

Symbiotic Strategies in Enterprise Ecology: Modeling Commercial Aviation as an Enterprise of Enterprises

By

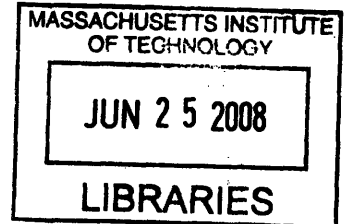
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By

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Abstract

We investigate the effectiveness of strategic alternatives that are designed to dampen the cyclicity manifest in the commercial aviation (CA)-related industries. In this research we introduce the conceptual framework of Enterprise of Enterprises (EoE) as an extension and special case of a System of Systems, to facilitate the design of strategic alternatives in an enterprise ecosystem characterized by loosely coupled enterprises. The constituent enterprises in an EoE exhibit managerial and operational independence and have diverse value functions that are often viewed by the enterprises as zero-sum games.

We argue that this may not always be the case; for example, in the CA EoE both airline and airframe manufacturers constituents would benefit from a steadier influx of aircraft that counters the current situation that is characterized by relatively stable demand growth rate for air travel while airline profitability and aircraft ordering fluctuate intensely. A strategic alternative geared towards this EoE-wide desired state is “symbiotic”.

In order to identify such strategies, we use the EoE framework to analyze the CA-related industries and to specify their local value functions and the salient interfaces among them based on an extensive review of the literature on commercial aviation. We develop working hypotheses about the driving mechanisms of the cycle in the CA EoE informed by the literature on economy-wide and supply chain cyclicity. To test these hypotheses, we extend a system dynamics model of commercial aviation.

After testing several individual strategic alternatives, we find that capacity management is key to cycle moderation. We then compare two diverse, non-collusive ways for capacity management: faster aircraft deliveries and semi-fixed production schedules generated by long-term forecasts. While both are promising, only the latter alternative is shown to be Pareto optimal. We also examine the potential synergistic effects from combining more than one strategic alternatives for which we also discuss implementation implications.

The EoE framework and some of our findings can be applicable and generalizable to other industries facing intense cyclical behavior.

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*To those most vulnerable to the swings of business cycles:
Industrial workers and their families*

*To Georgeta Vidican
Her presence and ability to manage the swings of my moods
made this effort enjoyable*

Acknowledgments

“This dissertation is a result of a collective effort.” I used to ascribe this attribution commonly found in other theses to the modesty of the author. This is not the case anymore, as I have learned the truth of this statement firsthand; this dissertation is *indeed* the result of a collective effort. Of course the usual caveat applies: any remaining oversights or omissions are solely the responsibility of the author.

This work would not have been possible without input and continuous support from my committee. I would like to thank Prof. Joseph Sussman, my advisor and committee chair, for providing intellectual challenges, questioning my assumptions, guiding and supporting me when necessary. All three committee members, Dr. Kirkor Bozdogan, Prof. Olivier de Weck and Dr. Henry Weil, were instrumental in focusing my efforts on key aspects of the problem at hand and in providing insights and ideas based on their diverse experience at key stages of this work. In addition, Dr. Weil assisted in the development, calibration and validation of the system dynamics model that we developed using some of his prior work as a starting point. I would also like to acknowledge Prof. Annalisa Weigel for the discussions we had while this research was still under formulation.

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Chapter 1 Introduction

Enterprises do not operate in a vacuum. The actions of enterprises impact the industries they are in and the industries related to their value chain. This interdependence is not confined to pricing but extends to longer term strategic decisions. In some cases information about the competitor actions is only inferred and far from perfect, but even in cases where available information is adequate the decisions made do not necessarily align with a rational expectations framework as they are influenced by intuition, strategic gaming, and human psychology. In other words, all the central assumptions of the perfect market theory are challenged in varying degrees for large enterprise systems.

The airline industry and the air transportation value chain is no exception. The interdependence and strategic interactions between the enterprises active in this system combined with delays of varying length between an action and its consequences create a volatile environment which is characterized by cyclical¹ evident in profitability, employment, capacity growth rates, order rates, utilization and other enterprise metrics across the echelons of the value chain.

When an entire industry or the economy as a whole enters a protracted recession period with operating losses, this is an indicator of economic inefficiencies and societal problems. Economic inefficiencies stem from misallocation of capital and overinvestment while societal problems arise from painful employment adjustments that range from income cutbacks to job losses and overall insecurity. These non-seasonal oscillations are not confined to air transportation but they have been identified in diverse industries and the economy as a whole and they are generally referred to as *business cycles*.

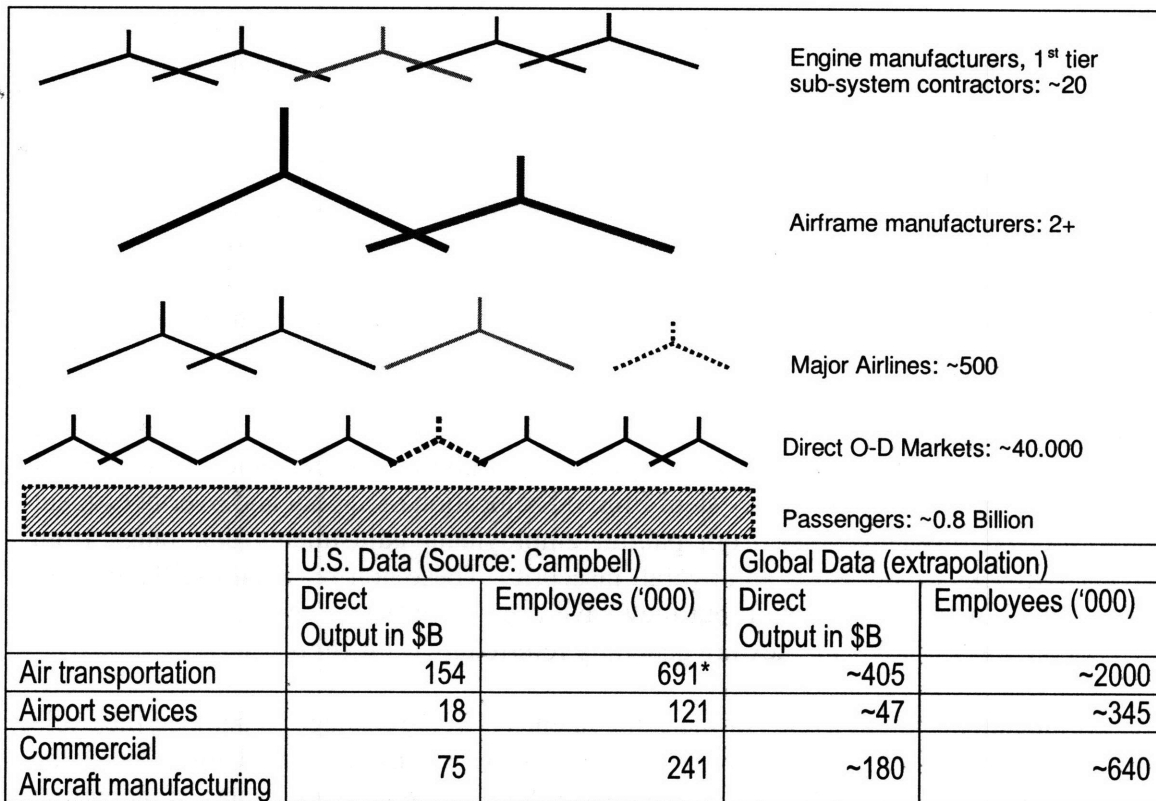
Not all industries exhibit cycles of the same intensity. Some manage to dampen the cycle and stabilize while for others there is a persistent low intensity cycle. Unlike them, the industries connected to air transportation have exhibited intensifying cycles of increasing amplitude and severity. This dissertation aims to (i) examine and understand the driving mechanisms of the business cycles in commercial aviation (CA), (ii) demonstrate that these cycles are costly, and (iii) identify the driving mechanisms for their generation and ways – strategic alternatives – to dampen these cycles.

In this introductory chapter we discuss our motivation for undertaking this study. Next we define testable hypotheses that direct our effort and discuss the methodological approach that we followed. Finally, we trace the structure of the dissertation summarizing the key points of each chapter.

¹ These non-seasonal oscillations do not exhibit a precise period and therefore the term cycle is not applied precisely when used to describe them. Nevertheless the term business cycle has prevailed in common usage.

1.1 Background and Motivation

A report commissioned by the Air Transport Association estimated that commercial aviation generated almost 6% of the US gross economic output including direct, indirect, and induced economic activity and employed about 8.8% of the total U.S. active workforce. Figure 1-1 provides a more detailed snapshot of the scale of operations for commercial aviation. Not only is its size substantial, but also the rate of its growth has been outpacing average economic growth rate significantly.



* Approximately 150K part-time (DOT reported data)

Figure 1-1 Relative Economic Output and Employment for the U.S. and Global Commercial Aviation
(Data Sources: (CAMPBELL 2006) and author calculations)

Air transportation relies on the existence of large-scale infrastructure (e.g. airports, airport access connectors, air traffic control system) and the manufacturing and operation of large numbers of complex technical artifacts (the modern commercial jetliners). In order for this level of technical complexity to be gainfully and safely constructed, manufactured, deployed, and operated, large-scale organizational capabilities are required.

From a high level view, commercial aviation can be considered as a value chain that involves operation of aircraft, ownership and maintenance of aircraft, and aircraft production. While each of these activities can be broken down into a large number of smaller value-adding activities, this view serves for delineating the boundaries of the enterprises involved as shown in Figure 1-2.

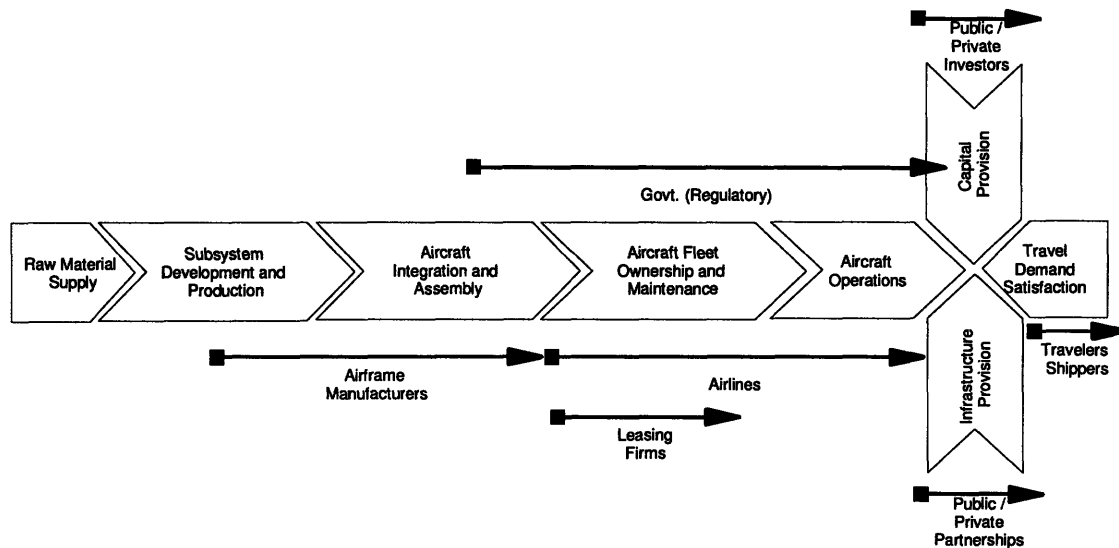


Figure 1-2 High level view of the commercial aviation value chain and the enterprise types involved

As mentioned previously, the commercial aviation enterprise has exhibited a tendency to oscillate. While the demand growth rate has been tracking and reacting to the global economic conditions (tight correlation with global gross domestic product (GDP) as shown in Fig. 1-3a), the net profitability of the global airline industry has been oscillating with increasing amplitude both in real and nominal terms (Fig. 1-3b). *These oscillations in profitability of airlines are transmitted upstream in the value chain as the orders placed for new aircraft are highly correlated to profitability fluctuations* (Fig. 1-3c).

Conventional wisdom attributes the cyclical behavior to factors as external to the commercial aviation enterprise. In reality, as we discuss in Chapters 6-8 and 10, the industry structure is a strong factor that endogenously can create and amplify cycles by the collective reactions of the individual enterprises. Given the different types of stakeholders involved and their numbers collective action to mitigate the cycles would pose significant coordination problems that have proven seemingly insurmountable for the past three decades.

Cyclical behavior in the airline industry has been identified by Jiang and Hansman (2004) and Weil (1996) among others. Similar instabilities of varying degree have been observed in shipping Dikos (2004), telecommunications, oil refineries (Weil and Stoughton 1998), and other industrial markets.

In a manifestation of the ‘bullwhip effect’ observed in supply chains, the cyclical instability faced by airlines increases the severity of variation in the demand that is faced by the airframe manufacturers. While the cycle can be observed *ipso facto*, attempts to predict it are faced with significant **uncertainty** and high stakes since erroneous forecasts may result at the very least in loss of ground to competitors. Given the unpredictability and high stakes, cyclical instabilities are associated with concomitant costs.

