVICE PRICE

Looking at the flip side, the reason prices decline is the learning curve. Learning curve theory is based on the principle that for each doubling of the production volume, prices will decline by the learning curve percentage. In Table 34, the initial price is $3000 and the learning curve is 80%. This can be seen in the price reduction from $1000 to $750 that is roughly 80%. Note that the volume doubled (with round off) to achieve the price decline.

Table 34: Industry Growth Effect on Device Price

Device Price	$2000	$1000	$750	$500	$400	$332
Subscribers	680K	4.5M	9M	24M	53M	80M
Penetration (%)	.3	1.8	3.6	9.6	21.2	32.0

In the cellular industry, device prices started at around $3000 in 1984. Prices have been tracking to an 80% learning curve. This is typical of many consumer electronic products. Figure 48 presents the relationship of price and volume.

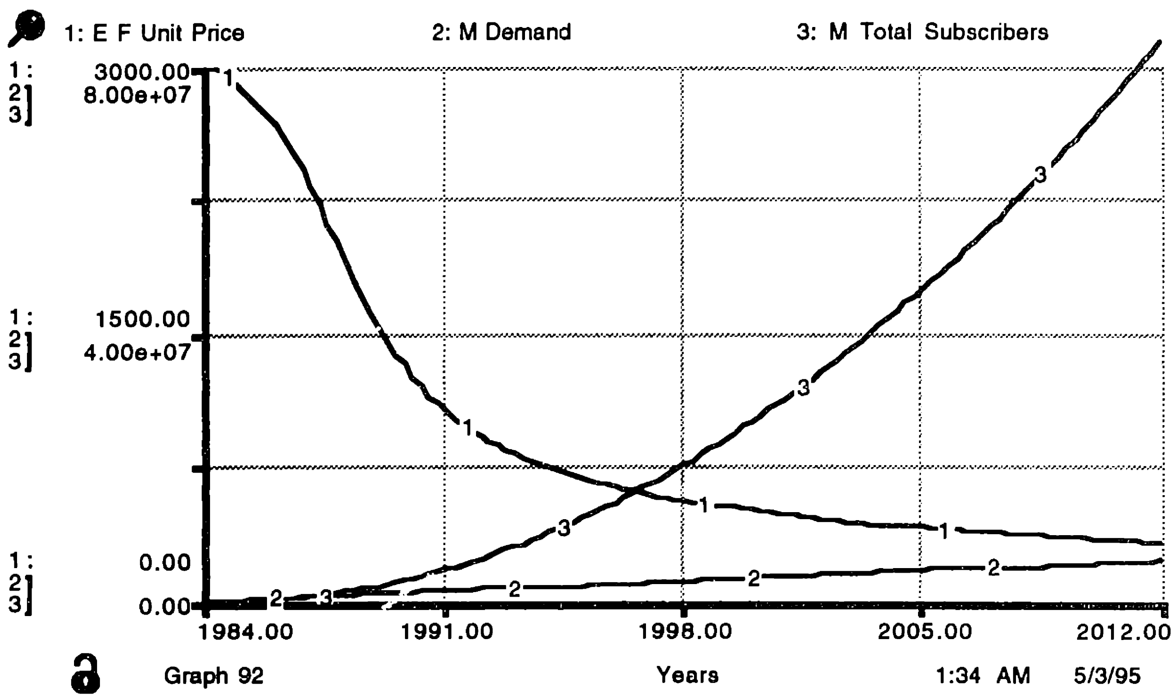


Figure 48: Industry Growth Effect on Device Price

The effect of learning curve is very important. An 80% learning curve produces faster price reductions than a 90% learning curve. Figure 49 shows the effect of the learning curve on price. Table 35 shows the learning curve values evaluated. Note that the volume is identical for each trace on the graph.

Table 35: Learning Curve Values

Run	1	2	3	4
Product Cost Learning Curve	0	.9	.8	.7

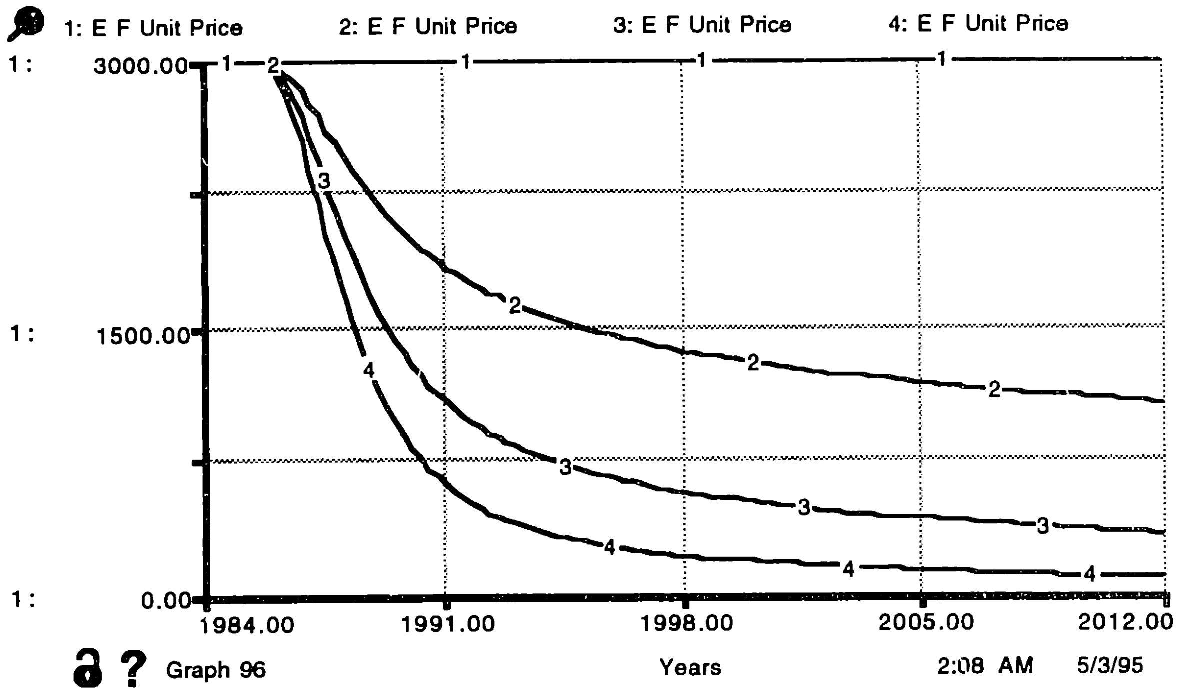


Figure 49: Learning Curve Effects on Device Price

As the industry grows, prices fall due to the learning curve. To summarize, as prices fall, the industry grows. This relationship is demonstrated in the model. The key management of technology issue is driving the learning curve on costs so that prices decline fast enough causing the industry to grow at rate that is economically viable for the players in the market.

4.1.3 EFFECT OF SERVICE PRICE ON INDUSTRY GROWTH

Service price does not directly effect industry growth, however, service price does effect churn. High service prices cause subscribers to terminate service. The model lets customers that exit the service rejoin later. The model assumes that these are new customers and will purchase another device. For this test, the model assumes the device cost is $0 and the service cost varies from free to $2000 per year as shown in Table 36. At that expense level, 25% of new subscribers will cancel their service. This is referred to as the Big Bill effect in the model. Figure 50 shows the effect on the subscriber base. Effectively, high service costs delay maximum penetration but these costs do not prevent eventual adoption.

Table 36: Subscriber Service Bill Effect on Industry Growth

Run	1	2	3	4
Annual Service Bill ($)	2000	1500	1000	0

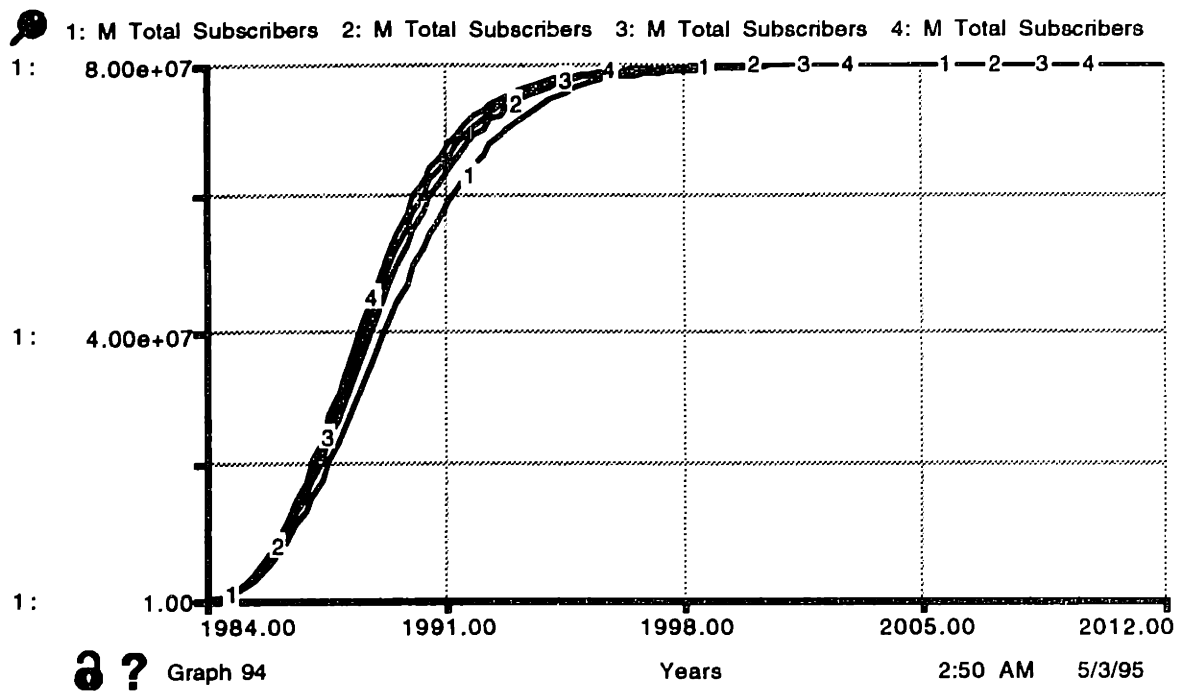


Figure 50: Subscriber Service Bill Effect on Subscribers

As can be seen from Figure 51, the effect of service price is very small on the subscriber base. The significant impact is really to the equipment providers. Figure 51 illustrates the shipment levels of devices given the same service price assumptions of Table 36.

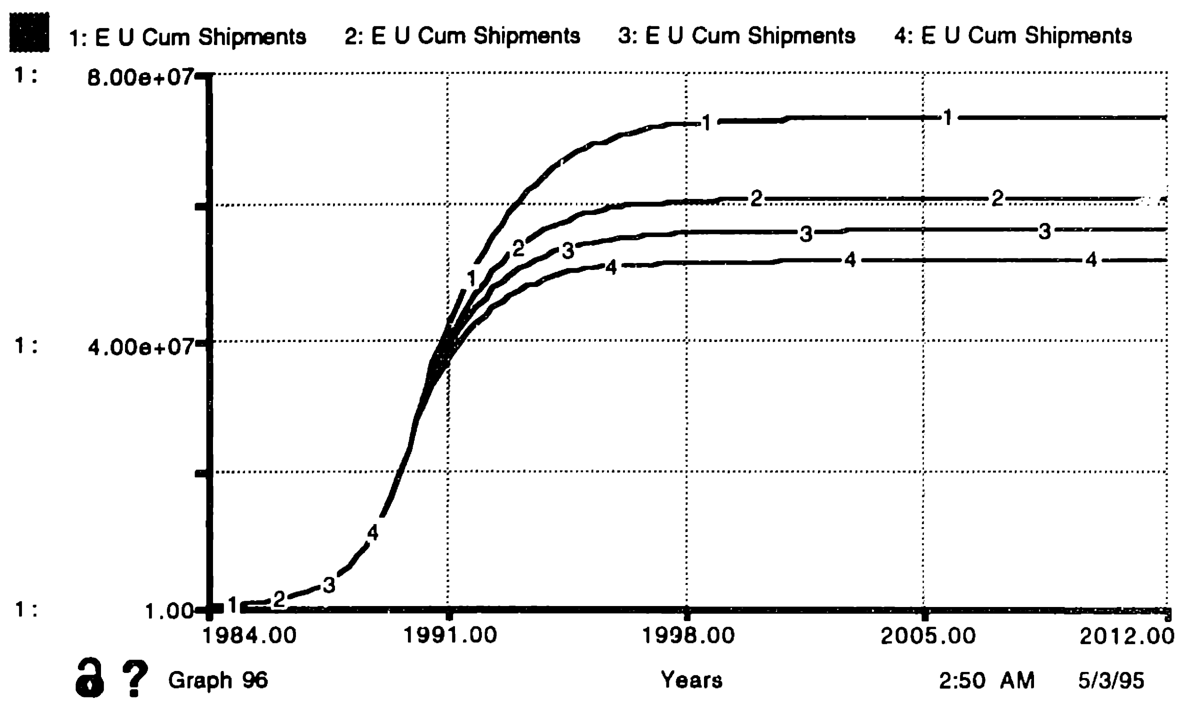


Figure 51: Subscriber Service Bill Effect on Cumulative Device Shipments

The effect of service price on industry growth is minor. High costs will slow the adoption rate but not to a significant degree. The case where subscribers leave the market permanently after quitting the service was not tested. In summary, service prices have little effect on industry growth.

4.1.4 EFFECT OF INDUSTRY GROWTH ON SERVICE PRICE

Like the case of device prices, industry growth reduces service prices. The graph below shows a similar relationship for service provider revenue per subscriber to that of the equipment suppliers. The reason for the decline in revenue is not primarily because of a learning curve effect on prices. In a network, more subscribers use the network less. Early adopters used the cellular network heavily because there were no substitutes. Whereas, later adopters typically have alternatives and only use the capability occasionally. An example is those subscribers who use the service only for emergency and security purposes. Therefore, the primary reason for the reduction in the average network prices is the decline in average usage per customer. Figure 52 shows the relationships of annual usage (airtime), revenue and the service fee per subscriber as it relates to industry growth.

Table 37: Legend for Figure 52.

Trace	1	2	3	4
Parameter (Per Subscriber)	Airtime (minutes)	Revenue ($)	Service Fee ($)	Subscribers

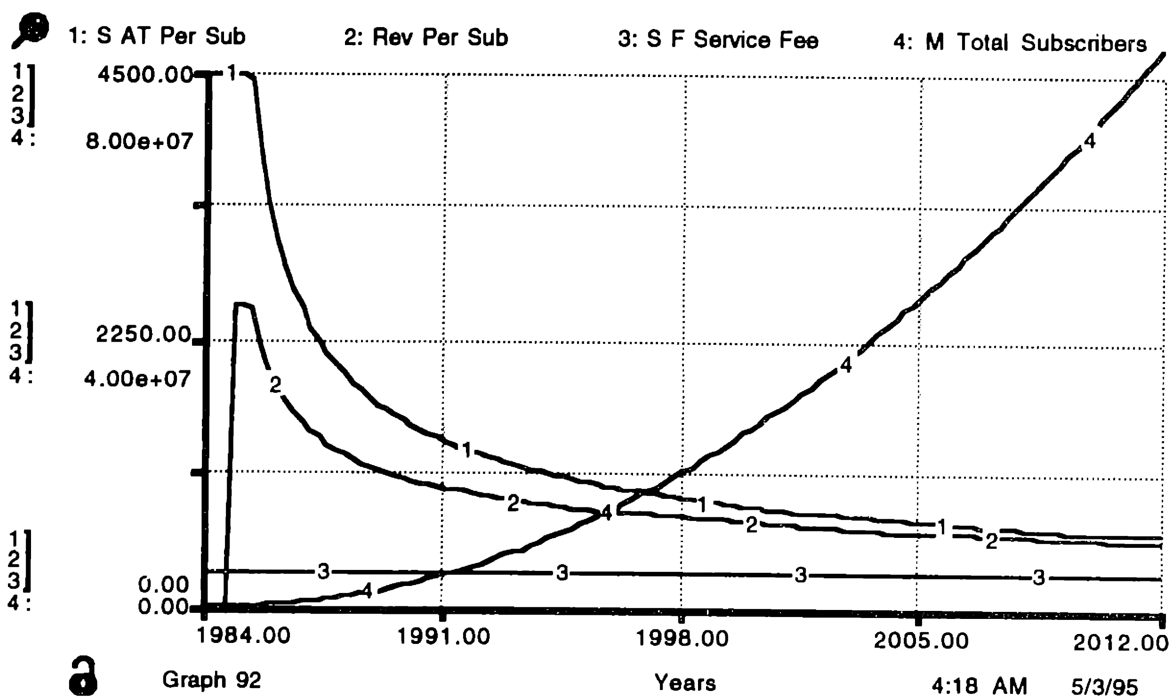


Figure 52: Industry Growth Effect on Service Revenues per Subscriber (with Usage Reductions)

Figure 53 shows the effect of eliminating the usage reduction as the network. Note the modest revenue reductions halfway through the simulation are caused by a reduction in the price per minute of airtime.

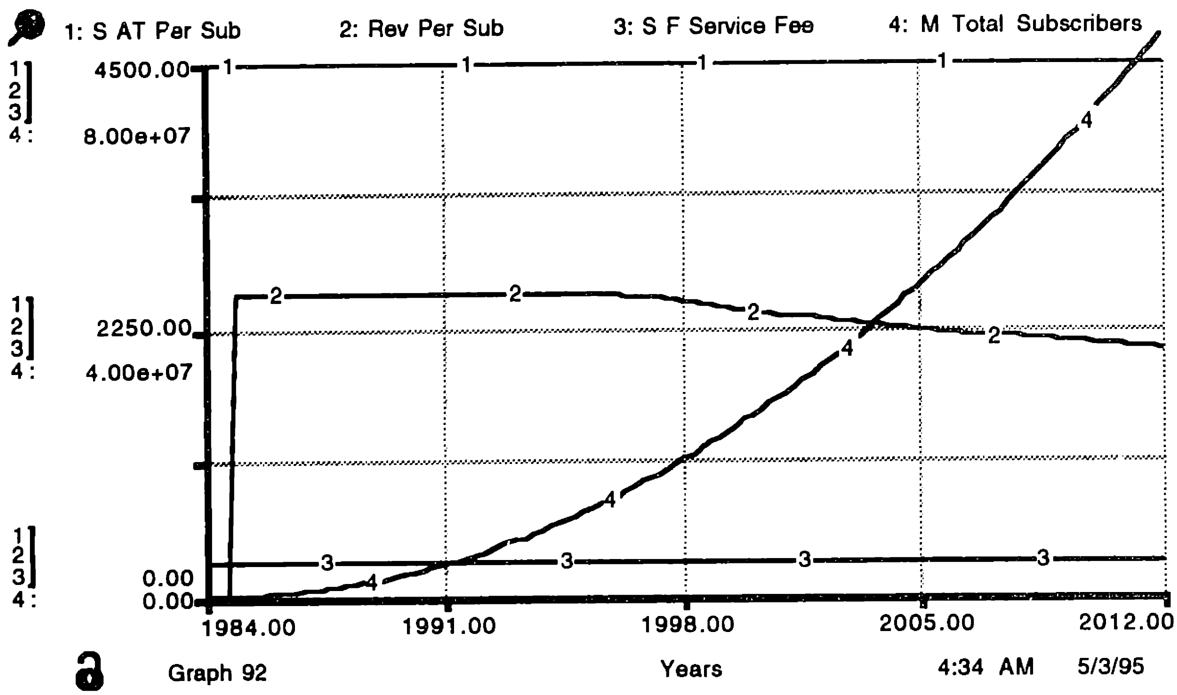


Figure 53: Industry Growth Effect on Service Revenues per Subscriber (without Usage Reductions)

Network usage prices are subject to learning curve considerations but not in the same way as the case of a manufactured product. Figure 55 shows the learning curve does have an effect on service prices. Table 38 indicates the service cost learning cost used in the tests. Early on, the costs associated with constructing and starting up a network prevent any price reductions. Later on, productivity improvements produce expected price reductions.

Table 38: Service Cost Learning Curve Values

Run	1	2	3	4
Service Cost Learning Curve	1	.9	.8	.7

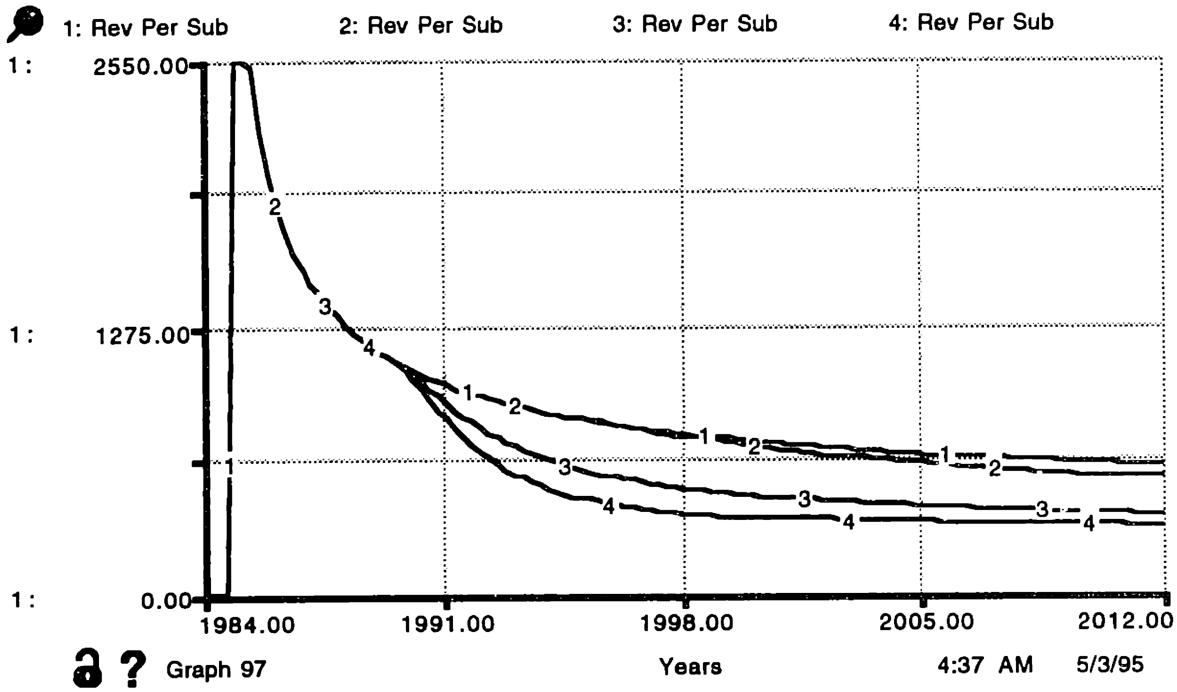


Figure 54: Service Cost Learning Curve Effect on Revenue per Subscriber

Another aspect to service pricing is the subscription fee. This flat fee is paid regardless of use. Increasing or decreasing this fee can significantly alter the price to the customer. The model accommodates changes in the service fee. A recent development in cellular pricing is a call plan package or bundle. For a monthly fee, an allotment of airtime or network usage is included. If the customer does not use all the airtime provided for in the package, there is not a credit. On the other hand, any airtime more than the allotment is charged to the customer. These plans obviously favor the service provider. Due to the added complexity, these plans are not considered in the model.

To summarize, industry growth reduces the average service price paid by subscribers. The key management of technology issue for the service provider is reducing the network operating costs.

4.1.5 EFFECT OF SHORTAGES ON INDUSTRY GROWTH

Shortages are caused by insufficient capacity, either of devices or services. Insufficient capacity is caused by inappropriate management policy, financial controls and/or capacity planning. The effect of insufficient device capacity on industry growth can be very traumatic as shown in Figure 55. Table 39 shows the policies used in the test.

Table 39: Equipment Supplier Capacity Policies

Run	1	2	3	4
Capacity Policy	No Shortages	Base Case 1	500,000 Units per Year	5,000,000 Units per Year

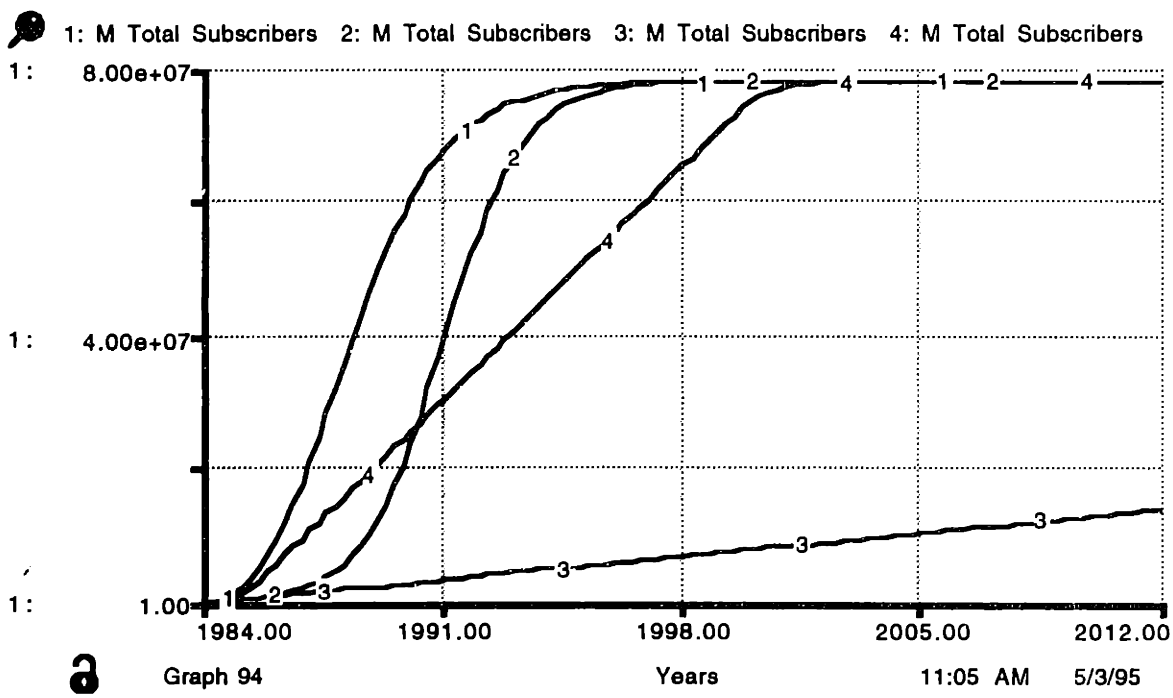


Figure 55: Equipment Supplier Capacity Policy Effect on Industry Growth

The effect of insufficient capacity to industry growth can be dramatic. On the other hand, it is one of the most powerful tools for managing growth and technology that is available to management.

Insufficient service provider capacity is evaluated as the effect of poor service quality. As the service quality degrades, subscribers leave the service. Table 40 shows the policies tested.

Table 40: Service Provider Capacity Scenarios

Run	1	2	3	4
Capacity Policy	No Shortages	Base Case 1	4 Billion Call Minutes per Year	40 Billion Call Minutes per Year

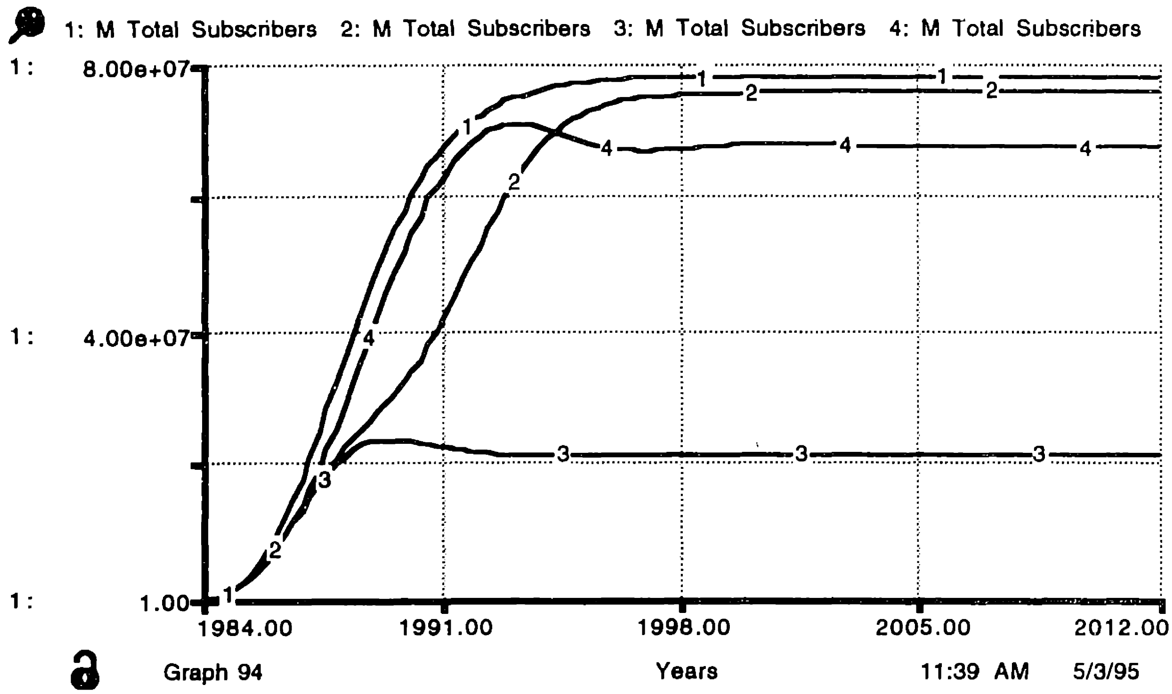


Figure 56: Service Provider Capacity Effect on Industry Growth

In summary, service provider capacity defines the number of subscribers the network can support. Equipment supplier capacity describes the rate at which the network can grow. The linkage between these characteristics is critical to the successful development of the market.

