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Commoditization of Technology-Based Products and Services: A Generic Model of Market Dynamics

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Abstract

The experience of many technology-based industries suggests the existence of powerful long-term dynamics that lead to "commoditization" of products and services. These industries exhibit recurring cycles in investment, capacity utilization, prices, margins, and return on capital. Research supported by the ICRMOT seeks to more clearly define the dynamics of commoditization and identify leverage points whereby a corporation could influence the effects of those dynamics on its business performance. A generic market dynamics model was developed using the System Dynamics methodology. It is being used to analyze the behavior of a cross-section of markets at different stages of maturity and liberalization, i.e., the airline industry, both fixed-link and mobile telecommunications, and refined petroleum products. A series of simulation experiments is exploring such questions as: How do technological trends and innovations impact the dynamics of commoditization? How does commoditization change the incentives for investments in new capacity and technologies? How does commoditization alter the character of markets and their cycles? And how should a corporations adjust its technology and business strategies to various stages of commoditization? This paper presents the causal structure and behavior of the most general version of the market dynamics model. It is described in terms of its application to the airline industry. The model's equations are included in an appendix.

Acknowledgment

Introduction

"Commoditization" is a fact of life for many technology-based products and services ranging from semi-conductors and personal computers to air transportation, telecommunications, and chemicals. This term is used to denote a competitive environment in which product differentiation is difficult, customer loyalty and brand values are low, and sustainable advantage comes primarily from cost (and often quality) leadership.

A simulation model is being used to illuminate:

- The principal drivers of commoditization dynamics;
- Key differences among industries and markets;
- Leverage points for influencing the dynamics; and
- Strategic responses for corporations contending with commoditization.

The multi-year research program began by analyzing commoditization in more mature service markets, specifically, air transportation and traditional fixed-link telecommunications. The next step has been to investigate the early stages of service commoditization in more rapidly growing advanced technology markets and the commoditization of "hard products" related to technology-based services. In this phase the model is being applied to several markets for mobile telecommunication services and hand sets.

A third stage of work is focusing on the causes and strategic implications of industry cycles when commoditization has become quite advanced. Many process industries such as petroleum, chemicals, and metals involve products at advanced stages of commoditization. They also are notoriously cyclical. There are note-worthy similarities with the industries analyzed in earlier phases of the research program and some very significant differences. The third stage focuses on the market for refined petroleum products. It extends the research to markets that are more mature, complex, and international.

This paper presents the causal structure and behavior of the most general version of the market dynamics model. It is described in terms of its application to the airline industry. An equation-level flow diagram of the model can be found in Appendix 1. Its equations are included in Appendix 2.

Objectives

The research focuses on important links between technology and business strategies. Many technology-based industries exhibit recurring cycles in capital investment, capacity utilization, prices, margins, and return on capital. Analyses of the air transportation and semi-conductor industries suggest that powerful long-term dynamics make such cycles more severe and change their character as commoditization progresses.

The objective of this research is to more clearly define the dynamics of commoditization and to identify leverage points whereby a corporation could influence the effects of those dynamics on its business performance. Among the specific questions being addressed are:

- How do technological innovations and investments impact the dynamics of commoditization?

- How are the incentives to invest in new capacity and technologies affected?

- How does commoditization alter the character of markets and their cycles?

- How do these cycles relate to the long-term trend in return on capital?

- Do imports and exports amplify the cycles?

- Are there reliable leading indicators of the major turning points?

- What are the effects of market liberalization and changes in industry structure?

- What is the best timing for capacity additions and retirements?

- Is commoditization of technology-based products and services inevitable?

- How should corporate strategy be adjusted to each phase of the dynamics?

- What actions could be taken to anticipate and even influence the future?

The findings are applicable to a wide range of technology-based services and products.
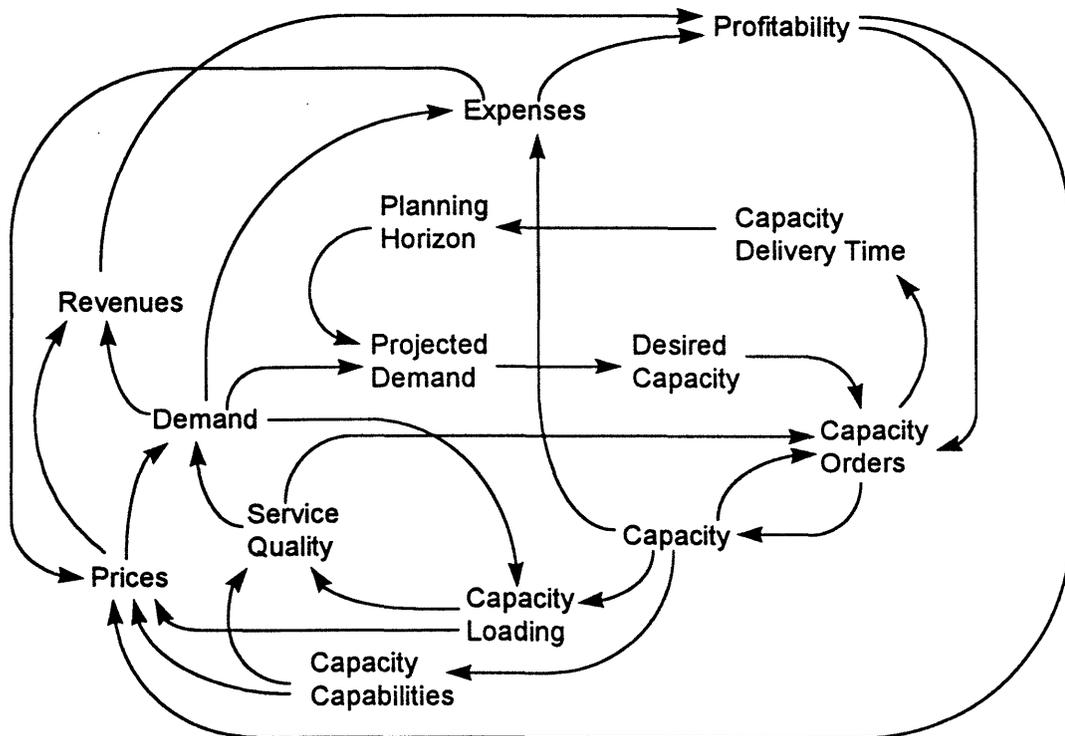
Approach

This multi-year program involves a series of detailed studies of market dynamics. Each case has many similarities with the others but also adds some important new dimensions, for example, with respect to demand growth, technology trends, market structure, and regulatory factors. As described above the research involves studying quite different stages of market development ranging from infant high-tech markets (e.g., mobile telephony), to ones that are becoming mature (e.g., air transport), to others at a very advanced stage of commoditization (e.g., petroleum products). And it is addressing strategic issues that are common to all of these cases:

- Cycles in capital investment capacity utilization, prices, and profitability;

- Long-term trends for return on capital;

- Patterns of demand growth;

- Changes in capacity cost, productivity, operating efficiency, and technical performance;

- Market liberalization and internationalization;

- Alternative approaches to government regulation; and

- Evolution of industry structures.