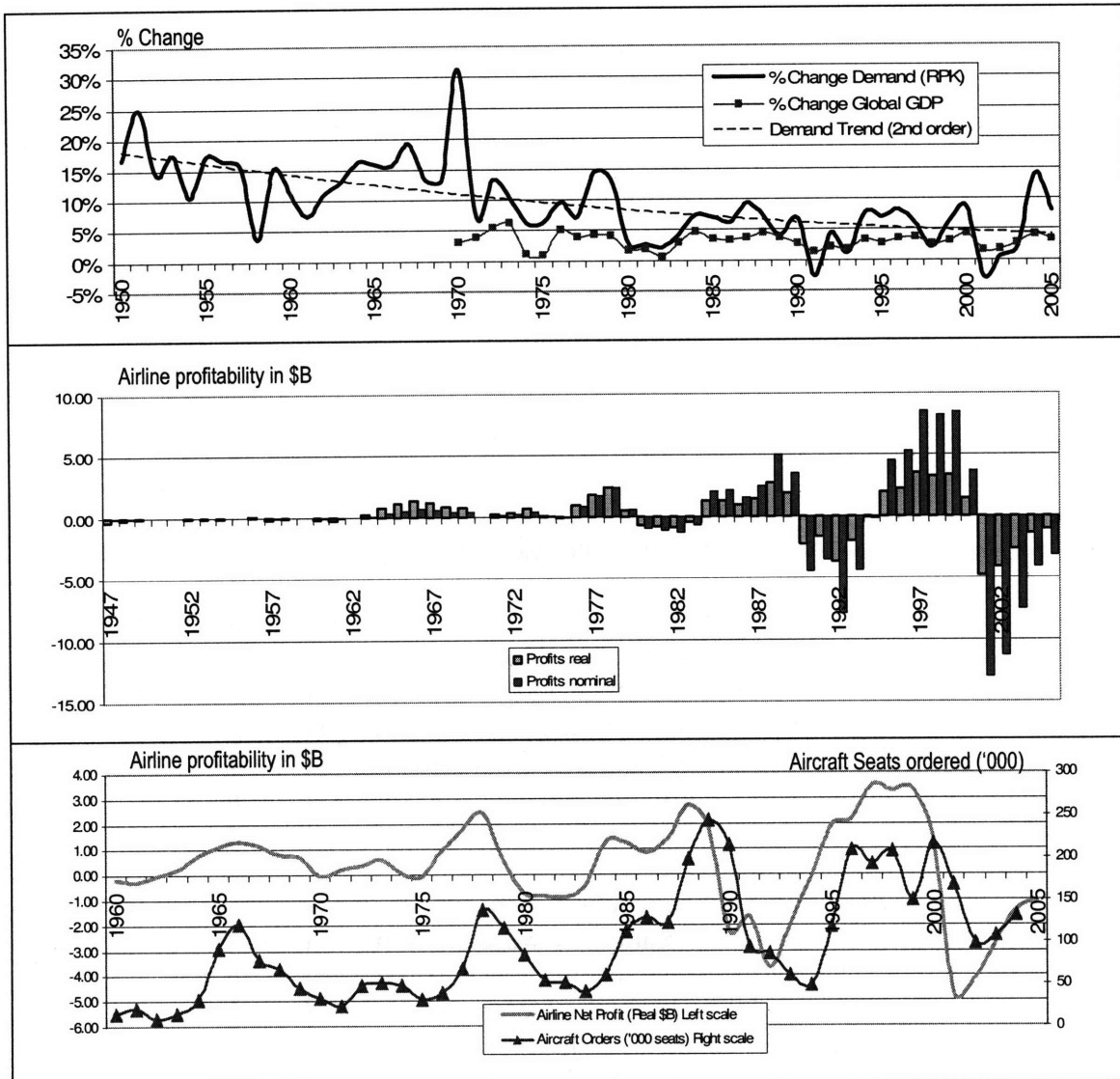


Figure 1-3 Evidence of cyclicity in demand growth rates (a), net real and nominal profitability (b), and aircraft order rates (c) (for sources and additional discussion see Ch. 3)

For the private sector, highly cyclical profitability has implications that range from liquidity constraints to vulnerabilities to bankruptcy, hostile take-over, or market-share loss. Attempts to adjust by following the cycle involve capacity adjustments through employee hire/fire cycles which in turn can result in loss of tacit knowledge ('institutional forgetting') and management-labor tensions. On the positive extreme of the cycle, implications include unsustainable growth, upward creeping unit costs, overestimation of future capacity requirements, and spurring a wave of new entrants. The society at large is also affected due to labor distress, tax payer assumption of defaults, and a general sub-optimal use of resources.

1.2 Thesis Objective and Research Questions

The contemporary commercial aviation industry seems bound to the ‘paradox’ described summarily above: it is comprised of a set of industries with a relatively small number of constituent enterprises that individually have the ability to make carefully scrutinized strategic decisions and yet they collectively create an unstable oscillatory environment.

Given the perceived negative implications of these cycles for commercial aviation, this work was designed to investigate the existence, severity, and root causal mechanisms of the cycles that seem to dominate the commercial aviation enterprise and identify strategies – we call these “bundles of strategic alternatives” – that could lead, cooperatively if need be, to a more stable and profitable business environment for the enterprises involved and ideally a better quality of service for the end consumer.

The above objectives can be articulated in the form of the following research questions:

- Q1. How is cyclicity manifested in commercial aviation? What are the impacts from cyclicity in commercial aviation?
- Q2. What are the salient causal mechanisms that induce the cyclical behavior in commercial aviation?
- Q3. What are implementable strategic alternatives for dampening that cyclicity and what are their benefits?

If stated in the form of hypotheses they could be phrased as following:

- H1. Cyclicity characterizes the Commercial Aviation EoE.
- H2. Cyclicity is costly to the industries involved and society at large.
- H3. There are identifiable and feasible strategies that can dampen the cycles in a long-term Pareto-efficient manner.

As part of H3, we examine a hypothesis proposed by Womack and Jones (Womack and Jones 1996). They anticipate dampening of the business cycle in a given industry by widespread adoption of a management practice known as lean production. Focusing on just-in-time (JIT) satisfaction of demand across all echelons of a supply chain they suggest would be a sufficient dampener and no additional coordinated action of the stakeholders should be needed.

1.3 Methodological approach

The methodology that we followed to investigate our hypotheses centered on three iterative and interdependent approaches:

1. Qualitative understanding
2. Framework-based analysis
3. Quantitative modeling and experimental testing

Qualitative understanding was pursued by study of the available literature. We focused on the commercial aviation enterprise looking especially into the interfaces between the echelons of the CA value chain. In addition to this we reviewed the literature related to

business cycles in this and other industries and their supply chain counterpart (the ‘bullwhip effect’).

Framework-based Analysis

In order to better structure and use the knowledge gained from reviewing the literature and also to define the type of systems problem that we are addressing, we developed the concept of ‘**Enterprise of Enterprises**’ (EoE). The implication is that the amalgamation of enterprises comprising commercial aviation can be described as an enterprise but one with loosely coupled constituents that are enterprises in and of themselves. EoE extends the system-of-systems (SoS) concept and modifies the architecting heuristics developed for SoS to be applicable in the EoE context.

Defining our system at hand using the EoE concept helps in structuring the available information on commercial aviation and in distilling the interactions that appear to be the most promising candidate mechanisms for dampening the CA EoE cyclicity. Thus we identify the leverage points available for a possible re-architecture and the stakeholders that have both the interest and the capacity to pursue such change.

Quantitative Analysis

Direct experimentation on the CA EoE is, of course, not a feasible proposition and no known ‘natural’ experiments were extensive enough as to provide solid confirmation of the causal mechanisms of the cycles identified using the analysis above. As a result, in order to verify the effectiveness of strategic alternatives that aim to change the identified leverage points and quantify their actual impact in such a way as to make comparisons between alternatives possible, a quantitative model was necessary.

Business cycles have been studied primarily on an economy-wide level and more narrowly under the guise of the ‘bullwhip effect’ on a supply chain basis. The tools developed for the high level analysis include econometric regression analysis for testing hypotheses against data time series and theoretical general equilibrium macroeconomic models. These instruments were too broad for dynamically testing strategic alternatives followed by only a subset of the stakeholders in a system that changes dynamically. In the ‘bullwhip effect’ literature the system dynamics (SD) methodology had been applied to model cyclical behavior in a supply chain system. Furthermore, the CA EoE itself had been modeled on different levels of analysis using SD as well. In addition to these favorable points, SD is a flexible modeling tool and has the ability to model individual agent-behavior which was a desirable characteristic for our multi-stakeholder system.

Given the advantages outlined above, we developed a system dynamics model of the CA EoE that expanded on a previously published system dynamics model by Weil (1996). After extensive calibration and validation testing using historical data, we conducted a number of experiments using the SD model to test the modeled behavior of the CA EoE under different strategic alternatives and across a set of three future scenarios. This effort allowed us to rank the causal mechanisms of cyclicity in the CA EoE based on their relative impact by testing the related strategic alternatives. The ability to implement the most promising strategic alternatives was discussed using the EoE framework.

1.4 Dissertation structure overview

The sequence in the methodological approach as outlined above is reflected in the structure of the dissertation. In Chapters 2, 3, and 4 we present the key characteristics of the echelons of the commercial aviation value chain starting from demand generation from passengers and freight shippers and moving progressively upstream to airlines and aircraft manufacturers. The way that cyclicity is manifested and how it affects each echelon is discussed in parallel. Chapter 5 introduces the concept of Enterprises of Enterprises and applies it to commercial aviation (CA EoE). Chapter 6 reviews the literature on business cycles in economy-wide and supply chain-specific settings. Chapter 7 applies the themes and mechanisms of cycles, as identified in Chapter 6, to the CA EoE and proposes stakeholder-specific sets of strategic alternatives for dampening the CA EoE cyclicity. Moving towards experimental testing of these alternatives, Chapter 8 reviews the methodologies that have been used for enterprise modeling and may be applicable for our purposes, discusses their comparative advantages and disadvantages, and identifies the reasons that qualify system dynamics as more appropriate. Chapter 9 describes the SD model of the CA EoE in detail and presents the verification and validation process that we followed. In Chapter 10, we execute experimental comparisons using the SD model to identify the salient mechanisms of cyclicity in the CA EoE and test the effectiveness of relevant strategic alternatives (as outlined in Chapter 7). The implementability of these alternatives is also discussed and recommendations are made based on our findings. Finally, Chapter 11 summarizes the findings and conclusions and indicates directions for further research to supplement our findings.

Chapters 2-4 are intended to have a dual role in the dissertation: on one hand they introduce the basics and the nuances of the key commercial aviation stakeholders and what cyclicity means to them, and on the other hand these chapters form the knowledge-base on which the CA EoE representation and the SD model rest.

With this in mind, in **Chapter 2** we introduce how demand for air transportation is formed, how is it measured, the different types of consumers (passengers and shippers), how they can be represented with different elasticities of demand, and what are the key attributes that make air transportation appealing to consumers (passengers and shippers) compared to competing modes. We look at how demand for air transportation evolved over time, globally and in different regional markets. Finally, we note that given the nature of travel (i.e. meeting the need to transfer from a given origin to a given destination or O-D pair) competition in transportation always boils down to the ability to service this O-D market and therefore (as we discuss further in Ch. 3 on contestability) measures of nation-wide industry concentration are less accurate predictors of competition that in non-transport industries.

Along the same lines, **Chapter 3** focuses on airlines; their fundamental operations, performance metrics, cost and revenue structures. The important for airline competition concept of yield management is introduced along with the strategic choices airlines face in network planning and fleet composition. The different types of airlines are introduced with attention paid to the relative differences in the business models between incumbent legacy carriers (including new full-service carriers) and the low-cost carriers (LCCs) that

in deregulated markets increasingly gain market share. Alliances, legacy carrier restructuring, and the realities of network economies that precludes dominance of the point-to-point network structure (favored by LCCs) indicate that in the near future, airline business structure would not be dominated by LCCs. They should be expected to gain in market share but the dominant force would likely be consolidated alliances. In discussing the impact of cyclicalities we conclude that if pure economic measures are used, airlines would not have added value to their investors (practically zero real return) which is an absurd state. Airlines did add enormous value to the global economy but have not been rewarded for that contribution due to the cyclical characteristic of their industry. We also note the observation by Jiang and Hansman (2004) that the oscillations in that cycle have been amplifying after deregulation.

Chapter 4 is the final chapter in the industry background sequence. It reviews how the modern duopoly market for large commercial aircraft (LCA) dominated entirely by Boeing, a U.S. based manufacturer with a history going back to the beginning of air transportation, and Airbus, a European consortium with an unlikely collaborative structure. We discuss Airbus's ascent and how it managed to overcome advantages held by the dominant manufacturer. Advantages that are particularly strong in aircraft manufacturing include economies of scale and scope, steep learning curves, and vendor lock-in effects. Because of these, airframe manufacturers have an incentive to inflate their order book and thus gain an edge over the competitor even if that means that they are accepting increasing shares of the aircraft ownership risks.

Strong collaboration in the extended enterprise, including suppliers, labor, government, and capital markets provides an advantage in increasing and retaining market share in this competitive, duopolistic market. As the aircraft performance envelope is pushed the financing requirements and risk involved in launching a new product line increase, making the aforementioned collaboration all the more critical. Airframe manufacturers are particularly affected by cyclicalities in the airline industry as they receive orders with an amplified variation and correlated to airline profitability, in a phenomenon that approximates closely the bullwhip effect discussed in Ch. 6. They react by changing their production rates with corresponding impacts on their employees and their position on the learning curve.

Having presented the characteristics of the commercial aviation-related industries in some detail, in **Chapter 5** we aim to integrate and organize this information into a coherent framework. Since the base component at this level of analysis is the enterprise, one section of Chapter 5 reviews the literature on the phenomenology of the enterprise as a complex system; i.e. ways to represent and interpret the actions and observed behavior of enterprises. Another section of Ch. 5 explores the concept of loosely-coupled system-of-systems (SoS) and the parallels with the system at hand. This leads to the introduction of the *Enterprise of Enterprises* (EoE) concept as a specific case of SoS. Commercial aviation is presented as an Enterprise of Enterprises (CA EoE) by identifying the local value functions of the constituents, the global value function of the EoE, and the major interfaces among the constituents. Based on the understanding of the value functions and potential influence over the system by the different constituents, we conclude that

airframe manufacturers given the consolidation of their industry and direct influence over capacity are the prime candidates to affect system-wide change. Airline alliances, capital markets in the form of “universal owners” and labor unions in both industries have the incentive but less of a potential to stabilize the CA EoE. We note the similarity of the CA EoE short-term equilibria with the “prisoner’s dilemma” game in which a collaborative outcome is more efficient but the incentive structure is lacking to promote it.

Chapter 6 looks closely into the business cycle literature in order to find the dominant explanations for such behavior in other industries. Not unexpectedly, the field proved to be rich with references dating back to the beginning of free markets. Industrial cycles in the economic literature have been identified in several industries with maritime shipping being a prominent one. While the period of these cycles could be longer than five years, the supply chain-specific literature noted early on that a very similar phenomenon can be found on the micro level in supply chains with periods that can be as short as weeks. The causal mechanisms and defining characteristic of industries that are prone to the cycle are summarized below²:

Triggers.

- *Macroeconomic cycle.*
- *Final demand and Input variability.*

Psychological Factors.

- *Bounded rationality.*
- *Supply chain discounting.* Underweighting of existing backlog.
- *Investment exuberance and strategic optimism.*

Industry Structure. These are endogenous characteristics of the supply chain that promote cyclicity or bullwhip volatility.

- *Imperfect financing and capital market volatility.*
- *Investment irreversibility and intertemporal substitution.*
- *Underutilized capacity and labor ‘hoarding’.*
- *Inventories.*
- *Technological change.*
- *Low barriers to entry, high barriers to exit.*

Supply chain characteristics. Imprecise forecasting and planning due to

- *lack of transparency* of downstream demand
- *Order batching*
- *Order gaming* due to constrained supply
- *Price fluctuations* (promotions, bulk discounts)
- *Strong seasonality* or network effects
- *Multiple supply chain echelons*

Interestingly, empirical evidence suggests that even in the absence of most of the procyclical factors, ‘bullwhip’ behaviors can still be observed Croson, Donohue et al. (2004).