4.1.6 MARKET GROWTH SUMMARY

The analysis of industry growth provides several important conclusions. The key management of technology issues is the reduction in device price and the growth of device and network capacity to support a rapid development of the market.

4.2 PROFITABILITY

As stated earlier, System Dynamics is not an optimizing tool. To find the maximum profitability for the equipment suppliers, the service providers and the industry in total, extensive testing is performed. This testing determined which parameters significantly improve the discounted cash flow of each party. Any parameter that affected only the equipment suppliers or only the service providers was ignored. For example, a lower initial product cost improves the profitability of the equipment supplier but has no effect on the market or the service provider. It is assumed that all firms will pursue appropriate strategies to maximize profitability regardless of the effect on the other player or the industry. The bases for the profit maximizing test are the key management parameters of Table 21.

4.2.1 MAXIMIZING EQUIPMENT SUPPLIER PROFITABILITY

Testing of the model identified several parameters for the equipment suppliers that are key to maximizing profitability in the two tier market. Table 41 identifies the key management parameters and the ability of the equipment suppliers to effect the parameter.

Table 41: Equipment Supplier Key Management Parameters and Actions

Parameter	Industry Significance	Industry Behavior	ES Effect	ES Action
Discard Rate	Small	Less is better	Major, opposite	None
Equipment Subsidies - Generation 1	Significant	Higher is better	Major	None
Initial Capacity - Service Provider	Significant	Not enough is bad but too much is a killer	Minor	None
Initial Capacity - Equipment Supplier	Small	More is better and excess is bad	Major	ES Decision
Capacity Growth - Equipment Supplier	Small	Expected, faster is better	Major	ES Decision
Capacity Delivery Delay - Equipment Supplier	Significant	Expected, shorter is better	Major	None
Capacity Excess - Service Provider	Significant	Test case is best but too small is a killer	Minor, opposite	None
Initial Device Price	Significant	Lower is better	Major, opposite	ES Decision
Time to Change Price Equipment Supplier	Small	Shorter is better	Major, opposite	ES Decision
Cost Learning Curve Equipment Supplier	Significant	Steeper is better, too little, market dies	Major	ES Decision

The equipment suppliers do not have any control over the subsidy and capacity decisions of the service providers. Furthermore, capacity vendors control the capacity delivery delay. Good management practice suggests monitoring this parameter closely during periods of rapid growth. The discard rate is designed as the result of subscriber exits. Although this is favorable to the equipment suppliers, the decision is made by the subscriber as a result of the price and quality of the service. As constructed, the equipment suppliers do not have any influence over this parameter. A capability not implemented in the model is the desire of a subscriber to upgrade to a new model without exiting as a subscriber. This is clearly a very advantageous strategy for the equipment supplier though not evaluated in the model.

Evaluating the parameters the equipment suppliers control, two are critical only at the launch of the industry. These include the initial capacity and the initial price. Since those decisions have already been made, no further investigation is pursued. This leaves three parameters for investigation. They are the capacity growth policy, product cost learning curve and the time to change prices.

The key to maximizing profitability is (1) to maximize the ability to meet demand by having sufficient but not excess capacity, (2) reducing product cost as quickly as possible to grow the market and (3) reducing prices more slowly than costs are falling to modulate market growth and capture additional profits. The importance of monitoring the delay is to assure that capacity is added at the rate the market requires. Figure 57 shows the impact of the various scenarios in Table 42. Scenario 5 results in a $3 billion improvement in discounted cash flows for the equipment suppliers.

Table 42: Equipment Supplier Profit Maximizing Scenarios

Scenario	1	2	3	4	5
Policy	Base Case 1	Aggressive Capacity Growth	Improve Learning Curve 10%	Increase Price Reduction Delay	Scenarios 2 + 3 + 4

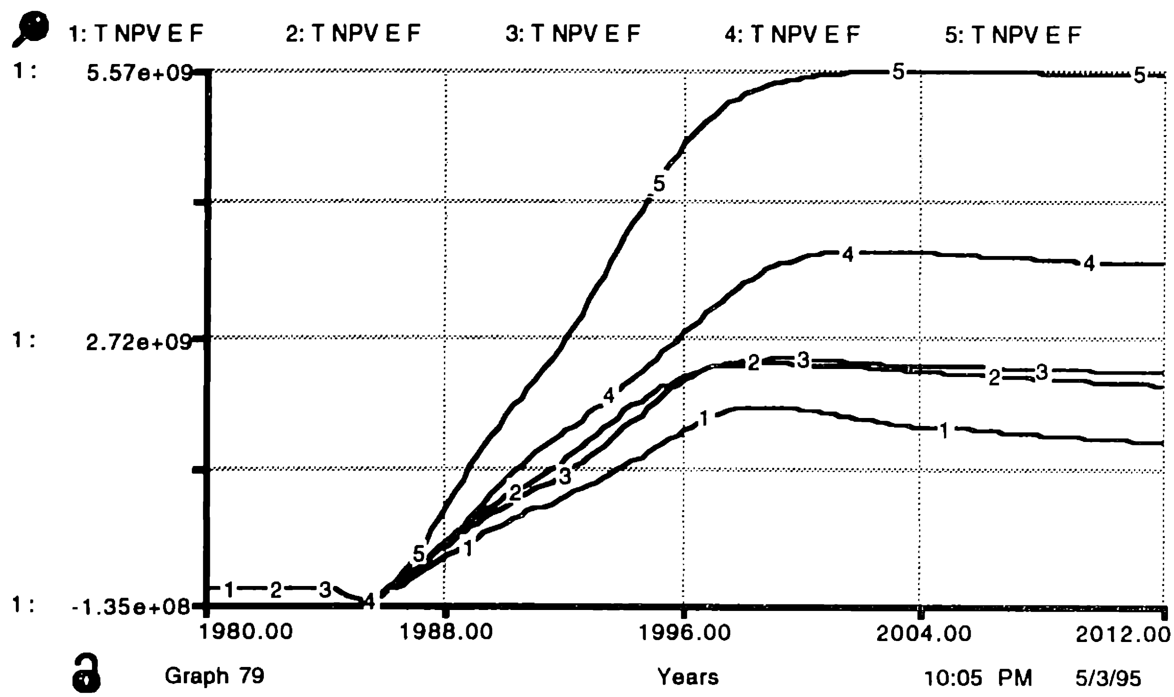


Figure 57: Equipment Supplier Profit Maximizing Scenarios Effect on NPV

The scenario that is best for the equipment suppliers is not best for the service providers. As Figure 58 shows, the capacity and learning curve actions positively influence the profitability of the service providers. This is the result of lowering prices to increase demand and adding capacity aggressively to meet this demand. However, slowing the price reductions has a significant negative impact on the discounted cash flows of the service providers.

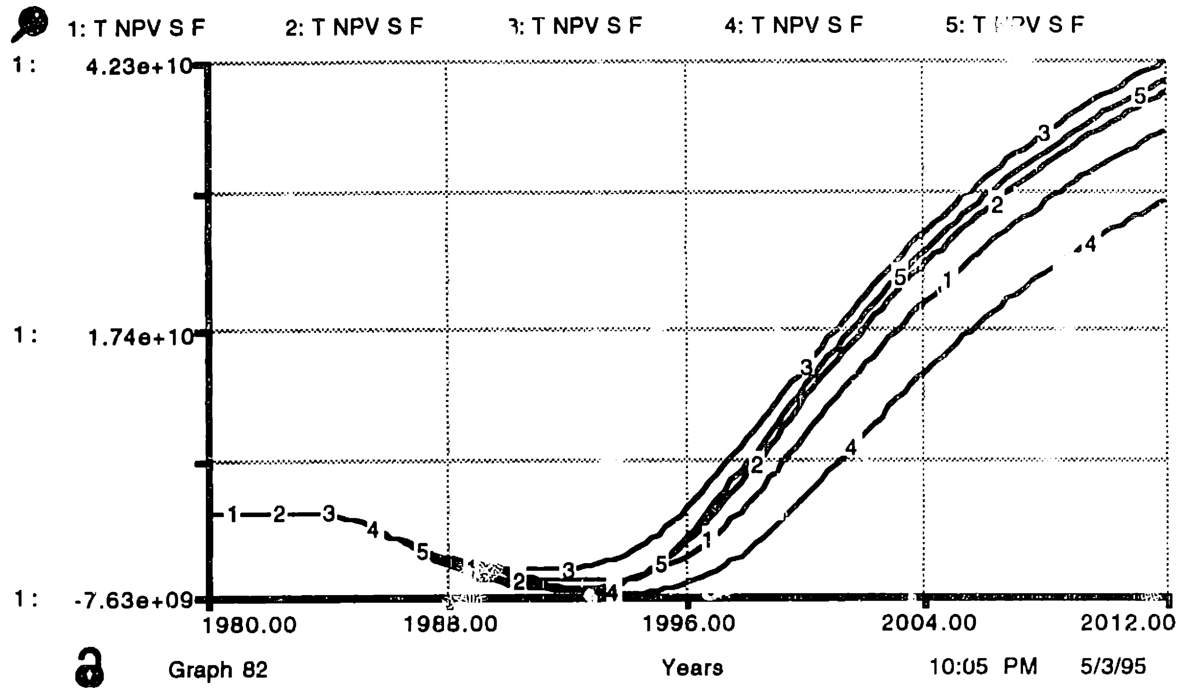


Figure 58: Equipment Supplier Profit Maximizing Effect on Service Provider NPV

As expected, the industry as a whole behaves similarly to the service providers. As Figure 59 shows, this one of the few situations where what is best for the equipment suppliers is best for the industry.

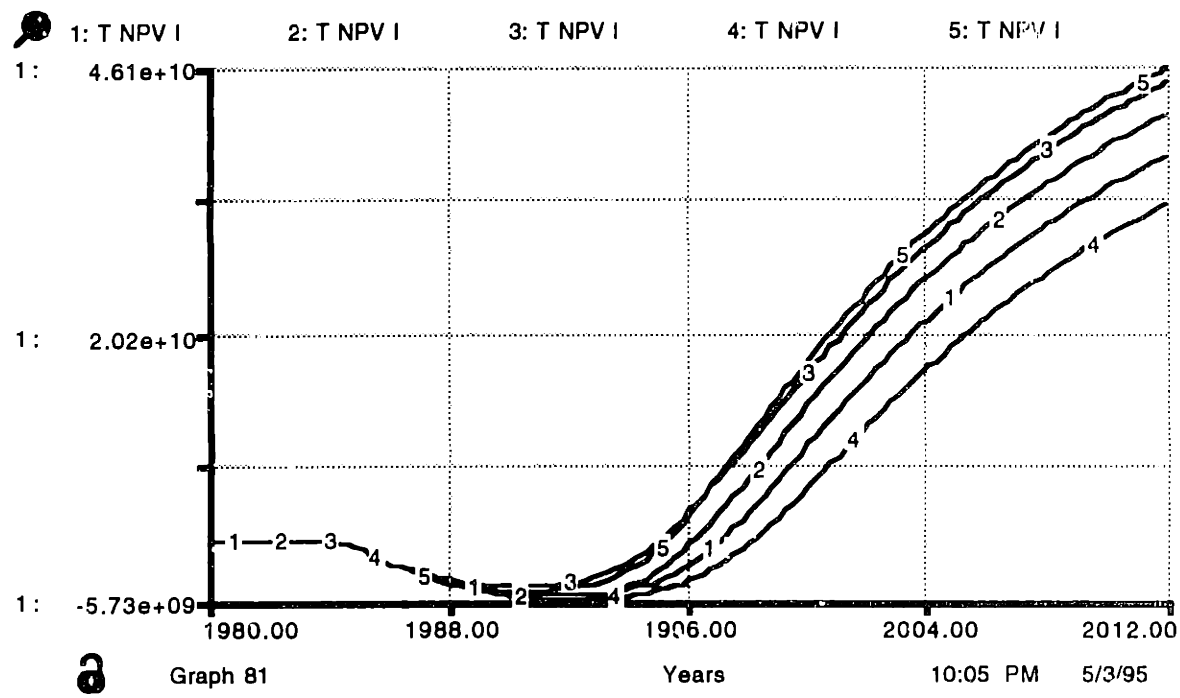


Figure 59: Equipment Supplier Profit Maximizing Effect on the Industry NPV

Only the slower price reduction scenario slows market growth of the subscriber. The other scenarios increase the rate of market growth. To summarize, the optimum scenario for the equipment supplier is to have in place the capacity required to meet demand, aggressively cut product costs and slowly reduce prices as the volume rises. While managing these dynamics, it is important to monitor the delays in obtaining capacity and, if possible, strive for device upgrades from the installed base.

4.2.2 MAXIMIZING SERVICE PROVIDER PROFITABILITY

A similar approach is used to determine the optimum profit scenario for the service providers. Table 43 identifies the key management parameters and the ability of the service providers to effect the parameter. This table is derived from Table 21 after various tests.

Table 43: Service Provider Key Management Parameters and Actions

Parameter	Industry Significance	Industry Behavior	SP Effect	SP Action
Discard Rate	Small	Less is better	Minor	None
Equipment Subsidies	Significant	Higher is better	Major	SP Decision
Initial Capacity - Service Provider	Significant	Not enough is bad but too much is a killer	Major	SP Decision
Initial Capacity - Equipment Supplier	Small	More is better and excess is bad	Minor	None
Capacity Growth - Equipment Supplier	Small	Expected, faster is better	Minor	None
Capacity Delivery Delay - Equipment Supplier	Significant	Expected, shorter is better	Major	None
Capacity Excess - Service Provider	Significant	Test case is best but too small is a killer	Major	SP Decision
Initial Device Price	Significant	Lower is better	Major	None
Time to Change Price Equipment Supplier	Small	Shorter is better	Minor	None
Cost Learning Curve Equipment Supplier	Significant	Steeper is better, too little, market dies	Major	None

Interpreting the parameters for profit maximizing potential, the discard rate has a small impact and is nearly impossible to eliminate. Though the service providers have no way of controlling the capacity policies of the equipment suppliers, it is clear adequate device capacity is essential for the successful growth of the industry. Where the service providers can help is to provide accurate subscriber information to the equipment suppliers. The Cellular Telecommunications Industry Association provides this information to anyone that requests it. Service providers also have no control over the prices and costs of the equipment suppliers.

That leaves three decisions that service providers can make to maximize profitability. The initial capacity decision has already been made and is not investigated further. The key parameters the service providers can use are device subsidies and excess network capacity (target utilization). Figure 61 shows the effect of the scenarios of Table 44. The effects of these actions are to increase the size of the market by reducing the price of the device to the subscriber and adding capacity more quickly by using a lower target utilization.

Table 44: Service Provider Profit Maximizing Scenarios

Scenario	1	2	3	4
Policy	Base Case 1	Increasing Excess Network Capacity	Increase Device Subsidy	Scenarios 2 + 3

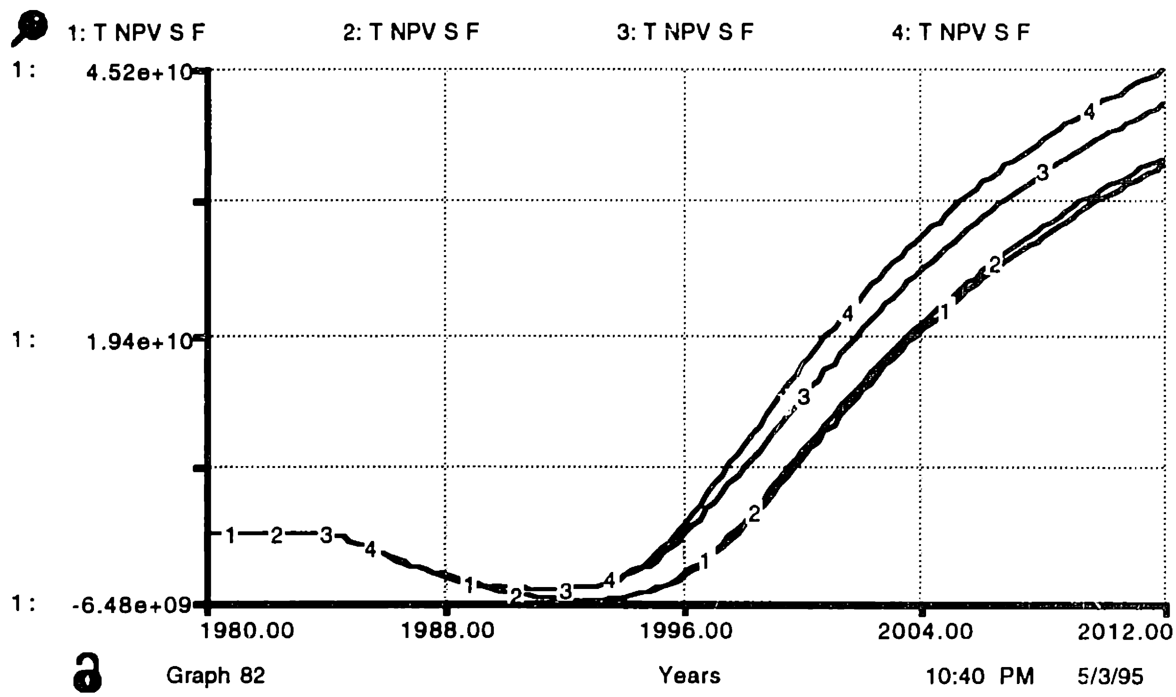


Figure 60: Service Provider Profit Maximizing Effect on NPV

The equipment supplier sees improved profitability caused by higher shipment rates in the faster growing market. On the other hand, the additional network capacity slightly reduces profitability.

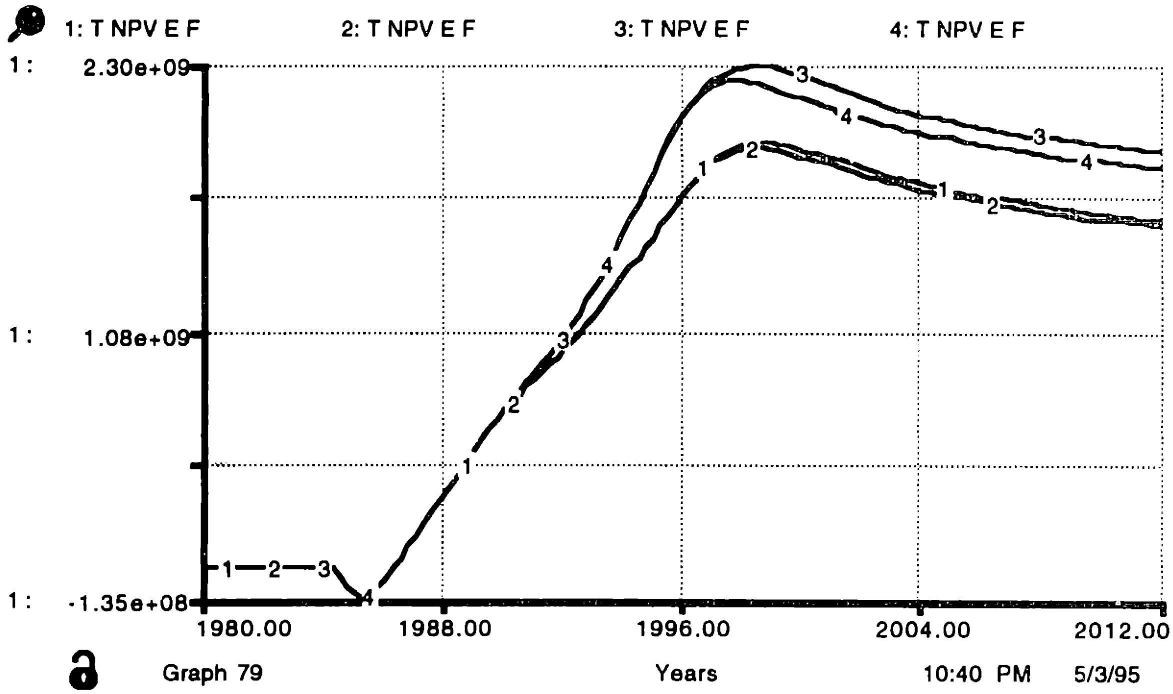


Figure 61: Service Provider Profit Maximizing Effect on Equipment Supplier NPV

It is interesting to find that only two management variables have such a significant effect on the performance of the service providers. The effect may not seem large but that is caused by the fact that the base case values are very near optimal. Testing has verified the significance of planned capacity utilization and device subsidies on the growth of the market. Conversely, if it was possible, starting with low prices from the equipment suppliers results in very poor financial performance for the device suppliers. Subsidies are the best way to develop a two tier market but there is need for caution. Subsidies remove an incentive on the part of the equipment suppliers to reduce prices. Further, as today's cellular market is demonstrating, there is a time when the device becomes free. It seems that a rebate program for 10% of the device price is a more appropriate way to reduce the initial device price as a market develops. In summary, maximizing the profitability of the service providers requires subsidization of the device price and the appropriate network utilization target.

4.2.3 MAXIMIZING EQUIPMENT SUPPLIER PROFITABILITY IN A TECHNOLOGY TRANSITION

The incentives for the equipment supplier to invest in new technologies are quite compelling. On the one hand equipment suppliers can go out of business after the market has saturated. On the other hand, the manufacturers can increase discounted profits by $1.5 billion (almost double a single technology generation industry as documented in Chapter 3.4) with the introduction of a new, incompatible standard sold to the existing installed base. It is true that the device is more complex. However, the new generation device can be offered at a higher price as a result of additional features. Though not modeled, it is conceivable that a trade in or rebate program would have a dramatic, positive effect on the conversion process. Equipment suppliers should be strong advocates of a technology transition.

Even though the equipment supplier may not have any control over the timing of a technology transition, it is important to understand when it is most advantageous. Figure 66 shows the NPV of the scenarios listed in Table 45. The best scenario occurs when demand for the current generation is at its maximum. The primary issue concerns capacity. It is impossible to avoid additional capacity requirements. Adding the upgrades on top of the existing demand forces the equipment suppliers to add capacity that is required only for the duration of the upgrade. Whether by plan or accident, now is the best time to introduce the digital standard in the U.S. market. By the way, the impact to the service providers regarding the timing of the transition is insignificant.

Table 45: Equipment Supplier Technology Transition Timing Scenarios

Scenario	1	2	3
Policy	Transition At Peak Demand Base Case 2	Early Transition	Late Transition

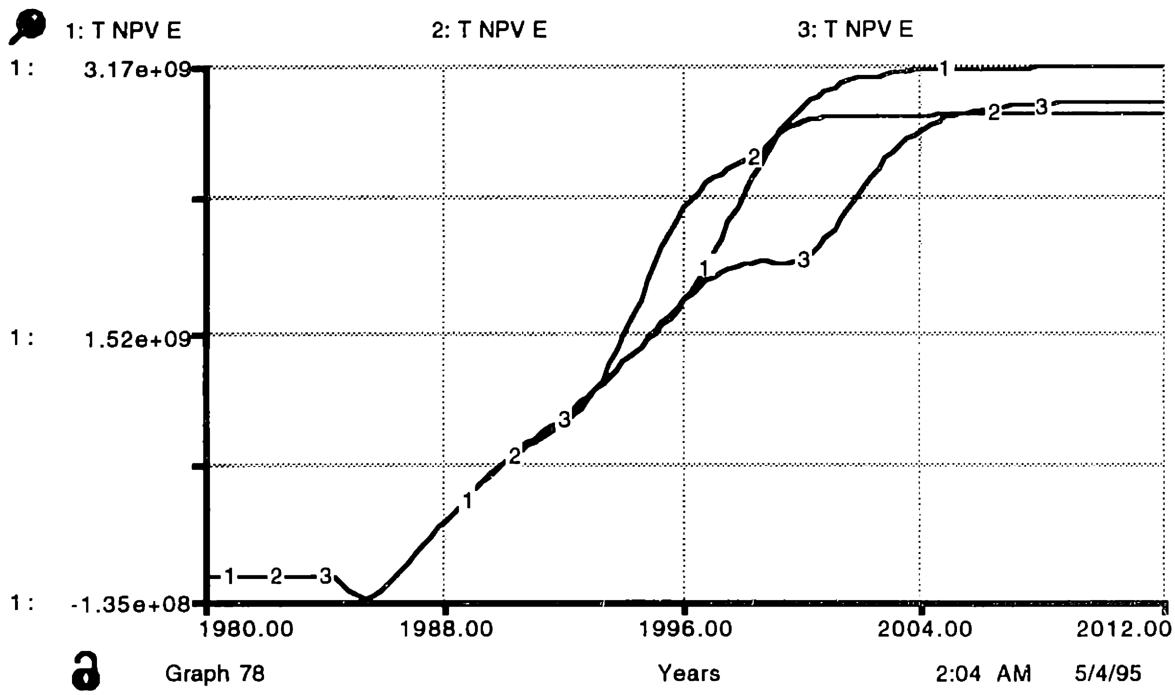


Figure 62: Equipment Supplier Technology Transition Timing Effect on NPV

Maximizing the profitability of the equipment suppliers involved in a technology transition is very similar to the single technology two tier market. The key parameters are aggressive capacity planning and growth, serious product cost reduction and slow price reductions for the first generation product. For the second generation, key parameters are a higher initial price, serious product cost reduction, leisurely price reduction and a short technology transition that occurs in the middle of the product like cycle of the first generation product. Table 46 summarizes these recommendations. Always, it is important to monitor capacity delivery delays and signs of excess capacity. Using this scenario, the profit of the equipment supplier can be maximized.

Table 46: Key Technology Transition Management Parameters

Parameter	Industry Significance	Industry Behavior	SP Effect	ES Effect
Initial Device Price - Generation 2	Small	Lower is better	Minor	Major, opposite
Time to Change Price - Gen. 2 Equipment Supplier	Small	Shorter is better	Minor	Major, opposite
Cost Learning Curve - Gen. 2 Equipment Supplier	Significant	Steeper is better, too little, market dies	Major	Major
Upgrade Time Frame	Small	Longer is better	Minor	Major, opposite

4.2.4 MAXIMIZING SERVICE PROVIDER PROFITABILITY IN A TECHNOLOGY TRANSITION

Besides purely economic benefit, there may be other reasons why a service provider may be interested in a new standard such as additional capacity or better service quality. At this time, those other considerations have not been included in the model. In looking a little closer at a technology transition several issues require investigation.

As modeled, the service provider incentives to invest in new technology are not as apparent. Looking more closely at the dynamics, the new technology lowers the operating costs of the network. This means that the price of a minute of airtime is reduced by the savings the new technology provides. If the service providers chose not to pass all of these savings onto their customers, an additional $54 billion (14%) of discounted pretax profit would be generated as Figure 67 shows. Table 47 describes the two scenarios.