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A simple, generic, market dynamics model has been developed using the System Dynamics methodology. It is based on previous models of the airline and telecommunications industries developed by me and several collaborators. An overview of this model is shown in Figure 1.

Figure 1
GENERIC MARKET MODEL
Overview

Revenues · Profitability · Expenses · Planning Horizon · Capacity Delivery Time · Projected Demand · Desired Capacity · Demand · Capacity Orders · Service Quality · Capacity · Prices · Capacity Loading · Capacity Capabilities

System Dynamics is a powerful methodology for developing and analyzing computer simulation models of complex problems. It has its roots in engineering feedback control systems analysis. The methodology was pioneered at MIT in the 1960s and subsequently has been used by major corporations, government ministries, academic institutions, and research centers around the world. System Dynamics models have contributed to corporate strategy formulation and implementation, analysis of technology-based markets, risk management, and evaluation of government regulations. The distinguishing features of System Dynamics models are:

- They take a high-level, strategic perspective on problems;

- They embody rich, realistic theories of how the elements of a complex "system" (e.g., a market or individual company) interact to produce its overall behavior;

- They include many behavioral factors (e.g., perceptions, goals, pressures, trade-offs); and

- They integrate in a common framework a wide range of relevant information (e.g., time series data, subjective estimates, direct observations, expert opinions).

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System Dynamics models are easily developed and simulated on high-performance lap-top computers. The generic model originally was programmed in the "iThink" simulation language and run on Apple Macintosh hardware. The model recently was converted to the more powerful "Vensim" software. It now operates on both IBM-compatible and Macintosh platforms.

The generic model is being used to analyze the six combinations of industries and markets. These case studies were selected to compare and contrast among different stages of industry/market maturity, liberalization, concentration, and integration. Each step requires some adaptation of the model. Many cause/effect relationships, parameters, and inputs must be changed to capture the specifics of the market and industry being analyzed. In some instances, the model's structure must be modified. For example, the generic model is being extended to include the determinants of the price of mobile handsets and the effect of handset prices on demand for mobile services. It will represent the feedbacks from intensity of service competition and market growth to handset prices. It also will represent the effect of an installed base of handsets of an older technology (e.g., analog) on the demand for new-technology-based mobile services (e.g., digital GSM or PCS).

The original generic model represented a service market and an industry of service providers. In the third stage of work the model was extensively modified to represent a *product* market and industry. For example, the determinants of the production rate were added. In a service industry there is no equivalent decision about how much output to produce. The analogous decision in those industries is how much capacity to offer in a market. Strategically significant inventories also were added, i.e., ones that affect the mid-term behavior of production and prices. It generally is not possible to inventory services. Furthermore, several significant interconnections between a national market and global markets will be reflected in this version of the model. Imports and exports can balance domestic capacity with demand. Imports, if lower priced, will displace domestic production. Over-capacity and thus lower prices elsewhere in the world will affect domestic prices through the threat (or reality) of "cheap" imports. Excess domestic capacity may be offered at very aggressive prices in export markets.

Each application of the generic model is very revealing. The required differences in inputs, parameters, cause/effect relationships, and structure provide an explicit "map" of the key similarities and differences among the family of case studies. The recurring similarities define the common ground. They support development of broad, general theories of market behavior. The differences also are highly significant. They indicate factors that must be considered in applying the general theories to new situations. And they suggest how markets may evolve in the future, for example, the factors that would cause the Hong Kong telecommunications market to become much more like air transportation in the U.S.

The Airline Industry Model

The air transport version of the model was implemented more than a year ago. It is calibrated to historical data for the U.S. market. Simulations start in 1985 and run through 2005. The Base Case simulation reproduces quite well the patterns of past behavior of this market. It uses a "middle of the road" future scenario for macro-economic conditions, technological trends, capacity production, airline industry management objectives and policies, and the behavior of their

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customers. The Base Case serves as a reference for analyzing other tests. A range of sensitivity tests have been performed with the model, i.e., exploring how the simulation results are affected by changes in various inputs and cause-effect relationships. These tests have focused on:

- Cost trends (e.g., industry restructuring and new technologies);

- Market liberalization (e.g., the strategies of new entrants and responses of incumbents);

- Pricing behavior (e.g., aggressiveness in reacting to capacity utilization and profitability); and

- Capacity planning (e.g., conservatism and changes in delivery times).

The remainder of this paper describes the structure and behavior of the airline version of the generic model. The model is discussed in terms of the specifics of that industry to demonstrate its capacity to capture the pertinent relationships and interpret the key dynamics of a particular case. Readers knowledgeable about the airline industry should be reassured that the generic model applies well. Readers with backgrounds in industries such as telecommunications, financial services, petroleum, chemicals, semi-conductors, and personal computers should find much of what follows remarkably familiar. The transferability of learning, and indeed of formal models, across industries is the fundamental premise of the research.

Causal Structure

The generic market model is a framework within which a complex web of dynamic cause/effect relationships operate. These relationships embody an explicit view of: (a) management decision-making within the airline industry; (b) the behavior of consumers of air transportation services; (c) technological factors that influence airline costs and fleet utilization; and (d) the effects of government regulations and policies on the airlines.

The major relationships in the model are presented in Figure 2. This diagram is conceptually the same as Figure 1 but expressed in terms of the specifics of the airline industry. Starting on the left side of the diagram the model computes the demand for air transportation services (defined in terms of revenue passenger kilometers per year, i.e., "RPK") within a regional market. Demand growth in the model depends on several factors. The principal drivers are:

- Growth in the region's GDP (an external input);
- An effect of changes in the fare per RPK; and
- An effect of changes in service quality (e.g., flight frequency).

Declining fares and increasing flights stimulate more rapid demand growth than otherwise indicated by GDP trends. Demand elasticities have been estimated from historical data. They reflect the market's state of development, for example, the balance between business and personal travel. The sensitivity of demand to service quality is quite non-linear.

Moving now to the center of Figure 2, the recent trend in demand is projected forward as the basis for fleet planning. The normal fleet planning horizon is extended when aircraft delivery

times become excessively long. Desired future fleet capacity is determined from demand forecasts.

Aircraft orders are placed so as to adjust the current fleet toward this desired future capacity. These decisions take account of expected aircraft replacements and retirements, plus any perceived need to add capacity in order to improve service quality. If airline profitability is substantially below target, the ordering of new aircraft will be constrained. This results from a combination of financial restraint by the airlines and more costly or difficult to obtain financing as a consequence of their reduced credit-worthiness.

After a delay, these orders result in a flow of new aircraft into the fleet. The aircraft manufacturers' delivery times depend on the size of their order backlog relative to their production rate. When the manufacturers are flooded with orders, as happened during 1988-90, delivery times can rise to 2-3 times the normal delay.