² Detailed explanations for these are given in Section 6-4.

Using this list of potential causes of the business cycle, in the first part of **Chapter 7** we piece together a narrative description of the different mechanisms with which the CA EoE can generate and amplify cyclical behavior. The transition from a regulated to a deregulated environment is shown to be important but not necessary in producing cyclical behavior. This narrative is then codified into specific stakeholder actions as cycle-inducing mechanisms. Based on these observations, strategic alternatives that target these behaviors are generated in the last part of Chapter 7. The intent of investigating these strategies is to promote “symbiosis.” We define **symbiotic strategy** as an *action taken by one or more EoE constituents that improves aggregate EoE system performance over a long-term horizon. Ideally, this action is Pareto efficient and not detrimental to the short-term interests of the actor(s) but not necessarily so.*

A sample of such strategies identified for the CA EoE is given below³ :

- Supply chain visibility
- Information sharing
- Uncertainty management
- Lead time reductions
- Output stabilization
- Capacity constraining
- Price stabilization (demand management)
- Technical/operational product improvements
- Extensive use of leasing (for capacity flexibility)
- Off-cyclical behavior (buy low, sell high)
- Capacity constraining
- Less aggressive revenue management
- Mergers
- Subsidies / long-term financing
- Total subsidy withdrawal
- Re-regulation (price or market capping)

Having analyzed CA EoE in qualitative perspectives, we need to test our hypothesis with regard to the effectiveness of these strategic alternatives. As direct experimentation is prohibitive and our mental models could not fully anticipate the impacts of the strategies on the various stakeholders and their corresponding reactions, quantitative modeling was deemed necessary. In **Chapter 8** we review the different methods available for modeling enterprise systems and their strengths and weaknesses. Extensive mention is given to previous efforts to model the parts or the whole of the CA EoE. After examination of modeling methods, we note that qualitative analysis that makes use of mental models is a necessary step in the application of quantitative methods. We conclude that the desired model for our purposes is to create a system dynamics model that allows for agent differentiation and is supported, where necessary, by application of econometrics and game theory.

³ The constituent enterprises that can upon these strategies and more details about them are given in Chapter 7.

In **Chapter 9** we present the basic structure of the system dynamics CA EoE model that we built to perform quantitative experimentation. The calibration, verification, and validation techniques that were employed to ensure that the model is a useful simulation of reality for our purposes are also described.

Finally, in **Chapter 10** the SD model of the CA EoE is used to test the different proposed causal mechanisms of the cycles and their corresponding strategic alternatives. The model simulated a period of 40 years, starting in 1984 and extending 17 years into the future. In order to take different possible futures into account, three scenarios were used that were developed based on plausible alternate hypotheses that echoed similar exercises found in the literature. Based on these experiments we confirm our hypothesis that exogenous factors contribute only to a limited degree in the generation and propagation of cycles in the CA EoE and that endogenous mechanisms are critical. We find that among the endogenous mechanisms, correcting for the apparent collective disregard by airlines of the industry-wide aircraft backlog when ordering has the greatest impact on reducing the cycles. The other mechanism that has similar impact requires the reversal of the effects of deregulation in the competitive environment. Given that the latter option is unpalatable because it would relieve any competitive pressures on operating costs and is also politically infeasible, we focus our attention on the former and develop a composite strategy that would not require collusive behavior between manufacturers but would require a paradigm shifting move of one manufacturer to becoming an on-demand aircraft service provider thus optimizing over the aircraft's operational lifecycle. Such a change is neither easy nor intuitive and how it may be played out is extensively discussed.

Chapter 11 is the concluding chapter where we summarize our key findings and discuss how future research can build off from this work.

We now begin our journey with Chapter 2 where we discuss the primary reason for the existence of the CA EoE: the generation and characteristics of demand for air transportation.

Chapter 2 Demand for Air Travel: Drivers of Growth

In order to satisfy our objective as stated in Chapter 1, that is to specify the causes and propose strategies that could dampen the boom-bust cycle in the commercial aviation industries, it is necessary to acquire a solid understanding of the details in the industries involved. We start the journey of understanding commercial aviation starting with their *raison d'être*: satisfying the demand for air travel. Commercial aviation exists first and foremost to provide reliable, safe, and affordable travel and shipping options to passengers and shippers. Could the volatility in airline profitability as shown in Figure 1-1 have its root cause in volatile demand?

Airlines and airframe manufacturers interact in balancing the demand for air transportation services with the availability of supply and the effects of macroeconomic factors. While this is a basic economic function, the markets involved are usually far from perfect.

In this chapter we review what drives the global demand for air travel and how passenger and freight preferences influence the strategies of the providers (Airlines in Chapter 3 and aircraft manufacturers in Chapter 4) and vice versa. We examine the needs that air transportation satisfies in Section 2.1. These needs are diverse and so is the expected utility from air transportation exhibited by different customer segments. We break down the different types of customers that use air travel and the resulting markets in Section 2.2. Finally, in Section 2.3 we discuss modal competition, review the historic growth trends of air travel, and generate some plausible scenarios of its future potential.

2.1 Valuing Air Transportation.

2.1.1 Human Needs and Air Transportation as a Derived Demand

Maslow (1954) categorized human needs into a hierarchy of four fundamental sets:

1. *Safety, security, and sustenance.* (“*These are the needs we have for food on our tables, a roof over our heads, and clothing to protect us from weather – the essentials of life.*”)
2. *Competence, efficacy, and self-esteem:* *To satisfy these needs we must “be capable of doing what we set out to do and of obtaining the things we value.”*
3. *Connectedness:* *Humans have a strong desire to be intimate and close to others. “We need to feel that we belong and are connected with others’ lives, be it as parents, friends, neighbors, or coworkers.”*
4. *Autonomy and authenticity:* *It is human nature to “constantly strive for increased freedom and more opportunities to experience life in a self-directed manner.”*

Hall and Sussman (2004) argued that consumption of goods and by implication freight transportation is primarily driven by the first two sets of needs while the desire for personal travel is driven by the two latter sets. With some exceptions (Mokhtarian and

Salomon 2001) that apply to general aviation but not as much to commercial aviation, the demand for transport is a “**derived demand**” that is, **it is generated as a direct or indirect consequence of another economic activity**. Furthermore, the demand for air transport can be **induced**, which means that the existence of air connection between an origin and a destination, creates additional demand than the demand measured before the connection was established just because of the perceived qualities of air travel (e.g. ease, speed, novelty, etc).

From the perspective of the needs hierarchy, passenger travel is a higher level need and therefore it is expected to exhibit a higher degree of elasticity when lower level needs are harder to meet. In other words, during economic slowdowns or recessions demand for air travel is expected to be lower. Anecdotal evidence to this is given by Masashi Izumi, VP at All Nippon Airways in 2003 who notes that “[e]specially during the [...] long recession, [...] consumers have become very sensitive to price and now look for value in purchasing their [...] services.”⁴ Business travelers who are traditionally considered as less price sensitive are not immune to this phenomenon; Taneja (2003) notes that “*airline passenger traffic, particularly the part relating to business, has become overly sensitive to corporate profits.*”⁵

Similarly freight transportation by air, which as we discuss in Chapter 3 contributes significantly in the revenues of civil aviation, should be also affected by macroeconomic changes both because of a reduction in the demand for the high value, low volume (and usually but not necessarily low weight) goods that are usually transported by air and of a shift to cheaper albeit slower modes of transport.

It is implicit in the discussion above that the customers (passengers and shippers) value certain aspects of air transportation differently. In the next section we explore the distinguishing characteristics of air transportation products that will allow us to construct the first link in the value delivery chain, as presented in Figure 1-2, and give us insights on how to measure it.

2.1.2 Attributes of Value for the Air Transportation Product

Evaluations of transportation needs started with urban transportation; Zahavi (1981) postulated that travelers make their decisions on their Travel Time Budget (TTB) and Travel Money Budget (TMB). The first has been shown to be practically constant across societies and the second is shown to be constant as a percentage of expenditure income (Schafer and Victor 2000)(see pg. 175, Fig. 1 and pg. 177 Fig 3). This attribute of constancy across societies provides a strong support that Zahavi’s postulates are a valid way for establishing the utility of a transport mode.

Building on this observation, the air transportation product is fundamentally simple: *it provides to consumers the ability to reach a desired destination from a given origin at a*

⁴ Taneja 2003. pg. xvi.

⁵ Taneja 2003. pg. 12.

*competitive combination of schedule, travel time, price, and comfort*⁶. This view suggests that there is a vector of four fundamental attributes that define value for air transport:

- Network coverage,
- Speed (total trip time), frequency, and reliability (including door-to-door access and egress) as part of TTB,
- Fare (or tariff) as part of TMB, and
- Amenities and comfort (including connecting vs. direct flight)

Each consumer makes their choice on whether to travel or not and which mode to take based on their available information on the alternatives and their relative balance placed on the attributes of the offered products. The consumers' decision process can be graphed onto a decision tree as shown in Figure 2-1.

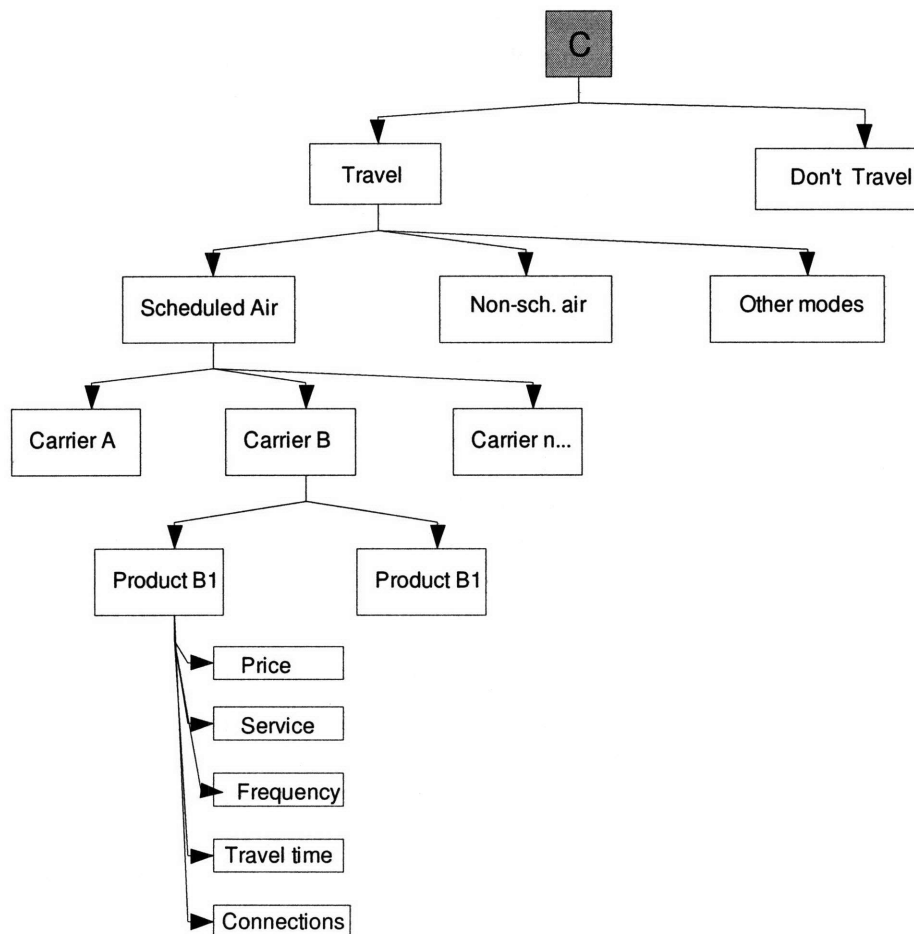


Figure 2-1 A passenger choice decision-tree

⁶ In the text we refer to both passenger and freight transport. In some cases it is easier to refer to attributes of the dominant passenger traffic that have their equivalent to air travel. In this case, for example, comfort for a shipment would be on-line tracking or desired temperature and vibration environment. Similarly when referred to fares the implied terminology for shipments is tariff

There are several approaches or theories of choice for understanding and predicting consumer choices as summarized by Ben-Akiva and Lerman (1985)⁷. Each theory requires the definition of (i) a decision maker, (ii) alternatives, (iii) their attributes, and (iv) decision rules. The fundamental assumption is that consumers make an informed choice based on the available alternative products for their desired purpose by comparing their relative perceived value.

One way of deciding between the alternative choices is dominance: the alternative that is perceived as equal or better for each identified attribute is the one chosen. While this is straightforward and not controversial, in reality few are the cases where an alternative is clearly dominant. To address this problem in a quantitative function the concept of scalar **utility** was first introduced by Von Neumann and Morgenstern (1953); that is the assumption that the vector of attributes for any given alternative can be represented as a scalar which can then be used to compare among alternatives. According to this view, the maximization of the utility function is therefore the objective of rational consumers.

This allows the description of the utility function equation with variables that represent the attributes of the decision maker and of each alternative. Some attributes for air travel products were given in the opening paragraph of this section. The attributes of the decision maker / passenger or shipper can include socio-economic factors like income level, education, residency, age etc.

By estimating the parameters of a hypothesized regression equation based on an observed dataset the researcher can then calculate the probability of a given alternative to be chosen by a given individual and thus estimate the coefficients of the utility function equation. While this approach is conveniently quantitative it can soon run into difficulties in reconciling the differences across consumer preferences. Some studies for example may indicate that consumers value the time spent for a commute positively which runs counter to our rational expectations. In such cases the “errors” may be attributed to unobserved attributes of the alternative, unobserved variations in the tastes and other characteristics of the decision maker, imperfect information, or the use of inaccurate proxy (instrumental) variables in place of the non-observable real attributes.

Another challenge to the validity of utility theory application was given by Simon (1982) who cautioned that perfect rationality is not observed in practice given the limited capacity of decision makers to retain and compare information **even if** complete information was available, which of course is not the case in most real-world problems. This obstacle was overcome by normative decision theory by assuming “*consistent and transitive preferences*”⁸ for decision makers. That is by treating the decision maker as a black box and thus avoiding dealing with the information processing part of choice altogether. For the scope of our research this assumption is acceptable when it comes to

⁷ Chapter 3, pg. 31-58.

⁸ Ben-Akiva and Lerman (1987), pg. 38. Consistent: under the same conditions, the choice of a decision maker would not change. Transitivity: if choice A is preferable to B, and choice B preferable to C, then A is preferable to C.

individual consumer choices but it will be challenged in Chapters 2 and 3 when the discussion turns to the choices made by enterprises.