Table 47: Service Provider Airtime Pricing Scenarios

Scenario	1	2
Policy	Cost Savings Passed Directly to Subscribers Base Case 2	Cost Savings Retained Base Case 1 Prices

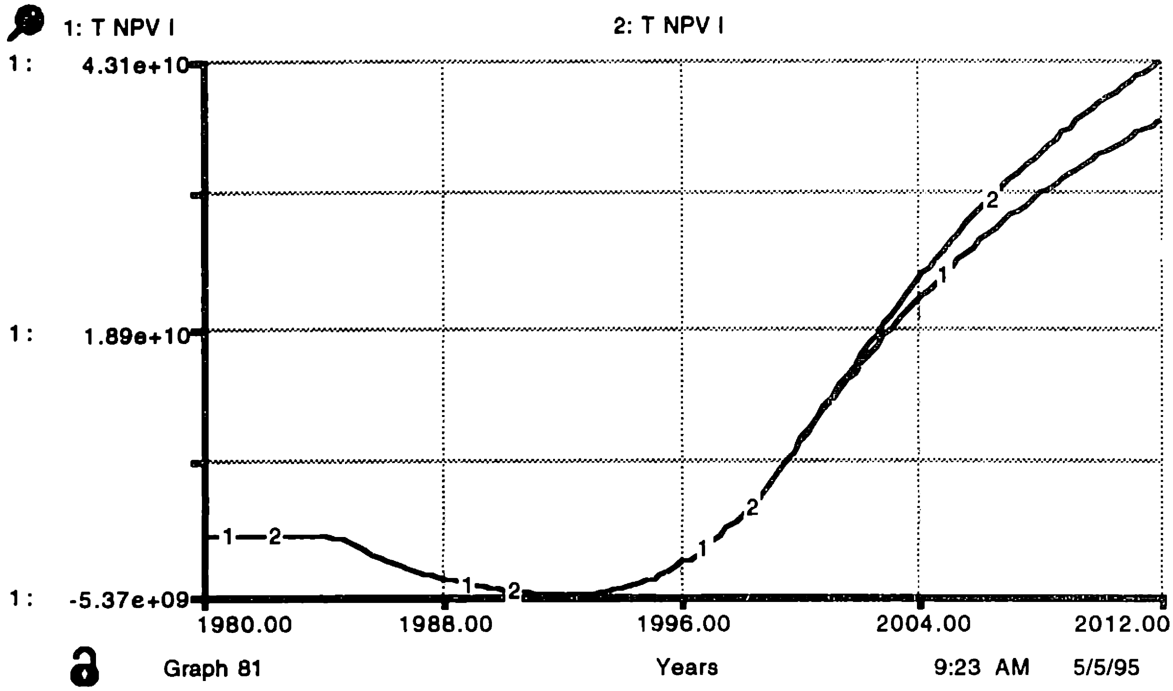


Figure 63: Service Provider Airtime Pricing Effect on NPV

In the first generation of service, the key management parameters are the target capacity utilization and device subsidies. For the second generation, target capacity utilization becomes less important due to the slower growth of network capacity. In addition, subsidies for the second generation of product have little effect on the growth of the market. As Table 46 shows, rapid price reductions of second generation devices are as important to the second generation as the first generation. Service providers must also monitor second generation device capacity so that the service transition occurs in synchronization with device availability. There may also be additional benefits of the new technology that must be taken into consideration. These include network quality or capacity benefits that have not been quantified in the existing model.. It appears there is a combination of price, quality and capacity that makes the two generations of service technology too attractive for the service providers to pass up. The key second generation management parameters are coordination with the equipment provider and managing the service advantages provided by the new technology.

4.2.5 MAXIMIZING PROFITABILITY SUMMARY

For both the equipment supplier and the service provider, significant profitability exists in a two tier market. The equipment supplier must aggressively manage capacity growth and product cost reductions while reducing prices as slowly as the market allows. Each additional generation of the product is very advantageous to the equipment supplier and the same management of technology parameters applies. The service provider stimulates market growth with device subsidies and manages capacity growth by maintaining the appropriate target capacity utilization. Another generation of service produces mixed profitability benefits with few management of technology considerations.

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET:
A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

CHAPTER 5: RECOMMENDATIONS

5.0 OVERVIEW

A thorough understanding of the two tier markets, especially for cellular telecommunications, has been achieved. A system dynamics model with the important structure and behavior is available. The history of the cellular market is explained and forecasts of the future market are available. The mechanisms of market growth and profitability are well understood. With this in mind, the following recommendations are offered.

5.1 INDUSTRY RECOMMENDATIONS

For a two tier market to develop successfully and profitably, both players must recognize the contribution of the other toward their mutual success. By working together, equipment suppliers, service providers, end users and investors all benefit from two tier markets. On the other hand, failure to work together can kill market development. For instance, if the service providers choose not to subsidize the device or the equipment suppliers do not achieve the required cost reductions, the market will not take off. The recommendations that follow highlight the required actions of each player in the creation and successful development of a two tier market.

5.1.1 EQUIPMENT SUPPLIERS

Equipment suppliers hold the keys to the growth of a two tier market. The key driver is device price. The factors which influence prices are product costs and capacity. The management strategies for equipment suppliers follow.

- LOW PRICES - The growth of a two tier market is primarily driven on device price. The market gets larger as the price gets lower. For electronic devices, there is a barrier at approximately $1000. Market development is slow above that price. The market begins to take off as device prices fall below $1000.
- DRAMATIC COST REDUCTIONS - Getting low prices is only possible with purposeful cost reduction programs. Manufacturers must achieve product cost learning curves that are around 80%. This is accomplished with investments in engineering, manufacturing and the component suppliers. Failure to achieve these cost reductions kills the market.

- AGGRESSIVE CAPACITY GROWTH - As prices fall, demand increases. Satisfying increased demand requires additional capacity. When the market takes off, it moves very fast. Management must be ready to move as fast as the market. Insufficient capacity hurts market development. Excess capacity hurts the equipment suppliers profitability. The right balance is required.
- PUSH NEW STANDARDS - To avoid the boom bust cycle, equipment suppliers need new generations of product that can be sold to the same customer base. Without this opportunity, the long term success of device manufacturers is limited

5.1.2 SERVICE PROVIDERS

It might seem that service providers are at the mercy of the equipment suppliers. At the beginning this may seem true, especially considering the huge investments that are required to construct a network. Working together with the manufacturers, service providers significantly help their cause. The most important strategies follow.

- SUBSIDIES - When device prices are high, service providers can jump start the market by lowering the barriers to entry. Reducing the device price is the most effective way to get the market started. It may even be better than huge advertising campaigns. Yes, it is expensive, but its worth it in the long run. In the future, an incentive based on a percentage off list price is preferable to today's flat rate.
- AGGRESSIVE CAPACITY GROWTH - It is very important to start a network with the right amount of capacity. Once the market takes off, capacity growth is very rapid requiring difficult management decisions. Failure to heavily invest in sufficient capacity really hurts profitability in the long run.

5.2 INDIVIDUAL FIRM RECOMMENDATIONS

Even though all analysis has focused on the aggregated equipment suppliers and service providers, several strategies have emerged which may provide an advantage to individual firms operating in a two tier market. These strategies follow.

5.2.1 EQUIPMENT SUPPLIERS

Typically, barriers to entry in an emerging market are relatively low in the electronics industry. This leads to some obvious strategies.

- FIRST MOVER - Being the first in the market has the primary advantage of getting down the learning curve first. This advantage is very powerful in a technology transition. Being first on the new standard provides immediate access to knowledgeable customers and avoids the inevitable bust firms face in manufacturing device to the previous standard.

- LOWEST COSTS - Low costs means low prices. Low prices mean market share (assuming the quality is there). Having high market share in a growing market is a great position to be in.
- ENOUGH CAPACITY - Insufficient capacity limits growth. Without growth, its hard to reduce costs. When the market takes off, a firm has to spend money to make money.

5.2.2 SERVICE PROVIDERS

Barriers to entry are very high for service providers. Licenses to operate are limited and the network construction investments are significant. Usually there is a limited number of operators in a given area. The key strategy for service providers is finding and keeping the most subscribers. Reasonable pricing policies that avoid churn are recommended. For instance, pricing the service too high causes the early exit of customers and allowing the price of the device to reach $0.00 is asking for undesirable customers. The appropriate mix of service quality, pricing, capacity, subsidies and distribution is required

5.3 STRATEGIC CONCLUSIONS

The two tier market represents a particular structure and behavior. This gives rise to a set of challenging strategic issues. An understanding of these issues is critical to the profitable participation in a two tier market.

5.3.1 PRICES

Equipment suppliers and service providers must work together to assure the lowest device price possible. This may mean a subsidy or rebate on the part of the service provider to facilitate lower device prices. The price pressure on service prices is minimal thereby allowing recovery of the subsidy in the future.

5.3.2 COSTS

Equipment suppliers control the growth of the market with their ability to reduce costs as volume increases. The steeper the cost learning curve, the better for the market. Service providers must also reduce costs but not to the same degree as manufacturers.

5.3.3 CAPACITY

Both parties must grow capacity as fast as the market requires. Failure to make rapid and sustained capacity investments seriously effects the profitability and growth of the market.

5.3.4 TECHNOLOGY

A technology transition to a new standard is required to maintain the device manufacturing capability. Without it, equipment suppliers face a boom bust cycle that is not survivable. This new standard is best launched at the peak of demand for the existing standard. A slow or prolonged conversion to the new standard must be avoided. The delay wipes out any financial gains pursuing the next generation product would have produced. A rebate or trade in program is recommended to stimulate conversion demand should that situation occur.

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET:
A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

BIBLIOGRAPHY

Abernathy, W.J. & J.M. Utterback, "Patterns of Industrial Innovation", Technology Review, June/July 1978, pg. 44.

Arthur, W.B., "Competing Technologies; An Overview," Technical Change and Economic Theory, Edited By G. Dosi, Columbia University Press, New York, NY, 1988, pg. 603.

Baldwin, W.L. & J.T. Scott, Market Structure and Technological Change, Harwood Academic Publishers, Chur, Switzerland, 1987, pg. 146.

Calhoun, G., Digital Cellular Radio, Artech House, Norwood, MA, pp. 12-16.

David, P.A., "Some New Standards for the Economics of Standardization in the Information Age," in Economic Policy and Technological Performance, Edited by Dasgupta, P. & Stoneman, P., Cambridge University Press, Cambridge, England, 1987, pg. 217.

The Economist Staff Writers, "Mobile Telephones: A Way of Life," The Economist, May 30, 1992, pg. 19.

The Economist Staff Writers, "Telecommunications: A Softer Sell," The Economist, October 23, 1993, pg. SS8.

Forrester, J.W., Industrial Dynamics, Portland OR, Productivity Press, 1961

Forrester, J.W. "System Dynamics - Future Opportunity," in System Dynamics, TIMS Studies in the Management Sciences, Edited by Legasto, Jr., A.A., J.W. Forrester, J.M. Lyneis, New York, NY, North Holland Publishing Company, 1980, pg. 8.

Forrester, J.W. & P.M. Senge, "Test for Building Confidence in System Dynamics Models," in System Dynamics, TIMS Studies in the Management Sciences, Edited by Legasto, Jr., A.A., J.W. Forrester, J.M. Lyneis, New York, NY, North Holland Publishing Company, 1980, pp. 209-228.

High Performance Systems, Introduction to Systems Thinking and iThink, Hanover, NH, 1994, pg. 25.

Huber, Kellogg & Thorne, The Geodesic Network II, 1992, pg. 4.23.

Leibowitz, D., E. Buck & J. Whittier, "The Wireless Communications Industry," Report for Donaldson, Lufkin & Jenrette Securities Corporation, Winter 1994, pg. 12.

Lyneis, J.M., Corporate Planning and Policy Design: A System Dynamics Approach, Cambridge, MA Pugh-Roberts Associates, Inc., 1988, pp. 9 & 211.

Lyneis, J.M., "A Dynamic Model of Technology Diffusion," Cambridge, MA, Pugh-Roberts Associates, Inc., Unpublished.

Lyneis, J.M. & H.B. Weil, "Tactical vs. Strategic Approaches to Competitive Positioning -- An Example from the Telecommunications Industry," Cambridge, MA, Pugh-Roberts Associates, Inc., April 24, 1994, Unpublished.

Morecroft, J.D.W., "System Dynamics and Microworlds for Policymakers," European Journal of Operational Research, 1988, pg. 310.

Morecroft, J.D.W. & J.D. Sterman, Modeling for Learning Organizations, Portland, OR, Productivity Press, 1994.

Roberts, E.B., "Strategies for Effective Implementation of Complex Corporate Models," Edited by E.B. Roberts, MIT Press, Cambridge, MA, 1977, pg. 80.

Roberts, E.B., Managerial Applications of System Dynamics, Cambridge, MA, Productivity Press, 1978.

Rogers, E.M., Diffusion of Innovation, Macmillan, New York, NY, 1983, pg. 217-240.

Senge, P.M. The Fifth Discipline: The art and Practice of the Learning Organization, New York, NY: Doubleday, 1990. This example is discussed in pp. 74-79.

Sterman, J.D., "A Skeptics Guide to Computer Models," Foresight and National Decisions, by L. Grant, University Press of America, 1988. pp. 138-150.

Teece, D.J., "Profiting From Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," Research Policy, 1986, pg. 288.

Weil, H. B., ""Strategic Learning: Preparing Senior Managers for the Future," Cambridge, MA, Pugh-Roberts Associates, Inc., 1990.

Weil, H. B., "Commodization of Technology-Based Service," October 20, 1984, Cambridge, MA, MIT Sloan School of Management, Unpublished.

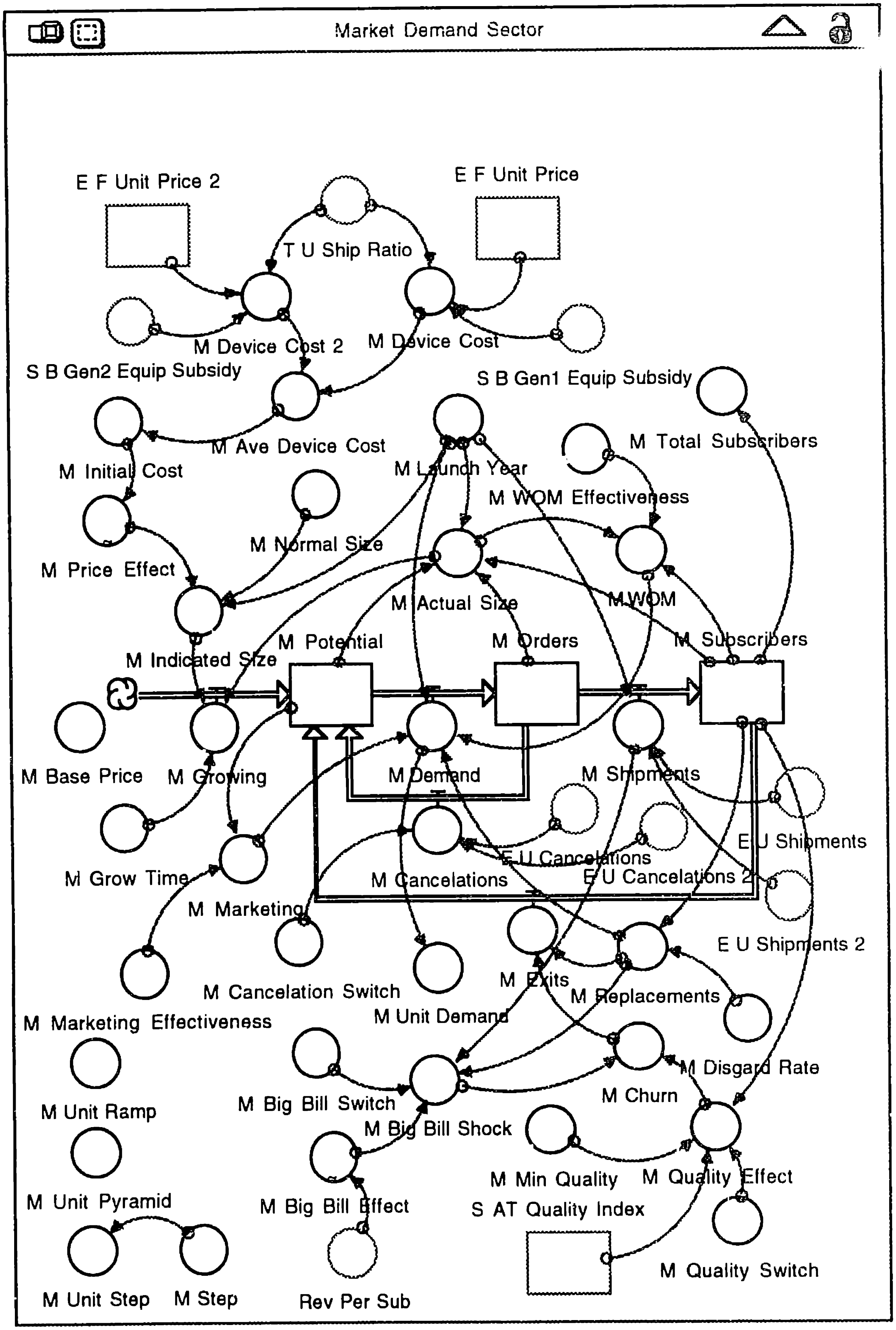
Weil, H. B., "Commodization of Technology-Based Service: Progress Report," Cambridge, MA, MIT Sloan School of Management January 27, 1995, Unpublished.

MANAGEMENT OF TECHNOLOGY IN A TWO TIER MARKET:
A SYSTEM DYNAMICS INVESTIGATION OF WIRELESS COMMUNICATIONS

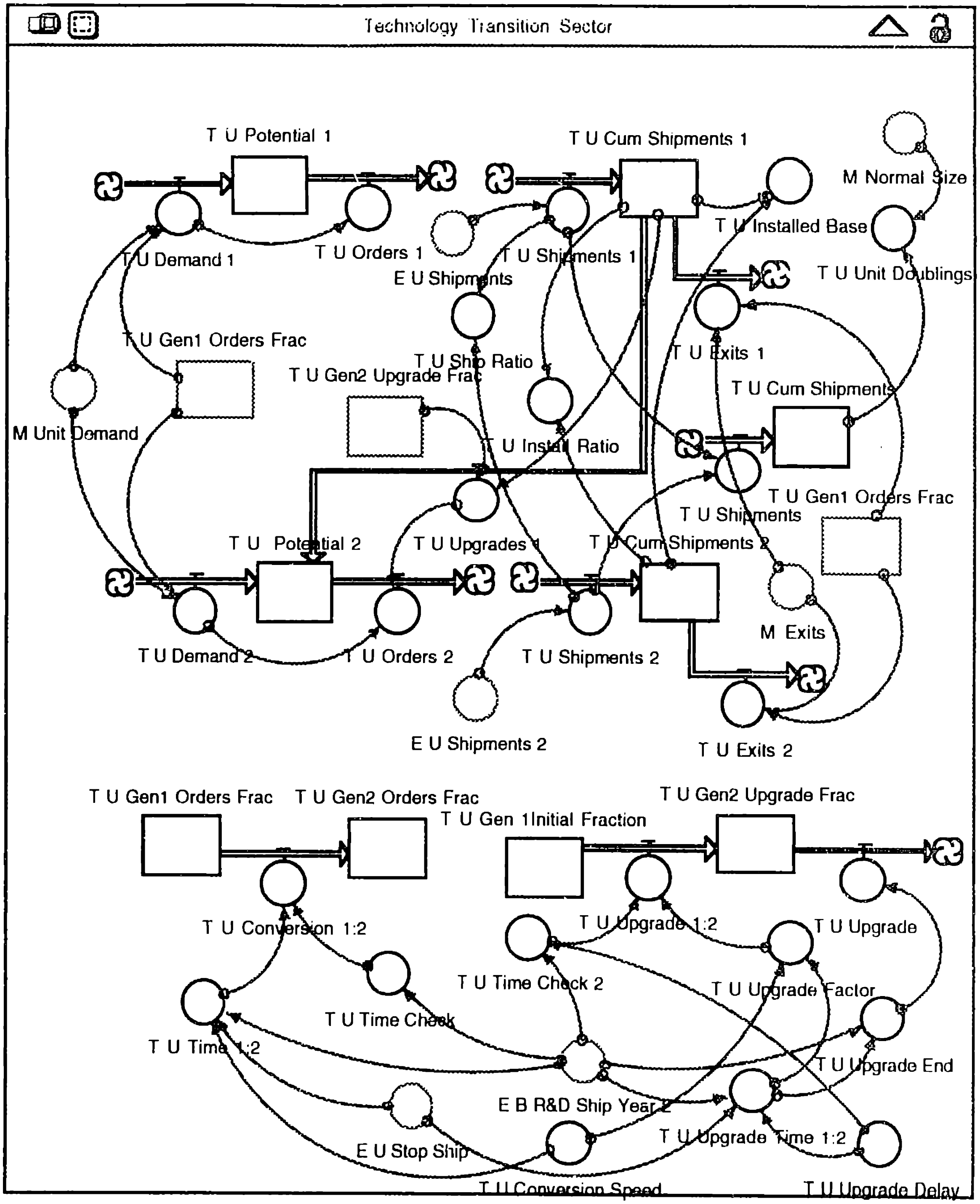
APPENDIX: CELLULAR TELECOMMUNICATIONS INDUSTRY MODEL DOCUMENTATION

Table 48: Documentation Index

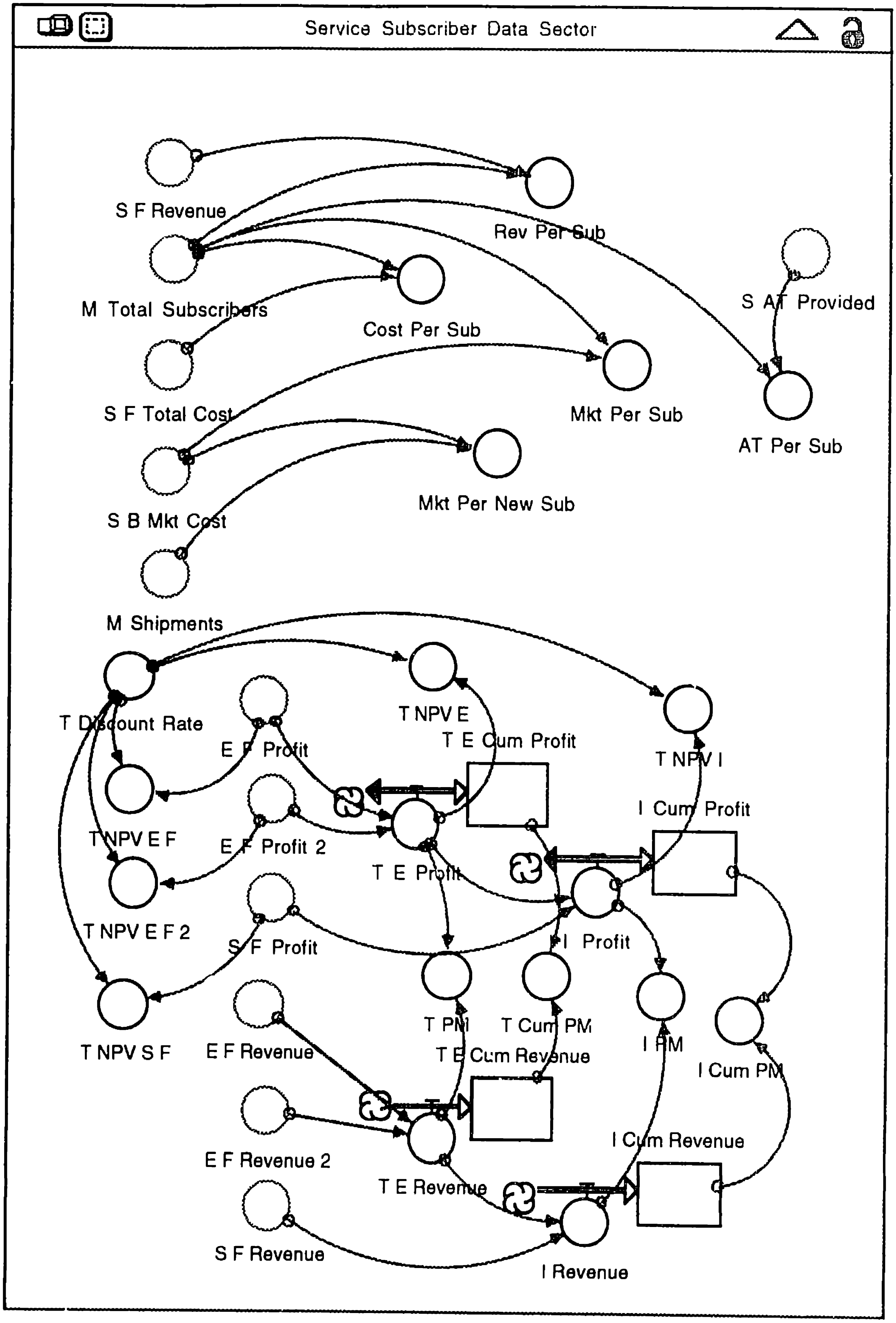
Sector/Page Cross Reference	Technology Generation	Flow Diagram	Program Listing
Market Demand	1 & 2	98	127
Technology Transition	2	99	142
Service Provider Subscriber Data	1 & 2	100	141
Service Provider Airtime Demand	1 & 2	101	131
Service Provider Capacity Planning	1 & 2	102	134
Service Provider Budgeting	1 & 2	103	132
Service Provider Financial	1 & 2	104	137
Equipment Supplier Unit Demand	1	105	125
Equipment Supplier Capacity Planning	1	106	116
Equipment Supplier Budgeting	1	107	113
Equipment Supplier Financial	1	108	120
Equipment Supplier Unit Demand	2	109	126
Equipment Supplier Capacity Planning	2	110	118
Equipment Supplier Budgeting	2	111	114
Equipment Supplier Financial	2	112	123



Market Demand Sector
E F Unit Price 2
E F Unit Price
T U Ship Ratio
M Device Cost 2
M Device Cost
S B Gen2 Equip Subsidy
S B Gen1 Equip Subsidy
M Ave Device Cost
M Initial Cost
M Launch Year
M Total Subscribers
M WOM Effectiveness
M Normal Size
M Price Effect
M Actual Size
M WOM
M Potential
M Orders
M Subscribers
M Indicated Size
M Base Price
M Growing
M Demand
M Shipments
E U Shipments
M Grow Time
E U Cancelations
E U Cancelations 2
M Cancelations
M Marketing
E U Shipments 2
M Cancelation Switch
M Exits
M Replacements
M Marketing Effectiveness
M Unit Demand
M Disgard Rate
M Churn
M Unit Ramp
M Big Bill Switch
M Big Bill Shock
M Min Quality
M Quality Effect
M Unit Pyramid
M Big Bill Effect
S AT Quality Index
M Quality Switch
M Unit Step
M Step
Rev Per Sub



Technology Transition Sector
T U Potential 1
T U Cum Shipments 1
M Normal Size
T U Installed Base
T U Unit Doublings
T U Demand 1
T U Orders 1
T U Shipments 1
E U Shipments
T U Gen1 Orders Frac
T U Ship Ratio
T U Gen2 Upgrade Frac
T U Exits 1
T U Cum Shipments
M Unit Demand
T U Install Ratio
T U Gen1 Orders Frac
T U Shipments
T U Potential 2
T U Upgrades 1
T U Cum Shipments 2
T U Demand 2
T U Orders 2
T U Shipments 2
M Exits
E U Shipments 2
T U Exits 2
T U Gen1 Orders Frac
T U Gen2 Orders Frac
T U Gen2 Upgrade Frac
T U Gen 1Initial Fraction
T U Conversion 1:2
T U Upgrade 1:2
T U Upgrade
T U Time Check 2
T U Upgrade Factor
T U Time Check
T U Time 1:2
T U Upgrade End
E B R&D Ship Year 2
T U Upgrade Time 1:2
E U Stop Ship
T U Conversion Speed
T U Upgrade Delay