Figure 2
GENERIC MARKET MODEL
Basic Relationships in the Airline Version

At the bottom of Figure 2, load factors (i.e., capacity utilization) are determined by demand and current fleet capacity. Service quality (e.g., the number of flights per year) in a market is, in the first instance, a function of the size of the region's fleet. That is, the airlines plan for each aircraft to operate a certain number of flights per year. As new aircraft flow into the fleet the number of flights, and thus service quality, increase. The model represents the adverse impact

of very high capacity utilization on service quality. For example, comfort and in-flight service levels deteriorate if load factors are significantly above target.

Moving now to the lower left in Figure 2, the model contains a representation of the airlines' pricing decisions. The average fare in a market (expressed in $ per RPK) result from a balancing of capacity utilization and profit considerations. The airlines desire a fare level that covers their cost per RPK and target operating margin. However, actual fares will be substantially lower when load factors are below target. This reflects the generally futile attempts of individual airlines to improve their load factors by winning traffic from competitors (a zero-sum game) and a collective attempt to stimulate faster demand growth. And when load factors are above target (e.g., during a strong market up-cycle), the airlines will raise fares or, at a minimum, let a large fraction of any efficiency gains accrue to their "bottom line."

The feedback from airline profitability (down the right side and across the bottom of Figure 2) can off-set the effect of load factors on fares. As profitability erodes and losses mount, the airlines must balance short-term and longer-term financial pressures. Selling seats at a loss to improve load factors may be justifiable in the short term, but is not sustainable indefinitely. Hence, in the model the profitability effect on fares pushes in the other direction. The strength of this effect reflects assumptions about the "personalities," business strategies, and competitive dynamics of the airlines in a regional market.

The key financial relationships are shown in the upper left of Figure 2. Airline revenues result from demand and fares. Variable expenses are driven by demand, i.e., they are per RPK. Fixed expenses are driven by the size and characteristics of the fleet, e.g., depreciation and interest. Profits are determined by revenues minus expenses. The model calculates airline operating profits and margin (excluding profit or loss from other areas of business). As discussed above, profit performance compared with targets affects decisions about aircraft orders and pricing.

Systematic Analysis

The generic market model represents the decision making and behavior of air transportation consumers and the managers of airlines. It richly captures the dynamic interactions among these actors via pricing, service quality, fleet planning, and aircraft ordering. Systematic analysis with the model can assist in more clearly understanding the historical behavior of air transportation markets, foreseeing the likely future patterns of market behavior, and evaluating business strategy options. Moreover these lessons are transferable to many other similar markets.

The model's *behavior is the direct result of its structure.* Specifically, it is caused by the complex web of cause/effect relationships summarized in Figure 2. These relationships drive the "boom and bust" cycles that characterize the commercial aircraft market. They explain the steady commoditization of air transportation services. They illuminate how markets change as they are liberalized and mature. And they reveal leverage points whereby the market's future development may be influenced.

The next section provides a systematic analysis of the current (and most violent) cycle in the airline industry. What factors caused the extraordinary peak of aircraft orders in 1988-90? Why was so much excess capacity created? Why did airline profits collapse so dramatically? What role did market liberalization play in the debacle? How much permanent damage was done? What are the mid-term prospects for recovery?

These questions are addressed within the framework of the model's causal structure. Versions of Figure 2 are used to highlight the contributions of various sub-sets of model structure to the behavior modes being discussed. The analysis is entirely qualitative and conceptual, though it is based on results from many simulations. The goal is *to paint a clear, compelling picture of how the model -- and the market -- behave and why!* This "mental model" is essential for understanding, interpreting, and explaining the results from simulation tests.

Past is Prologue

The future of the airline industry has its roots in the past, particularly, in the dramatic events of 1988-93. At the heart of the dynamics of this market are three long-term trends:

- Worsening cycles in airline capacity utilization, profits, and investment and in demand growth;

- Eroding return on capital in the airline industry; and

- Liberalizing of major air transportation markets.

The first two trends result from the emergence and persistence of *very significant excess capacity*. The last trend is a major contributor to regional and global over-capacity.

Analyses with the generic market model indicate that excess capacity in a regional market arises from a complex set of causes:

- Over-estimation of demand growth;

- Proliferation of players;

- Amplification of planning errors;

- Lapse of financial constraints; and

- Impacts of market liberalization.

Over-estimation of demand growth has been the result of inadequate understanding of how markets "work." For example, the U.S. airlines did not recognize the transient effects of deregulation. Deregulation brought many new entrants into the market with lower costs and more aggressive, market-oriented management cultures. A significant decline in real fares and expansion of flights stimulated a transient surge in demand. For a period of 5-8 years, demand growth was far above the average rate before deregulation. But this rapid growth was not

sustained, and recent projections indicate that demand in the U.S. will grow at a rate in between the two extremes.

In addition, the airlines do not appear to understand how markets change as they mature. As air transportation markets mature, the price elasticities increase steadily. This reflects the predominance of discretionary, highly price-sensitive, non-business demand, e.g., tourism, visiting friends and family, in more mature markets. Business travelers become more cost-sensitive, too. And as markets mature, the GDP and flight frequency elasticities decline, as does the strength of any self-reinforcing "experience effect." A maturing market is one where base demand is saturating, but discretionary demand can continue to grow in response to declining fares.

The consequences of over-estimating demand growth are shown in Figure 3. Imagine a situation where demand growth accelerates. The higher rate of growth is projected in to the future, leading to greater desired capacity and increased aircraft orders.

Figure 3
GENERIC MARKET MODEL
Over-estimation of Demand Growth
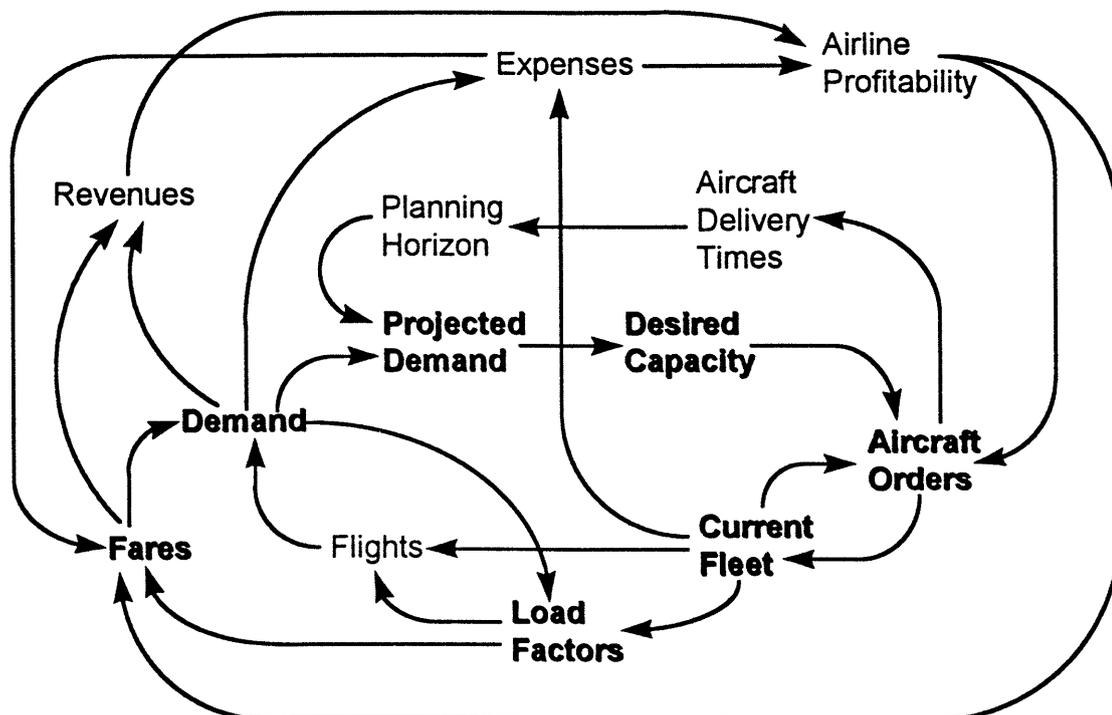
As the new capacity joins the fleet, load factors may well decline. Lower load factors are almost certain if the acceleration of demand growth is transient, e.g., because of deregulation or an economic up-cycle. As described above, load factors below target will lead to fare cutting which in turn will stimulate additional demand. This is a self-reinforcing "positive feedback loop." More capacity leads to increased demand; more demand, to increased capacity. Because of the