There are numerous studies that use utility theory to estimate consumer valuation of certain attributes of air travel (for a recent example see Parker and Walker (2006)). Yet given the scope of this dissertation, this level of analysis contains a large number of details that are region or study specific. In order to describe and model the effect of airline competition, or lack thereof, on aggregate demand for a number of markets we need to focus on the distinguishing fundamental characteristics of a product that is nearing commoditization (Weil 1996). This means that most categories of air travel passengers are not interested on the aircraft brand or type as long as the industry standard levels of safety and comfort are met, or as stated in an airline industry ‘motto’ “a seat is a seat.”

To capture this aggregate choice behavior, summing the probability of choices for a given set of alternatives and estimated utility functions of all customers in a market should provide the total demand. In a formula form if we define demand for services from a provider i with competitors k in a given origin destination (O-D) market as a function of:

- customer attributes (C),
- demographic attributes of the region (D),
- product attributes (P), and
- time (t).

we should be able to establish an equation of total demand for air travel⁹.

$$\text{Eq. 2-1 } RPK_i = f(C, D, P_i, P_k, t)$$

Following traditional industrial economic analysis, airlines can affect the share of demand, or **market share**, that they command for a given demand curve and their profitability by adjusting the attributes of their products in view of the competitive environment. The effects of similar scale adjustments can be captured by using empirical demand curves.

The price quantity demand curve from classical economics is well known but similarly constructed curves with service attributes like frequency or comfort can be used. In the generic demand curve diagram shown in Figure 2-2, the curve can portray changes in consumer behavior due to changes the price of a product (moving along the curve) or due to changes in the attributes of the consumer (moving to a different curve). For air travel shifts in the demand curve can occur due to macroeconomic effects (e.g. recessions) or due to external shocks (e.g. pandemics).

The tangential line on any point of the demand curve provides a measure of the price elasticity of the consumers at that point; if a percent change in price induces a greater percent change in demand then demand is considered elastic.

⁹ Revenue Passenger Kilometers is a convenient measure of actualized demand for passenger air travel demand. The equivalent metric for freight demand is Revenue Ton Kilometers (RTK). They are explained further and presented in context in Chapter 3.

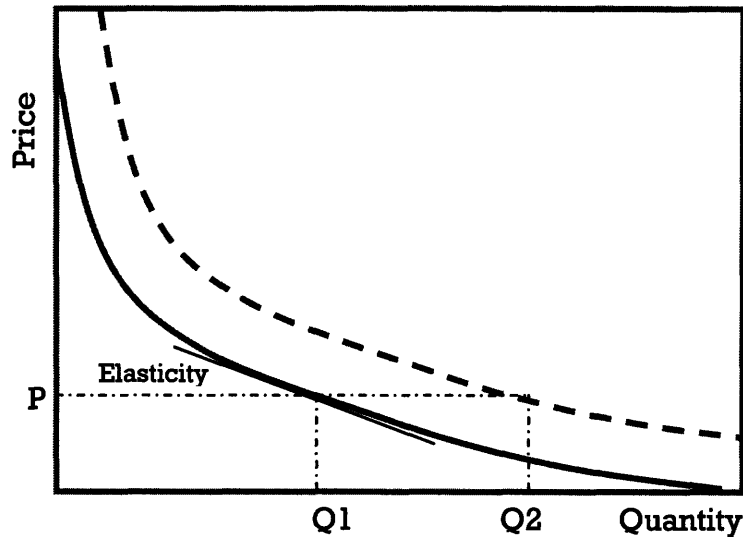


Figure 2-2 Generic Demand Curve

Shifts in demand curves imply that the consumers with different sets of characteristics behave differently with respect to the change in the price of the good. These changes, though, can also occur with stable pricing precipitated by changing income levels or new substitutes. To account for these effects empirical studies aim to define the “**own-price**” elasticities of goods instead. Own price elasticity is estimated after controlling for all other variables causing a shift in the demand function besides price.

The next section, explores the air transportation markets from the demand perspective on different scales. The empirical findings on air travel elasticities are discussed in Section 2.2.5.

2.2 Market Level Perspectives in Air-transportation.

On a fundamental level all business functions exist because of their ability to efficiently satisfy certain needs for their customers (individuals, other businesses, or departments within the same organization). Even in monopolistic situations, a form of a market exists that can be characterized as “*a social arrangement that allows buyers and sellers to discover information and carry out a voluntary exchange of goods or services.*” (Pindyck and Rubinfeld 2000).

The air-transportation markets can be analyzed from multiple perspectives: geographically, based on population characteristics, institutionally or based on the types of services offered. The firms that provide these services use the characteristics of consumers across the different market segments to differentiate their products or to set pricing strategies. We will discuss the institutional and service aspects of markets in Chapter 3 where the airline perspective is provided. In this section we review the geographic and target population characteristics of markets for air travel.

Geographically, we distinguish three levels of view:

- macro level: aggregate global demand,
- meso-level: aggregate regional demand in routes that share common institutional and regulatory environments, and
- micro level: Origin-Destination (O-D) pair.

The scope of our study, understanding the cyclicity in the global civil aviation, indicates that we consider mainly the market on the macro-level; the market for large commercial aircraft (LCA), after all *is* a global market. Yet, the extent of differences on the meso-level and the airline competitive game that is essentially framed primarily on the micro-level compel us to analyze them individually.

2.2.1 Global Demand: the Macro-level

At the macro-level, the trends for passenger and cargo demand have been consistently rising over the history of aviation as the global RPK figures, as shown in Figure 2-3. While the rate of growth in RPK since the beginning of the century has slowed down it still shows a respectable 6% growth per year on average over the past thirty years and has been negative only two years (1991 and 2001) in the 75-year span of available historical data. The growth in cargo transport (RTK) has been high with an average growth rate of 7% per year over the past 30 years.

This trend seemingly contradicts the assertion made in Section 2.11 of a causal relationship between the growth in aggregate demand for passenger and cargo and the growth of the economy as a whole. What is missing in this picture is the supply side: the effort of air transport providers to meet the needs of their customers at lower real fares and more importantly the ability to clear the market of a perishable product (the scheduled seat) by using yield management (a set of complex pricing techniques briefly reviewed in Section 3.2.2). Even after these counter-cyclical corrective actions there is still a strong correlation between the growth rate of demand and the GDP rate as discussed further in Chapter 3.

In any case, because transportation facilitates the satisfaction of fundamental needs, the demand for it is unlikely to die out as long as no efficient alternative can be used. This is especially true for air transportation as long as it still provides the fastest way for crossing medium to very long distances over both land and sea.

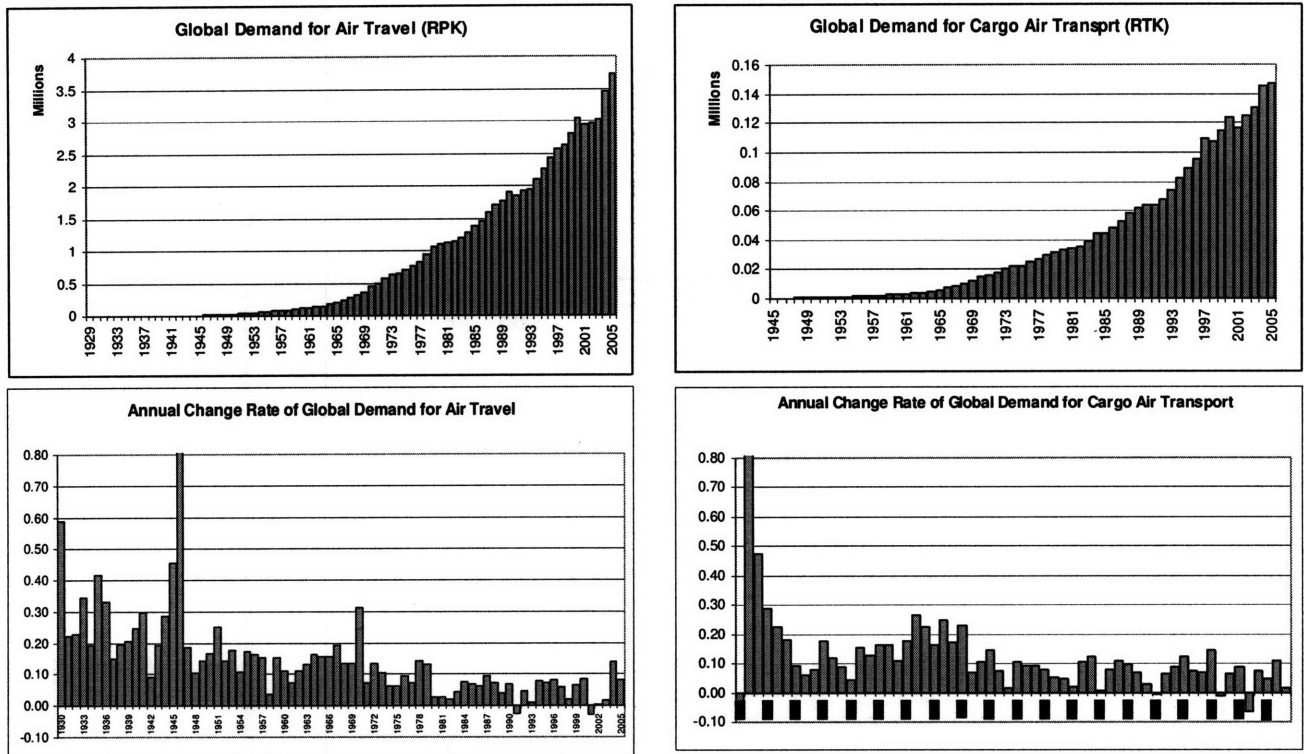


Figure 2-3 Global Air-travel demand trends (Data source: ATA (2006))

2.2.2 Regional Variations: the Meso-level view

The aggregate graphs in Fig. 2-3 paint a positive picture despite the reductions in the growth rates but they do not tell the whole story. Different regions show different potential in growth and, even in high-growth regions, most airlines face significant volatility in the demand for their services. In order to later transition to the causes of cyclicity in the industry it is useful to review how this volatility is expressed on the meso- and micro- levels of the market.

Demographic characteristics of regional markets

The “derived” property of demand for air transportation suggests that it is strongly dependent on the **economic activity** levels present in the origin and destination of trips as well as the condition of the entire regional economy. This correlation of air transportation demand has been observed repeatedly, and on a global scale is shown in Figure 2-4. The scatter plot on the bottom left of the figure shows that there is indeed a positive correlation between the real (inflation adjusted) GDP growth rate and air travel demand growth rate (correlation = 0.74) while this is not true for the airline profitability and GDP (bottom right diagram and a correlation value = 0.10).

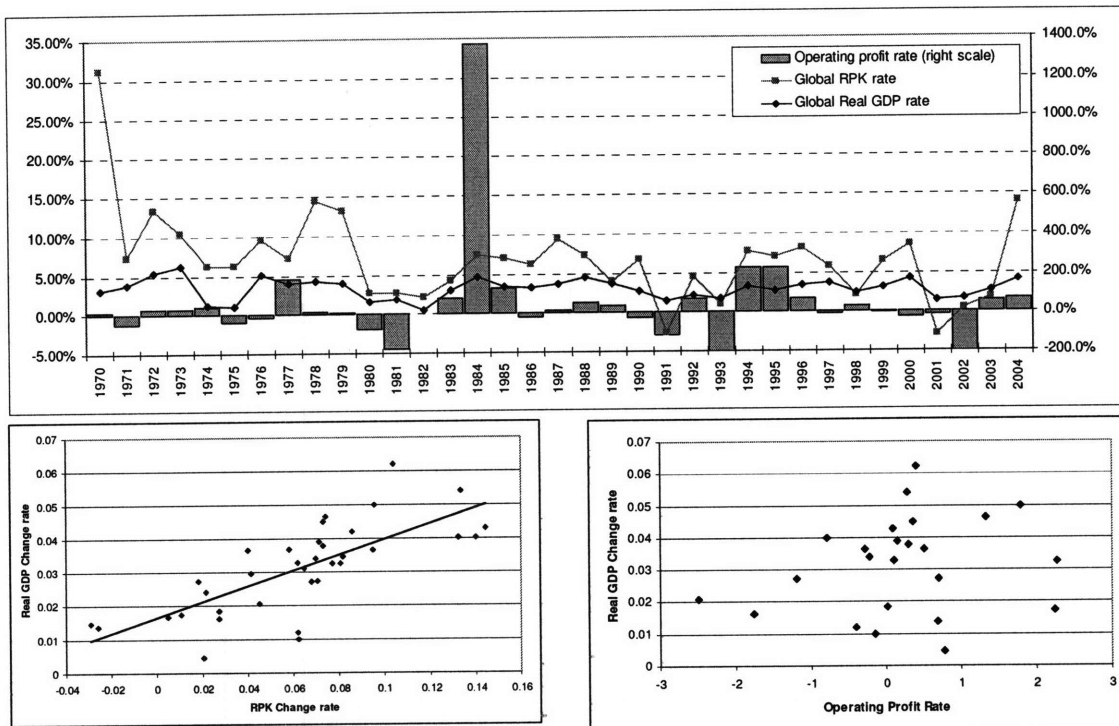


Figure 2-4 Relationship between global GDP rate in real \$, air travel demand rate, and airline operating profit. (Data sources: Shane (2006), ATA (2006))

In addition to varying rates because of changing economic conditions in one region, regions with different economic conditions exhibit different dynamics in generating demand for air travel. Economic activity is not distributed evenly across the world with some regions lagging and others accelerating at different times in recent history. Therefore, the regional demand for air travel is expected to diverge based on demographic characteristics like:

- population size,
- per capita income,
- income inequality, and
- special characteristics of the region:
 - tourist attractions,
 - industrial and trade centers,
 - political outlook,
 - regional conflicts etc.