Service Subscriber Data Sector
S F Revenue
Rev Per Sub
M Total Subscribers
Cost Per Sub
S AT Provided
S F Total Cost
Mkt Per Sub
AT Per Sub
S B Mkt Cost
Mkt Per New Sub
M Shipments
T Discount Rate
T NPV E
T E Cum Profit
T NPV I
E F Profit
I Cum Profit
T NPV E F
E F Profit 2
T E Profit
T NPV E F 2
S F Profit
I Profit
T PM
T Cum PM
I PM
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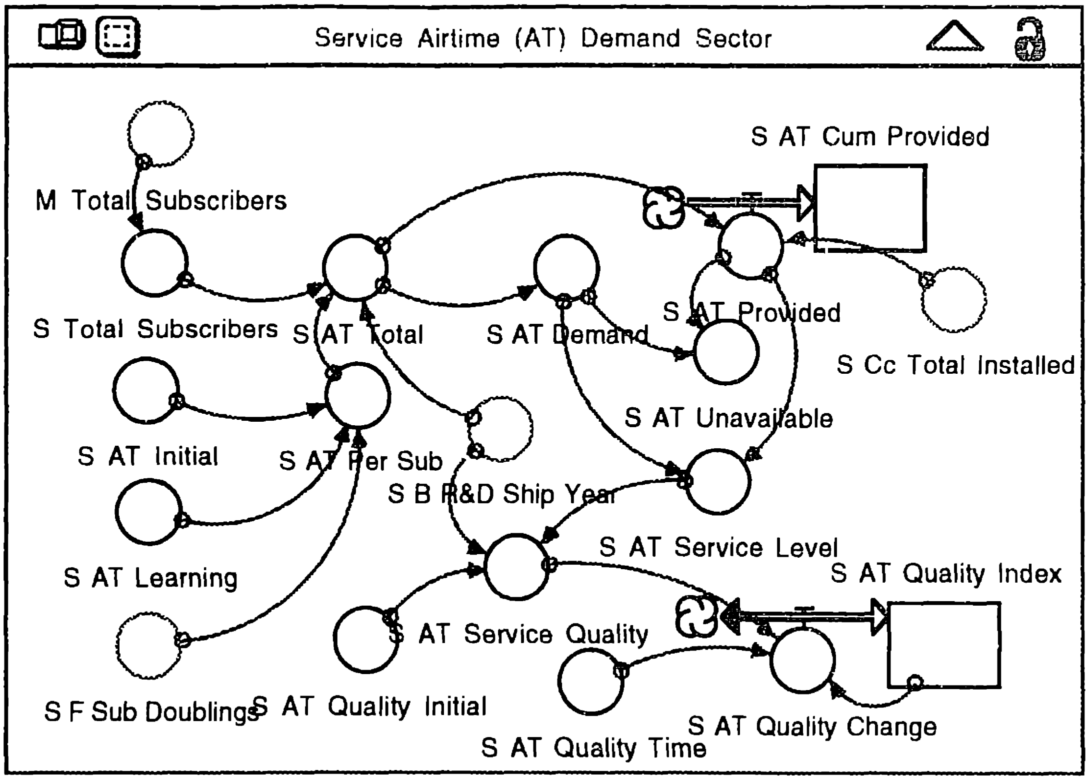
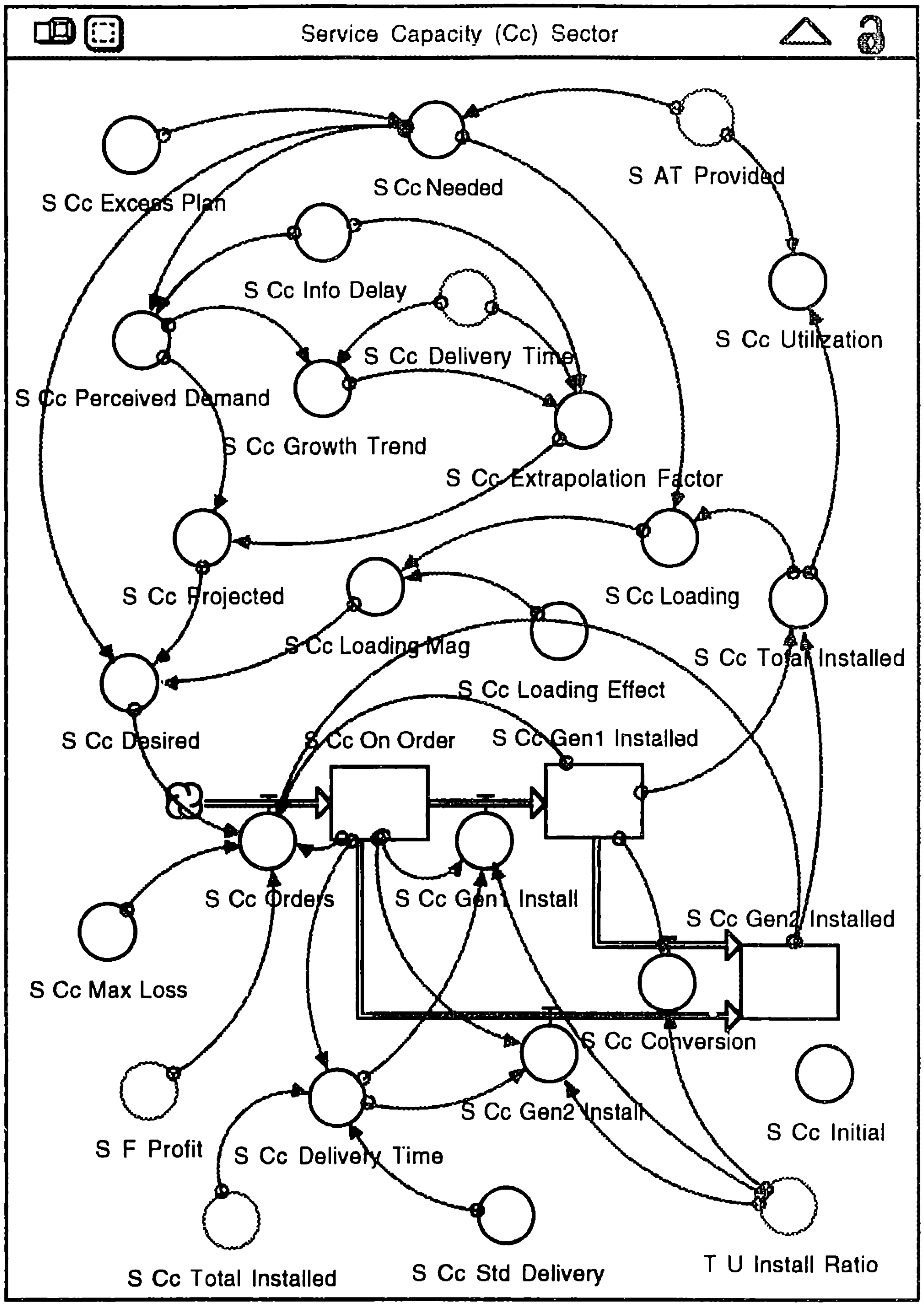
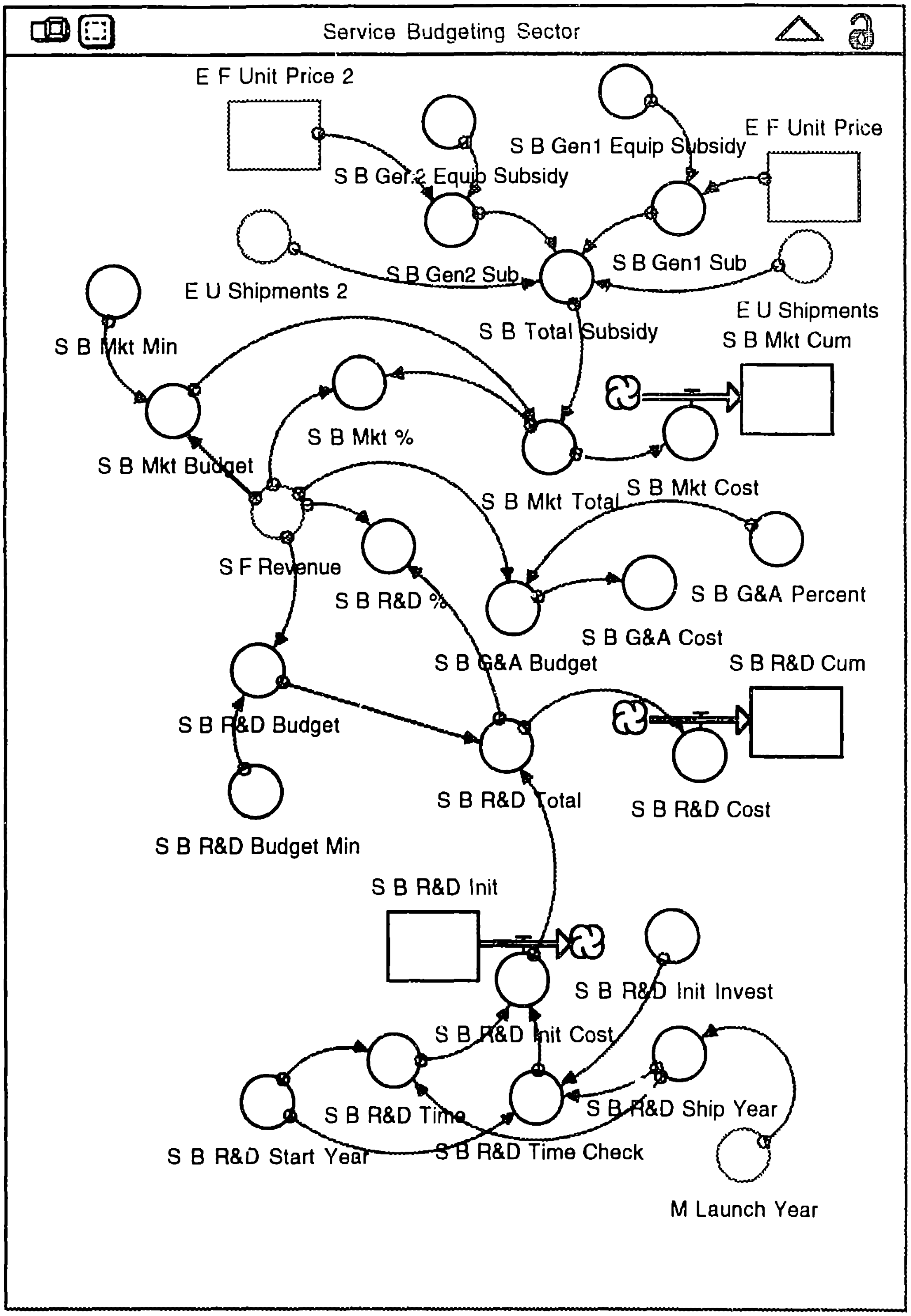
T NPV S F
E F Revenue
T E Cum Revenue
I Cum Revenue
E F Revenue 2
T E Revenue
S F Revenue
I Revenue

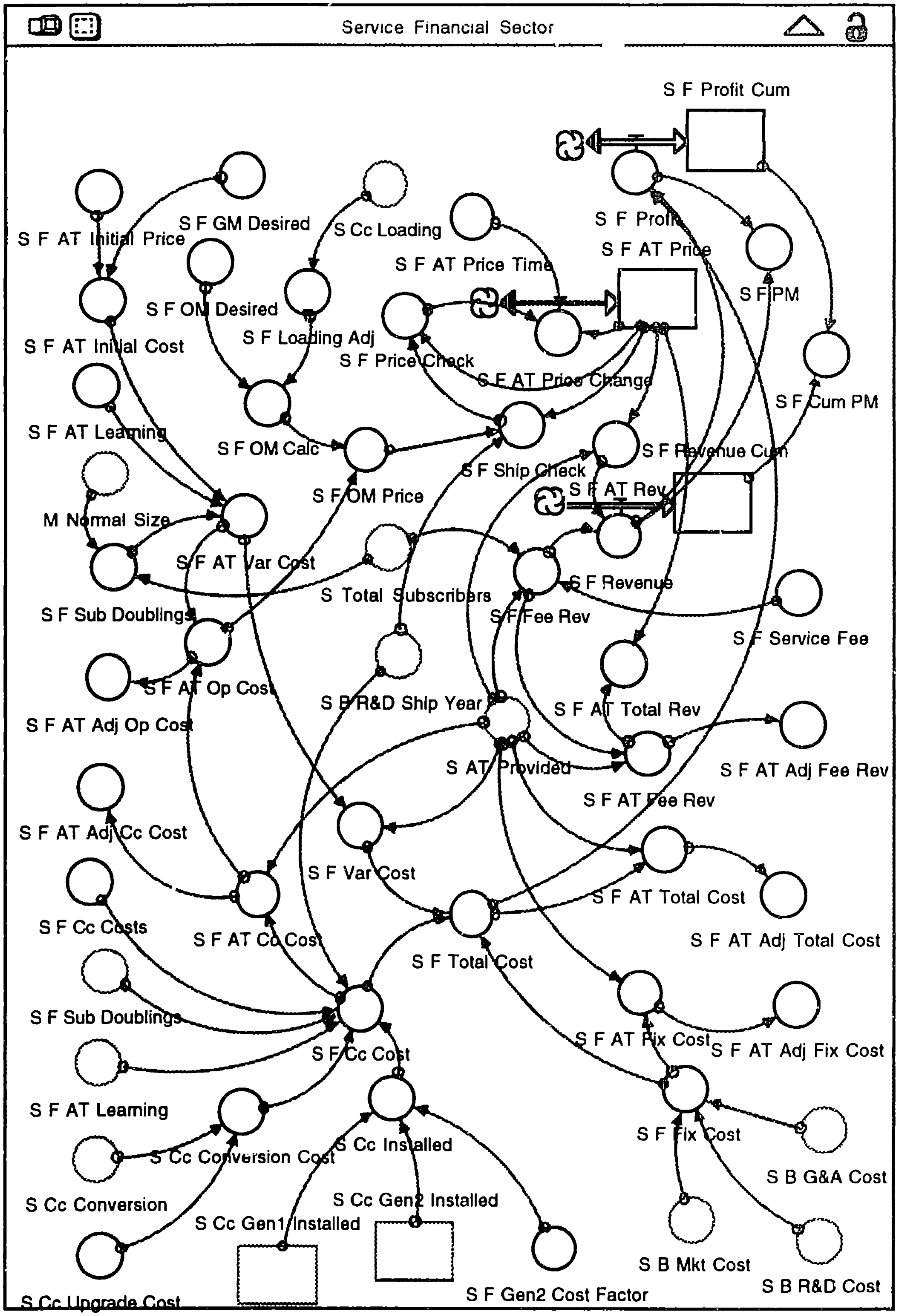

Service Airtime (AT) Demand Sector
S AT Cum Provided
M Total Subscribers
S Total Subscribers
S AT Total
S AT Demand
S AT Provided
S Cc Total Installed
S AT Initial
S AT Per Sub
S AT Unavailable
S B R&D Ship Year
S AT Learning
S AT Service Level
S AT Quality Index
S AT Service Quality
S F Sub Doublings
S AT Quality Initial
S AT Quality Change
S AT Quality Time

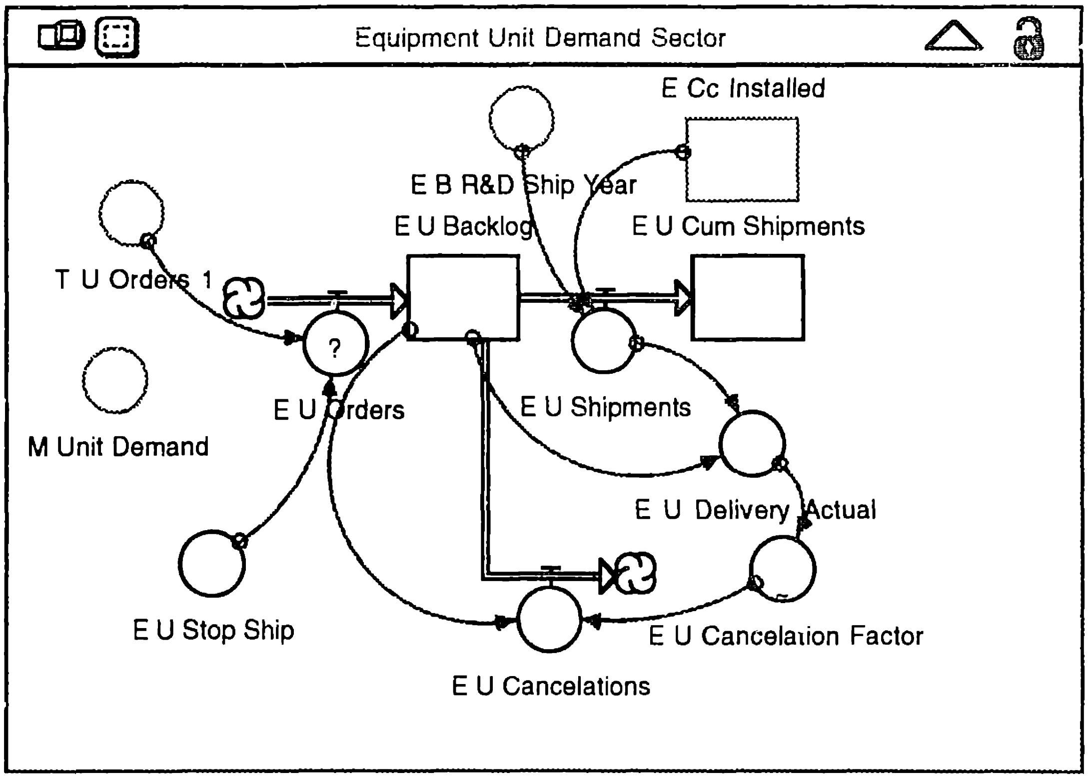


Service Capacity (Cc) Sector
S Cc Excess Plan
S Cc Needed
S AT Provided
S Cc Info Delay
S Cc Utilization
S Cc Perceived Demand
S Cc Delivery Time
S Cc Growth Trend
S Cc Extrapolation Factor
S Cc Projected
S Cc Loading
S Cc Loading Mag
S Cc Total Installed
S Cc Loading Effect
S Cc Desired
S Cc On Order
S Cc Gen1 Installed
S Cc Orders
S Cc Gen1 Install
S Cc Gen2 Installed
S Cc Max Loss
S Cc Conversion
S Cc Gen2 Install
S Cc Initial
S F Profit
S Cc Delivery Time
S Cc Total Installed
S Cc Std Delivery
T U Install Ratio

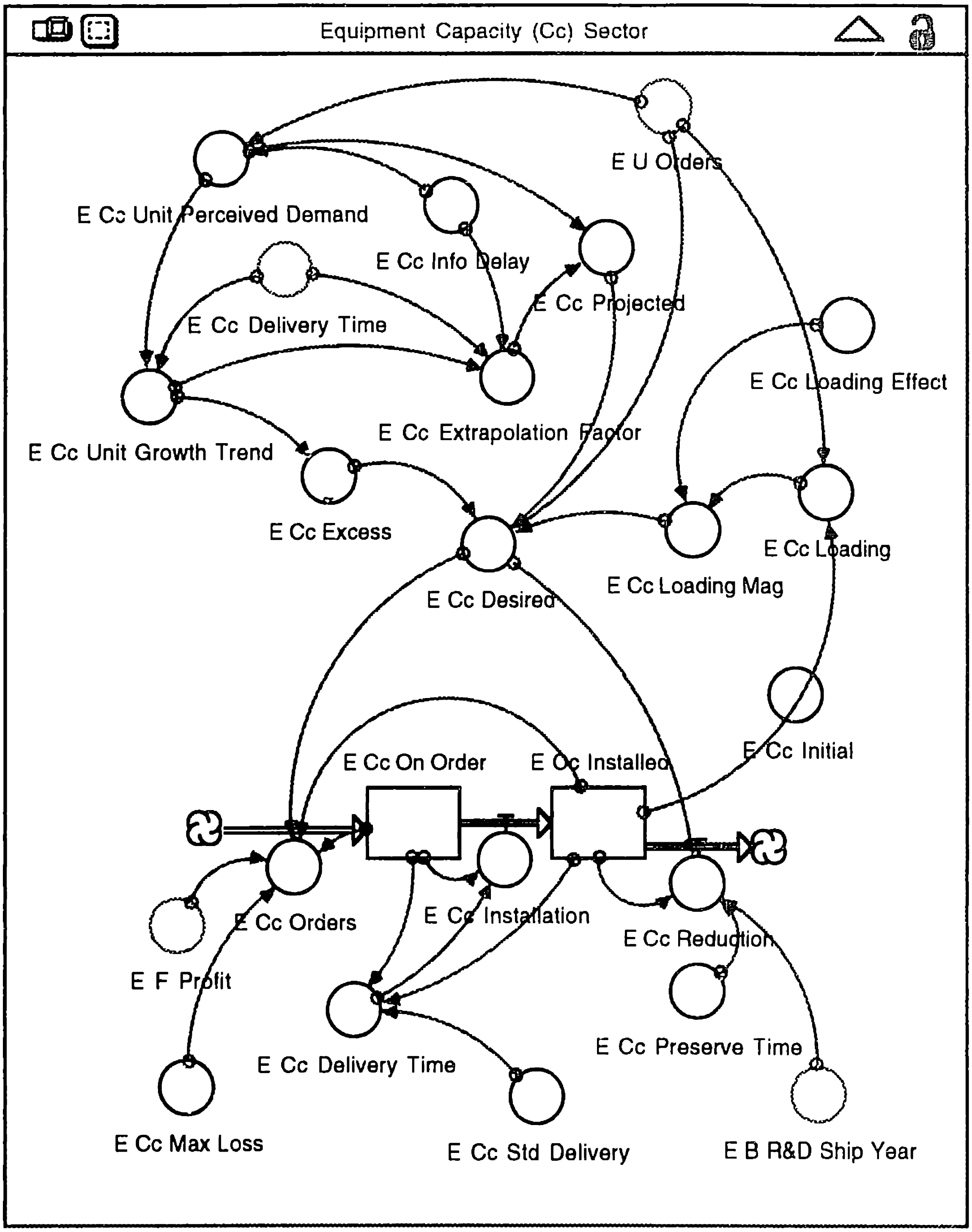


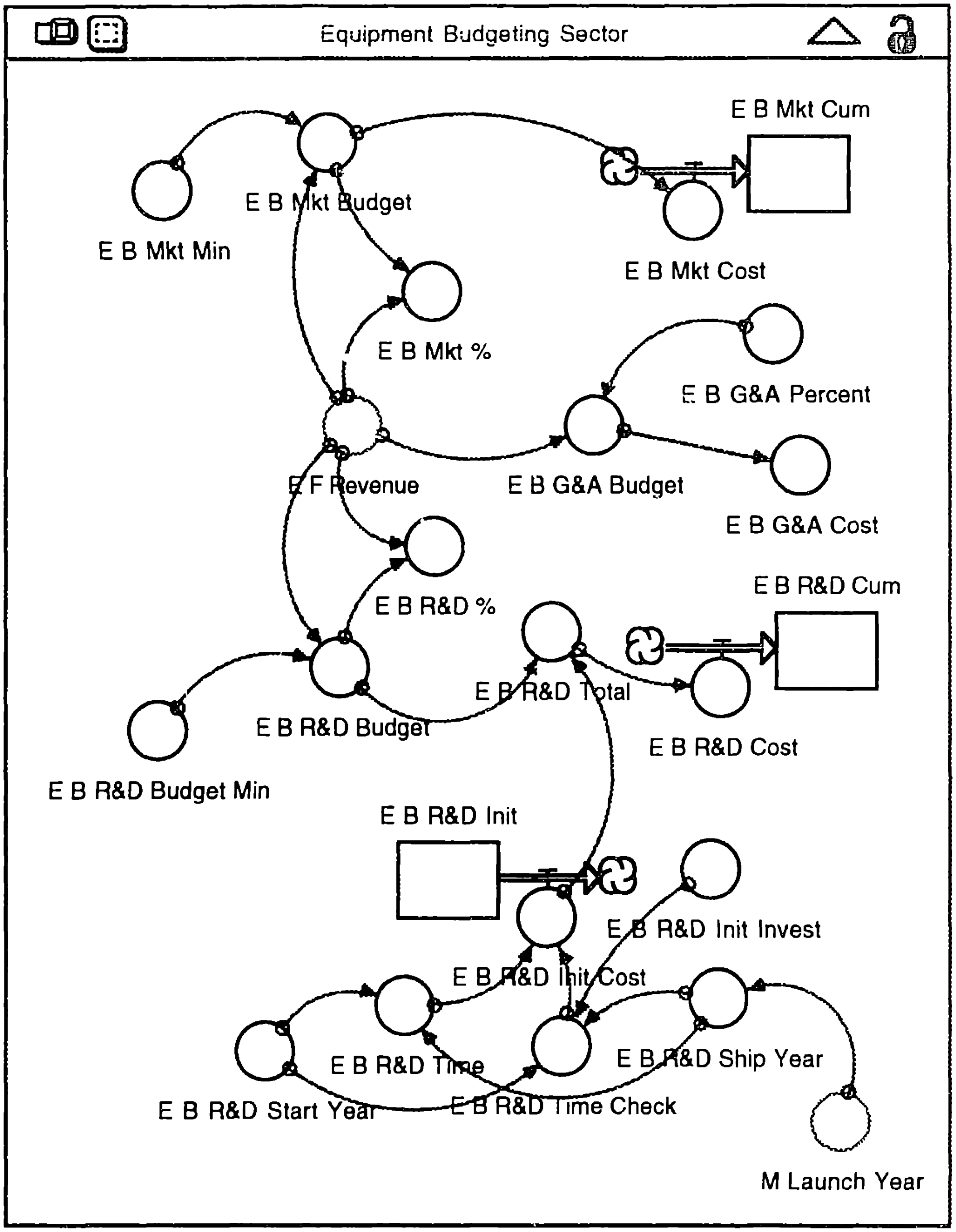
Service Budgeting Sector
E F Unit Price 2
S B Gen1 Equip Subsidy
E F Unit Price
S B Gen2 Equip Subsidy
S B Gen2 Sub
S B Gen1 Sub
E U Shipments 2
S B Total Subsidy
E U Shipments
S B Mkt Cum
S B Mkt Min
S B Mkt %
S B Mkt Budget
S B Mkt Total
S B Mkt Cost
S F Revenue
S B R&D %
S B G&A Percent
S B G&A Cost
S B G&A Budget
S B R&D Cum
S B R&D Budget
S B R&D Total
S B R&D Cost
S B R&D Budget Min
S B R&D Init
S B R&D Init Invest
S B R&D Init Cost
S B R&D Time
S B R&D Ship Year
S B R&D Start Year
S B R&D Time Check
M Launch Year

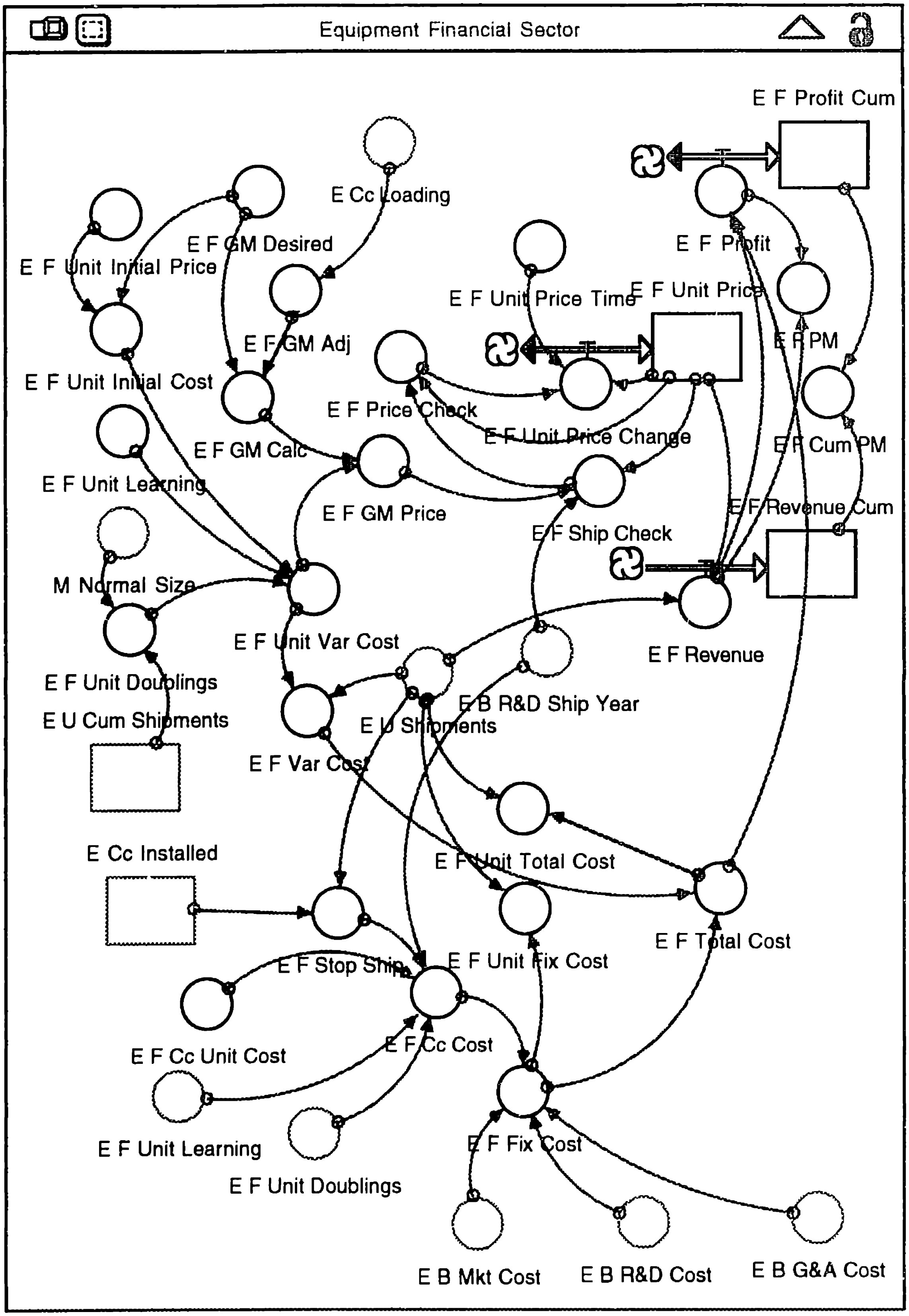

Service Financial Sector
S F Profit Cum
S F Profit
S F AT Price
S F PM
S F AT Initial Price
S F GM Desired
S Cc Loading
S F AT Price Time
S F OM Desired
S F Loading Adj
S F AT Initial Cost
S F Price Check
S F AT Price Change
S F Cum PM
S F AT Learning
S F OM Calc
S F Revenue Cum
S F Ship Check
S F OM Price
S F AT Rev
M Normal Size
S F AT Var Cost
S Total Subscribers
S F Revenue
S F Sub Doublings
S F Fee Rev
S F Service Fee
S F AT Op Cost
S B R&D Ship Year
S F AT Total Rev
S F AT Adj Op Cost
S AT Provided
S F AT Adj Fee Rev
S F AT Fee Rev
S F AT Adj Cc Cost
S F Var Cost
S F AT Total Cost
S F Cc Costs
S F AT Cc Cost
S F Total Cost
S F AT Adj Total Cost
S F Sub Doublings
S F Cc Cost
S F AT Fix Cost
S F AT Adj Fix Cost
S F AT Learning
S Cc Installed
S Cc Conversion Cost
S F Fix Cost
S B G&A Cost
S Cc Conversion
S Cc Gen2 Installed
S Cc Gen1 Installed
S B Mkt Cost
S B R&D Cost
S Cc Upgrade Cost
S F Gen2 Cost Factor