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lengthy planning horizon and aircraft delivery times, excess capacity builds up in response to cyclical or surging growth in demand.

Other parts of the model's structure control the strength of this positive feedback. An example is the effect of profitability on aircraft orders. The *proliferation of players*, i.e., entry of more competitors into a regional market as occurred following U.S. deregulation, weakens those control mechanisms. Specifically, more competitors in a market means more independent decision makers engaged in demand projection, fleet planning, capacity ordering, and fare cutting. The opportunities for misjudgments are increased. In addition, the proliferation of competitors almost inevitably leads to a situation where their market share aspirations cumulate to far above 100% of the market. New entrants start with nothing and expect to build market share. The established airlines, however, are not prepared to concede share to the same extent. Market share objectives can cumulate to 150% or more of the actual market under such circumstances.

Another version of this phenomenon resulted from the growing prominence of aircraft leasing companies. The leasing companies aggressively increased their market share targets, well beyond the capacity that the airlines planned to obtain from them. In effect, they partially duplicated orders placed directly by the airlines. Aircraft ordering based on these overlapping objectives leads to substantial excess capacity. In addition, new entrants are usually willing to sacrifice profitability for a period of time (often expressed as "for the first 2-3 years") in order to build market share. The established airlines feel compelled to sacrifice profitability in order to defend their positions.

The last effect is shown in Figure 4. The fare cutting that results from lower load factors has an adverse impact on yields, revenues, and airline profitability. Reduced profits, in turn, constrain aircraft orders. This is a self-correcting "negative feedback loop." Excess capacity reduces profits; poor profits reduce aircraft orders, thereby allowing demand growth to absorb excess capacity. The proliferation of competitors in a market weakens the feedback from profitability to orders, thereby increasing the likelihood of persistent excess capacity.

Planning errors are amplified by unusually long aircraft delivery times. The capacity planning horizon of the airlines must be extended when delivery times increase. Over-estimations of demand growth or market share, projected much farther into the future, cause even greater misjudgments of desired capacity. As shown in Figure 5, these relationships form another self-reinforcing positive feedback loop. A surge in aircraft orders (as in 1988-90) can cause delivery times to become substantially longer than normal. In response airlines extend their planning horizon, project higher demand and desired future capacity, and increase their aircraft orders. Unless manufacturer production rates respond proportionally, their order backlogs and deliver times will grow substantially. Here increased orders lead to longer planning horizons; and longer planning horizons, to further increases in orders.

Figure 4
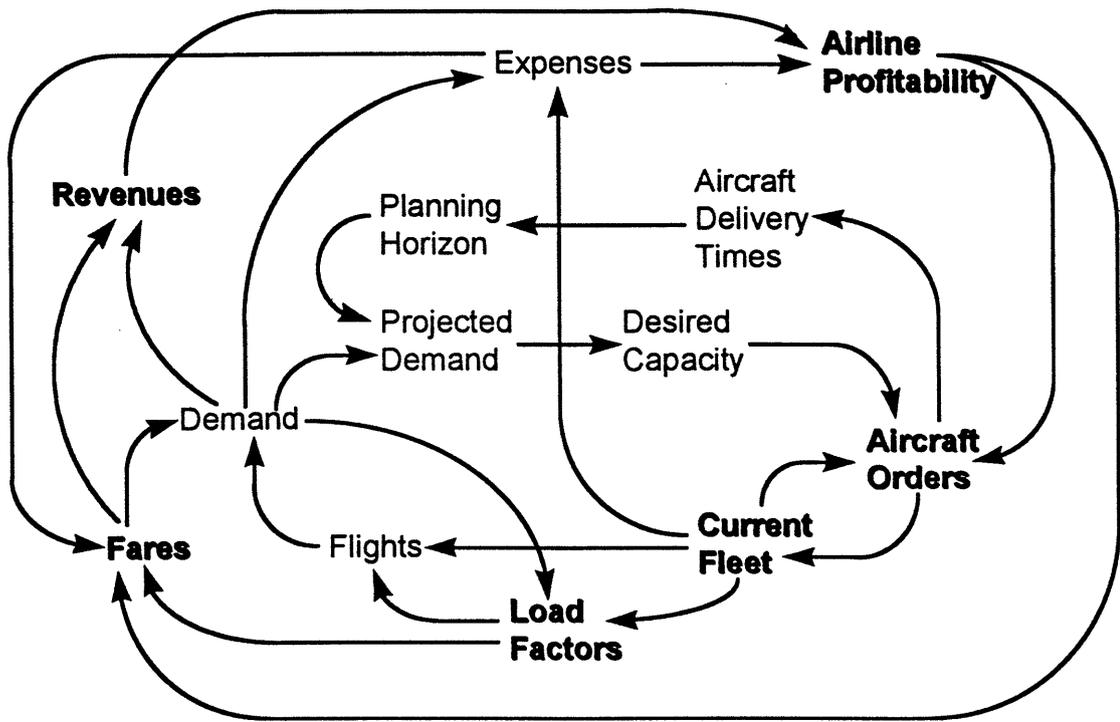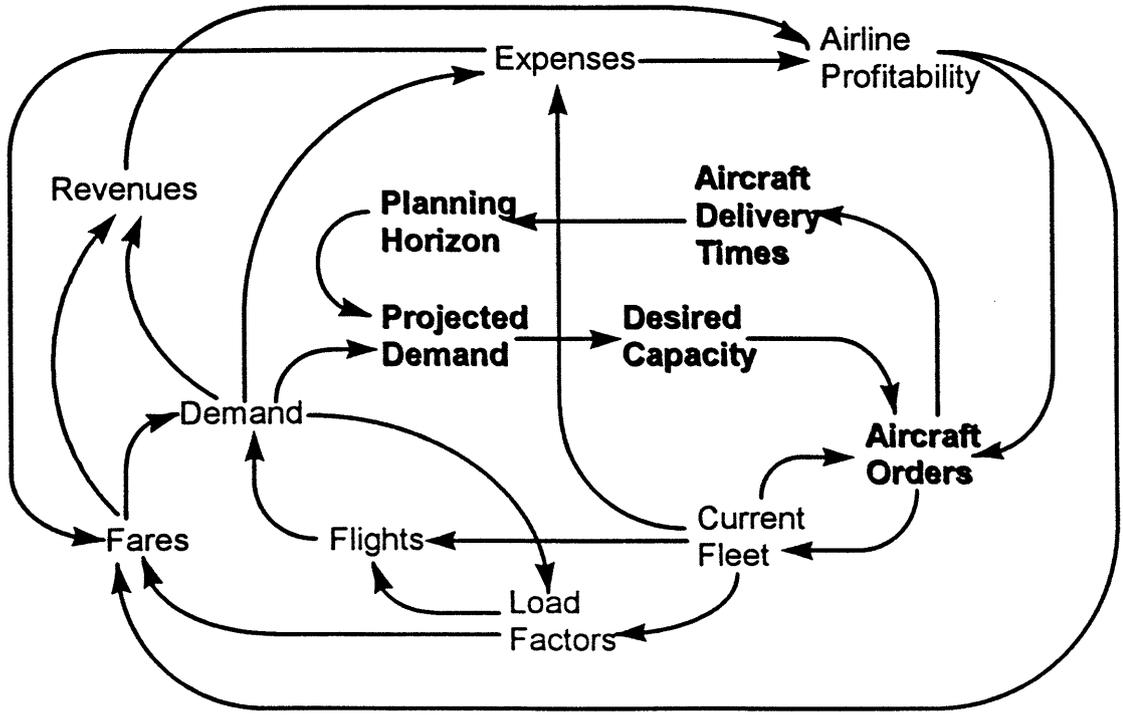**GENERIC MARKET MODEL**
Proliferation of Players