This correlation is demonstrated in Figure 2-5 where it is shown that the relatively small increases in wealth in emerging economies can generate substantial increases in travel demand (the circled region) while in mature economies that trend is marginal as other variables like the availability of discretionary time and desire to travel provide trade-offs. Most forecasters agree that, barring other problems, increasing urbanization and standards of living in the developing world will keep similar rates of increase in the demand for air travel (Taneja 2002). Reflecting these differences in expectations, the

Table 2-2 Average regional growth rates (2003) for passenger demand (Data source: (Boeing 2005))

	North America	Central America	South America	Europe	Africa	Middle East	CIS Region	China	Southwest Asia	Northeast Asia	Southeast Asia	Oceania
North America	1.00%	4.50%	-12.00%	-0.50%	2.00%	-7.00%		-25.00%		-13.00%	-12.00%	-2.00%
Central America		6.00%	0.70%	4.00%								
South America			-9.00%	0.50%								
Europe				4.61%	2.00%	0.50%		-19.00%	7.00%	-9.50%	-1.50%	
Africa					6.00%	5.00%						
Middle East						6.50%			9.00%		10.00%	
CIS Region							10.50%					
China								-2.00%		-18.00%	25.00%	-19.51%
Southwest Asia									1.70%		-0.50%	
Northeast Asia										1.30%	-16.00%	-7.00%
Southeast Asia											-2.00%	-10.00%
Oceania												10.50%

Table 2-3 and Table 2-4, taking the view of the distribution of demand (as opposed to growth rates), show a much steadier picture between 1990 and 2003. The global distribution of demand is actually relatively stable with North America and Europe being the largest generators of demand for air travel, with a combined contribution of more than 50% of global demand with Europe slightly increasing and North America decrease in its share. The only significant difference between the two tables is the stagnation in the demand experienced by the states of the former Soviet Union that went from 10% of global demand in 1990 to less than 2% in 2003¹⁰. The distribution and magnitude of the busiest 150 world airports as marked on the world map shows that North America, Europe, and to a lesser extent, East Asia, dominate with only a few contenders in the rest of the globe.

Table 2-3 Regional Demand as a Percent of Global Demand for Passenger Travel 1990 (Data source: Boeing (2005))

	North America	Central America	South America	Europe	Africa	Middle East	CIS Region	China	Southwest Asia	Northeast Asia	Southeast Asia	Oceania
North America	27.00%	2.92%	0.90%	10.57%	0.06%	0.30%		0.62%		4.36%	0.70%	0.87%
Central America		0.66%	0.16%	1.27%								
South America			1.55%	1.02%								
Europe				11.84%	2.19%	1.90%		0.78%	0.80%	1.35%	2.13%	
Africa					0.67%	0.34%						
Middle East						0.89%			0.76%		0.50%	
CIS Region							10.28%					
China								0.84%		0.50%	0.66%	0.27%
Southwest Asia									0.53%		0.27%	
Northeast Asia										2.29%	1.49%	0.59%
Southeast Asia											1.37%	1.11%
Oceania												1.20%

¹⁰ The trend is definitely reversing since the CIS posted high growth rates (>10%) even in a very weak year like 2003.

Table 2-4 Regional Demand as a Percent of Global Demand for Passenger Travel 2003 (Data source: Boeing (2005))

	North America	Central America	South America	Europe	Africa	Middle East	CIS Region	China	Southwest Asia	Northeast Asia	Southeast Asia	Oceania
North America	24.44%	3.06%	1.15%	10.63%	0.13%	0.29%		0.76%		3.22%	0.82%	0.79%
Central America		0.76%	0.22%	2.22%								
South America			1.47%	1.51%								
Europe				14.52%	3.03%	1.80%		1.06%	0.90%	1.48%	2.91%	
Africa					0.69%	0.42%						
Middle East						0.90%			1.04%		0.81%	
CIS Region							1.75%					
China								2.91%		0.61%	0.85%	0.32%
Southwest Asia									0.54%		0.38%	
Northeast Asia										2.63%	1.40%	0.70%
Southeast Asia											1.82%	1.28%
Oceania												1.70%

2.2.3 Market as O-D pair: the micro-level view

For the level of analysis that we are interested in, industry-wide and macro, it is tempting (and easier) to stay focused on the aggregate market level (macro and meso). This approach though would attribute a homogeneity level to the industry that is unrealistic and hide some important attributes of the industry. Several researchers (Holloway 1997) state as a principle of the industry, that **each O-D pair is a market** in and of itself. The implications of this maxim affect how the competitive status of the industry is viewed and generates additional characteristics that airlines have to consider when making fleet decisions.

Business and leisure

Maybe the most important micro-level characteristic of demand is the different utility functions that characterize customers in different segments of the market. The differentiation between business and leisure travelers is especially important since it defines the characteristics of the product service and how it competes with the other market offerings.

As a general description, business travelers value high frequency services and the ability to change itineraries and dates easily as the reasons for their business trips change while their flexibility in travel dates is also limited. Given the number of hours they spend traveling, they want amenities and the ability to rest or work accordingly. Finally, they are less sensitive to price.

The leisure travelers on the other hand are more flexible in the dates they choose, more sensitive to the ticket price, and they value in-travel comfort less than business travelers.

In more technical economics terminology, consumer groups exhibit substantially different elasticities of demand and more generally different aggregate utility functions. Market segmentation and other airline business models that have evolved allow airlines to exploit, with varying effectiveness, these basic differences among their customers.

Similarly, cargo types differ in terms of the utility preferences of the shippers but less radically than the utility functions characterizing passenger markets. Cargo servicing is done either by dedicated carriers that focus on different market segments (e.g. FedEx, UPS and DHL, focus on parcel deliveries while others like Cargolux and cargo subsidiaries of legacy carriers focus on consolidated cargo). Freight forwarders and postal services also use the cargo bay of airliners for their shipments and this revenue stream may provide a substantial part of an airline's revenues and thus influence its decision on the type of aircraft it may operate.

Substitutes and complements

For both classes of passengers as well as for cargo, demand for the airline product depends not only on the attributes of the product itself but also on the availability and relative attractiveness of substitute products.

For business travelers substitute products may range from IT solutions like teleconferencing to business jet time ownership. To cater to this market niche, several business models have emerged in recent years like fractional ownership, time-share, and lease by-the-hour for business jets. In short-haul distances, high-speed rail or car can also be attractive options.

For the leisure traveler, the number of options is greater and usually they include the complement products (e.g. hotels and vacation spots). If air ticket or hotel prices are unattractive then a change of destination to a more affordable overall option is usually an easy trade-off.

Distances and availability of other modes also play a role and it should be expected that passengers on short-haul flights would evidence a higher price-elasticity as other means of transportation (e.g. train, bus, or driving) may be available as seen in Figure 2-6.

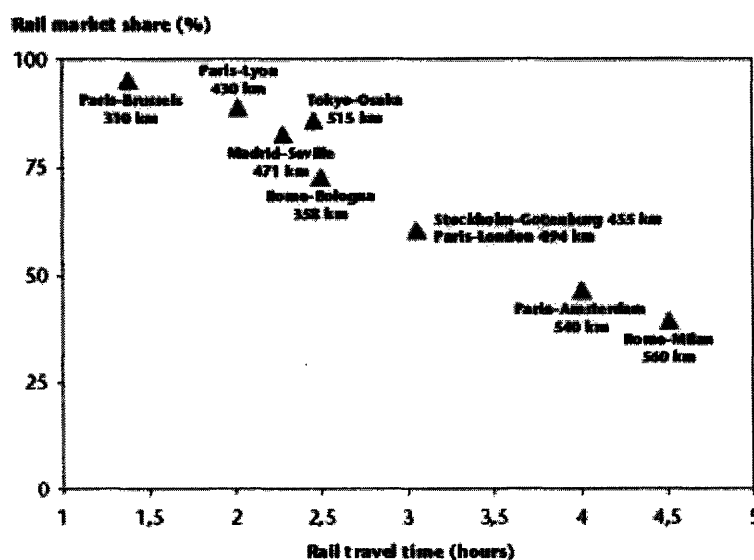


Figure 2-6 Curve of rail/air modal split for distances between 300 and 600km (Source: (WBCSD 2001) (pg. 5-13))

Empirical Verification

These theoretical expectations have been verified repeatedly by empirical observations. The meta-studies by Gillen et al. (2004) and Brons et al. (2002) provide a good overview of the different demand curves for different categories of passengers. Gillen et al. aggregated the empirical observations of 21 econometric studies of air travel demand and showed that there is a consistently difference estimation of elasticities across market segments as shown in Figure 2-7.

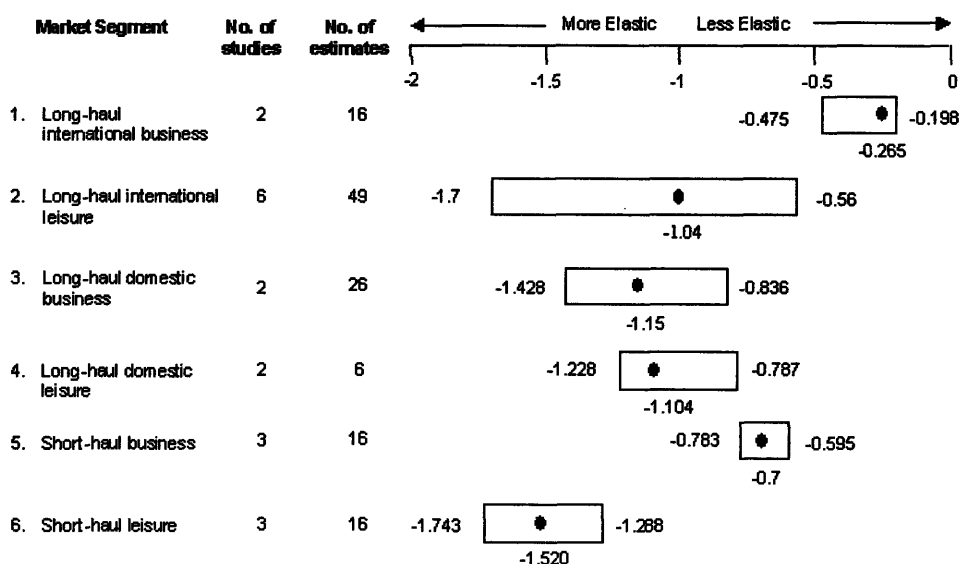


Figure 2-7 Estimated Elasticities of Demand for Air Travel (Source: Gillen et al. (2004))

As anticipated, business travelers exhibit more inelastic demand behavior than leisure passengers. Similarly, short-haul passengers exhibit more elastic demand than travelers on long haul trips. Based on their findings, Gilen et al. caution against using a single point estimate of price elasticity averaged across market segments – a recommendation that is important for the calibration of our modeling in Chapter 9.

Seasonality and travel reciprocity

Seasonality is another characteristic of the air transportation industry that emerges at the micro level view; it is expected that in most O-D pairs there are peaks in demand for several reasons ranging from vacation destinations to large business conferences. Holloway (1997)(p. 70) reports that the average high-to-low ratio of demand is 1.7 for European airlines but reaches 2.4 for the highly seasonal demand faced by Olympic Airways in the leisure travel segment. Airlines try to plan their fleets around and ideally to use the idle capacity on one route to supplement the peaking demand in another (e.g. planes used in trans-Atlantic routes over the summer can be used for Caribbean destination over the winter). Seasonality, as a type of cyclicity, has a well defined period and can be forecasted with relative accuracy, unlike the aperiodic business cycles discussed in Chapter 5.

In spite of the demand peculiarities mentioned above, one characteristic, at least for passenger traffic, is that it is fairly well equalized over O-D pairs – that is the majority of trips are two way. This is not generally the case for cargo traffic though, since the time-sensitive, high value products that make use of the service tend to follow one way routes from production to consumption.

2.3 Chapter 2 Summary

Chapter 2 has explored the customer/used dimension of air transportation. This represents the fundamental starting point where airlines (Chapter 3) and aircraft manufacturers (Chapter 4) base their forecasts on and consequently their decisions. We showed that demand for air travel, as it satisfies a basic human need for mobility, will most likely continue to grow. The growth in demand is dependent upon both the characteristics of the customer and the attributes of the product. For passengers, their characteristic time and monetary budgets constrain their decisions and determines their demand elasticity curve. As emerging economies mature their populations are expected to increase their relative proportion of air travel demand faster as compared to the more mature economies.

In the next chapter we proceed one level upstream in the commercial aviation value chain to present the fundamental aspects of aircraft operators and owners.

Chapter 3 Aircraft Ownership and Operation: Airline Organizations and Infrastructure

As shown in Chapter 2, demand for air travel has been growing with a year to year growth rate of about 5% for the last two decades. This continuous growth is made possible through the efforts of airlines that manage to steadily decrease the real (adjusted for inflation) fares despite continuous increases in equipment ownership costs and volatile fuel prices. In response to these challenges, airlines create a difficult competitive environment faced with trade-offs on the passenger utility arena. For example, in the US domestic market, the trend for using smaller aircraft (average seats per flight dropped from 154 in 2000 to 137 in 2007) offers the advantages of flexibility and frequency but at the expense of taxing the airport and air traffic control system resources. These combined with efficiency initiatives that reduce the number of stand-by crews and aircraft make a system prone to cascading failures and consequent deterioration of the on-time performance thus impacting the utility of their customers.

More importantly for airlines, their profitability is highly cyclical compromising their operations by restricting their access to financial resources during troughs and hampering their ability to adhere to their long-term planning. These have negative repercussions for their labor relations that more often than not are adversarial.

As airlines are such a critical link to the commercial aviation system, this chapter reviews the basics on their operation and their interactions as a competitive market as well as their interface with customers and suppliers. This review provides us with a critical understanding for developing modeling and strategic alternative implementation solutions.

In Section 3.1 we review the basic quantitative parameters that are used to describe aircraft ownership and operation cost and revenue streams. In Section 3.2 we discuss the operating consideration of airlines and in Section 3.3 present the different business models and types of enterprises that are active in the airline industry. In Section 3.4, the relationship between airlines and other stakeholders in commercial aviation (governments, airframe manufacturers, leasing firms, and labor unions) is examined. Finally Section 3.5X examines the evidence on cyclical behavior for airlines.

3.1 Fundamental Airline Economics

Like all markets, the air transportation market consists of **buyers** (potential passengers and cargo operators) which we explored in the previous chapter, a **product** (air transportation for goods and people), and **sellers** (airlines). While passengers are accustomed to dealing with firms generically known as airlines, aircraft ownership and air transportation service provision is in reality organized around a diverse ecology of enterprises. In this chapter we present the fundamentals of this ecology by reviewing the taxonomy, structure, and interrelationship of the enterprises and the markets that they operate in.

(Belobaba 2006) distinguishes the enterprises involved in the provision of air transportation services by their function into:

- Carriers
- Aircraft operators
- Aircraft owners

Carriers are the end suppliers of transportation services to the consumers. A carrier defines the prices, schedules, marketing and service type. An operator is responsible for supplying the carrier with aircraft operations at specified schedules and prices. Finally, owners make capital investments in aircraft, airport gates, etc and lease (and/or sell) them to operators.

Most airlines perform all three functions to some degree and the extents in which they vary signify different business models. There are passenger carriers, passenger-centric carriers with a freight component, and dedicated freight carriers. These can additionally be characterized as low-cost, no-frill, low-fare, legacy, differentiated, full-service, parcel etc. In the next section we define the common characteristics, differences and comparative advantages of the prevailing business models.