Equipment Unit Demand Sector
E Cc Installed
E B R&D Ship Year
E U Backlog
E U Cum Shipments
T U Orders 1
?
E U Orders
E U Shipments
M Unit Demand
E U Delivery Actual
E U Stop Ship
E U Cancelation Factor
E U Cancelations


Equipment Capacity (Cc) Sector
E U Orders
E Cc Unit Perceived Demand
E Cc Info Delay
E Cc Projected
E Cc Delivery Time
E Cc Loading Effect
E Cc Unit Growth Trend
E Cc Extrapolation Factor
E Cc Excess
E Cc Loading
E Cc Desired
E Cc Loading Mag
E Cc Initial
E Cc On Order
E Cc Installed
E Cc Orders
E Cc Installation
E Cc Reduction
E F Profit
E Cc Preserve Time
E Cc Delivery Time
E Cc Max Loss
E Cc Std Delivery
E B R&D Ship Year


Equipment Budgeting Sector
E B Mkt Cum
E B Mkt Budget
E B Mkt Min
E B Mkt Cost
E B Mkt %
E B G&A Percent
E F Revenue
E B G&A Budget
E B G&A Cost
E B R&D Cum
E B R&D %
E B R&D Total
E B R&D Budget
E B R&D Cost
E B R&D Budget Min
E B R&D Init
E B R&D Init Invest
E B R&D Init Cost
E B R&D Ship Year
E B R&D Time
E B R&D Start Year
E B R&D Time Check
M Launch Year


Equipment Financial Sector
E F Profit Cum
E Cc Loading
E F GM Desired
E F Unit Initial Price
E F Profit
E F Unit Price Time
E F Unit Price
E F GM Adj
E F PM
E F Unit Initial Cost
E F Price Check
E F Unit Price Change
E F Cum PM
E F GM Calc
E F Unit Learning
E F GM Price
E F Revenue Cum
E F Ship Check
M Normal Size
E F Unit Var Cost
E F Revenue
E F Unit Doublings
E B R&D Ship Year
E U Cum Shipments
E U Shipments
E F Var Cost
E Cc Installed
E F Unit Total Cost
E F Total Cost
E F Stop Ship
E F Unit Fix Cost
E F Cc Unit Cost
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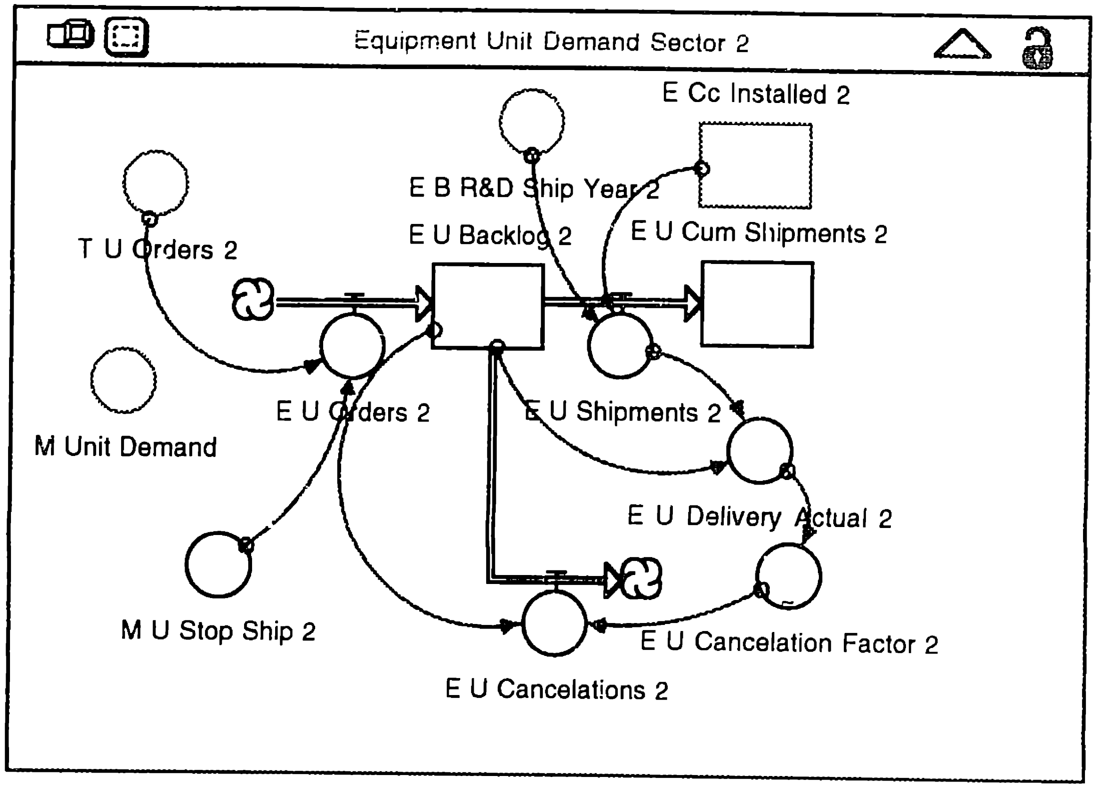
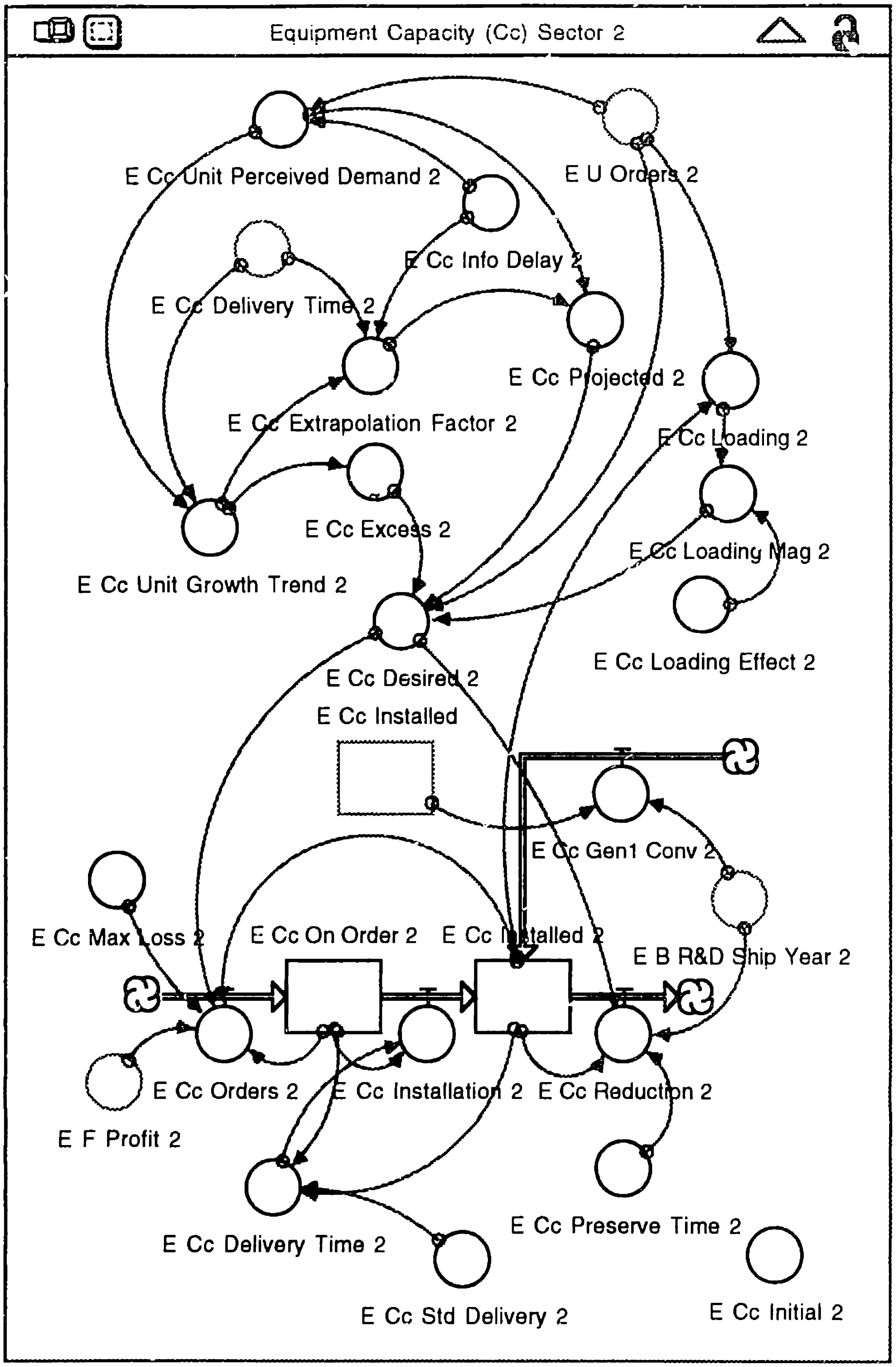
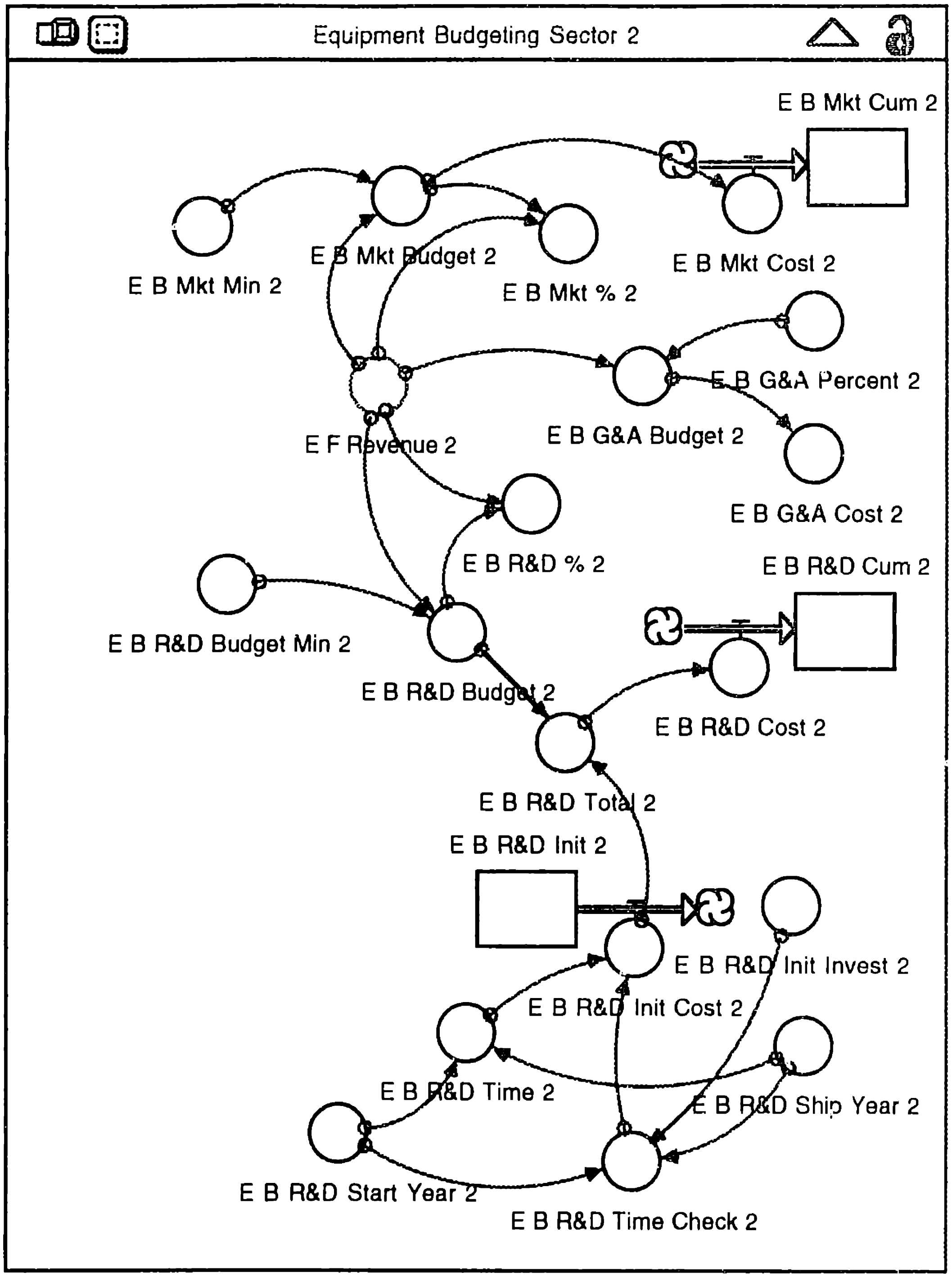
E F Fix Cost
E F Unit Doublings
E B Mkt Cost
E B R&D Cost
E B G&A Cost


Equipment Unit Demand Sector 2
E Cc Installed 2
E B R&D Ship Year 2
T U Orders 2
E U Backlog 2
E U Cum Shipments 2
E U Orders 2
E U Shipments 2
M Unit Demand
E U Delivery Actual 2
M U Stop Ship 2
E U Cancelation Factor 2
E U Cancelations 2


Equipment Capacity (Cc) Sector 2
E Cc Unit Perceived Demand 2
E U Orders 2
E Cc Info Delay 2
E Cc Delivery Time 2
E Cc Projected 2
E Cc Extrapolation Factor 2
E Cc Loading 2
E Cc Excess 2
E Cc Loading Mag 2
E Cc Unit Growth Trend 2
E Cc Loading Effect 2
E Cc Desired 2
E Cc Installed
E Cc Gen1 Conv 2
E Cc Max Loss 2
E Cc On Order 2
E Cc Installed 2
E B R&D Ship Year 2
E Cc Orders 2
E Cc Installation 2
E Cc Reduction 2
E F Profit 2
E Cc Delivery Time 2
E Cc Preserve Time 2
E Cc Std Delivery 2
E Cc Initial 2



Equipment Budgeting Sector 2
E B Mkt Cum 2
E B Mkt Budget 2
E B Mkt Min 2
E B Mkt % 2
E B Mkt Cost 2
E B G&A Percent 2
E F Revenue 2
E B G&A Budget 2
E B G&A Cost 2
E B R&D % 2
E B R&D Cum 2
E B R&D Budget Min 2
E B R&D Budget 2
E B R&D Cost 2
E B R&D Total 2
E B R&D Init 2
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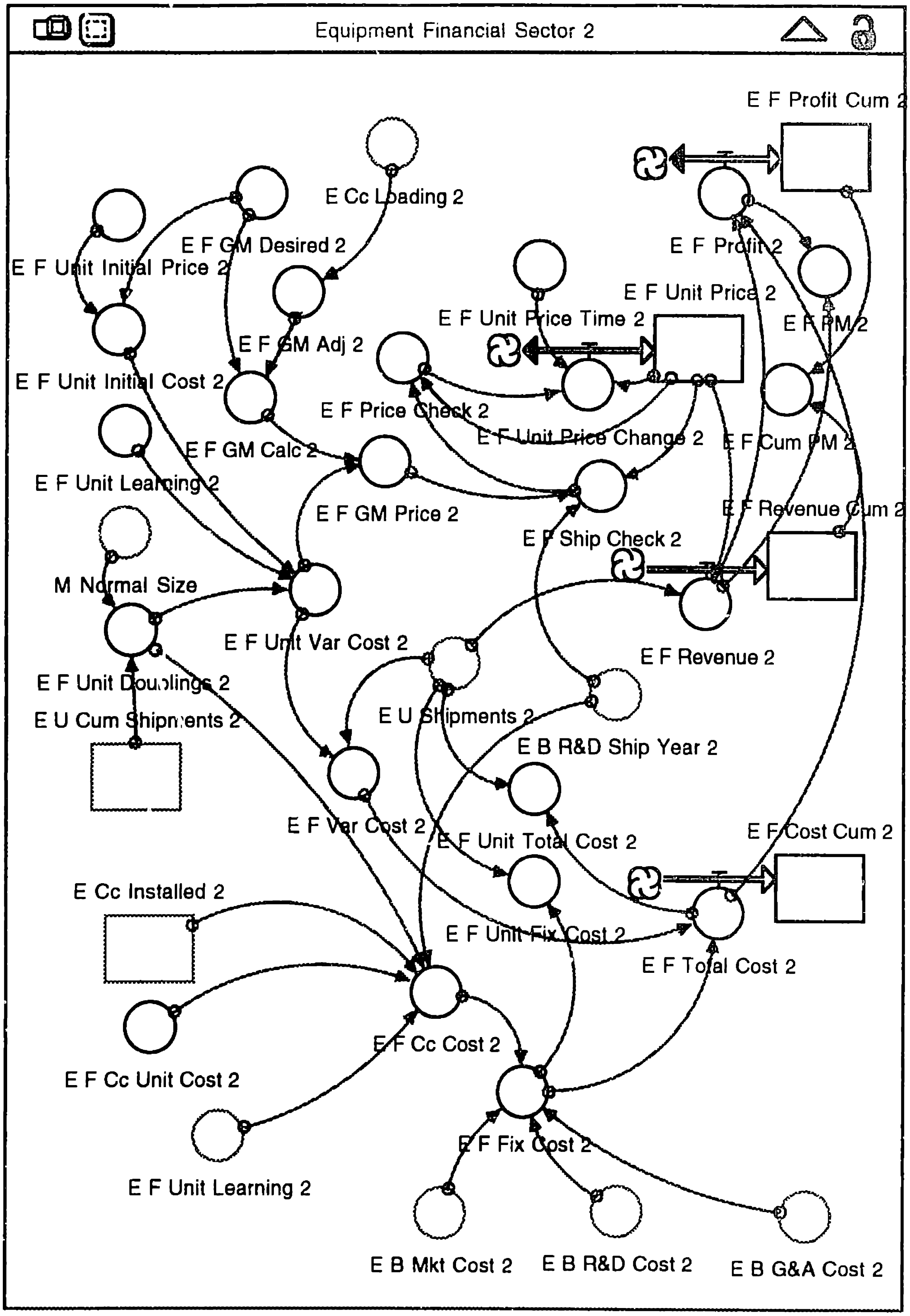
E B R&D Start Year 2
E B R&D Time Check 2


Equipment Financial Sector 2
E F Profit Cum 2
E Cc Loading 2
E F GM Desired 2
E F Unit Initial Price 2
E F Profit 2
E F Unit Price 2
E F Unit Price Time 2
E F PM 2
E F GM Adj 2
E F Unit Initial Cost 2
E F Price Check 2
E F Unit Price Change 2
E F Cum PM 2
E F GM Calc 2
E F Unit Learning 2
E F GM Price 2
E F Revenue Cum 2
E F Ship Check 2
M Normal Size
E F Unit Var Cost 2
E F Revenue 2
E F Unit Doublings 2
E U Cum Shipments 2
E U Shipments 2
E B R&D Ship Year 2
E F Var Cost 2
E F Unit Total Cost 2
E F Cost Cum 2
E Cc Installed 2
E F Unit Fix Cost 2
E F Total Cost 2
E F Cc Cost 2
E F Cc Unit Cost 2
E F Fix Cost 2
E F Unit Learning 2
E B Mkt Cost 2
E B R&D Cost 2
E B G&A Cost 2

Equipment Budgeting Sector

E_B_Mkt_Cum(t) = E_B_Mkt_Cum(t - dt) + (E_F_Mkt_Cost) * dt
INIT E_B_Mkt_Cum = 0

DOCUMENT: Mkt Cum = Cummulative Marketing Expenditures ($)
The cummulative marketing expenditures for this generation of the device.

INFLOWS:
E_B_Mkt_Cost = E_B_Mkt_Budget
DOCUMENT: Mkt Budget = Marketing budget ($/year).
The marketing expenditures for this generation of product.

E_B_R&D_Cum(t) = E_B_R&D_Cum(t - dt) + (E_B_R&D_Cost) * dt
INIT E_B_R&D_Cum = 0
DOCUMENT: R&D Cum = Cummulative R&D expenditures ($).
The cummulative expenditures on R&D for this generation of device.

INFLOWS:
E_B_R&D_Cost = E_B_R&D_Total
DOCUMENT: R&D Total = R&D expenditures ($/year).
The yearly R&D expenditures for this generation of product.

E_B_R&D_Init(t) = E_B_R&D_Init(t - dt) + (- E_B_R&D_Init_Cost) * dt
INIT E_B_R&D_Init = E_B_R&D_Init_Invest
DOCUMENT: R&D Init Invest = Initial R&D investment ($)
The initial R&D investment for this generation of product.

OUTFLOWS:
E_B_R&D_Init_Cost = SMTH3(E_B_R&D_Time_Check,E_B_R&D_Time,0)
DOCUMENT: R&D Init Cost = Initial yearly R&D costs ($/year).
The R&D costs to develop this generation of device over the specified time frame. Implemented as a draining function (third order smooth).

E_B_G&A_Budget = E_B_G&A_Percent*E_F_Revenue
DOCUMENT: G&A Budget = G&A budget ($/year)
The general and administrative budget for each time period. Calculated as a percentage of revenue.

E_B_G&A_Cost = E_B_G&A_Budget
DOCUMENT: G&A Cost = G&A cost ($/year
The general and administrative cost expendited each year. Assumed to be equal to the budget.

E_B_G&A_Percent = .15
DOCUMENT: G&A Percent = G&A percent (dimensionless)
The percent of revenue that is budgeted to general and administrative expenses each year.

E_B_Mkt_% = E_B_Mkt_Budget/E_F_Revenue*100
DOCUMENT: Mkt % = Marketing expenses percentage (dimensionless).
The percentage of yearly revenue spent on marketing programs.

E_B_Mkt_Budget = E_B_Mkt_Min*E_F_Revenue
DOCUMENT: Mkt Budget = Marketing budget ($/year).
The marketing budget calculated by multiplying the projected revenue by the derived marketing percentage.

E_B_Mkt_Min = .2
DOCUMENT: Mkt Min = Minimum marketing percentage (dimensionless).
The minimum percentage of revenue that can be allocated to marketing per year.

E_B_R&D_% = E_B_R&D_Budget/E_F_Revenue*100
DOCUMENT: R&D % =R&D expenses percentage (dimensionless).
The percentage of yearly revenue spent on R&D programs.

E_B_R&D_Budget = E_B_R&D_Budget_Min*E_F_Revenue
DOCUMENT: R&D Budget = R&D budget ($/year).
The R&D budget calculated by multiplying the projected revenue by the derived R&D percentage.

E_B_R&D_Budget_Min = .05
DOCUMENT: R&D Min = Minimum R&D percentage (dimensionless).
The minimum percentage of revenue that can be allocated to R&D per year.

E_B_R&D_Init_Invest = 2.5e7
DOCUMENT: R&D Init Invest = Initial R&D Investment ($).
The total R&D investment required to develop this generation of device.

E_B_R&D_Ship_Year = M_Launch_Year
DOCUMENT: R&D Ship Year = R&D ship year (year).
The year that this generation of device starts to ship.

E_B_R&D_Start_Year = 1980
DOCUMENT: R&D Start Year = R&D start year (year).
The year that R&D starts for this generationof device.

E_B_R&D_Time = (E_B_R&D_Ship_Year-E_B_R&D_Start_Year)*2
DOCUMENT: R&D Time = R&D time (Years)
The development time of a generation of device used in a smoothin function.

E_B_R&D_Time_Check = IF(TIME<E_B_R&D_Start_Year OR (TIME>E_B_R&D_Ship_Year+1)) THEN(0) ELSE(E_B_R&D_Init_Invest)
DOCUMENT: R&D Time Check = Time check (Year)
Checks to see if the current year equals the year that R&D investments begin.

E_B_R&D_Total = E_B_R&D_Init_Cost+E_B_R&D_Budget
DOCUMENT: R&D Total = Total R&D expenditures ($/year).
The sum of the initial investment and the current expenditures for R&D on a per year basis for this generation of device.

Equipment Budgeting Sector 2

E_B_Mkt_Cum_2(t) = E_B_Mkt_Cum_2(t - dt) + (E_B_Mkt_Cost_2) * dt
INIT E_B_Mkt_Cum_2 = 0
DOCUMENT: Mkt Cum = Cummulative Marketing Expenditures ($)
The cummulative marketing expenditures for this generation of the device.

INFLOWS:
E_B_Mkt_Cost_2 = E_B_Mkt_Budget_2
DOCUMENT: Mkt Budget = Marketing budget ($/year).
The marketing expenditures for this generation of product.

E_B_R&D_Cum_2(t) = E_B_R&D_Cum_2(t - dt) + (E_B_R&D_Cost_2) * dt
INIT E_B_R&D_Cum_2 = 0
DOCUMENT: R&D Cum = Cummulative R&D expenditures ($).
The cummulative expenditures on R&D for this generation of device.

INFLOWS:
E_B_R&D_Cost_2 = E_B_R&D_Total_2
DOCUMENT: R&D Total = R&D expenditures ($/year).
The yearly R&D expenditures for this generation of product.

E_B_R&D_Init_2(t) = E_B_R&D_Init_2(t - dt) + (- E_B_R&D_Init_Cost_2) * dt
INIT E_B_R&D_Init_2 = E_B_R&D_Init_Invest_2
DOCUMENT: R&D Init Invest = Initial R&D investment ($)
The initial R&D investment for this generation of product.

OUTFLOWS:
E_B_R&D_Init_Cost_2 = SMTH3(E_B_R&D_Time_Check_2,E_B_R&D_Time_2,0)
DOCUMENT: R&D Init Cost = Initial yearly R&D costs ($/year).
The R&D costs to develop this generation of device over the specified time frame. Implemented as a draining function (third order smooth).

E_B_G&A_Budget_2 = E_B_G&A_Percent_2*E_F_Revenue_2
DOCUMENT: G&A Budget = G&A budget ($/year)
The general and administrative budget for each time period. Calculated as a percentage of revenue.

E_B_G&A_Cost_2 = E_B_G&A_Budget_2
DOCUMENT: G&A Cost = G&A cost ($/year
The general and administrative cost expendited each year. Assumed to be equal to the budget.

E_B_G&A_Percent_2 = .15
DOCUMENT: G&A Percent = G&A percent (dimensionless)
The percent of revenue that is budgeted to general and administrative expenses each year.

E_B_Mkt_%_2 = E_B_Mkt_Budget_2/E_F_Revenue_2*100
DOCUMENT: Mkt % = Marketing expenses percentage (dimensionless).
The percentage of yearly revenue spent on marketing programs.

E_B_Mkt_Budget_2 = E_B_Mkt_Min_2*E_F_Revenue_2
DOCUMENT: Mkt Budget = Marketing budget ($/year).
The marketing budget calculated by multiplying the projected revenue by the derived marketing percentage.

E_B_Mkt_Min_2 = .15
DOCUMENT: Mkt Min = Minimum marketing percentage (dimensionless).
The minimum percentage of revenue that can be allocated to marketing per year.

E_B_R&D_%_2 = E_B_R&D_Budget_2/E_F_Revenue_2*100
DOCUMENT: R&D % = R&D expenses percentage (dimensionless).
The percentage of yearly revenue spent on R&D programs.

E_B_R&D_Budget_2 = E_B_R&D_Budget_Min_2*E_F_Revenue_2
DOCUMENT: R&D Budget = R&D budget ($/year).
The R&D budget calculated by multiplying the projected revenue by the derived R&D percentage.

E_B_R&D_Budget_Min_2 = .05
DOCUMENT: R&D Min = Minimum R&D percentage (dimensionless).
The minimum percentage of revenue that can be allocated to R&D per year.

E_B_R&D_Init_Invest_2 = 1e8
DOCUMENT: R&D Init Invest = Initial R&D Investment ($).
The total R&D investment required to develop this generation of device.

E_B_R&D_Ship_Year_2 = 2020
DOCUMENT: R&D Ship Year = R&D ship year (year).
The year that this generation of device starts to ship.

E_B_R&D_Start_Year_2 = 2019
DOCUMENT: R&D Start Year = R&D start year (year).
The year that R&D starts for this generationof device.

E_B_R&D_Time_2 = (E_B_R&D_Ship_Year_2-E_B_R&D_Start_Year_2)*2
DOCUMENT: R&D Time = R&D time (Years)
The development time of a generation of device used in a smoothing function.

E_B_R&D_Time_Check_2 = IF(TIME<E_B_R&D_Start_Year_2 OR (TIME>E_B_R&D_Ship_Year_2+1)) THEN(0) ELSE(E_B_R&D_Init_Invest_2)
DOCUMENT: R&D Time Check = Time check (Year)
Checks to see if the current year equals the year that R&D investments begin.

E_B_R&D_Total_2 = E_B_R&D_Init_Cost_2+E_B_R&D_Budget_2
DOCUMENT: R&D Total = Total R&D expenditures ($/year).
The sum of the initial investment and the current expenditures for R&D on a per year basis for this generation of device.