Figure 5
GENERIC MARKET MODEL
Amplification of Planning Errors

The two positive feedback loops shown in Figures 3 and 5 reinforce each other and amplify the growth of excess capacity. The *lapse of financial constraints* within the airline industry allows their perverse dynamics to go out of control. Traditional barriers to entry into the industry and conservatism in decision making have been eroded by freely available financing, e.g., from capital markets, financial institutions, leasing companies, and aircraft manufacturers. For a while, the airline industry was "hot." Entrepreneurs had no difficulty raising the capital to launch new airlines. New entrants ordered capacity in anticipation of building market share and, as described above, put market share growth ahead of short-term profitability.

When things turned bad for the industry, the normal industrial ecology did not apply. In the U.S., airlines were kept alive by the bankruptcy courts rather than going out of business. In other parts of the world, direct or indirect government subsidies have supported sick airlines. The leasing companies, desperate to place aircraft, have offered amazing deals. And the aircraft manufacturers, swamped with "white tails," became the financiers of last resort. Thus instead of a rapid shake-out of the industry and rationalization of capacity, new capacity continued to flow in.

Figure 6 indicates another important negative feedback loop through airline profitability. A wave of new capacity increases the airlines' expenses, reduces their profitability (for a time), and ordinarily would limit their access to financing and further capacity growth. The lapse of financial constraints severely weakened this feedback. It has contributed very significantly to the growth and persistence of excess capacity.

Market liberalization has amplified the dynamics described here by changing critical cause-effect relationships. Liberalization causes new competitors to enter a regional market with lower costs than the established airlines. These may be start-ups or more efficient airlines from other regions. They under-price the established competitors, and add capacity in anticipation of market share growth. For a period of time, they expect to operate with lower capacity utilization and to sacrifice profitability. Of course, the established players try to defend their position through more aggressive pricing, cost reduction campaigns, and also a willingness to sacrifice profitability.

The principal cause-effect relationships changed by market liberalization are summarized in Figure 7. The effect of load factors on fares is stronger, and the effects of expenses and profitability are weaker. Why? Because new entrants price relative to the established players (attempting to under-price them) rather than based on their
own costs. And because all players are more willing to sacrifice profitability as part of their offensive and defensive strategies. The expense drivers themselves are changed by the entry of lower cost competitors and the cost-cutting efforts of the established airlines. This is captured by the links to expenses from demand and current fleet. And as noted before, the effect of airline profitability on aircraft orders is reduced.

The initial effect of market liberalization is to de-stabilize the airline industry. The negative feedback structure that controls capacity growth is weakened, and excess capacity is almost inevitable. What happens next depends on the barriers to exit. If the normal industrial ecology is allowed to work, there will be a shake-out and consolidation of the industry along with rationalization of capacity. In the mid-term, it is possible for an oligopoly to emerge and for the