In traditional economics, the theory of the firm suggests that firms operate as rational long-term profit maximizers. While this statement is subject to qualifiers, defining the sources of revenue and costs for airline operations and the relevant performance metrics is useful for comparative analysis for airline firms and their strategies.

3.1.1 Basic Airline Performance Metrics

In order to compare the performance of airlines, their costs and their revenue potential, on a common basis the academic and business literature has converged towards metrics that identify units of analysis, e.g. revenue per passenger per mile flown, rather than absolute size, e.g. total revenues, total passengers boarded etc. In this section we review those basic performance metrics and how they can be derived by aggregate measures as these metrics form the foundation for most of the quantitative cross-company comparisons for the rest of the dissertation.

For any operation the basic equation of operating performance can be written as:

$$1 \quad \textit{Operating performance} = \textit{demand} \cdot \textit{unit revenue} - \textit{supply} \cdot \textit{unit cost}$$

The most widely used aggregate metric for supply, or output, for airline production is **Available Seat Kilometers**¹¹ (ASK). This is the total number of seat-kilometers offered by an airline during a period of operation. Similarly for cargo traffic, the metric used is

¹¹ Available Seat Miles (ASM) is more commonly used in the U.S. aviation press but for this dissertation we will consistently use the International System units.

Available Ton Kilometers (ATK) which can alternatively be used for all traffic (Clark 2001).¹²

There are two equivalent ways to calculate airline supply:

$$2 \quad \text{Supply} = P \cdot C \cdot D \cdot F \cdot T, \text{ or}$$

$$3 \quad \text{Supply} = P \cdot C \cdot S \cdot U \cdot T$$

Where

P: Number of airplanes

C: Average capacity of airplanes in number of seats

D: Average stage length (distance flown per flight)

F: Number of flights per unit of time (frequency)

T: Time period of interest

S: Average aircraft block speed (note that this speed is not equivalent to cruise speed since it includes take-off and landing procedures. As a result, short stage lengths have lower stage speeds compared to longer stage lengths for the same type of aircraft.)

U: Aircraft utilization in block hours per day. (**Block hours** are defined as the time in which the aircraft is in use, i.e. from the time the doors close -- after boarding -- at the gate to the time they open again for disembarkation.)

The latter method is generally easier to obtain data for.

Once aircraft go into service, available capacity can be moderated in response to a reduction in demand by:

- Retiring older aircraft,
- Temporarily withdrawing from active service older or new aircraft by parking (mothballing), and
- Reducing the utilization of active aircraft.

The two last bullets imply that it is critical to distinguish between **operated capacity** (which is usually measured by the ASK metric) and **active capacity** which is the offered capacity at the maximum possible utilization of the equipment. In other words, airlines may choose to fly an airplane four routes a day based on demand (operated capacity) but they may be able to use the plane in six routes (active capacity). While airlines may draw down their operated capacity their pricing and costs still depend on their active capacity as the aircraft becomes an expensive underutilized asset.

Following logically from the ASK definition, unit costs are the monetized resources (operating expenses¹³) expended to provide one ASK under the given capabilities of the airline. In a similar fashion, actualized demand for airline travel is measured in **Revenue Passenger Kilometers (RPK)** and Revenue Ton Kilometers (RTK).

Unit costs are usually measured in currency / seat-kilometer.

$$4 \quad \text{Unit cost} = \text{Operating Expenses} / \text{ASK}$$

¹² Clark (2001, pg. 49) suggests the conversion of ASK to ATK by assuming an average weight for passengers and their luggage. We will not follow this method since it obscures the actual separation between the productivity of the two market segments.

¹³ As we discuss in the next subsection, ownership and system/administrative costs are included in the calculation of operating expenses. They do not include finance charges (interest) though.

An important utilization metric that combines output and demand is the **load factor (LF)**¹⁴.

$$5 \quad LF = RPK / ASK$$

The last component of Equation 1, unit revenue, is usually referred to as **yield** in the airline/aviation literature. Yield is equal to the total operating revenue of a given airline divided by the total demand.

$$6 \quad Yield = Operating\ revenue / RPK$$

A measure more consistent with unit costs, is unit revenue, and is the revenue generated by paying customers divided by the total ASK provided (RASK).

$$7 \quad Unit\ revenue = Operating\ revenue / ASK$$

If the sole source of airline revenues were the paying passengers, then yield would represent the average fare per RPK. As we shall see in the business model section 3.3.5.1, airlines anticipate revenues from ancillary sources so this is not strictly true but it is representative in most of the cases.

By definition, RPK is always less than or equal to ASK ($LF \leq 1$). But as we shall explore later in this section, the demand for air travel is highly seasonal and, as a result, there are cases where demand exceeds supply. In those instances excess demand is called **spill**. While spill is a “necessary evil” excessive spill signals poor management and invites competition in non-monopolistic environments. (Clark 2001) (pg 65) discusses the concept of spill and gives an extensive presentation on how it can be represented using statistical analysis.

Based on the terms introduced above, we can rewrite the fundamental Equation 1 as:

$$8 \quad Operating\ performance = RPK \cdot yield - ASK \cdot unit\ cost$$

Identifying the winning balance between the revenue and cost side is key for airline managers. To do so, one needs to understand what drives the costs and the revenues or, in other words, the break-down of the cost and revenue components. We will review these using sample time series from aggregate databases.

3.1.2 Airline Cost Components

Starting from the cost components, there is not complete consensus on the categories best describing the cost breakdown. Different data aggregators tend to favor slightly different

¹⁴ Service quality can be compromised as load factors increase; this is not only a matter of comfort in the air but also it is a result of the increased probability of delays due to the entire aircraft/airport system being close to capacity.

categories as they balance the reluctance of airlines to divulge data that may provide sensitive information to their competitors.¹⁵

A cost categorization introduced by (Belobaba and Simpson 2006) consistent with the Form 41 data and other studies of operating costs is summarized in Table 3-1.

Table 3-1 Categorization of Airline Operating Costs and average values for U.S. Airlines Domestic Operations (source: Belobaba and Simpson 2006)

Cost Category	Description	Annual Percentage*		
		1980	1990	2003
Flight Operating Costs		55.6	44.9	44.5
Direct Flying Operations		40.9	31.4	31.3
Flight Crew (Pilots)	Includes direct wages, benefits, pensions, training etc. Larger aircraft have higher crew costs in the same airline as senior pilots are flying them.	11.1	6.3	7.8
Fuel	Variable. Depending on aircraft fuel burn and cost of fuel.	29.8	17.1	13.2
Flight Maintenance		8.7	10.0	9.5
Direct Airframe and Engine	Variable. Labor and parts for scheduled and unscheduled inspection and repair.	4.8	6.4	5.9
Indirect (burden)	Supervision, inventory carrying costs.	3.9	3.6	3.7
Flight Equipment Ownership	Depreciation, leasing costs, insurance but not interest.	5.1	3.5	3.7
Depreciation		4.0	2.6	3.7
Ground Operating Costs		25.1	33.2	25.4
Traffic Servicing	Loading and unloading aircraft. Check-in, ticket collection, boarding. Gate leasing.	8.0	10.0	11.2
Aircraft Servicing	Landing fees, ramp and flight dispatch activities.	5.9	6.1	6.4
Landing Fees	Variable.	1.5	1.8	2.1
Reservations and Sales		10.3	17.2	7.7
Commissions		4.8	10.4	1.8
System Operating Costs		19.3	21.9	30.2
Passenger Service (In-Flight)		9.6	10.2	10.0
Cabin Crew		5.0	5.4	6.4
Meals		4.4	3.6	2.2
Advertising		1.8	2.1	1.0
General and Administrative		3.2	4.7	6.2
Ground Equipment	Ownership and maintenance of facilities and equipment.	3.5	2.4	2.1
Other	Includes interest payments for equipment.	1.2	2.5	10.9
Total Operating Costs		100	100	100

Source : Belobaba and Simpson (with changes)

* Percentage of total operating costs for major U.S. airlines.

¹⁵ As a first approach we utilize the breakdown introduced by BTS in Form-41. Form-41 has been a primary source of real airline data. It is collected by the Bureau of Transportation Statistics (BTS) under the auspices of the U.S. Department of Transportation (DOT). Major U.S. airlines were obligated to report the requested data on their operations as means for monitoring competitive behavior and the effectiveness of the airline deregulation act in 1978.

While the table has average values, it is interesting to notice some trends like the significant decline of the costs of reservations and sales and of commissions specifically with the advent of electronic ticketing and the almost commensurate increase in the percentage of system operating costs.

Figure 3-1 provides a graphical representation of the average cost allocation of U.S airlines using data from the Air Transport Association. While the allocation percentages are slightly different from the previous table the three cost types that stand out are labor costs, fuel costs, ownership costs, and other which includes interest payments for equipment and payments to subsidiaries or third parties for the provision of feeder services. While landing fees and leasing of gate slots are a small percentage of total operating costs, increasing congestion at key airport hubs is likely to raise those costs.

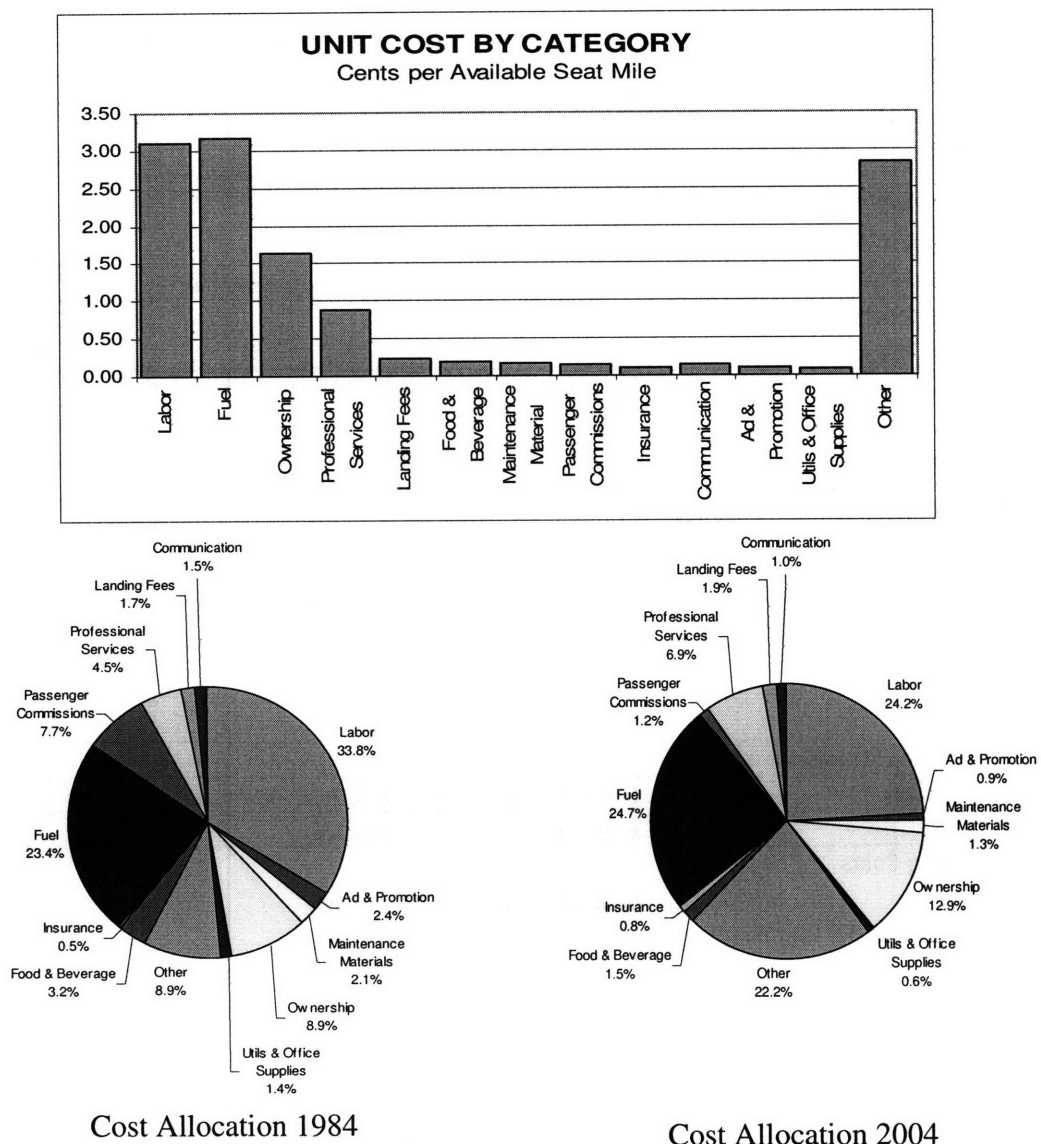


Figure 3-1 Airline cost allocation per seat mile and as a percentage of total operating costs (Source: (ATA 2006))

While the view of aggregate industry costs is informative, different airlines exhibit drastic differences in the level and allocation of those costs which depend on their business models.

3.1.3 Airline Revenue Streams

Traditionally airlines have relied on revenues from their passenger and cargo operations. There were instances where revenues from freight operations were used to cross-subsidize passenger operations (early mail carriers or flights to Hawaii from continental U.S.) and other cases where the reverse can be true (commuter flights with high load factors and the majority of luggage as carry-on have an underutilized cargo hold that can be sold for additional revenue for cargo).

Airline operators can also get revenues from ancillary sources which can include advertising, special in-flight services and sales, partnerships with other service providers like telephone and internet providers in flight or at the gates, rental car agencies, and hotels, car parking revenues etc. While the low-cost charter operators, as we discuss in the next section, were traditionally relying on similar types of revenue given their tight vertical integration, scheduled airlines are catching-up with Ryan Air being the poster child of first-mover towards such 'unconventional' revenue streams to the point where they equal or exceed the ticket revenue.

If ticket prices and seat availability are fixed (as is usually the case in price regulated or monopolistic markets) then there is a direct relationship between load factors, revenues and profitability. This relationship though breaks down when yield management systems were put into place in response to competitive pressures as we will discuss in the following section.

So for an airline, the ability to be profitable depends on how effectively it can balance the two components of Equation 8, i.e. the number of tickets it can sell vs. the costs it incurs to provide these services. In the sections that follow we explore the operational, tactical, and strategic actions taken by airlines in their pursuit of profitable operations, what impedes them in achieving this goal, and how they act on and react to changes in their markets. In the next section, we describe the functions that are more or less common across all airlines and in the section after how they differ based on their strategies and enterprise structure.