Equipment Capacity (Cc) Sector

E_Cc_Installed(t) = E_Cc_Installed(t - dt) + (E_Cc_Installation - E_Cc_Reduction) * dt
INIT E_Cc_Installed = E_Cc_Initial
DOCUMENT: Cc Installed = Units of manufacturing capacity installed (units/year)
The amount of capacity available to manufacture units.

INFLOWS:
E_Cc_Installation = E_Cc_On_Order/E_Cc_Delivery_Time
DOCUMENT: Cc Installation = Capacity installation (units/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

OUTFLOWS:
E_Cc_Reduction = IF(TIME>E_B_R&D_Ship_Year+E_Cc_Preserve_Time) THEN((E_Cc_Installed-E_Cc_Desired)) ELSE(0)
DOCUMENT: Cc Reduction = Capacity reduction (units/year)
The amount of capacity that is reduced in an excess capacity situation determined by the amount of capacity that is excess divided by the time to reduce capacity. During the model startup, an excess capacity situation is allowed for the first four years of the simulation.

E_Cc_On_Order(t) = E_Cc_On_Order(t - dt) + (E_Cc_Orders - E_Cc_Installation) * dt
INIT E_Cc_On_Order = 0

DOCUMENT: Cc On Order = Units of manufacturing capacity on order (units/year)
The amount of capacity to be added for the manufacture of more units. The amount of capacity on order is the difference between the capacity installed and the capacity desired.

INFLOWS:
E_Cc_Orders = IF(E_F_Profit>E_Cc_Max_Loss) THEN(E_Cc_Desired-E_Cc_On_Order-E_Cc_Installed) ELSE(0)
DOCUMENT: Cc Orders = Capacity orders (units/year)
The rate at which new capacity is ordered. Determined by the capacity desired minus the capacity already installed divided by the time it takes to add capacity.

OUTFLOWS:
E_Cc_Installation = E_Cc_On_Order/E_Cc_Delivery_Time
DOCUMENT: Cc Installation = Capacity installation (units/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

E_Cc_Delivery_Time = (E_Cc_On_Order/E_Cc_Installed)+E_Cc_Std_Delivery
DOCUMENT: Cc Delivery Time = Capacity delivery time (years)
The time the placement of an order for capacity and its delivery. Normally, this is half a year, however, in situation were significant capacity must be added quickly, the time lengthens.

E_Cc_Desired = IF(E_U_Orders<1000) THEN(0) ELSE(E_Cc_Projected*E_Cc_Excess*E_Cc_Loading_Mag)
DOCUMENT: Cc Desired = Desired capacity (units/year)
Desired capacity is the product of the capacity projected, the loading on the existing capability and the desired excess capacity.

E_Cc_Extrapolation_Factor = IF(E_Cc_Unit_Growth_Trend>=.4) THEN 1.5 ELSE (1+E_Cc_Info_Delay*E_Cc_Unit_Growth_Trend)^(1+E_Cc_Delivery_Time*E_Cc_Unit_Growth_Trend)
DOCUMENT: Cc Extrapolation Factor = Capacity extrapolation factor (dimensionless)
This is an extrapolation factor that looks forward to predict what will happen to unit demand in the indicated time period ahead based on past trends. In the startup mode, the extrapolation factor is limited to smooth the initial ramp.

E_Cc_Info_Delay = 1
DOCUMENT: CC Info Delay = Capacity information collection delay (years)
The delay in collecting information describing the amount of capacity installed in a given period.

E_Cc_Initial = 5e5
DOCUMENT: Cc Initial = Initial Capacity (units/year)
The initial capacity that is installed when shipments begin.

E_Cc_Loading = E_U_Orders/E_Cc_Installed
DOCUMENT: Cc Loading = Capacity loading (dimensionless)
The normalized ratio of actual unit demand to available capacity multiplied to magnify the effect of an under or over capacity situation.

E_Cc_Loading_Effect = .1
DOCUMENT: E Cc Loading Effect = Capacity loading effect (dimensionless).
Factor to adjust the impact of capacity loading on desired capacity.

E_Cc_Loading_Mag = E_Cc_Loading^E_Cc_Loading_Effect
DOCUMENT: E Cc Loading Mag = Capacity loading magnification (dimensionless).

Determines the magnified loading value.

E_Cc_Max_Loss = -2E10
DOCUMENT: Cc Max Loss = Capacity maximum loss (dollars)
Maximum financial loss that prevents the ordering of additional capacity.

E_Cc_Preserve_Time = 3
DOCUMENT: E Cc Preserve Time = Capacity preservation time (years).
The number of years the initial capacity should be preserved once shipping is started to avoid immediately reducing capacity to meet the initial ship levels.

E_Cc_Projected = E_Cc_Unit_Perceived_Demand*E_Cc_Extrapolation_Factor
DOCUMENT: Cc Projected = Projected capacity (units/year)
The product of the perceived unit demand and the extrapolation factor which produces an estimate of projected capacity the indicated number of years out.

E_Cc_Std_Delivery = .5
DOCUMENT: E Cc Std Delivery = Standard capacity delivery delay (years).
The standard amount of time required to dliever capacity that has been ordered.

E_Cc_Unit_Growth_Trend = TREND(E_Cc_Unit_Perceived_Demand,E_Cc_Delivery_Time,1)
DOCUMENT: Capacity Unit Growth Trend = Growth trend of unit capacity (dimensionless)
A built in function that outputs the outputs the trend of unit growth based on past history.

E_Cc_Unit_Perceived_Demand = SMTH1(E_U_Orders,E_Cc_Info_Delay)
DOCUMENT: Cc Unit Perceived Demand = Perceived unit demand (units/year)
This the instaneous industry demand smoothed by the time it takes to collect the information.

E_Cc_Excess = GRAPH(E_Cc_Unit_Growth_Trend)
(-5.00, 0.8), (-4.00, 0.825), (-3.00, 0.85), (-2.00, 0.9), (-1.00, 1.00), (0.00, 1.10), (1.00, 1.20), (2.00, 1.23), (3.00, 1.25), (4.00, 1.27), (5.00, 1.30)
DOCUMENT: Cc Excess = Capacity excess (dimensionless)
The excess capacity that management plans for in a growth situation and vice versa in a declining market situation reflected as a graph.

Equipment Capacity (Cc) Sector 2

E_Cc_Installed_2(t) = E_Cc_Installed_2(t - dt) + (E_Cc_Installation_2 + E_Cc_Gen1_Conv_2 - E_Cc_Reduction_2) * dt
INIT E_Cc_Installed_2 = E_Cc_Initial_2
DOCUMENT: Cc Installed = Units of manufacturing capacity installed (units/year)
The amount of capacity available to manufacture units.

INFLOWS:
E_Cc_Installation_2 = E_Cc_On_Order_2/E_Cc_Delivery_Time_2
DOCUMENT: Cc Installation = Capacity installation (units/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

E_Cc_Gen1_Conv_2 = IF(TIME>E_B_R&D_Ship_Year_2 AND(TIME<=E_B_R&D_Ship_Year_2+4)) THEN((TIME-E_B_R&D_Ship_Year_2)*E_Cc_Installed/10) ELSE(0)
OUTFLOWS:

E_Cc_Reduction_2 = IF(TIME>E_B_R&D_Ship_Year_2+E_Cc_Preserve_Time_2) THEN(E_Cc_Installed_2-E_Cc_Desired_2) ELSE(0)
DOCUMENT: Cc Reduction = Capacity reduction (units/year)
The amount of capacity that is reduced in an excess capacity situation determined by the amount of capacity that is excess divided by the time to reduce capacity. During the model startup, an excess capacity situation is allowed for the first four years of the simulation.

E_Cc_On_Order_2(t) = E_Cc_On_Order_2(t - dt) + (E_Cc_Orders_2 - E_Cc_Installation_2) * dt
INIT E_Cc_On_Order_2 = 0
DOCUMENT: Cc On Order = Units of manufacturing capacity on order (units/year)
The amount of capacity to be added for the manufacture of more units. The amount of capacity on order is the difference between the capacity installed and the capacity desired.

INFLOWS:
E_Cc_Orders_2 = IF(E_F_Profit_2>E_Cc_Max_Loss_2) THEN(E_Cc_Desired_2-E_Cc_On_Order_2-E_Cc_Installed_2) ELSE(0)
DOCUMENT: Cc Orders = Capacity orders (units/year)
The rate at which new capacity is ordered. Determined by the capacity desired minus the capacity already installed divided by the time it takes to add capacity.

OUTFLOWS:
E_Cc_Installation_2 = E_Cc_On_Order_2/E_Cc_Delivery_Time_2
DOCUMENT: Cc Installation = Capacity installation (units/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

E_Cc_Delivery_Time_2 = (E_Cc_On_Order_2/E_Cc_Installed_2)+E_Cc_Std_Delivery_2
DOCUMENT: Cc Delivery Time = Capacity delivery time (years)
The time the placement of an order for capacity and its delivery. Normally, this is half a year, however, in situation were significant capacity must be added quickly, the time lengthens.

E_Cc_Desired_2 = IF(E_U_Orders_2<10) THEN(0) ELSE(E_Cc_Projected_2*E_Cc_Excess_2*E_Cc_Loading_Mag_2)
DOCUMENT: Cc Desired = Desired capacity (units/year)
Desired capacity is the product of the capacity projected, the loading on the existing capability and the desired excess capacity.

E_Cc_Extrapolation_Factor_2 = IF(E_Cc_Unit_Growth_Trend_2>=.4) THEN 1.5 ELSE (1+E_Cc_Info_Delay_2*E_Cc_Unit_Growth_Trend_2)^(1+E_Cc_Delivery_Time_2*E_Cc_Unit_Growth_Trend_2)
DOCUMENT: Cc Extrapolation Factor = Capacity extrapolation factor (dimensionless)
This is an extrapolation factor that looks forward to predict what will happen to unit demand in the indicated time period ahead based on past trends. In the startup mode, the extrapolation factor is limited to smooth the initial ramp.

E_Cc_Info_Delay_2 = 1
DOCUMENT: CC Info Delay = Capacity information collection delay (years)
The delay in collecting information describing the amount of capacity installed in a given period.

E_Cc_Initial_2 = 1
DOCUMENT: Cc Initial = Initial Capacity (units)
The initial capacity that is installed when shipments begin.

E_Cc_Loading_2 = E_U_Orders_2/E_Cc_Installed_2

DOCUMENT: Cc Loading = Capacity loading (dimensionless)
The normalized ratio of actual unit demand to available capacity multiplied to magnify the effect of an under or over capacity situation.

E_Cc_Loading_Effect_2 = .1
DOCUMENT: E Cc Loading Effect = Capacity loading effect (dimensionless).
Factor to adjust the impact of capacity loading on desired capacity.

E_Cc_Loading_Mag_2 = E_Cc_Loading_2^E_Cc_Loading_Effect_2
DOCUMENT: E Cc Loading Mag = Capacity loading magnification (dimensionless).
Determines the magnified loading value.

E_Cc_Max_Loss_2 = -5e9
DOCUMENT: Cc Max Loss = Capacity maximum loss (dollars)
Maximum financial loss that prevents the ordering of additional capacity.

E_Cc_Preserve_Time_2 = 5
DOCUMENT: E Cc Preserve Time = Capacity preservation time (years).
The number of years the initial capacity should be preserved once shipping is started to avoid immediately reducing capacity to meet the initial ship levels.

E_Cc_Projected_2 = E_Cc_Unit_Perceived_Demand_2*E_Cc_Extrapolation_Factor_2
DOCUMENT: Cc Projected = Projected capacity (units/year)
The product of the perceived unit demand and the extrapolation factor which produces an estimate of projected capacity the indicated number of years out.

E_Cc_Std_Delivery_2 = .5
DOCUMENT: E Cc Std Delivery = Standard capacity delivery delay (years).
The standard amount of time required to dliever capacity that has been ordered.

E_Cc_Unit_Growth_Trend_2 = TREND(E_Cc_Unit_Perceived_Demand_2,E_Cc_Delivery_Time_2)
DOCUMENT: Capacity Unit Growth Trend = Growth trend of unit capacity (dimensionless)
A built in function that outputs the outputs the trend of unit growth based on past history.

E_Cc_Unit_Perceived_Demand_2 = SMTH1(E_U_Orders_2,E_Cc_Info_Delay_2)
DOCUMENT: Cc Unit Perceived Demand = Perceived unit demand (units/year)
This the instaneous industry demand smoothed by the time it takes to collect the information.

E_Cc_Excess_2 = GRAPH(E_Cc_Unit_Growth_Trend_2)
(-5.00, 0.8), (-4.00, 0.825), (-3.00, 0.85), (-2.00, 0.9), (-1.00, 1.00), (0.00, 1.10), (1.00, 1.20), (2.00, 1.23), (3.00, 1.25), (4.00, 1.27), (5.00, 1.30)
DOCUMENT: Cc Excess = Capacity excess (dimensionless)
The excess capacity that management plans for in a growth situation and vice versa in a declining market situation reflected as a graph.

Equipment Financial Sector

E_F_Profit_Cum(t) = E_F_Profit_Cum(t - dt) + (E_F_Profit) * dt
INIT E_F_Profit_Cum = 0
DOCUMENT: Profits Cum = Cummulative profits ($)
The cummulative profits of the industry.

INFLOWS:

E_F_Profit = E_F_Revenue-E_F_Total_Cost
DOCUMENT: Profit = Profit ($/year)
The profits of the industry in the current period.

E_F_Revenue_Cum(t) = E_F_Revenue_Cum(t - dt) + (E_F_Revenue) * dt
INIT E_F_Revenue_Cum = 0
DOCUMENT: Revenue Cum = Cummulative revenue ($)
The cummuiative revenues for the industry.

INFLOWS:
E_F_Revenue = E_U_Shipments*E_F_Unit_Price
DOCUMENT: Revenue = Revenue ($/year)
The revenue per year of the industry.

E_F_Unit_Price(t) = E_F_Unit_Price(t - dt) + (E_F_Unit_Price_Change) * dt
INIT E_F_Unit_Price = E_F_Unit_Initial_Price
DOCUMENT: Unit Price = Unit price ($/unit/year)
The selling price of each unit in a given year.

INFLOWS:
E_F_Unit_Price_Change = SMTH1(E_F_Price_Check,E_F_Unit_Price_Time,INIT(E_F_Unit_Price))-E_F_Unit_Price
DOCUMENT: Unit Price Change = Unit price change ($/unit/year)
The proposed change from the current price for a given time period.

E_F_Cc_Cost = IF(TIME<E_B_R&D_Ship_Year-1) THEN(0) ELSE(E_F_Stop_Ship*E_F_Cc_Unit_Cost*(E_F_Unit_Learning^E_F_Unit_Doublings))
DOCUMENT: Cc Cost = Capacity cost ($/year)
The cost of installed capacity for a year. Productivity improvements are realized through the learning curve of cummulative volume.

E_F_Cc_Unit_Cost = 500
DOCUMENT: Initial Cc Cost = Initial capacity cost ($/year)
The cost of plant and equipment per unit for the intial production run. Value is derived as 20% of the initial sales price.

E_F_Cum_PM = IF(E_F_Profit_Cum>0) THEN(E_F_Profit_Cum/E_F_Revenue_Cum) ELSE(0)
DOCUMENT: Cum PM = Cummulative profit margin (dimensionless).
The cummulative profit margin of the business once a profit has been achieved.

E_F_Fix_Cost = (E_B_G&A_Cost+E_B_Mkt_Cost)+(E_B_R&D_Cost+E_F_Cc_Cost)
DOCUMENT: Fix Cost = Fixed costs ($/year)
Total fixed costs of capacity and capability per year.

E_F_GM_Calc = E_F_GM_Desired*E_F_GM_Adj
DOCUMENT: E F GM Calc = Calculated gross margin (dimensionless).
The calulcated gross margin adjusted for capacity loading.

E_F_GM_Desired = .5
DOCUMENT: GM Desired = Gross margin desired (dimensionless)
The desired gross margin used to determine the price from the unit cost.

E_F_GM_Price = E_F_Unit_Var_Cost/(1-E_F_GM_Calc)
DOCUMENT: GM Price = Calculated gross margin price ($/unit)

The unit price calculated by dividing the unit cost by the calculated gross margin.

E_F_PM = IF(E_F_Profit<=0) THEN(0) ELSE(E_F_Profit/E_F_Revenue)
DOCUMENT: PM = Profit margin (dimensionless)
The profit margin calculated as profit divided by revenue. If there is a loss, then the profit margin is zero.

E_F_Price_Check = IF(E_F_Unit_Price<E_F_Ship_Check) THEN(E_F_Unit_Price) ELSE(E_F_Ship_Check)
DOCUMENT: E F Price Check = Check Price ($/unit).
A check to see if the calcluated price is higher than the current price in the market. Currently set to prevent price increases.

E_F_Ship_Check = IF(TIME<E_B_R&D_Ship_Year) THEN(E_F_Unit_Price) ELSE(E_F_GM_Price)
DOCUMENT: E F Ship Check = Check Shipments ($/unit).
A check to see if this device generation is shipping before adjusting the price.

E_F_Stop_Ship = IF(E_U_Shipments<10) THEN(0) ELSE(E_Cc_Installed)
DOCUMENT: Stop Ship = Stop ship (units)
Flag that determines if a technology transition has occured.

E_F_Total_Cost = E_F_Fix_Cost+E_F_Var_Cost
DOCUMENT: Total Costs = Total costs ($/year)
The total costs per year of the industry.

E_F_Unit_Doublings = IF(E_U_Cum_Shipments/(M_Normal_Size/1000)>1) THEN(LOG10(E_U_Cum_Shipments/(M_Normal_Size/1000))/LOG10(2)) ELSE(0)
DOCUMENT: Unit Doublings = Unit doublings (dimensionless)
The number of times the cummulative production has doubled since the initial production run.

E_F_Unit_Fix_Cost = IF(E_U_Shipments<100000) THEN(0) ELSE(E_F_Fix_Cost/E_U_Shipments)
DOCUMENT: Unit Fix Cost = Unit Fixed Cost ($/unit/year)
The total fixed costs in a year amortized over the shipment volume for that same year.

E_F_Unit_Initial_Cost = E_F_Unit_Initial_Price*(1-E_F_GM_Desired)
DOCUMENT: Unit Initial Cost = Cost of initial unit ($/unit)
The initial cost of producing the first production units.

E_F_Unit_Initial_Price = 3000
DOCUMENT: Unit Initial Price = Initial unit price ($/unit)
The initial selling price of a unit.

E_F_Unit_Learning = .8
DOCUMENT: Unit Learning = Unit learning curve (dimensionless)
The cost learning curve of production.

E_F_Unit_Price_Time = 1
DOCUMENT: Unit Price Time = Unit price time (years)
The amount of time it takes for a price change to take effect in the market.

E_F_Unit_Total_Cost = IF(E_U_Shipments<100000) THEN(0) ELSE(E_F_Total_Cost/E_U_Shipments)
DOCUMENT: Unit Total Cost = Total unit costs ($/unit)
The total unit cost per unit per time period.

E_F_Unit_Var_Cost = E_F_Unit_Initial_Cost*E_F_Unit_Learning^E_F_Unit_Doublings

DOCUMENT: Unit Var Cost = Unit variable cost ($/unit)
The cost to produce each unit as a function of the learning curve. Learnig curve means that for each doubling of the volume, the cost to produce units is reduced by the learning curve percentage.

E_F_Var_Cost = E_U_Shipments*E_F_Unit_Var_Cost
DOCUMENT: Var Cost = Variable costs ($/year)
The total variable costs of manufacturing for each time period.

E_F_GM_Adj = GRAPH(E_Cc_Loading)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.85), (0.6, 0.9), (0.8, 0.95), (1.00, 1.00), (1.20, 1.00), (1.40, 1.00), (1.60, 1.00), (1.80, 1.00), (2.00, 1.00)
DOCUMENT: GM Adj = Adjusted gross margin (dimensionless)
The gross margin adjusted for the resource loading. High loading causes an increase in price and vice versa.

Equipment Financial Sector 2

E_F_Cost_Cum_2(t) = E_F_Cost_Cum_2(t - dt) + (E_F_Total_Cost_2) * dt
INIT E_F_Cost_Cum_2 = 0
DOCUMENT: Cost Cum = Cummulative costs ($)
The cummulative costs of the industry.

INFLOWS:
E_F_Total_Cost_2 = E_F_Fix_Cost_2+E_F_Var_Cost_2
DOCUMENT: Total Costs = Total costs ($/year)
The total costs per year of the industry.

E_F_Profit_Cum_2(t) = E_F_Profit_Cum_2(t - dt) + (E_F_Profit_2) * dt
INIT E_F_Profit_Cum_2 = 0
DOCUMENT: Profits Cum = Cummulative profits ($)
The cummulative profits of the industry.

INFLOWS:
E_F_Profit_2 = E_F_Revenue_2-E_F_Total_Cost_2
DOCUMENT: Profit = Profit ($/year)
The profits of the industry in the current period.

E_F_Revenue_Cum_2(t) = E_F_Revenue_Cum_2(t - dt) + (E_F_Revenue_2) * dt
INIT E_F_Revenue_Cum_2 = 0
DOCUMENT: Revenue Cum = Cummulative revenue ($)
The cummulative revenues for the industry.

INFLOWS:
E_F_Revenue_2 = E_U_Shipments_2*E_F_Unit_Price_2
DOCUMENT: Revenue = Revenue ($/year)
The revenue per year of the industry.

E_F_Unit_Price_2(t) = E_F_Unit_Price_2(t - dt) + (E_F_Unit_Price_Change_2) * dt
INIT E_F_Unit_Price_2 = E_F_Unit_Initial_Price_2
DOCUMENT: Unit Price = Unit price ($/unit/year)
The selling price of each unit in a given year.

INFLOWS:

E_F_Unit_Price_Change_2 =
SMTH1(E_F_Price_Check_2,E_F_Unit_Price_Time_2,INIT(E_F_Unit_Price_2))-E_F_Unit_Price_2
DOCUMENT: Unit Price Change = Unit price change ($/unit/year)
The proposed change from the current price for a given time period.

E_F_Cc_Cost_2 = IF(TIME<E_B_R&D_Ship_Year_2) THEN(0)
ELSE(E_Cc_Installed_2*E_F_Cc_Unit_Cost_2*E_F_Unit_Learning_2^E_F_Unit_Doublings_2)
DOCUMENT: Cc Cost = Capacity cost ($/year)
The cost of installed capacity for a year. Productivity improvements are realized through the learning curve of cummulative volume.

E_F_Cc_Unit_Cost_2 = 100
DOCUMENT: Initial Cc Cost = Initial capacity cost ($/year)
The cost of plant and equipment per unit for the intial production run. Value is derived as 20% of the initial sales price.

E_F_Cum_PM_2 = IF(E_F_Profit_Cum_2>0) THEN(E_F_Profit_Cum_2/E_F_Revenue_Cum_2)
ELSE(0)
DOCUMENT: Cum PM = Cummulative profit margin (dimensionless).
The cummulative profit margin of the business once a profit has been achieved.

E_F_Fix_Cost_2 = E_F_Cc_Cost_2+E_B_Mkt_Cost_2+E_B_R&D_Cost_2+E_B_G&A_Cost_2
DOCUMENT: Fix Cost = Fixed costs ($/year)
Total fixed costs of capacity and capability per year.

E_F_GM_Calc_2 = E_F_GM_Desired_2*E_F_GM_Adj_2
DOCUMENT: E F GM Calc = Calculated gross margin (dimensionless).
The calulcated gross margin adjusted for capacity loading.

E_F_GM_Desired_2 = .5
DOCUMENT: GM Desired = Gross margin desired (dimensionless)
The desired gross margin used to determine the price from the unit cost.

E_F_GM_Price_2 = E_F_Unit_Var_Cost_2/(1-E_F_GM_Calc_2)
DOCUMENT: GM Price = Calculated gross margin price ($/unit)
The unit price calculated by dividing the unit cost by the calculated gross margin.

E_F_PM_2 = IF(E_F_Profit_2<=0) THEN(0) ELSE(E_F_Profit_2/E_F_Revenue_2)
DOCUMENT: PM = Profit margin (dimensionless)
The profit margin calculated as profit divided by revenue. If there is a loss, then the profit margin is zero.

E_F_Price_Check_2 = IF(E_F_Unit_Price_2<E_F_Ship_Check_2) THEN(E_F_Unit_Price_2)
ELSE(E_F_Ship_Check_2)
DOCUMENT: E F Price Check = Check Price ($/unit).
A check to see if the calcluated price is higher than the current price in the market. Currently set to prevent price increases.

E_F_Ship_Check_2 = IF(TIME<E_B_R&D_Ship_Year_2) THEN(E_F_Unit_Price_2)
ELSE(E_F_GM_Price_2)
DOCUMENT: E F Ship Check = Check Shipments ($/unit).
A check to see if this device generation is shipping before adjusting the price.

E_F_Unit_Doublings_2 = IF(E_U_Cum_Shipments_2/(M_Normal_Size/1000)>1)
THEN(LOG10(E_U_Cum_Shipments_2/(M_Normal_Size/1000))/LOG10(2)) ELSE(0)

DOCUMENT: Unit Doublings = Unit doublings (dimensionless)
The number of times the cummulative production has doubled since the initial production run.

E_F_Unit_Fix_Cost_2 = IF(E_U_Shipments_2<100000) THEN(0)
ELSE(E_F_Fix_Cost_2/E_U_Shipments_2)
DOCUMENT: Unit Fix Cost = Unit Fixed Cost ($/unit/year)
The total fixed costs in a year amortized over the shipment volume for that same year.

E_F_Unit_Initial_Cost_2 = E_F_Unit_Initial_Price_2*(1-E_F_GM_Desired_2)
DOCUMENT: Unit Initial Cost = Cost of initial unit ($/unit)
The initial cost of producing the first production units.

E_F_Unit_Initial_Price_2 = 800
DOCUMENT: Unit Initial Price = Initial unit price ($/unit)
The initial selling price of a unit.

E_F_Unit_Learning_2 = .8
DOCUMENT: Unit Learning = Unit learning curve (dimensionless)
The cost learning curve of production.

E_F_Unit_Price_Time_2 = 1
DOCUMENT: Unit Price Time = Unit price time (years)
The amount of time it takes for a price change to take effect in the market.

E_F_Unit_Total_Cost_2 = IF(E_U_Shipments_2<100000) THEN(0)
ELSE(E_F_Total_Cost_2/E_U_Shipments_2)
DOCUMENT: Unit Total Cost = Total unit costs ($/unit)
The total unit cost per unit per time period.

E_F_Unit_Var_Cost_2 = E_F_Unit_Initial_Cost_2*E_F_Unit_Learning_2^E_F_Unit_Doublings_2
DOCUMENT: Unit Var Cost = Unit variable cost ($/unit)
The cost to produce each unit as a function of the learning curve. Learnig curve means that for each doubling of the volume, the cost to produce units is reduced by the learning curve percentage.

E_F_Var_Cost_2 = E_U_Shipments_2*E_F_Unit_Var_Cost_2
DOCUMENT: Var Cost = Variable costs ($/year)
The total variable costs of manufacturing for each time period.

E_F_GM_Adj_2 = GRAPH(E_Cc_Loading_2)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.85), (0.6, 0.9), (0.8, 0.95), (1.00, 1.00), (1.20, 1.00), (1.40, 1.00), (1.60, 1.00), (1.80, 1.00), (2.00, 1.00)
DOCUMENT: GM Adj = Adjusted gross margin (dimensionless)
The gross margin adjusted for the resource loading. High loading causes an increase in price and vice versa.

Equipment Unit Demand Sector

E_U_Backlog(t) = E_U_Backlog(t - dt) + (E_U_Orders - E_U_Shipments - E_U_Cancelations) * dt
INIT E_U_Backlog = 1
DOCUMENT: Backlog = Unit backlog (units).
The backlog of unfilled orders. Backlog occurs when there is more demand than available capacity.

INFLOWS:
E_U_Orders = IF(TIME>E_U_Stop_Ship) THEN(0) ELSE(T_U_Orders_1)

DOCUMENT: Orders = Unit orders (units)
New orders received by the industry based on demand.

OUTFLOWS:
E_U_Shipments = IF(TIME<E_B_R&D_Ship_Year) THEN(0) ELSE(E_Cc_Installed)
DOCUMENT: Shipments = Unit shipments (units/year)
The units shipped per year determined by the capacity available or the available backlog and new orders.

E_U_Cancelations = E_U_Backlog*E_U_Cancelation_Factor
DOCUMENT: Cancelation = Unit cancelations (units)
The fraction of orders that are cancelled each year due to the perceived inability of the industry to ship product in a reasonable amount of time.

E_U_Cum_Shipments(t) = E_U_Cum_Shipments(t - dt) + (E_U_Shipments) * dt
INIT E_U_Cum_Shipments = 1
DOCUMENT: Cum Shipments = Unit cummulative shipments (units)
The cummulative sum of all of the units sold in the industry over the model time frame.