Figure 6
GENERIC MARKET MODEL
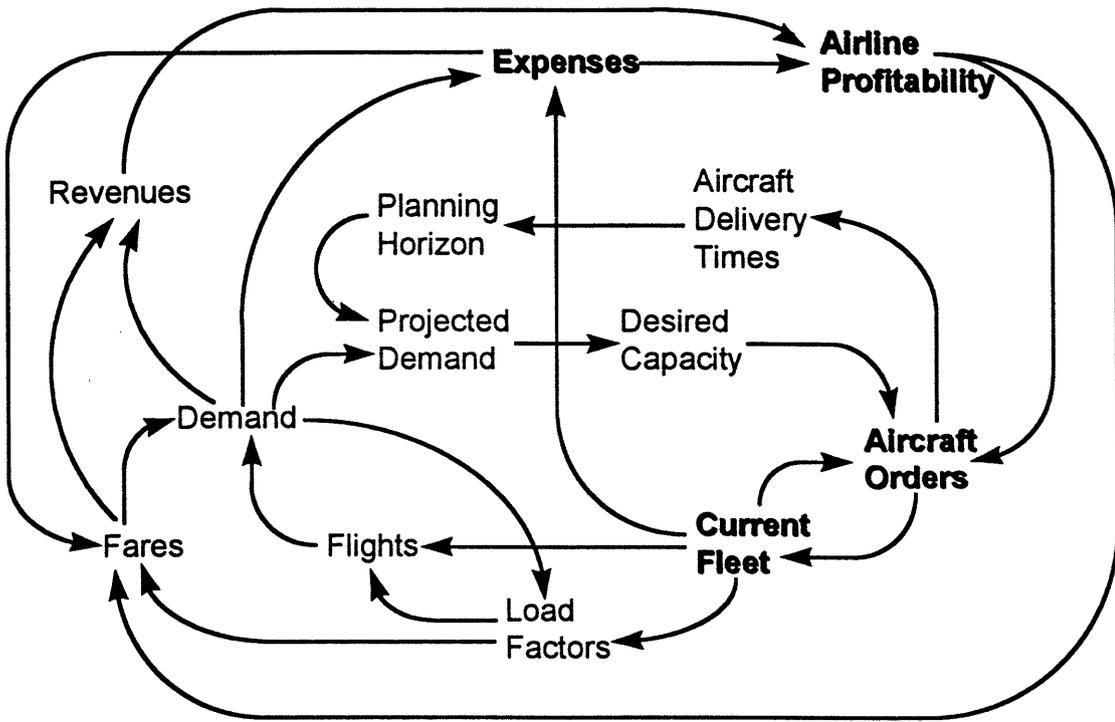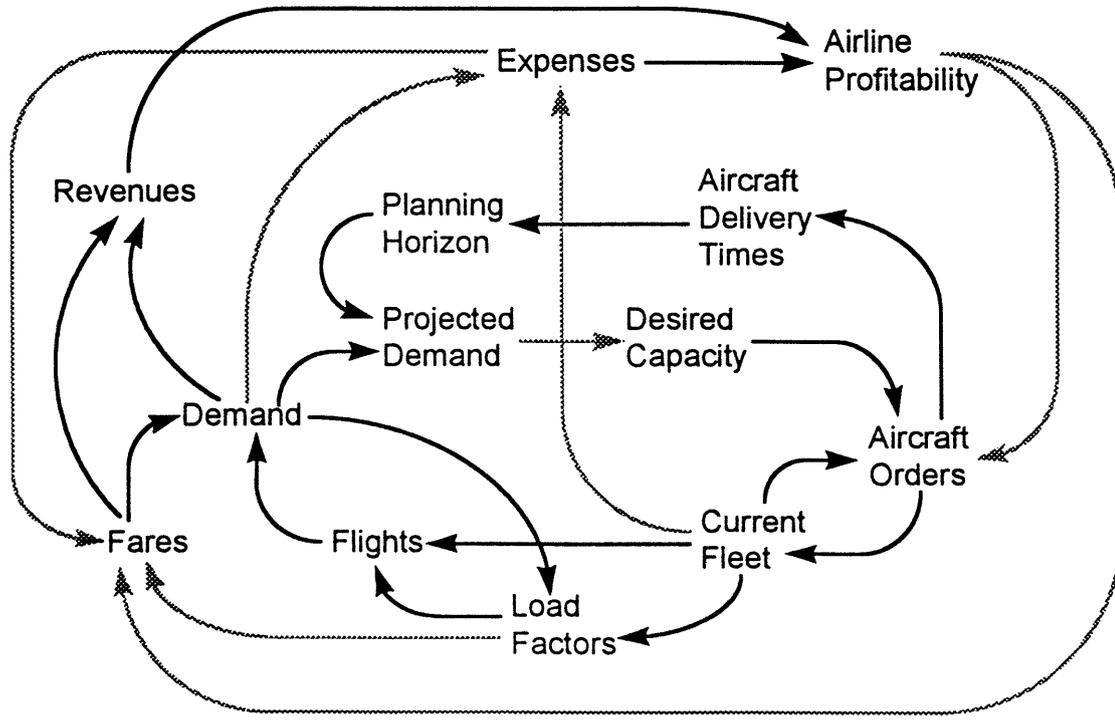**Lapse of Financial Constraints**

Figure 7
GENERIC MARKET MODEL
Effects of Liberalization

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market to go through an extended period of stability. If, however, the ecological solution is impeded by institutional barriers and governmental support excess capacity will persist indefinitely and the market will steadily commoditize.

Please recall that commoditization denotes the development of a competitive environment where:

- Product differentiation is very difficult;

- Customer loyalty and brand values are low;

- Competition is based primarily on price; and

- Sustainable advantage comes from cost (and sometimes quality) leadership.

Commoditization is driven by excess capacity.

Over an extended period of time, e.g., 10-20 years, the structures highlighted in Figures 3-7 and resulting dynamic change the character of air transportation markets. The cycles of "boom and bust" will grow increasingly severe and irregular. One should expect an "Andean landscape" of dramatic peaks separated by very wide valleys. This is in part because of asymmetries, i.e., it now is much easier to expand capacity than to reduce it. It also results from how markets change as the mature, i.e., demand growth becomes increasingly driven by the decline of fares, which happens in irregular waves because of cycles in capacity loading.

One should expect commoditization to spread progressively from one regional market to another. This is because excess capacity will move from markets where commoditization is more advanced into markets that offer relatively higher margins and demand growth, e.g., from the U.S. to Asia. Market liberalization will make such capacity movements more and more feasible. Finally, one should expect the return on capital in the airline industry to erode. This is because the periods with excess capacity will be longer than the periods where capacity is "right." Under these circumstances, the long-term trend in margins will be downward.

The following Appendices provides a much more detailed look at the model's structure, assumptions, and inputs. An equation-level flow diagram of the model can be found in Appendix 1. Its equations are included in Appendix 2.