3.2 Fundamental Airline Operations

Airlines, in order to provide their services competitively and efficiently, have to plan and take action on aspects of the business that are shared across the diverse set of airline business models. These 'primary' airline operations span different timescales. They can be short-term when adaptive changes and decisions need to be made every few hours or days, medium term for plans that change on monthly or quarterly basis and long-term when they involve planning from a year to over ten years. These functions include:

- **Crew scheduling** (short-, mid- term). The daily allocation of crews over the network satisfying union and regulatory occupational requirements (e.g. working hours, home base overnight stays, matching crew rating and aircraft assignment).
- **Fleet Scheduling** (mid-term). Assigning aircraft type and size based on the route requirements and aircraft availability.
- **Fleet maintenance** (short-, mid- term). Planned and unscheduled maintenance require aircraft to be taken off duty for certain periods. Deciding on whether to maintain aircraft in-house and in which location such facilities should be established can impact operations significantly.
- **Yield management** (short-, mid- term). The continuous adjustment of the capacity allotted for a given fare type based on observed demand.
- **Distribution and marketing** (mid-term). The channels offered to consumers for finding about airline services and purchasing and receiving their tickets. Companies can balance the use of solely direct channels (company web sites) that offer the advantage of significantly reducing overhead and third-party commissions with the visibility and access offered by large scale hub websites and travel agencies.
- **Network planning** (mid- term). Deciding on the routes and schedules offered by the airline.
- **Fleet acquisition and management** (long-term). Choosing the capacity, type, and other relevant aircraft attributes that fit best with the airlines' growth strategy.
- **Strategy planning**. Integrating the above functions and making corporate level decisions so that the objectives of the company are achieved.

Short- and mid- term operations can be formidably complex and may require elaborate optimization algorithms. There is a rich operations research literature focusing on optimal crew planning, yield management, and fleet scheduling which, accompanied by specialized software packages that run the optimization algorithms, facilitates decision-making on that level. For example, Hane, Barnhart et al. (1995) use integer programming to assign aircraft and Vance, Barnhart et al. (1997) to solve crew scheduling problems.

The planning continuum

Our work is focused on long-term effects but in reality it is hard to isolate those from the performance in the medium and short term. In fact there is a continuum of choice problems that should ideally be solved holistically and iteratively. Taneja (1982) (pg. 21-25) is advocating a similar holistic view from the strategy perspective as shown in Figure 3-2 which illustrates the connections among network planning, fleet planning, and short-term crew and fleet scheduling.

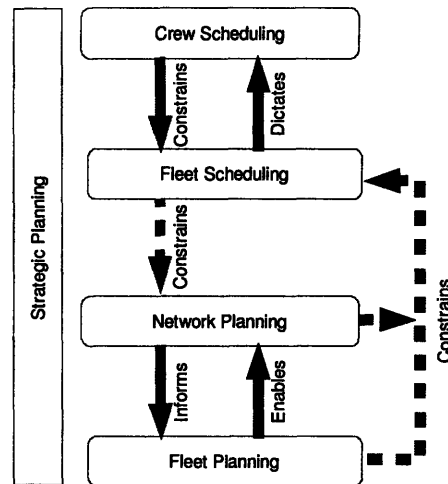


Figure 3-2 The Airline Planning Continuum

The type of network (hub-spoke vs. point-to-point and stage lengths) affects the possible utilization and the preferred type of aircraft. The types of aircraft have to be matched to the crew certification and their capacities to the forecasted demand for the given market. The higher level planning activities have to balance between designing for robustness and optimizing for cost-efficiency. Spare capacity or flexibility can be added in the system to provide resiliency against unanticipated disruptions. As competition and poor operating performance drove many carriers towards increasing efficiency, the networked nature of airlines became more apparent and ripple effects from a storm that disrupted operations in one airport spreads through the system and, in extreme cases, it may take days until normal schedules resume¹⁶.

Fundamentally, the planning continuum means that for true system optimization, the ideal planning process or algorithm should address all levels either simultaneously or sequentially and iteratively. The simultaneous solving is computationally unattainable with today's machines and the iterative planning approach is deficient given the organizational barriers between the different airline departments.

The widespread availability of scheduling optimization algorithms means that their application has become the industry standard and does not constitute a competitive advantage anymore but rather a necessity. Therefore we will focus instead on the other short term operations and how they fit into strategy planning. We will start by examining yield management continue on to network planning present other strategies for growth and leave fleet management and maintenance issues to be discussed in Section 3.4.9, as a critical link to the airframe manufacturing industry.

¹⁶ These type of cascading failures were traditionally buffered by the ability of airlines to reshuffle aircraft overnight and start the next day with a clean slate but in recent years as the availability of stand-by aircraft and crews is small and the booking is so high, reshuffling loses its effectiveness as the passenger stranded at an airport will not fit in next day's normal operations.

3.2.2 Yield Management and Pricing Strategies for Airlines

Yield (or revenue) management by airlines was precipitated by market liberalization and the consequent increased competition among airlines. It is a fundamental tool in the competition between airlines on the same route but it can be used in unchallenged routes equally well as it relies on demand signals. Yield management systems are a sophisticated tool to address the age-old capitalist problem of **clearing the market of a perishable good at maximum profit**. The perishable good in this case is a seat on a flight which has zero value after the airplane departs. Yield management systems use forecasting based on historical data to estimate demand for a given flight. Based on the forecasts, they allocate the airplane capacity to be sold at different prices as defined by fare types. These forecasts are updated on real-time as travelers are booking tickets for that flight and so they can detect non-seasonal variations like the additional demand created by a large conference or the lost demand due to bad weather at a tourist destination. Yield management systems are therefore the engines behind the drastic changes in ticket price that most airplane travelers have experienced while searching for booking their flights.

Yield management relies on a combination of **third-degree price discrimination** and **peak-load pricing**. Economists like (Pindyck and Rubinfeld 2000) (pg. 376) define third-degree price discrimination¹⁷ as “*[the] practice of dividing consumers into two or more groups with separate demand curves and charging different prices to each group*” Market segmentation depends on successfully discriminating between the different types of travelers (primarily business and leisure). This is made possible by offering different fare types that range from first class to regular economy to discount fares and are tied to certain restrictions like weekend stayover, advance purchasing, non-refundability, non-upgradeability, or high fees for cancellations and rebooking. These restrictions are thought to effectively differentiate between passengers with different demand curves (e.g., business and leisure travelers). While this has been proven correct and led to as many as 32 fare types and a commensurately wide gap between ticket prices by some airlines, the success of low-cost carriers that offer a substantially simpler fare type selection with smaller gaps forced a simplification of fares on the legacy carriers as well.

Peak-load pricing is also used but with a twist: by reducing the number of seats offered at discounted fares thus effectively increasing the average ticket price but without explicitly doing so as the fare type pricing remains as announced. Belobaba (1987) offers a review of yield management practices while Belobaba and Farkas (1999) discuss its effect on spill. As an extension of these, Subramanian, Stidham et al. (1999) develop algorithms to optimize yield that include no-shows and cancellations see.

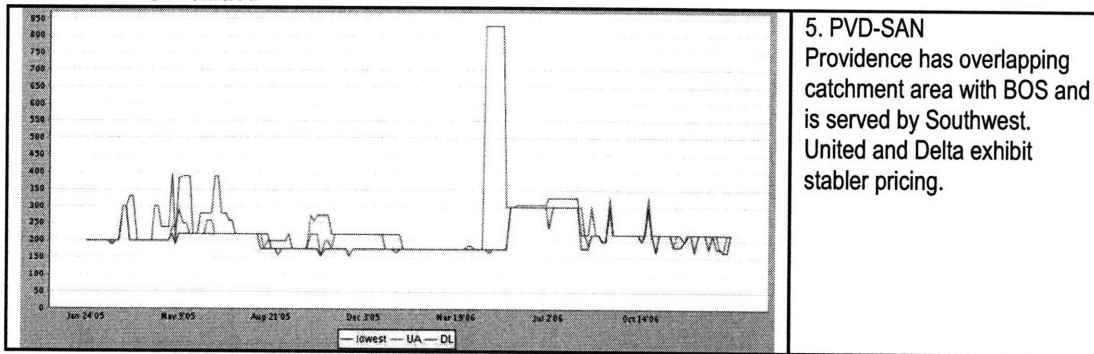
Table 3-2, using historical data, illustrates the seemingly erratic behavior of airline prices based on economy type tickets and their response to new entrant competitors.

¹⁷ First degree of price discrimination is charging customers their reservation price, and second degree is offering quantity discounts. These types of price discrimination are utilized more in the aircraft market rather than the air travel market as we see in Chapter 4.

Table 3-2 Comparative Historical Prices for the Boston San Francisco Market from Jan 05 to Jan 07
 (Source: (FareCompare 2006))

<p>JetBlue MinFare</p> <p>Jan 2005 May 2005 Aug 21 05 Dec 2005 Mar 13 06 Jul 2006 Oct 14 06</p> <p>— lowest — B6</p>	<p>1. BOS-SAN JetBlue (B6) Minimum Fare</p>
<p>Delta</p> <p>Jan 24 05 May 2005 Aug 11 05 Dec 2005 Mar 13 06 Jul 2006 Oct 14 06</p> <p>— lowest — DL — B6</p>	<p>2. BOS-SAN JetBlue (B6) Delta Delta matched and then undercut JetBlue's price.</p>
<p>United</p> <p>Jan 24 05 May 2005 Aug 11 05 Dec 2005 Mar 13 06 Jul 2006 Oct 14 06</p> <p>— lowest — UA — DL — B6</p>	<p>3. BOS-SAN JetBlue (B6) Delta United United followed Delta with brief drops in price until just before JetBlue's entrance where its pricing was erratic.</p>
<p>US Airways AA</p> <p>Jan 24 05 May 2005 Aug 11 05 Dec 2005 Mar 13 06 Jul 2006 Oct 14 06</p> <p>— lowest — US — AA</p>	<p>4. BOS-SAN Similar behavior for U.S Airways and American Airlines.</p>

Table 3-2: Continued



The reduction in ticket prices (and consequently yield) showed in Table 3-3 when legacy airlines are faced by competition by a low cost-carrier has been informally termed the “Southwest effect.” Its existence is supported by Table 3-2 where the entrance of JetBlue in the Boston San Francisco market similarly forced the prices lower. Windle and Dresner (1999) concurred with a set of previous studies (see pg. 61 of cit) and demonstrated this effect empirically. They also showed that legacy airlines do not resort to price increases to other routes when they lower their prices in response to low-cost entry.

Table 3-3 Revenue yields of other airlines (OA) and Southwest (SW) (Source Gillen et al. 2004)

Market type	Yields (cents per passenger mile)	
	500 Miles	1000 Miles
OA-no SW presence	51	26
OA-SW connecting competition	31	20
OA- SW direct competition	26	19
SW-connect	21	14
SW-non-stop	18	12

Due to elasticity in demand, a reduction in price should be expected to increase leisure travel yet. Whether to what extent this is real total growth or simply substitution from airports in the same catchment area is not clearly established yet.

Tactical, Strategic, and Predatory Pricing

While the O-D market is the primary competitive ground for airlines (see Section 2.2.5) airlines operate networks which they strive to expand either through organic growth, via acquisitions, or with alliances. The primary rationale behind expansion for airlines is that growth signals two outcomes: (i) increased appeal to passengers due to network effects and (ii) in the case of organic growth, a means to control unit costs by utilizing scale economies (distributing administrative costs) and more importantly (yet probably not sustainable in the long term) by keeping average fleet age and average personnel seniority low.

Therefore it is not surprising to see the competitive strategies extend on that level. Fournier and Zuehlke (2004) note the antitrust case brought by the U.S. DOJ against the Airline Tariff Publishing Company (1994) where carriers were accused of colluding to “*trade fare changes in certain markets in exchange for fare changes in other markets.*” They find small but persistent indications that this practice continues.¹⁸

Using Table 3-2 for illustrative purposes, we can see that from January '05 to October '05, Delta, U.S. Airways, United and American maintained what can be called a tacitly collusive equilibrium. In that period U.S. Airways and United occasionally cut prices leading to brief “price wars” (defined in game theoretic terms as a period of non-cooperative equilibrium). The entrance of JetBlue changed the competitive environment as prevailing prices stabilized to a lower level in what could be called a predatory pricing move; i.e. an effort by incumbents to undercut a new entrant in hopes of making entrance costly. The erratic price behavior prior entrance could be conceived as a preemptive signal of predatory pricing.

Busse (2002) reviews several models of price wars.

- (i) *Low demand price wars (cyclical pricing)*: firms with high fixed costs or underutilization of capacity have an incentive to undercut prices in period of low demand.
- (ii) *False signal price wars*: a firm misinterprets a drop in their demand as (secret) pricing change from their competitors thus undercutting their prices.
- (iii) *High demand price wars (countercyclical pricing)*: in anticipation of a high demand period firms may cut their prices with the expectation of gaining greater market share.
- (iv) *Ticket Fire sales*: Financially weakened firms may strive to raise “*badly needed cash*” in the short term by reducing their prices.

She finds that firms with financial trouble are more likely to start a price war (model IV) and in contrast to previous studies she does not find a significant effect of demand.

While the above discussion focused on pricing strategies among network carriers, the effect of low-cost carriers can in fact be stabilizing once they have an established presence in a market.

3.2.3 Network Planning: Competitive Behaviors and the Balancing of Hubs and Points-to-Point

As we saw previously, airlines carve market niches and defend against entrants through pricing¹⁹. A more implicit form of signaling than price is commitment in terms of aircraft

¹⁸ Fournier and Zhuelke (2004) used by “reciprocal pairs” of routes to test their hypothesis that airlines with multi-market contact may balance market shares with their competitors in a tacit form of collusion. Stylized, this form of collusion it works by airline A not pursuing a strong presence in a lucrative market and its competitor B does not compete strongly in another market which is lucrative for A.

¹⁹ Contestability theory, which we discuss in Section 3.4.1, postulates that airlines do not use predatory pricing but instead hold consistently low prices if they want to discourage competition. Empirical evidence does not support this hypothesis.

capacity and network planning. Legacy airlines moved from point-to-point type of networks before deregulation to hub-and-spoke networks post-deregulation in pursuit of efficiency. This move also gave them significant and often close to monopolistic market power at their hub airports. Their strong presence created a shortage of available gate slots in the increasingly more congested airports thus providing an effective means of warding off competitors. Gate shortage at major airports constitutes a market failure and as such, several regulatory attempts have been tried with some success. Low-cost airlines when trying to enter these markets could wait either for a serendipitous free-up of gates (e.g., JetBlue at Newark) or, more commonly, utilize satellite airports²⁰ reasonably close to large metropolitan areas. Thus these airlines revert to a point-to-point scheme.

The characterization of an airline as point-to-point or hub-and-spoke is not absolute and simply characterizes the dominant type in what is essentially a mix.