INFLOWS:
E_U_Shipments = IF(TIME<E_B_R&D_Ship_Year) THEN(0) ELSE(E_Cc_Installed)
DOCUMENT: Shipments = Unit shipments (units/year)
The units shipped per year determined by the capacity available or the available backlog and new orders.

E_U_Delivery_Actual = IF(E_U_Shipments=0) THEN(0) ELSE(E_U_Backlog/E_U_Shipments)
DOCUMENT: Delivery Actual = Actual unit delivery delay (years)
The average time between placing and receiving orders measured by the ratio of the backlog to the shipment rate.

E_U_Stop_Ship = 2020
DOCUMENT: Stop Ship = Stop ship (year)
The year in which this generation of product stops shipping.

E_U_Cancelation_Factor = GRAPH(E_U_Delivery_Actual)
(0.00, 0.00), (1.00, 0.9), (2.00, 0.9), (3.00, 0.9), (4.00, 0.9), (5.00, 0.9), (6.00, 0.9), (7.00, 0.9), (8.00, 0.9), (9.00, 0.9), (10.0, 0.9)
DOCUMENT: Cancelation Factor = Unit cancelation factor (dimensionless)
The fraction of orders that are canceled to an unacceptable delivery delay. The factor is represented as graph which depicts a longer delay results in a higher cancellation rate.

Equipment Unit Demand Sector 2

E_U_Backlog_2(t) = E_U_Backlog_2(t - dt) + (E_U_Orders_2 - E_U_Shipments_2 - E_U_Cancelations_2) * dt
INIT E_U_Backlog_2 = 1
DOCUMENT: Backlog = Unit backlog (units).
The backlog of unfilled orders. Backlog occurs when there is more demand than available capacity.

INFLOWS:
E_U_Orders_2 = IF(TIME>M_U_Stop_Ship_2) THEN(0) ELSE(T_U_Orders_2)
DOCUMENT: Orders = Unit orders (units)
New orders received by the industry based on demand.

OUTFLOWS:

E_U_Shipments_2 = IF(TIME<E_B_R&D_Ship_Year_2) THEN(0) ELSE(E_Cc_Installed_2)
DOCUMENT: Shipments = Unit shipments (units/year)
The units shipped per year determined by the capacity available or the available backlog and new orders.

E_U_Cancelations_2 = E_U_Backlog_2*E_U_Cancelation_Factor_2
DOCUMENT: Cancelation = Unit cancelations (units)
The fraction of orders that are cancelled each year due to the perceived inability of the industry to ship product in a reasonable amount of time.

E_U_Cum_Shipments_2(t) = E_U_Cum_Shipments_2(t - dt) + (E_U_Shipments_2) * dt
INIT E_U_Cum_Shipments_2 = 1
DOCUMENT: Cum Shipments = Unit cummulative shipments (units)
The cummulative sum of all of the units sold in the industry over the model time frame.

INFLOWS:
E_U_Shipments_2 = IF(TIME<E_B_R&D_Ship_Year_2) THEN(0) ELSE(E_Cc_Installed_2)
DOCUMENT: Shipments = Unit shipments (units/year)
The units shipped per year determined by the capacity available or the available backlog and new orders.

E_U_Delivery_Actual_2 = IF(E_U_Shipments_2=0) THEN(0) ELSE(E_U_Backlog_2/E_U_Shipments_2)
DOCUMENT: Delivery Actual = Actual unit delivery delay (years)
The average time between placing and receiving orders measured by the ratio of the backlog to the shipment rate.

M_U_Stop_Ship_2 = 2020
DOCUMENT: Stop Ship = Stop ship (year)
The year in which this generation of product stops shipping.

E_U_Cancelation_Factor_2 = GRAPH(E_U_Delivery_Actual_2)
(0.00, 0.00), (1.00, 0.9), (2.00, 0.9), (3.00, 0.9), (4.00, 0.9), (5.00, 0.9), (6.00, 0.9), (7.00, 0.9), (8.00, 0.9), (9.00, 0.9), (10.0, 0.9)
DOCUMENT: Cancelation Factor = Unit cancelation factor (dimensionless)
The fraction of orders that are canceled to an unacceptable delivery delay. The factor is represented as graph which depicts a longer delay results in a higher cancellation rate.

Market Demand Sector

M_Orders(t) = M_Orders(t - dt) + (M_Demand - M_Cancelations - M_Shipments) * dt
INIT M_Orders = 10
DOCUMENT: Orders = Orders (units)
The number of orders received by the industry in a time period.

INFLOWS:
M_Demand = IF(TIME<M_Launch_Year) THEN(0) ELSE(M_WOM+M_Marketing+M_Replacements)
DOCUMENT: Demand = Demand (units/year)
The demand of the industry in a time period represented as the sum of the word of mouth and marketing effects.

OUTFLOWS:
M_Cancelations = (E_U_Cancelations+E_U_Cancelations_2)*M_Cancelation_Switch
DOCUMENT: Cancelations = Cancelations (units/year)
The number of orders that are canceled by an unacceptable delivery delay.

M_Shipments = IF(TIME<M_Launch_Year) THEN(0) ELSE(E_U_Shipments+E_U_Shipments_2)
DOCUMENT: Shipments = Shipments (units/year)
The number of orders that ship each year driven by the unit shipments during a given time period.

M_Potential(t) = M_Potential(t - dt) + (M_Cancelations + M_Growing + M_Exits - M_Demand) * dt
INIT M_Potential = 100000
DOCUMENT: Potential = Potential (customers)
The number of potential customers in the industry.

INFLOWS:
M_Cancelations = (E_U_Cancelations+E_U_Cancelations_2)*M_Cancelation_Switch
DOCUMENT: Cancelations = Cancelations (units/year)
The number of orders that are canceled by an unacceptable delivery delay.

M_Growing = IF(M_Indicated_Size=0) THEN(0) ELSE((M_Indicated_Size-M_Actual_Size)/M_Grow_Time)
DOCUMENT: Growing = Growing (customers/year)
the rate at which the market grows each year derived as the difference between the market's indicated size and its actual size divided by the time it takes for the market to grow.

M_Exits = M_Churn+M_Replacements
OUTFLOWS:
M_Demand = IF(TIME<M_Launch_Year) THEN(0) ELSE(M_WOM+M_Marketing+M_Replacements)
DOCUMENT: Demand = Demand (units/year)
The demand of the industry in a time period represented as the sum of the word of mouth and marketing effects.

M_Subscribers(t) = M_Subscribers(t - dt) + (M_Shipments - M_Exits) * dt
INIT M_Subscribers = 1
DOCUMENT: Subscribers = Subscribers (units)
The total number of customers in the industry. This is equal to the cummulative number of units that have shipped.

INFLOWS:
M_Shipments = IF(TIME<M_Launch_Year) THEN(0) ELSE(E_U_Shipments+E_U_Shipments_2)
DOCUMENT: Shipments = Shipments (units/year)
The number of orders that ship each year driven by the unit shipments during a given time period.

OUTFLOWS:
M_Exits = M_Churn+M_Replacements
M_Actual_Size = IF(TIME<M_Launch_Year) THEN(0) ELSE(M_Potential+M_Orders+M_Subscribers)
DOCUMENT: Actual Size = Actual size (customers/year)
The actual size of the market in a time period. It is the sum of the potential customers, those customers that have ordered product and those that have received their product.

M_Ave_Device_Cost = M_Device_Cost+M_Device_Cost_2
DOCUMENT: Ave Device Cost = Average device cost (dollars)
Determines the average device cost of two generations of device.

M_Base_Price = 100
DOCUMENT: Base Price = Base price (dollars)
Dummy variable used for testing.

M_Big_Bill_Shock = IF(M_Shipments-M_Replacements<0) THEN(0) ELSE(M_Big_Bill_Effect*(M_Shipments-M_Replacements)*M_Big_Bill_Switch)
DOCUMENT: Big Bill Shock = Big bill shock (subscribers)
Determines the number of new subscribers that leave the network because the first bill is too high.

M_Big_Bill_Switch = 1
DOCUMENT: Big Bill Switch = Big bill switch (flag)
Binary switch to turn the big bill function on or off. Used for testing purposes.

M_Cancelation_Switch = 1
DOCUMENT: Cancellation Switch = Cancellation switch (flag)
Binary switch to turn the order cancellation function on or off. Used for testing purposes.

M_Churn = M_Quality_Effect+M_Big_Bill_Shock
DOCUMENT: Churn = Churn (subscribers)
Number of subscribers the exit the service due to big bills or poor service.

M_Device_Cost = IF(E_F_Unit_Price-S_B_Gen1_Equip_Subsidy<0) THEN(0) ELSE((E_F_Unit_Price-S_B_Gen1_Equip_Subsidy)*(1-T_U_Ship_Ratio))
DOCUMENT: Device Cost = Device cost (dollars)
Determines the price customers pay for the device. It is the device price minus the subsidy.

M_Device_Cost_2 = IF(E_F_Unit_Price_2-S_B_Gen2_Equip_Subsidy<0) THEN(0) ELSE((E_F_Unit_Price_2-S_B_Gen2_Equip_Subsidy)*(T_U_Ship_Ratio))
DOCUMENT: Device Cost = Device cost (dollars)
Determines the price customers pay for the device. It is the device price minus the subsidy.

M_Disgard_Rate = .1
DOCUMENT: Discard Rate = Discard rate (dimensionless)
The percentage of the installed base that is replaced because the device wore out or was upgraded.

M_Grow_Time = 2
DOCUMENT: Grow Time = Grow time (years)
The amount of time it takes for the market to grow. In other words, the amount of time for the market to realize that prices have been reduced.

M_Indicated_Size = IF(TIME<M_Launch_Year) THEN(0) ELSE(M_Normal_Size*M_Price_Effect)
DOCUMENT: Indicated Maket Size = Indicated market size (customers)
The number of people that could potentially become customers in the market at the indicated price point.

M_Initial_Cost = M_Ave_Device_Cost
DOCUMENT: Initial Cost = Initial Cost (dollars)
The average price the subscriber pays for the device after subsidies.

M_Launch_Year = 1984
DOCUMENT: Launch Year = Launch year (year).
The year that initial shippments begin for the industry.

M_Marketing = M_Potential*M_Marketing_Effectiveness
DOCUMENT: Marketing = Marketing (customers)
The ability of marketing to convert potential customers into orders.

M_Marketing_Effectiveness = .14
DOCUMENT: Marketing Effectiveness = Marketing effectiveness (dimensioless)

The effectiveness of the marketing program.

M_Min_Quality = .02
DOCUMENT: Min Quality = Minimum quality (dimensionless)
The percent of subscribers that leave the service regardless of the service quality.

M_Normal_Size = 8e7
DOCUMENT: Normal Size = Normal size (customers)
The maximum size of the market given an ideal price point and product characteristics.

M_Quality_Effect = IF(S_AT_Quality_Index>1-M_Min_Quality)
THEN(M_Min_Quality*M_Subscribers*M_Quality_Switch) ELSE((1-
S_AT_Quality_Index)*M_Subscribers*M_Quality_Switch)
DOCUMENT: Quality Effect = Quality effect (subscribers)
The number of subscribers that leave the service because of poor quality.

M_Quality_Switch = 1
DOCUMENT: Quality Factor = Quality factor (dimensionless)
Determines the relationship of poor service quality on subscriber cancellations.

M_Replacements = M_Subscribers*M_Disgard_Rate
M_Step = 8e5
DOCUMENT: Step = Step (customers)
The step size for step model varification.

M_Total_Subscribers = M_Subscribers
DOCUMENT: Total Subscribers = Total Subscribers (subscribers/year)
The total number of subscribers serviced by the service providers each year.

M_Unit_Demand = M_Demand
DOCUMENT: Unit Demand = Unit demand (units)
The conversion of demand into orders and units. For this model, one unit of demand equals one order for one unit.

M_Unit_Pyramid = 1000+RAMP(5e5)-RAMP(10e5,2000)
DOCUMENT: Unit Pyramid = Unit pyramid (orders/year)
A pyramid demand curve used to validate the model.

M_Unit_Ramp = 1+ramp(4e5,1984)
DOCUMENT: Unit Ramp = Unit ramp (orders/year)
A constant ramp up of demand used to validate the model.

M_Unit_Step =
1000+STEP(M_Step,1986)+STEP(M_Step,1988)+STEP(M_Step,1990)+STEP(M_Step,1992)+STEP(M_
Step,1994)+STEP(M_Step,1996)+STEP(M_Step,1998)+STEP(M_Step,2000)+STEP(M_Step,2002)+STE
P(M_Step,2004)+STEP(M_Step,2006)
DOCUMENT: Unit Step = Unit step (orders/year)
A step function demand used to validate the model.

M_WOM = (M_Subscribers-(1/M_Actual_Size*M_Subscribers^2))*M_WOM_Effectiveness
DOCUMENT: WOM = Word of mouth (customers/year)
The number of customers that order the porduct in the industry because of a positive word of mouth effect with current owners.

M_WOM_Effectiveness = .58
DOCUMENT: WOM Effectiveness = Word of mouth effectiveness (dimensionless)
The effectiveness of word of mouth.

M_Big_Bill_Effect = GRAPH(Rev_Per_Sub)
(0.00, 0.05), (200, 0.06), (400, 0.07), (600, 0.08), (800, 0.09), (1000, 0.1), (1200, 0.12), (1400, 0.14), (1600, 0.16), (1800, 0.2), (2000, 0.25)
DOCUMENT: Price Effect = Price effect (dimensionless)
The effect of price on the size of the market. The lower the price, the larger the number of potential customers in the market limited by the normal market size.

M_Price_Effect = GRAPH(M_Initial_Cost)
(0.00, 1.00), (100, 0.98), (200, 0.95), (300, 0.9), (400, 0.8), (500, 0.55), (600, 0.45), (700, 0.4), (800, 0.36), (900, 0.33), (1000, 0.31), (1100, 0.25), (1200, 0.1)
DOCUMENT: Price Effect = Price effect (dimensionless)
The effect of price on the size of the market. The lower the price, the larger the number of potential customers in the market limited by the normal market size.

Service Airtime (AT) Demand Sector

S_AT_Cum_Provided(t) = S_AT_Cum_Provided(t - dt) + (S_AT_Provided) * dt
INIT S_AT_Cum_Provided = 0

INFLOWS:
S_AT_Provided = MIN(S_Cc_Total_Installed,S_AT_Total)
DOCUMENT: AT Provided = Airtime provided (minutes/year)
The airtime demanded that is satified by the available capacity. Excess demand is lost.

S_AT_Quality_Index(t) = S_AT_Quality_Index(t - dt) + (S_AT_Quality_Change) * dt
INIT S_AT_Quality_Index = S_AT_Quality_Initial
DOCUMENT: AT Quality Index = AT (service) quality index (dimensionless)
The quality index for the airtime service as perceived by subscribers. One is defined as very good with the service level declining as the index approaches zero.

INFLOWS:
S_AT_Quality_Change =
SMTH1(S_AT_Service_Quality,S_AT_Quality_Time,INIT(S_AT_Quality_Index))-S_AT_Quality_Index
DOCUMENT: AT Quality Change = Airtime (service) quality change (dimensionless)
The proposed change from the current service level for a given time period

S_AT_Demand = S_AT_Total
DOCUMENT: AT Demand = Airtime Demand (minutes)
The demand equals the total airtime.

S_AT_Initial = 4500
DOCUMENT: AT Initial = Initial airtime per subscriber (minutes/subscriber)
The usage in minutes of the initial customers of the system.

S_AT_Learning = .82
DOCUMENT: AT Learning = Airtime learning curve (dimensionless)
The usage learning curve of subscribers. As more people become customers of the service, the average total usage falls on a per subscriber basis.

S_AT_Per_Sub = S_AT_Initial*S_AT_Learning^S_F_Sub_Doublings
DOCUMENT: AT Per Subscriber = Airtime per subscriber (minutes/subscriber)
The airtime used by each subsciber as a function of the learning curve. Learnig curve means that for each doubling of the subscriber base, the minutes per subscriber is reduced by the learning curve percentage.

S_AT_Quality_Initial = .3
DOCUMENT: AT Quality Initial = Initial airtime service quality (dimensionless)
Initial value for the airtime service level.

S_AT_Quality_Time = 1
DOCUMENT: AT Quality Time = Time to notice a change in airtime quality (years)
The amount of time it takes for a change in the service quality to be noticed in the market.

S_AT_Service_Level = IF(S_AT_Provided<=0) THEN(1) ELSE(S_AT_Provided/S_AT_Demand)
DOCUMENT: AT Service Level = Airtime Service Level (dimensionless)
The percentage of airtime supplied divided by the total airtime demand.

S_AT_Service_Quality = IF(TIME<=S_B_R&D_Ship_Year) THEN(S_AT_Quality_Initial) ELSE(S_AT_Service_Level)
DOCUMENT: AT Service Quality = Airtime Service Quality (dimensionless)
Presents the service qulaity level from changing until the service starts up.

S_AT_Total = IF(TIME<=S_B_R&D_Ship_Year) THEN(0) ELSE(S_Total_Subscribers*S_AT_Per_Sub)
DOCUMENT: AT Total = Total airtime (minutes/year)
The total airtime used by all subscribers in a year.

S_AT_Unavailable = IF(S_AT_Demand<=0) THEN(0) ELSE(S_AT_Demand-S_AT_Provided)
DOCUMENT: AT Unavailable = Unavailable Airtime (minutes/year)
The airtime demanded that is not available each year due to the insufficient capacity.

S_Total_Subscribers = M_Total_Subscribers
DOCUMENT: Total Subscribers = Total subscribers (subscribers)
Dummy variable.

Service Budgeting Sector

S_B_Mkt_Cum(t) = S_B_Mkt_Cum(t - dt) + (S_B_Mkt_Cost) * dt
INIT S_B_Mkt_Cum = 0
DOCUMENT: Mkt Cum = Cummulative Marketing Expenditures ($)
The cummulative marketing expenditures for this generation of the device.

INFLOWS:
S_B_Mkt_Cost = S_B_Mkt_Total
DOCUMENT: Mkt Budget = Marketing budget ($/year).
The marketing expenditures for this generation of product.

S_B_R&D_Cum(t) = S_B_R&D_Cum(t - dt) + (S_B_R&D_Cost) * dt
INIT S_B_R&D_Cum = 0
DOCUMENT: R&D Cum = Cummulative R&D expenditures ($).
The cummulative expenditures on R&D for this generation of device.

INFLOWS:
S_B_R&D_Cost = S_B_R&D_Total

DOCUMENT: R&D Total = R&D expenditures ($/year).
The yearly R&D expenditures for this generation of product.

S_B_R&D_Init(t) = S_B_R&D_Init(t - dt) + (- S_B_R&D_Init_Cost) * dt
INIT S_B_R&D_Init = S_B_R&D_Init_Invest
DOCUMENT: R&D Init Invest = Initial R&D investment ($)
The initial R&D investment for this generation of product.

OUTFLOWS:
S_B_R&D_Init_Cost = SMTH3(S_B_R&D_Time_Check,S_B_R&D_Time,0)
DOCUMENT: R&D Init Cost = Initial yearly R&D costs ($/year).
The R&D costs to develop this generation of device over the specified time frame. Implemented as a draining function (third order smooth).

S_B_G&A_Budget = S_B_G&A_Percent*S_F_Revenue
DOCUMENT: G&A Budget = G&A budget ($/year)
The general and administrative budget for each time period. Calculated as a percentage of revenue.

S_B_G&A_Cost = S_B_G&A_Budget
DOCUMENT: G&A Cost = G&A cost ($/year
The general and administrative cost expendited each year. Assumed to be equal to the budget.

S_B_G&A_Percent = .15
DOCUMENT: G&A Percent = G&A percent (dimensionless)
The percent of revenue that is budgeted to general and administrative expenses each year.

S_B_Gen1_Equip_Subsidy = 300
DOCUMENT: Gen1 Equip Subsidy = Generation 1 Equipment Subsidy ($/unit)
The equipment subsidy provided by the the service providers to reduce the cost barriers for new subscribers.

S_B_Gen1_Sub = IF(E_F_Unit_Price-S_B_Gen1_Equip_Subsidy<=0) THEN(0) ELSE(E_F_Unit_Price-S_B_Gen1_Equip_Subsidy)
DOCUMENT: Gen1 Sub = Generation 1 device subsidy (dollars)
Determines the amount of the actual subsidy paid on each unit sold.

S_B_Gen2_Equip_Subsidy = 100
DOCUMENT: Gen2 Equip Subsidy = Generation 2 Equipment Subsidy ($/unit)
The equipment subsidy provided by the the service providers to reduce the cost barriers for new subscribers.

S_B_Gen2_Sub = IF(E_F_Unit_Price_2-S_B_Gen2_Equip_Subsidy<=0) THEN(0) ELSE(E_F_Unit_Price_2-S_B_Gen2_Equip_Subsidy)
DOCUMENT: Gen2 Sub = Generation 2 device subsidy (dollars)
Determines the amount of the actual subsidy paid on each unit sold.

S_B_Mkt_% = IF(S_F_Revenue<1000) THEN(0) ELSE(S_B_Mkt_Total/S_F_Revenue*100)
DOCUMENT: Mkt % = Marketing expenses percentage (dimensionless).
The percentage of yearly revenue spent on marketing programs.

S_B_Mkt_Budget = S_B_Mkt_Min*S_F_Revenue
DOCUMENT: Mkt Budget = Marketing budget ($/year).
The marketing budget calculated by multiplying the projected revenue by the derived marketing percentage.

S_B_Mkt_Min = .20
DOCUMENT: Mkt Min = Minimum marketing percentage (dimensionless).

The minimum percentage of revenue that can be allocated to marketing per year.

S_B_Mkt_Total = S_B_Mkt_Budget+S_B_Total_Subsidy
DOCUMENT: Mkt Total = Total Marketing ($/year)
The total expenditures for the time period.

S_B_R&D_% = IF(S_F_Revenue<1000) THEN(0) ELSE(S_B_R&D_Total/S_F_Revenue*100)
DOCUMENT: R&D % =R&D expenses percentage (dimensionless).
The percentage of yearly revenue spent on R&D programs.

S_B_R&D_Budget = S_B_R&D_Budget_Min*S_F_Revenue
DOCUMENT: R&D Budget = R&D budget ($/year).
The R&D budget calculated by multiplying the projected revenue by the derived R&D percentage.

S_B_R&D_Budget_Min = .02
DOCUMENT: R&D Min = Minimum R&D percentage (dimensionless).
The minimum percentage of revenue that can be allocated to R&D per year.

S_B_R&D_Init_Invest = 1e8
DOCUMENT: R&D Init Invest = Initial R&D Investment ($).
The total R&D investment required to develop this generation of device.

S_B_R&D_Ship_Year = M_Launch_Year
DOCUMENT: R&D Ship Year = R&D ship year (year).
The year that this generation of device starts to ship.

S_B_R&D_Start_Year = 1980
DOCUMENT: R&D Start Year = R&D start year (year).
The year that R&D starts for this generationof device.

S_B_R&D_Time = (S_B_R&D_Ship_Year-S_B_R&D_Start_Year)*2
DOCUMENT: R&D Time = R&D time (years)
The development time of the service used in a smoothing function.

S_B_R&D_Time_Check = IF(TIME<S_B_R&D_Start_Year OR (TIME>S_B_R&D_Ship_Year+1)) THEN(0) ELSE(S_B_R&D_Init_Invest)
DOCUMENT: R&D Time Check = Time check (years)
Checks to see if the current year equals the year that R&D investments begin.

S_B_R&D_Total = S_B_R&D_Budget+S_B_R&D_Init_Cost
DOCUMENT: R&D Total = Total R&D expenditures ($/year).
The sum of the initial investment and the current expenditures for R&D on a per year basis for this generation of device.

S_B_Total_Subsidy = E_U_Shipments*S_B_Gen1_Sub+E_U_Shipments_2*S_B_Gen2_Sub
DOCUMENT: Total Subsidy = Total Subsidy ($/year)
The total dollars spent by the service providers to reduce the cost of the device to new customer.

Service Capacity (Cc) Sector

S_Cc_Gen1_Installed(t) = S_Cc_Gen1_Installed(t - dt) + (S_Cc_Gen1_Install - S_Cc_Conversion) * dt
INIT S_Cc_Gen1_Installed = S_Cc_Initial
DOCUMENT: Cc Installed = Units of manufacturing capacity installed (units/year)

The amount of capacity available to manufacture units.

INFLOWS:
S_Cc_Gen1_Install = (1-T_U_Install_Ratio)*S_Cc_On_Order/S_Cc_Delivery_Time
DOCUMENT: Cc Gen 1 Install = Generation 2 Capacity installation (minutes/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

OUTFLOWS:
S_Cc_Conversion = S_Cc_Gen1_Installed*(T_U_Install_Ratio)/.15
DOCUMENT: Cc Conversion = Capacity conversion (minutes)
The function that converts capacity from generation 1 service to generation 2.

S_Cc_Gen2_Installed(t) = S_Cc_Gen2_Installed(t - dt) + (S_Cc_Conversion + S_Cc_Gen2_Install) * dt
INIT S_Cc_Gen2_Installed = 0
DOCUMENT: Cc Installed = Units of manufacturing capacity installed (units/year)
The amount of capacity available to manufacture units.

INFLOWS:
S_Cc_Conversion = S_Cc_Gen1_Installed*(T_U_Install_Ratio)/.15
DOCUMENT: Cc Conversion = Capacity conversion (minutes)
The function that converts capacity from generation 1 service to generation 2.

S_Cc_Gen2_Install = (T_U_Install_Ratio)*S_Cc_On_Order/S_Cc_Delivery_Time
DOCUMENT: Cc Gen 2 Install = Generation 2 capacity installation (minutes/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

S_Cc_On_Order(t) = S_Cc_On_Order(t - dt) + (S_Cc_Orders - S_Cc_Gen1_Install - S_Cc_Gen2_Install) * dt
INIT S_Cc_On_Order = 0
DOCUMENT: Cc On Order = Units of manufacturing capacity on order (units/year)
The amount of capacity to be added for the manufacture of more units. The amount of capacity on order is the difference between the capacity installed and the capacity desired.

INFLOWS:
S_Cc_Orders = IF(S_F_Profit>S_Cc_Max_Loss) THEN(S_Cc_Desired-(S_Cc_On_Order+S_Cc_Gen1_Installed+S_Cc_Gen2_Installed)) ELSE(0)
DOCUMENT: Cc Orders = Capacity orders (units/year)
The rate at which new capacity is ordered. Determined by the capacity desired minus the capacity already installed divided by the time it takes to add capacity.

OUTFLOWS:
S_Cc_Gen1_Install = (1-T_U_Install_Ratio)*S_Cc_On_Order/S_Cc_Delivery_Time
DOCUMENT: Cc Gen 1 Install = Generation 2 Capacity installation (minutes/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

S_Cc_Gen2_Install = (T_U_Install_Ratio)*S_Cc_On_Order/S_Cc_Delivery_Time
DOCUMENT: Cc Gen 2 Install = Generation 2 capacity installation (minutes/year)
The process of converting capacity on order to installed capacity derived by dividing the capacity on order by the capacity delivery time.

S_Cc_Delivery_Time = (S_Cc_On_Order/S_Cc_Total_Installed)+S_Cc_Std_Delivery
DOCUMENT: Cc Delivery Time = Capacity delivery time (years)
The time the placement of an order for capacity and its delivery. Normally, this is half a year, however, in situation were significant capacity must be added quickly, the time lengthens.

S_Cc_Desired = IF(S_Cc_Needed<10000) THEN(0) ELSE(S_Cc_Projected*S_Cc_Loading_Mag)
DOCUMENT: Cc Desired = Desired capacity (units/year)
Desired capacity is the product of the capacity projected, the loading on the existing capability and the desired excess capacity.

S_Cc_Excess_Plan = .75
DOCUMENT: Cc Excess Plan = Excess capacity plan (dimensionless)
Percentage of excess network capacity targeted to achieve the desired service level.

S_Cc_Extrapolation_Factor = IF(S_Cc_Growth_Trend>=1) THEN 4 ELSE (1+S_Cc_Info_Delay*S_Cc_Growth_Trend)^(1+S_Cc_Delivery_Time*S_Cc_Growth_Trend)
DOCUMENT: Cc Extrapolation Factor = Capacity extrapolation factor (dimensionless)
This is an extrapolation factor that looks forward to predict what will happen to unit demand in the indicated time period ahead based on past trends. In the startup mode, the extrapolation factor is limited to smooth the initial ramp.

S_Cc_Growth_Trend = TREND(S_Cc_Perceived_Demand,S_Cc_Delivery_Time,1)
DOCUMENT: Capacity Unit Growth Trend = Growth trend of unit capacity (dimensionless)
A built in function that outputs the outputs the trend of unit growth based on past history.

S_Cc_Info_Delay = 1
DOCUMENT: CC Info Delay = Capacity information collection delay (years)
The delay in collecting information describing the amount of capacity installed in a given period.