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Appendix 1

Equation Level Diagram of the Generic Market Model
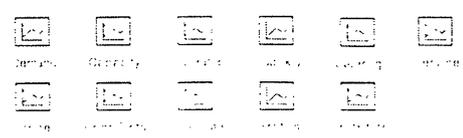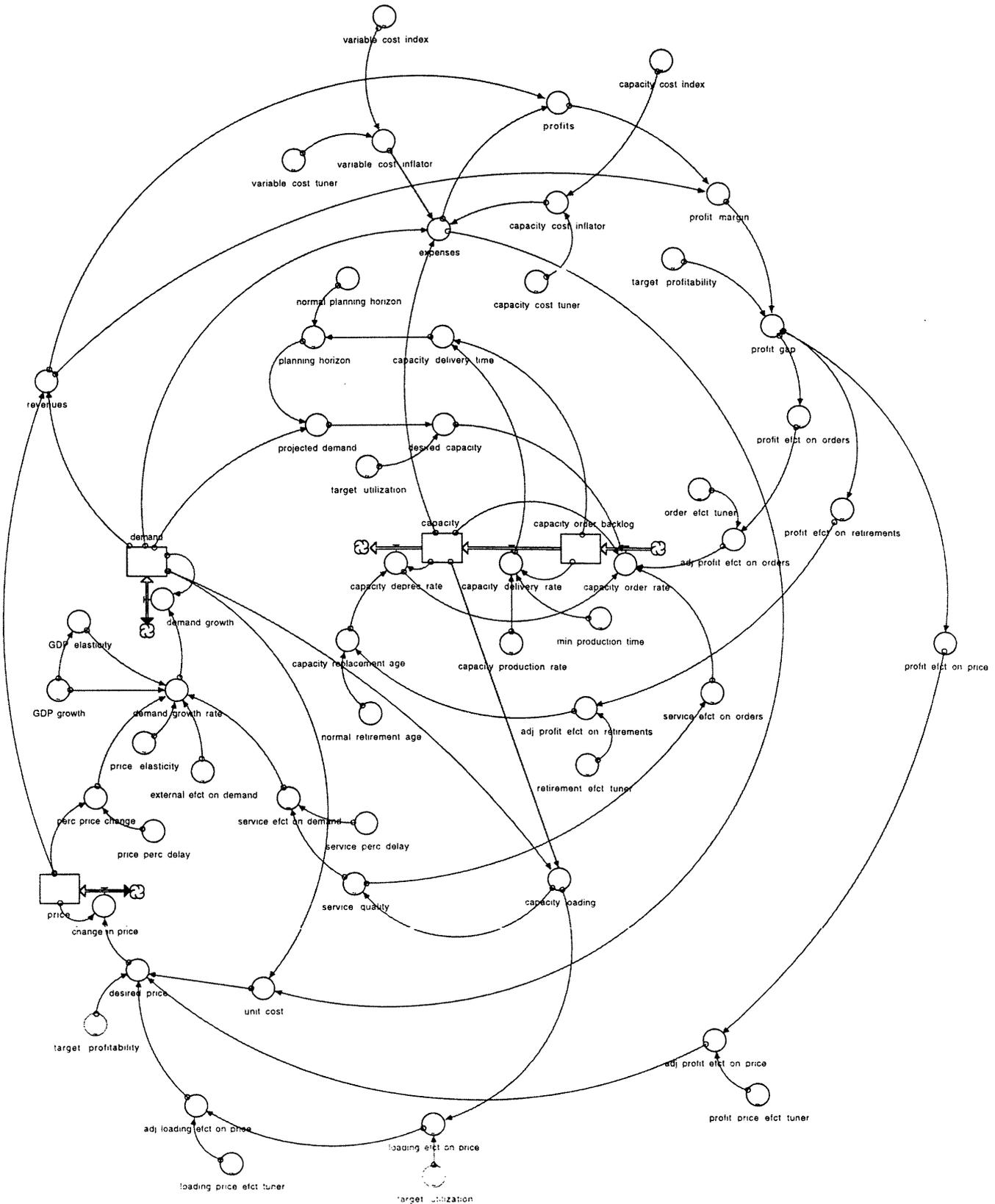
Appendix 2

"iThink" Equations of the Generic Market Model

☐ capacity(t) = capacity(t - dt) + (capacity_delivery_rate - capacity_deprec_rate) * dt
INIT capacity = 9.4e11
INFLOWS:
⇞ capacity_delivery_rate =
MIN(capacity_production_rate*1e11,capacity_order_backlog/min_production_time)
OUTFLOWS:
⇞ capacity_deprec_rate = capacity/capacity_replacement_age
☐ capacity_order_backlog(t) = capacity_order_backlog(t - dt) + (capacity_order_rate -
capacity_delivery_rate) * dt
INIT capacity_order_backlog = 2.54e11
INFLOWS:
⇞ capacity_order_rate =
(((desired_capacity-capacity)/2)+capacity_deprec_rate)*adj_profit_efct_on_orders*service
_efct_on_orders
OUTFLOWS:
⇞ capacity_delivery_rate =
MIN(capacity_production_rate*1e11,capacity_order_backlog/min_production_time)
☐ demand(t) = demand(t - dt) + (demand_growth) * dt
INIT demand = 6.1e11
INFLOWS:
⇌ demand_growth = demand*demand_growth_rate
☐ price(t) = price(t - dt) + (change_in_price) * dt
INIT price = 0.069
INFLOWS:
⇌ change_in_price = (desired_price-price)/1.0
○ adj_loading_efct_on_price =
loading_efct_on_price+((1-loading_efct_on_price)*(1-loading_price_efct_tuner))
○ adj_profit_efct_on_orders =
profit_efct_on_orders+((1-profit_efct_on_orders)*(1-order_efct_tuner))
○ adj_profit_efct_on_price =
profit_efct_on_price+((1-profit_efct_on_price)*(1-profit_price_efct_tuner))
○ adj_profit_efct_on_retirements =
profit_efct_on_retirements+((1-profit_efct_on_retirements)*(1-retirement_efct_tuner))
○ capacity_cost_inflator = capacity_cost_index+((1-capacity_cost_index)*(1-capacity_cost_tuner))
○ capacity_delivery_time = capacity_order_backlog/capacity_delivery_rate
○ capacity_loading = demand/capacity
○ capacity_replacement_age = normal_retirement_age*adj_profit_efct_on_retirements
○ demand_growth_rate =
(0.015+(SMTH1(GDP_growth,0.5)*GDP_elasticity)+(perc_price_change*price_elasticity))*service
_efct_on_demand*external_efct_on_demand
○ desired_capacity = projected_demand/target_utilization
○ desired_price =
(SMTH1(unit_cost,1.0)/(1.0-target_profitability))*adj_loading_efct_on_price*adj_profit_efct_on_p
rice
○ expenses = (demand*0.048*variable_cost_inflator)+(capacity*0.0135*capacity_cost_inflator)
○ GDP_elasticity = IF (SMTH1(GDP_growth,0.5)>0)
THEN (1.0)
ELSE (0.3)
○ normal_planning_horizon = 3
○ normal_retirement_age = 20

○ perc_price_change = SMTH1(TREND(price,1),price_perc_delay)

○ price_perc_delay = 0.25

○ profits = revenues-expenses

○ profit_gap = SMTH1(profit_margin,1.5,0.001)/target_profitability

○ profit_margin = profits/revenues

○ projected_demand = FORCST(demand,1.0,planning_horizon,0.04)

○ revenues = demand*price

○ service_perc_delay = 2.0

○ unit_cost = expenses/demand

○ variable_cost_inflator = variable_cost_index+((1-variable_cost_index)*(1-variable_cost_tuner))

⊘ capacity_cost_index = GRAPH(TIME)
(1985, 1.00), (1987, 1.10), (1989, 1.22), (1991, 1.34), (1993, 1.48), (1995, 1.63), (1997, 1.80), (1999, 1.98), (2001, 2.18), (2003, 2.41), (2005, 2.65)

⊘ capacity_cost_tuner = GRAPH(TIME)
(1985, 1.00), (1987, 1.00), (1989, 1.00), (1991, 1.00), (1993, 1.00), (1995, 1.00), (1997, 1.00), (1999, 1.00), (2001, 1.00), (2003, 1.00), (2005, 1.00)

⊘ capacity_production_rate = GRAPH(TIME)
(1985, 0.85), (1987, 0.85), (1989, 0.85), (1991, 0.85), (1993, 1.10), (1995, 1.00), (1997, 1.00), (1999, 1.10), (2001, 1.20), (2003, 1.30), (2005, 1.30)