S_Cc_Initial = 4e9
DOCUMENT: Cc Initial = Initial Capacity (minutes/year)
The initial capacity that is installed when service begins.

S_Cc_Loading = S_Cc_Needed/S_Cc_Total_Installed
DOCUMENT: Cc Loading = Capacity loading (dimensionless)
The normalized ratio of actual unit demand to available capacity multiplied to magnify the effect of an under or over capacity situation.

S_Cc_Loading_Effect = .5
DOCUMENT: E Cc Loading Effect = Capacity loading effect (dimensionless).
Factor to adjust the impact of capacity loading on desired capacity.

S_Cc_Loading_Mag = S_Cc_Loading^S_Cc_Loading_Effect
DOCUMENT: E Cc Loading Mag = Capacity loading magnification (dimensionless).
Determines the magnified loading value.

S_Cc_Max_Loss = -5e9
DOCUMENT: Cc Max Loss = Capacity maximum loss (dollars)
Maximum financial loss that prevents the ordering of additional capacity.

S_Cc_Needed = S_AT_Provided/S_Cc_Excess_Plan
DOCUMENT: Cc Needed = Capacity Needed (minutes)
The required network capacity needed at the current level of usage and the targeted excess capacity desired.

S_Cc_Perceived_Demand = SMTH1(S_Cc_Needed,S_Cc_Info_Delay)
DOCUMENT: Cc Unit Perceived Demand = Perceived unit demand (units/year)
This the instaneous industry demand smoothed by the time it takes to collect the information.

S_Cc_Projected = S_Cc_Perceived_Demand*S_Cc_Extrapolation_Factor
DOCUMENT: Cc Projected = Projected capacity (units/year)
The product of the perceived unit demand and the extrapolation factor which produces an estimate of projected capacity the indicated number of years out.

S_Cc_Std_Delivery = 1
DOCUMENT: E Cc Std Delivery = Standard capacity delivery delay (years).
The standard amount of time required to dliever capacity that has been ordered.

S_Cc_Total_Installed = S_Cc_Gen1_Installed+S_Cc_Gen2_Installed
DOCUMENT: Cc Total Installed = Total capacity installed (minutes)
The total capacity of service generation 1 and 2.

S_Cc_Utilization = S_AT_Provided/S_Cc_Total_Installed
DOCUMENT: Cc Utilization = Capacity utilization (dimensionless)
The actual utilization of network capacity.

Service Financial Sector

S_F_AT_Price(t) = S_F_AT_Price(t - dt) + (S_F_AT_Price_Change) * dt
INIT S_F_AT_Price = S_F_AT_Initial_Price
DOCUMENT: AT Price = Airtime price ($/minute)
The selling price of airtime in a given year.

INFLOWS:
S_F_AT_Price_Change = SMTH1(S_F_Price_Check,S_F_AT_Price_Time,INIT(S_F_AT_Price))-S_F_AT_Price
DOCUMENT: AT Price Change = Airtime price change ($/minute/year)
The proposed change from the current price for a given time period.

S_F_Profit_Cum(t) = S_F_Profit_Cum(t - dt) + (S_F_Profit) * dt
INIT S_F_Profit_Cum = 1
DOCUMENT: Profits Cum = Cummulative profits ($)
The cummulative profits of the industry.

INFLOWS:
S_F_Profit = S_F_Revenue-S_F_Total_Cost
DOCUMENT: Profit = Profit ($/year)
The profits of the industry in the current period.

S_F_Revenue_Cum(t) = S_F_Revenue_Cum(t - dt) + (S_F_Revenue) * dt
INIT S_F_Revenue_Cum = 1
DOCUMENT: Revenue Cum = Cummulative revenue ($)
The cummulative revenues for the industry.

INFLOWS:
S_F_Revenue = IF(S_F_AT_Rev<1000) THEN(0) ELSE(S_F_Fee_Rev+S_F_AT_Rev)
DOCUMENT: Revenue = Revenue ($/year)
The revenue per year of the industry.

S_Cc_Conversion_Cost = S_Cc_Upgrade_Cost*S_Cc_Conversion
DOCUMENT: Cc Conversion Cost = Capacity conversion cost ($)
The cost to convert generation 1 capacity to geneeration 2.

S_Cc_Installed = S_Cc_Gen1_Installed+S_Cc_Gen2_Installed*S_F_Gen2_Cost_Factor
DOCUMENT: Cc Installed = Cost of installed capacity ($)
The total cost of all installed capacity.

S_Cc_Upgrade_Cost = .10
DOCUMENT: Cc Upgrade Cost = Capacity upgrade cost ($/minute)
The cost to upgrade one minute of network capacity from generation 1 to generation 2.

S_F_AT_Adj_Cc_Cost = IF(S_F_AT_Cc_Cost>2) THEN(2) ELSE(S_F_AT_Cc_Cost)
DOCUMENT: AT Adj Cc Cost = Adjusted airtime capacity cost ($/minute)
Clips the cost calculation so that the graphs look better.

S_F_AT_Adj_Fee_Rev = IF(S_F_AT_Fee_Rev>2) THEN(2) ELSE(S_F_AT_Fee_Rev)
DOCUMENT: AT Adj Fee Rev = Adjusted airtime fee revenue ($/minute)
Clips the revenue calculation so that the graphs look better.

S_F_AT_Adj_Fix_Cost = IF(S_F_AT_Fix_Cost>2) THEN(2) ELSE(S_F_AT_Fix_Cost)
DOCUMENT: AT Adj Fix Cost = Adjusted airtime fixed cost ($/minute)
Clips the cost calculation so that the graphs look better.

S_F_AT_Adj_Op_Cost = IF(S_F_AT_Op_Cost>2) THEN(2) ELSE(S_F_AT_Op_Cost)
DOCUMENT: AT Adj Op Cost = Adjusted airtime operating cost ($/minute)
Clips the cost calculation so that the graphs look better.

S_F_AT_Adj_Total_Cost = IF(S_F_AT_Total_Cost>2) THEN(2) ELSE(S_F_AT_Total_Cost)
DOCUMENT: AT Adj Total Cost = Adjusted airtime total cost ($/minute)
Clips the cost calculation so that the graphs look better.

S_F_AT_Cc_Cost = IF(S_AT_Provided<100000) THEN(0) ELSE(S_F_Cc_Cost/S_AT_Provided)
DOCUMENT: AT Cc Cost = Airtime capacity cost ($/minute)
Calculates the cost of capacity per minute of airtime sold.

S_F_AT_Fee_Rev = IF(S_AT_Provided<1000) THEN(0) ELSE(S_F_Fee_Rev/S_AT_Provided)
DOCUMENT: AT Fee Rev = Airtime fee revenue ($/minute)
Calculates the fee revenues per minute of airtime sold.

S_F_AT_Fix_Cost = IF(S_AT_Provided<10) THEN(0) ELSE(S_F_Fix_Cost/S_AT_Provided)
DOCUMENT: Unit Fix Cost = Unit Fixed Cost ($/unit/year)
The total fixed costs in a year amortized over the shipment volume for that same year.

S_F_AT_Initial_Cost = S_F_AT_Initial_Price*(1-S_F_GM_Desired)
DOCUMENT: AT Initial Cost = Cost of initial airtime ($/minute)
The initial cost of providing the initial service.

S_F_AT_Initial_Price = .5
DOCUMENT: AT Initial Price = Initial airtime price ($/minute)
The initial selling price of airtime.

S_F_AT_Learning = .9

DOCUMENT: AT Learning = Airtime learning curve (dimensionless)
The cost learning curve of providing the service.

S_F_AT_Op_Cost = S_F_AT_Cc_Cost+S_F_AT_Var_Cost
DOCUMENT: AT Op Cost = Airtime operating costs ($)
The sum of capacity and variable costs equals the operating costs fo a network.

S_F_AT_Price_Time = 2
DOCUMENT: AT Price Time = Airtime price time (years)
The amount of time it takes for a price change to take effect in the market.

S_F_AT_Rev = S_F_AT_Price*S_AT_Provided
DOCUMENT: AT Rev = Airtime Revenue ($)
Calculates the total airtime revenue by multiplying the airtime by the price.

S_F_AT_Total_Cost = IF(S_AT_Provided<100000) THEN(0) ELSE(S_F_Total_Cost/S_AT_Provided)
DOCUMENT: AT Total Cost = Airtime total cost ($/minute)
Calculates the total cost per minute of airtime sold.

S_F_AT_Total_Rev = S_F_AT_Price+S_F_AT_Fee_Rev
DOCUMENT: AT Total Rev = Airtime total revenue ($/minute)
Total revenues per minute of airtime.

S_F_AT_Var_Cost = S_F_AT_Initial_Cost*S_F_AT_Learning^S_F_Sub_Doublings
DOCUMENT: AT Var Cost = Airtime variable cost ($/minute)
The cost to produce each minute of service as a function of the learning curve. Learning curve means that for each doubling of the subscriber base, the cost to produce the service is reduced by the learning curve percentage.

S_F_Cc_Cost = IF(TIME<S_B_R&D_Ship_Year) THEN(0)
ELSE(S_Cc_Conversion_Cost+S_Cc_Installed*S_F_Cc_Costs*S_F_AT_Learning^S_F_Sub_Doublings)
DOCUMENT: Cc Cost = Capacity cost ($/year)
The cost of installed capacity for a year. Productivity improvements are realized through the learning curve of cummulative volume.

S_F_Cc_Costs = .25
DOCUMENT: Cc Cost Ratio= Initial capacity cost ratio(dimensionless)
The cost of plant and equipment per minute for the initial service level. Value is derived as a percentage of the initial service price.

S_F_Cum_PM = IF(S_F_Profit_Cum>0 AND (S_F_Revenue_Cum>100))
THEN(S_F_Profit_Cum/S_F_Revenue_Cum) ELSE(0)
DOCUMENT: Cum PM = Cummulative profit margin (dimensionless).
The cummulative profit margin of the business once a profit has been achieved.

S_F_Fee_Rev = IF(S_AT_Provided<1000) THEN(0) ELSE(S_Total_Subscribers*S_F_Service_Fee)
S_F_Fix_Cost = S_B_Mkt_Cost+S_B_R&D_Cost+S_B_G&A_Cost
DOCUMENT: Fix Cost = Fixed costs ($/year)
Total fixed costs of capacity and capability per year.

S_F_Gen2_Cost_Factor = .5
DOCUMENT: Gen 2 Cost Factor = Generation 2 cost factor (dimensionless)
The cost advantage of generation 2 capacity per minute.

S_F_GM_Desired = .5
DOCUMENT: GM Desired = Gross margin desired (dimensionless)
The desired gross margin used to determine the price from the airtime cost.

S_F_OM_Calc = S_F_OM_Desired*S_F_Loading_Adj
DOCUMENT: E F GM Calc = Calculated gross margin (dimensionless).
The calulcated gross margin adjusted for capacity loading.

S_F_OM_Desired = .5
DOCUMENT: GM Desired = Gross margin desired (dimensionless)
The desired gross margin used to determine the price from the airtime cost.

S_F_OM_Price = S_F_AT_Op_Cost/(1-S_F_OM_Calc)
DOCUMENT: GM Price = Calculated gross margin price ($/unit)
The unit price calculated by dividing the unit cost by the calculated gross margin.

S_F_PM = IF(S_F_Profit<10) THEN(0) ELSE(S_F_Profit/S_F_Revenue)
DOCUMENT: PM = Profit margin (dimensionless)
The profit margin calculated as profit divided by revenue. If there is a loss, then the profit margin is zero.

S_F_Price_Check = IF(S_F_AT_Price<S_F_Ship_Check) THEN(S_F_AT_Price)
ELSE(S_F_Ship_Check)
DOCUMENT: E F Ship Check = Check Shipments ($/minute).
A check to see if the calcluated price is higher than the current price in the market. Currently set to prevent price increases.

S_F_Service_Fee = 300
DOCUMENT: Service Fee = Service Fee ($/year)
The service fee charged each customer to subscribe to the service.

S_F_Ship_Check = IF(TIME<=S_B_R&D_Ship_Year+5) THEN(S_F_AT_Price) ELSE(S_F_OM_Price)
DOCUMENT: E F Ship Check = Check Shipments ($/unit).
A check to see if the service has started before adjusting the price.

S_F_Sub_Doublings = IF(S_Total_Subscribers/(M_Normal_Size/1000)>1)
THEN(LOG10(S_Total_Subscribers/(M_Normal_Size/1000))/LOG10(2)) ELSE(0)
DOCUMENT: Sub Doublings = Subscriber doublings (dimensionless)
The number of times thesubscriber base has doubled since the initial start of the service.

S_F_Total_Cost = S_F_Var_Cost+S_F_Cc_Cost+S_F_Fix_Cost
DOCUMENT: Total Cost = Total costs ($)
Teh sum of variable, capacity and fixed cost is the total cost.

S_F_Var_Cost = S_AT_Provided*S_F_AT_Var_Cost
DOCUMENT: Var Cost = Variable costs ($/year)
The total variable costs of the service for each time period.

S_F_Loading_Adj = GRAPH(S_Cc_Loading)
(0.00, 0.8), (0.2, 0.8), (0.4, 0.8), (0.6, 0.8), (0.8, 0.9), (1.00, 1.00), (1.20, 1.10), (1.40, 1.20), (1.60, 1.20), (1.80, 1.20), (2.00, 1.20)
DOCUMENT: GM Adj = Adjusted gross margin (dimensionless)
The gross margin adjusted for the resource loading. High loading causes an increase in price and vice versa.

Service Subscriber Data Sector

I_Cum_Profit(t) = I_Cum_Profit(t - dt) + (I_Profit) * dt
INIT I_Cum_Profit = 0
DOCUMENT: Cum Profit = Cummulative profit ($)
The cummulative profit for the industry.

INFLOWS:
I_Profit = T_E_Profit+S_F_Profit
DOCUMENT: Profit = Profit ($/year)
The sum of the equipment supplier and service provider profit is the profit for the industry.

I_Cum_Revenue(t) = I_Cum_Revenue(t - dt) + (I_Revenue) * dt
INIT I_Cum_Revenue = 0
DOCUMENT: Cum Revenue = Cummulative revenue ($)
The cummulative revenue for the industry.

INFLOWS:
I_Revenue = T_E_Revenue+S_F_Revenue
DOCUMENT: Revenue = Revenue ($/year)
The sum of the equipment supplier and service provider revenue is the revenue for the industry.

T_E_Cum_Profit(t) = T_E_Cum_Profit(t - dt) + (T_E_Profit) * dt
INIT T_E_Cum_Profit = 0
DOCUMENT: Cum Profit = Cummulative profit ($)
The cummulative profit the equipment suppliers for both generations of device.

INFLOWS:
T_E_Profit = E_F_Profit+E_F_Profit_2
DOCUMENT: Profit = Profit ($/year)
The sum of the equipment suppliers profit for both generations of device.

T_E_Cum_Revenue(t) = T_E_Cum_Revenue(t - dt) + (T_E_Revenue) * dt
INIT T_E_Cum_Revenue = 0
DOCUMENT: Cum Revenue = Cummulative revenue ($)
The cummulative revenue the equipment suppliers for both generations of device.

INFLOWS:
T_E_Revenue = E_F_Revenue+E_F_Revenue_2
DOCUMENT: Revenue = Revenue ($/year)
The sum of the equipment suppliers revenue for both generations of device.

AT_Per_Sub = S_AT_Provided/M_Total_Subscribers
DOCUMENT: At Per Sub = Airtime per subscriber (minutes/subscriber/year)
The average minutes of usage per subscriber.

Cost_Per_Sub = IF(M_Total_Subscribers<1000) THEN(0) ELSE(S_F_Total_Cost/M_Total_Subscribers)
DOCUMENT: Cost Per Sub = Cost per subscriber ($/subscriber/year)
The total cost of providing service to each subscriber.

I_Cum_PM = IF(I_Cum_Profit<=0) THEN(0) ELSE(I_Cum_Profit/I_Cum_Revenue)
DOCUMENT: Cum PM = Cummulative profit margin (dimensionless)
The cummulative profit margin for the industry.

I_PM = IF(I_Profit<=0) THEN(0) ELSE(I_Profit/I_Revenue)
DOCUMENT: PM = Profit margin (dimensionless)
The profit margin for the industry.

Mkt_Per_New_Sub = IF(M_Shipments<1000) THEN(0) ELSE(S_B_Mkt_Cost/M_Shipments)
DOCUMENT: Mkt Per New Sub = Marketing costs per new subscriber ($/susbscriber /year)
The total marketing costs divided by the number of new subscribers each year.

Mkt_Per_Sub = IF(M_Total_Subscribers<1000) THEN(0) ELSE(S_B_Mkt_Cost/M_Total_Subscribers)
DOCUMENT: Mkt Per Sub = Marketing cost per susbriber ($/subscriber/year)
The total marketing costs divided by the total number of subscribers each year.

Rev_Per_Sub = IF(M_Total_Subscribers<1000) THEN(0) ELSE(S_F_Revenue/M_Total_Subscribers)
DOCUMENT: Rev Per Sub = Revenues per subsciber ($/subscriber /year)
The total revenues divided by the subscriber base each year.

T_Cum_PM = IF(T_E_Cum_Profit<=0) THEN(0) ELSE(T_E_Cum_Profit/T_E_Cum_Revenue)
DOCUMENT: Cum PM = Cummulative profit margin (dimensionless)
The cummulative profit margin for the equipment suppliers of both generations of devices.

T_Discount_Rate = .08
DOCUMENT: Discount Rate = Discount rate (dimensionless)
The discount rate used in the net present value calculations.

T_NPV_E = NPV(T_E_Profit,T_Discount_Rate)
DOCUMENT: NPV E = Equipment supplier NPV ($)
The net present value of the discounted cash flows for the equipment suppliers of both generations of devices.

T_NPV_E_F = NPV(E_F_Profit,T_Discount_Rate)
DOCUMENT: NPV E F = Generation 1 equipment supplier NPV ($)
The net present value of the discounted cash flows for the equipment supplier of generation 1 devices.

T_NPV_E_F_2 = NPV(E_F_Profit_2,T_Discount_Rate)
DOCUMENT: NPV E F = Generation 2 equipment supplier NPV ($)
The net present value of the discounted cash flows for the equipment supplier of generation 2 devices.

T_NPV_I = NPV(I_Profit,T_Discount_Rate)
DOCUMENT: NPV I = industry NPV ($)
The net present value of the discounted cash flows for the entire industry including the service providers and both generations of equipment suppliers.

T_NPV_S_F = NPV(S_F_Profit,T_Discount_Rate)
DOCUMENT: NPV S = Service provider NPV ($)
The net present value of the discounted cash flows for the service provider.

T_PM = IF(T_E_Profit<=0) THEN(0) ELSE(T_E_Profit/T_E_Revenue)
DOCUMENT: PM = Profit Margin (dimensionless)
the profit margin of the equipment suppliers for both generations of devices.

Technology Transition Sector

T_U_Cum_Shipments(t) = T_U_Cum_Shipments(t - dt) + (T_U_Shipments) * dt

INIT T_U_Cum_Shipments = 0
DOCUMENT: Cum Shipments = Unit cummulative shipments (units)
The cummulative sum of all of the units sold in the industry over the model time frame.

INFLOWS:
T_U_Shipments = T_U_Shipments_1+T_U_Shipments_2
DOCUMENT: Shipments = Unit shipments (units/year)
The total units shipped per year of both generations of device.

T_U_Cum_Shipments_1(t) = T_U_Cum_Shipments_1(t - dt) + (T_U_Shipments_1 - T_U_Upgrades_1 - T_U_Exits_1) * dt
INIT T_U_Cum_Shipments_1 = 0
DOCUMENT: Cum Shipments 1= Installed base of generation 1 (units)
The installed base of generation 1 units.

INFLOWS:
T_U_Shipments_1 = E_U_Shipments
DOCUMENT: Shipments 1 = Generation 1 unit shipments (units/year)
The generation 1 units shipped per year determined by the capacity available or the available backlog and new orders.

OUTFLOWS:
T_U_Upgrades_1 = IF(T_U_Gen2_Upgrade_Frac>=.99) THEN(T_U_Cum_Shipments_1/1) ELSE(T_U_Cum_Shipments_1*T_U_Gen2_Upgrade_Frac)
DOCUMENT: Upgrades 1 = Unit Upgrades (units)
The units of generation 1 that are upgraded to generation 2.

T_U_Exits_1 = M_Exits*T_U_Gen1_Orders_Frac
DOCUMENT: Exits 1 = Exits (units)
The number of units that exit due to churn or replacement.

T_U_Cum_Shipments_2(t) = T_U_Cum_Shipments_2(t - dt) + (T_U_Shipments_2 - T_U_Exits_2) * dt
INIT T_U_Cum_Shipments_2 = 1
DOCUMENT: Cum Shipments 2 = Installed base of generation 2 (units)
The installed base of generation 2 units.

INFLOWS:
T_U_Shipments_2 = E_U_Shipments_2
DOCUMENT: Shipments 2 = Generation 2 unit shipments (units/year)
The generation 2 units shipped per year determined by the capacity available or the available backlog and new orders.

OUTFLOWS:
T_U_Exits_2 = M_Exits*(1-T_U_Gen1_Orders_Frac)
DOCUMENT: Exits 2 = Exits (units)
The number of units that exit due to churn or replacement.

T_U_Gen1_Orders_Frac(t) = T_U_Gen1_Orders_Frac(t - dt) + (- T_U_Conversion_1:2) * dt
INIT T_U_Gen1_Orders_Frac = 1
DOCUMENT: Gen 1 Orders Frac = Fraction of orders that are generation 1 (units)
The fraction of all orders that are generation 1 product.

OUTFLOWS:
T_U_Conversion_1:2 = SMTH3(T_U_Time_Check,T_U_Time_1:2,0)

DOCUMENT: Conversion 1:2 = Conversion of orders from Gen 1 to Gen 2 (dimensionless)
A smooth that drains from generation 1 to generation 2.

T_U_Gen2_Orders_Frac(t) = T_U_Gen2_Orders_Frac(t - dt) + (T_U_Conversion_1:2) * dt
INIT T_U_Gen2_Orders_Frac = 0
DOCUMENT: Gen 2 Orders Frac = Fraction of orders that are generation 2 (units)
The fraction of all orders that are generation 2 product.

INFLOWS:
T_U_Conversion_1:2 = SMTH3(T_U_Time_Check,T_U_Time_1:2,0)
DOCUMENT: Conversion 1:2 = Conversion of orders from Gen 1 to Gen 2 (dimensionless)
A smooth that drains from generation 1 to generation 2.

T_U_Gen2_Upgrade_Frac(t) = T_U_Gen2_Upgrade_Frac(t - dt) + (T_U_Upgrade_1:2 - T_U_Upgrade) * dt
INIT T_U_Gen2_Upgrade_Frac = 0
DOCUMENT: Gen 2 Upgrade Frac = Fraction of Gen 1 installed base that is upgraded (units)
The fraction of generation 1 installed base that are to be upgraded to generation 2 product.

INFLOWS:
T_U_Upgrade_1:2 = SMTH1(T_U_Time_Check_2,T_U_Upgrade_Factor,0)
DOCUMENT: Upgrade 1:2 = Conversion ration for upgrades to generation 2 (dimensionless)
The ratio of the installed base that is upgraded to generation 2 product.

OUTFLOWS:
T_U_Upgrade = IF(T_U_Upgrade_End=1) THEN(10) ELSE(0)
DOCUMENT: Upgrade = Upgrade (dimensionless)
Upgrade flag that drains the upgrade ratio when the upgrade program ends.

T_U_Gen_1Initial_Fraction(t) = T_U_Gen_1Initial_Fraction(t - dt) + (- T_U_Upgrade_1:2) * dt
INIT T_U_Gen_1Initial_Fraction = 1
OUTFLOWS:
T_U_Upgrade_1:2 = SMTH1(T_U_Time_Check_2,T_U_Upgrade_Factor,0)
DOCUMENT: Upgrade 1:2 = Conversion ration for upgrades to generation 2 (dimensionless)
The ratio of the installed base that is upgraded to generation 2 product.

T_U_Potential_1(t) = T_U_Potential_1(t - dt) + (T_U_Demand_1 - T_U_Orders_1) * dt
INIT T_U_Potential_1 = 10
DOCUMENT: Potential 1 = Potential generation 1 (customers)
The number of potential generation 1 customers in the industry.

INFLOWS:
T_U_Demand_1 = M_Unit_Demand*T_U_Gen1_Orders_Frac
DOCUMENT: Demand 1 = Demand for generation 1 (units)
The demand for generation 1 product.

OUTFLOWS:
T_U_Orders_1 = T_U_Demand_1
DOCUMENT: Orders 1 = Unit orders 1 (units)
New orders received generation 1 product.

T_U__Potential_2(t) = T_U__Potential_2(t - dt) + (T_U_Upgrades_1 + T_U_Demand_2 - T_U_Orders_2) * dt
INIT T_U__Potential_2 = 10
DOCUMENT: Potential 2 = Potential generation 2 (customers)

The number of potential generation 2 customers in the industry.

INFLOWS:
T_U_Upgrades_1 = IF(T_U_Gen2_Upgrade_Frac>=.99) THEN(T_U_Cum_Shipments_1/1) ELSE(T_U_Cum_Shipments_1*T_U_Gen2_Upgrade_Frac)
DOCUMENT: Upgrades 1 = Unit Upgrades (units)
The units of generation 1 that are upgraded to generation 2.

T_U_Demand_2 = M_Unit_Demand*(1-T_U_Gen1_Orders_Frac)
DOCUMENT: Demand 2 = Demand for generation 2 (units)
The demand for generation 2 product.

OUTFLOWS:
T_U_Orders_2 = T_U_Demand_2+T_U_Upgrades_1
DOCUMENT: Orders 2 = Unit orders 2 (units)
New orders received generation 2 product plus the generation 1 upgrades.

T_U_Conversion_Speed = 2
DOCUMENT: Conversion Speed = Upgrade conversion speed (dimensionless)
a factor to set the speed of the upgrade program.

T_U_Installed_Base = T_U_Cum_Shipments_1+T_U_Cum_Shipments_2
DOCUMENT: Installed Base = Installed base (customers)
The total installed base of generation 1 and generation 2 devices that are in use.

T_U_Install_Ratio = IF(T_U_Cum_Shipments_1+T_U_Cum_Shipments_2<10) THEN(0) ELSE(T_U_Cum_Shipments_2/(T_U_Cum_Shipments_1+T_U_Cum_Shipments_2))
DOCUMENT: Install Ratio = Install ratio (dimensionless)
The ratio of generation2 units to the total installed base.

T_U_Ship_Ratio = IF(T_U_Shipments_1+T_U_Shipments_2<10) THEN(0) ELSE(T_U_Shipments_2/(T_U_Shipments_1+T_U_Shipments_2))
DOCUMENT: Ship Ratio = Ship ratio (dimensionless)
The ratio of generation2 units to the total shipped units for that time period.

T_U_Time_1:2 = ((E_U_Stop_Ship-E_B_R&D_Ship_Year_2)*T_U_Conversion_Speed)-2
DOCUMENT: Time 1:2 = Time 1:2 (years)
The overlap between the start of shipments of generation 2 and end of generation 1 shipments.

T_U_Time_Check = IF(TIME<E_B_R&D_Ship_Year_2-1) THEN(0) ELSE(1)
DOCUMENT: Time Check = Time check (flag)
Checks to see if the current year is the year generation 2 ships.

T_U_Time_Check_2 = IF(TIME<E_B_R&D_Ship_Year_2+T_U_Upgrade_Delay) THEN(0) ELSE(1)
DOCUMENT: Time Check 2 = Time check 2 (flag)
Checks to see the current year is the year the upgrade program ends.

T_U_Unit_Doublings = IF(T_U_Cum_Shipments/(M_Normal_Size/1000)>1) THEN(LOG10(T_U_Cum_Shipments/(M_Normal_Size/1000))/LOG10(2)) ELSE(0)
DOCUMENT: Unit Doublings = Unit doublings (dimensionless)
The number of times the cummulative production has doubled since the initial production run.

T_U_Upgrade_Delay = 0
DOCUMENT: Upgrade Delay = Upgrade delay (years)

The number of years to delay the start of the upgrade program.

T_U_Upgrade_End = IF(TIME>=E_B_R&D_Ship_Year_2+T_U_Upgrade_Time_1:2) THEN(0) ELSE(0)
DOCUMENT: Upgrade End = Upgrade end (year)
Determines if the current year is the end of the upgrade program.

T_U_Upgrade_Factor = (T_U_Upgrade_Time_1:2^T_U_Conversion_Speed)/2
DOCUMENT: Upgrade Factor = Upgrade factor (dimensionless)
Factor input into the smoothing function to assure the transition occurs over the required timeframe.

T_U_Upgrade_Time_1:2 = E_U_Stop_Ship-E_B_R&D_Ship_Year_2+T_U_Upgrade_Delay+1
DOCUMENT: Upgrade Time 1:2 = Upgrade time 1:2 (years)
The number of years the upgrade is expected to take.

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