⊘ external_efct_on_demand = GRAPH(TIME)
(1985, 1.00), (1986, 1.00), (1987, 1.00), (1988, 1.00), (1989, 1.00), (1990, 0.95), (1991, 1.04), (1992, 1.01), (1993, 1.00), (1994, 1.00), (1995, 1.00), (1996, 1.00), (1997, 1.00), (1998, 1.00), (1999, 1.00), (2000, 1.00), (2001, 1.00), (2002, 1.00), (2003, 1.00), (2004, 1.00), (2005, 1.00)

⊘ GDP_growth = GRAPH(TIME)
(1984, 0.023), (1986, 0.034), (1986, 0.036), (1988, 0.03), (1988, 0.028), (1990, 0.011), (1990, -0.008), (1992, 0.024), (1992, 0.027), (1994, 0.032), (1994, 0.027), (1996, 0.022), (1996, 0.026), (1998, 0.026), (1998, 0.026), (2000, 0.026), (2000, 0.03), (2002, 0.03), (2002, 0.03), (2004, 0.03), (2004, 0.03)

⊘ loading_efct_on_price = GRAPH(SMTH1(capacity_loading/target_utilization,1.0))
(0.75, 0.7), (0.8, 0.82), (0.85, 0.9), (0.9, 0.95), (0.95, 0.98), (1.00, 1.00), (1.05, 1.02), (1.10, 1.05), (1.15, 1.10), (1.20, 1.18), (1.25, 1.30)

⊘ loading_price_efct_tuner = GRAPH(TIME)
(1985, 1.00), (1987, 1.00), (1989, 1.00), (1991, 1.20), (1993, 1.40), (1995, 1.60), (1997, 1.80), (1999, 2.00), (2001, 2.00), (2003, 2.00), (2005, 2.00)

⊘ min_production_time = GRAPH(TIME)
(1985, 3.00), (1987, 3.00), (1989, 3.00), (1991, 3.00), (1993, 3.00), (1995, 3.00), (1997, 3.00), (1999, 3.00), (2001, 3.00), (2003, 3.00), (2005, 3.00)

⊘ order_efct_tuner = GRAPH(TIME)
(1985, 1.00), (1987, 1.00), (1989, 1.00), (1991, 1.00), (1993, 1.00), (1995, 1.00), (1997, 1.00), (1999, 1.00), (2001, 1.00), (2003, 1.00), (2005, 1.00)

⊘ planning_horizon = GRAPH(capacity_delivery_time/normal_planning_horizon)
(0.00, 0.75), (0.5, 2.00), (1.00, 3.00), (1.50, 3.90), (2.00, 4.70), (2.50, 5.40), (3.00, 6.00), (3.50, 6.50), (4.00, 6.90), (4.50, 7.30), (5.00, 7.50)

⊘ price_elasticity = GRAPH(TIME)
(1985, -0.66), (1987, -0.66), (1989, -0.66), (1991, -0.66), (1993, -0.66), (1995, -0.66), (1997, -0.66), (1999, -0.66), (2001, -0.66), (2003, -0.66), (2005, -0.66)

⊘ profit_efct_on_orders = GRAPH(SMTH1(profit_gap,3.0))
(0.00, 0.25), (0.1, 0.27), (0.2, 0.32), (0.3, 0.4), (0.4, 0.52), (0.5, 0.7), (0.6, 0.82), (0.7, 0.9), (0.8, 0.95), (0.9, 0.98), (1, 1.00)

⊘ profit_efct_on_price = GRAPH(SMTH1(profit_gap,1.0))
(0.00, 1.15), (0.2, 1.10), (0.4, 1.06), (0.6, 1.03), (0.8, 1.01), (1, 1.00), (1.20, 0.99), (1.40, 0.97), (1.60, 0.94), (1.80, 0.9), (2.00, 0.85)

⊘ profit_efct_on_retirements = GRAPH(SMTH1(profit_gap,2.0))
(0.00, 1.50), (0.1, 1.36), (0.2, 1.26), (0.3, 1.20), (0.4, 1.14), (0.5, 1.10), (0.6, 1.06), (0.7, 1.04), (0.8, 1.02), (0.9, 1.01), (1, 1.00)

⊘ profit_price_efct_tuner = GRAPH(TIME)
(1985, 1.00), (1987, 1.00), (1989, 1.00), (1991, 1.00), (1993, 1.00), (1995, 1.00), (1997, 1.00), (1999, 1.00), (2001, 1.00), (2003, 1.00), (2005, 1.00)

⊘ retirement_efct_tuner = GRAPH(TIME)
(1985, 1.00), (1987, 1.00), (1989, 1.00), (1991, 1.00), (1993, 1.00), (1995, 1.00), (1997, 1.00), (1999, 1.00), (2001, 1.00), (2003, 1.00), (2005, 1.00)

⊘ service_efct_on_demand = GRAPH(SMTH1(service_quality,service_perc_delay))
(0.4, 0.5), (0.5, 0.7), (0.6, 0.82), (0.7, 0.9), (0.8, 0.95), (0.9, 0.98), (1, 1.00), (1.10, 1.02), (1.20, 1.05)

⊘ service_efct_on_orders = GRAPH(SMTH1(service_quality,2))
(0.00, 1.65), (0.1, 1.54), (0.2, 1.44), (0.3, 1.35), (0.4, 1.27), (0.5, 1.20), (0.6, 1.14), (0.7, 1.09), (0.8, 1.05), (0.9, 1.02), (1, 1.00)

⊘ service_quality = GRAPH(capacity_loading)
(0.00, 1.50), (0.1, 1.30), (0.2, 1.18), (0.3, 1.10), (0.4, 1.05), (0.5, 1.02), (0.6, 1.00), (0.7, 0.98), (0.8, 0.95), (0.9, 0.85), (1, 0.7)

⊘ target_profitability = GRAPH(TIME)
(1985, 0.001), (1987, 0.02), (1989, 0.035), (1991, 0.05), (1993, 0.06), (1995, 0.07), (1997, 0.08), (1999, 0.09), (2001, 0.1), (2003, 0.1), (2005, 0.1)

⊘ target_utilization = GRAPH(TIME)
(1985, 0.65), (1987, 0.65), (1989, 0.65), (1991, 0.65), (1993, 0.66), (1995, 0.68), (1997, 0.7), (1999, 0.72), (2001, 0.74), (2003, 0.75), (2005, 0.75)

⊘ variable_cost_index = GRAPH(TIME)
(1985, 1.00), (1986, 0.95), (1987, 0.9), (1988, 0.86), (1989, 0.88), (1990, 0.91), (1991, 0.94), (1992, 0.96), (1993, 0.99), (1994, 0.91), (1995, 0.84), (1996, 0.77), (1997, 0.8), (1998, 0.82), (1999, 0.85), (2000, 0.87), (2001, 0.9), (2002, 0.92), (2003, 0.95), (2004, 0.98), (2005, 1.01)

⊘ variable_cost_tuner = GRAPH(TIME)
(1985, 1.00), (1987, 1.00), (1989, 1.00), (1991, 1.00), (1993, 1.00), (1995, 1.00), (1997, 1.00), (1999, 1.00), (2001, 1.00), (2003, 1.00), (2005, 1.00)