In summary, the hub-and-spoke model by consolidating demand in a few hubs offered two advantages:

- **Operationally**, it offered efficiency gains. Aircraft can be larger and still fly with high load factors, thus creating economies of scale. Service to small regional markets is made possible by using feeder lines to the hubs. The frequency even for small O-D markets is high.
- **Strategically**, it allowed for a regionalization of the markets and effective protection against entrants due to the market power of the airline developing the hub. This effect was facilitated by mergers.

When over-used, though, the hub-and-spoke system can backfire. First, it creates additional inconveniences for the travelers, which value direct flights more. Second, it creates an operating environment prone to cascading delays. The reason for this is that hub airports see their traffic coming in waves with the outgoing traffic scheduled to depart after the wave of the incoming flights has arrived. Thus delays incurred by the incoming flights propagate to the flights waiting to depart. Thirdly, that arrangement underutilizes the airport capacity which is designed to handle the peak loads.

Balancing between a point-to-point network structure and hub-and-spoke is not trivial as it impacts the business model, market share and the operating costs of an airline. While it is true that LCCs have been successful by following a point-to-point-dominated structure, the reality for the traveling public is that this structure is only feasible for relatively dense routes and even then, the frequencies offered rarely rival those of a hub-and-spoke network.

In practice all airlines operate some kind of hub network even if only for reasons of aircraft maintenance and crew housing. Furthermore, just the logistics of connecting a number of airports make the hub-spoke model practically indispensable if service to lower demand areas is to be maintained.²¹ Without at least regional hubs, barring a

²⁰ For example, the Boston metropolitan area is served by the Logan International, Manchester NH, and Providence RI airports.

²¹ For example, if an airline should cover one airport in all 48 continental States, then in a pure hub-spoke network this would require a minimum of $2 \times (48-1) = 94$ flights whereas a pure point-to-point one would

disruptive innovation on mass air travel, the population of smaller urban areas would be left without affordable air travel. On the international travel front, alliances and code sharing allowed the extension of networks with little direct cost to the airline but at the expense of decision independence.

3.2.4 Additional Strategic Planning Considerations

The airline product is the provision of a connecting service between an origin and a destination. In a regulated environment, airlines were only able to differentiate their products by the services offered in-flight in an attempt to capture market loyalty. Post-deregulation the driving force has been cost-cutting as evidenced by the success of no-frills LCCs that is the **commoditization** (Weil 1996) of the airline product become apparent. (a seat-kilometer offered between points A and B by one airline is indistinguishable from the passenger's perspective from a seat-kilometer on the same route by a different airline) and the effect of passenger loyalty diminished.

Differentiating characteristics of the airline product can include the following:

1. *Fare.*
2. *Network extent.*
3. *Frequency.*
4. *Safety record.*
5. *Reliability and on time performance.*
6. *Load factors. As a metric of service, at very high load factors the aircraft feels cramped.*
7. *Amenities*
 - i. *Airport lobbies.*
 - ii. *Security screening.*
 - iii. *In flight amenities*
 - a. *Ambiance*
 - b. *Entertainment*
 - c. *Personnel*
 - d. *Food / drinks*
8. *Frequent Flyer program.*

We discussed fare setting and network planning and how they can impact frequency. Safety is subject to stringent regulations so for our purposes it can be considered as equal across airlines although there are documented instances showing that cash-strapped airlines, especially in countries with reduced oversight, try to postpone maintenance sometimes with dire results. Reliability and on-time performance depend on the airline network type (point-to-point flights have generally better on-time performance) but also on the airport congestion and the state of the air-traffic control system (ATC).

require a minimum of $48 \times (48 - 1) = 2,256!$ In reality, the number of primary U.S. airports is ~550 which would require 301,950 flights to be operated in a pure point-to-point network for one connecting flight/day. In 2005, the total number of flights performed daily by all airlines (including charter and international) in 2005 totaled 20,000 (BTS data).

Despite the commoditization trend, airlines still try to present a differentiated face with occasional success. JetBlue's leather seats and personal screens, offered to all passengers, are a case in point for an LCC. Besides luxury and entertainment, comfort as evidenced by seat pitch and width is also a common theme of airline advertising. Many airlines also provide special services targeting the lucrative business/first class travelers in hopes of building loyalty. This kind of in-flight differentiation reflects on aircraft orders making aircraft more customized and thus less easily interchangeable across companies.²²

Perhaps the most successful effort for differentiation has been the frequent flyer programs introduced by American Airlines in 1981 and adopted since by most airlines worldwide. The expansion of the frequent flyer programs to include other companies as partners, from rental car agencies and hotels to retailers and credit cards, has contributed to the ancillary revenues generated by airlines (Grant 2005) (pg 34).

Other Strategic Planning Considerations

In decisions on pricing and network strategies, airlines ideally pursue their overarching corporate strategy. Decisions on employee relations, the availability and extend of unionization, market entrance, alliance participation, fare setting, organic growth vs. growth via mergers and acquisitions are shaped by the company culture (also referred to as DNA). We will explore this aspects and especially how it differs between airlines in Section 3.3 where we transition from the generic industry-wide perspective to discuss specific types of airline business models.

3.3 Airlines as Enterprises: Predominant Business Models

Airlines, like any business, can be managed well or mismanaged. Even so, airlines have been notorious for the ease with which they become unprofitable. Warren Buffet, investor extraordinaire and founder of Berkshire Hathaway, remarked during an interview:

"[] the airline business has been extraordinary. It has eaten up capital over the past century like almost no other business because people seem to keep coming back to it and putting fresh money in.

You've got huge fixed costs, you've got strong labour unions and you've got commodity pricing. That is not a great recipe for success.

I have an 800 number now that I call if I get the urge to buy an airline stock. I call at two in the morning and I say: "My name is Warren and I'm an aeroholic." And then they talk me down." (Lawson and Ringshaw 2002)

While many airlines have indeed been troubled by bankruptcies, liquidations, or heavy subsidization there are several others that have been successfully profitable over long stretches and some even with the perceived handicap of unionization. In this section we try to identify their critical differences as manifest by their business models.

On the airline operator side, we can distinguish between:

²² To give a recent example, the Airbus A380 delivery delays can be partly traced back to wiring complexity resulting from the non-standard requirements for in-flight entertainment systems.

- charter-only and scheduled airlines,
- low-cost and full-service legacy scheduled airlines,
- parcel and cargo freight carriers

although none of these distinctions are mutually exclusive, as within the same corporate entity, a mix of the above types can be present.

3.3.1 Scheduled Operators

3.3.1.1 Low-cost carriers (LCCs)

According to (Taneja 2004) (pg. 2) the low-cost airline business model was pioneered by Pacific Southwest Airlines in 1949 in the Californian markets. Southwest, which began operations in the early 1970s just before the airline deregulation in the U.S, has been the showcase example for the LCC business model. By choosing a sustainable growth rate of about 5% a year and focusing on niche underserved market, Southwest kept a low profile and avoided the mistake of direct confrontation with entrenched incumbent airlines at its formative years, a behavior which has exterminated other start-up airlines before and since. This was far from being the only distinguishing characteristic of Southwest and its low-cost brethren.

LCCs, as their name implies, are characterized by their ability to maintain a substantial cost advantage over the legacy operators. Yet, this is not what differentiates their business model; it is rather their perception of markets. LCCs view the market for air travel as commoditized and do not drastically differentiate between business travelers. In other words, they break the the 80/20 rule by not anticipating 80% of their revenue to come from 20% of the market (i.e. business and first class travelers).

Their ability to practice this stems from a large number of operational and organizational strategies. The synergistic properties of the strategies and their sometimes implicit non-transferable qualities make the replication of the successful model harder.

While some of the approaches differ, for example with regard to labor unionization some others are quite common. The distinguishing operating approaches of LCCs include:

- single aircraft type fleets,
- short to medium haul stages,
- point-to-point dominated networks,
- secondary airports,
- simple fare structure,
- little if any differentiation between seats,
- internal distribution networks (for ticketing),
- limited alliance membership

The comparative success of the LCC model drew the attention of the legacy carriers in the form of ‘when you cannot beat it, adopt.’ And, at least in the U.S. domestic market, they did *en masse* but with limited success. Continental launched Continental Lite in 1994, United “Shuttle by United” in 1995 and Ted in 2004, Delta launched Song in 2003, while American chose to outsource some of their feeder or competitive flights to smaller

airlines (Grant 2005). None of the imitation LCCs survived long enough to be considered successful for reasons that may range from not adopting critical aspects of the LCC model, to weighing the newly formed subsidiary with the existing burdens of the parent airline (e.g. labor agreements, network extent etc), to cross-subsidizing the parent company with resources needed for expansion of the subsidiary. The lack of success in imitating the ‘Southwest model’ can partly be attributed to the multiple and in several cases tacit facets of the business strategy followed by Herb Kelleher (Southwest’s founder) like employee empowerment, creating a ‘fun’ workplace environment, cultivation of team spirit towards common goals, and several others as described by Gittel (2003).

Characteristic LCCs are Southwest and JetBlue in the US and RyanAir and EasyJet in Europe. LCCs are by no means indomitable and can succumb to competition and mismanagement as the PeopleExpress rapid expansion and breakdown shows (described vividly by Petzinger (1995)).

3.3.1.2 Legacy or Network or Full-service Carriers

The carriers that evolved during under a more regulated regime period in their home countries developed on a different business model than the more recent low cost carriers as they were in most cases protected from competition by government-sanctioned semi-monopolies that could be entry controlled and/or price controlled. The government-supported approach made sense for a fledgling industry²³ with significant potential for helping economic development by offering much needed integration of national and international destinations and with great accident risks if left unregulated.

Airlines’ ‘cushioned’ existence continued, partly due to institutional inertia, even when the airline business was well established. The controlled competitive pressures in turn led to powerful companies like TWA and Pan Am but also to an insidious bloating of costs that could be passed on to consumers without much effort. In parallel, employee compensation and benefits, like pension plans which were critical for the post-deregulation developments, were mounting. With the advent of deregulation (see Section 3.4.8.1), these protections largely disappeared leaving the legacy airlines to adapt or perish although some subsidies do persist for flag carriers or disguised as emergency support. The way that legacy carriers changed to adapt and like the low-cost carriers, they come in many different flavors with varying levels of success.

There are legacy airlines that have completed successful transformations like Continental and United in the US or Air France, British Airways and Lufthansa in Europe and others that have tottered and survived with government support (e.g. Alitalia and Olympic Airways) and other that stumbled (like Swiss Air). There are also newer carriers which like Singapore Airlines and, more recently, Emirates that can be called full-service rather than legacy airlines as their primary field of competition is international travel between connecting hubs and their status as flag carriers for their home countries (and the presumably favorable regulatory environment that this entails) is of little relevance in their success.

²³ Railways, telegraph and highways were infrastructure projects that received similar support worldwide.

3.3.2 Charter Operators

While scheduled airlines may also offer charter services directly or through a subsidiary, charter operators operate only on a fixed scheduled basis and their services bound the high and low yield end of the passenger markets.

The primary advantage of charter services on the low yield market is that it can cater specifically to seasonal demand without an obligation to maintain year-round service. Their services are usually inclusive packages with bundled services like hotel stays, meals, transportation to and from the airport, sightseeing at destination etc. It was estimated that in 2000 about 80% of the charter seats were sold as inclusive packages and the rest to independent passengers (Williams 2002) (pg. 87). Passengers are not offered flexibility over the duration of their stay or the ability to reschedule their departures.

In Europe, where charter operators provide about 30% of the passenger traffic²⁴, 50% of the charter operators (60% by capacity) are vertically integrated enterprises with the travel agencies owning the airline and possibly other parts of the bundled services like hotels and restaurants at the destinations.

On the high yield end, charter operators, like fractional jet ownership²⁵, caters to the business traveler segment that is looking for flexibility and less boarding hassle than scheduled airlines.

From the industry perspective, high yield air charters have the potential to pose a significant revenue threat for scheduled carriers in the highly coveted business market but the aircraft that are operated in this market are mostly if not entirely less than 100 seats. On the low yield side, charter operators are still threatening scheduled carriers on their revenue side because of their low cost operation but they are also active in the new and secondary markets for mid to short range LCA²⁶ at very high density seating arrangements.

3.3.3 Freight Carriers

An important source of capacity for the freight airline industry comes from the belly capacity of scheduled passenger aircraft with up to 35% of scheduled revenue-ton-kilometers coming from passenger aircraft (US 1998 data as calculated by Gaier (1998)). The majority of dedicated freighters are also ex-passenger aircraft that are converted to freighters as they age and therefore are outlets of the second-hand market. Only a small minority of new aircraft are bought as freighters. Given this origin of capacity, it is not unexpected that passenger airlines have large freight subsidiaries usually contracting with a freight consolidator agency or third party logistics firms (3-PL) for renting their

²⁴ Williams 2002 pg. 87.

²⁵ Since 1998 and as of 2007, Berkshire Hathaway has the controlling interest of NetJets, a successful fractional jet company seemingly contradicting the quote in the opening paragraph of this section.

²⁶ Williams 2002 pg. 115 notes that British charter companies use A321 (220 seats) and B757 (235 seats) aircraft for medium haul and B767-300 (326 seats) and A330-200 (360 seats) for longer haul.

scheduled capacity. Seven of the ten largest air freight operators in revenue ton kilometers (RTK) are network carriers²⁷.

Demand for freight services has been fairly consistently in the past two decades and, in fact, grew faster than passenger demand which is an indicator of a less saturated market. Moreover, the growth rate volatility tracks economic activity in a very similar fashion to demand for passenger services that we discussed in Ch. 2 which is also shown in Fig. 3-3.

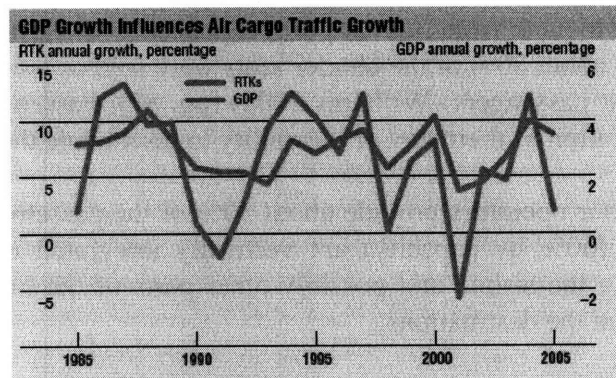


Figure 3-3 Correlation of Global Economic Activity and Demand for Air Freight (Source: Boeing 2006)

The similarities do not stop there as the competitive and commoditization dynamics that are encountered in the passenger side of the business are similarly strong if not stronger as indicated by the drop in real yields showed in Fig. 3-4.

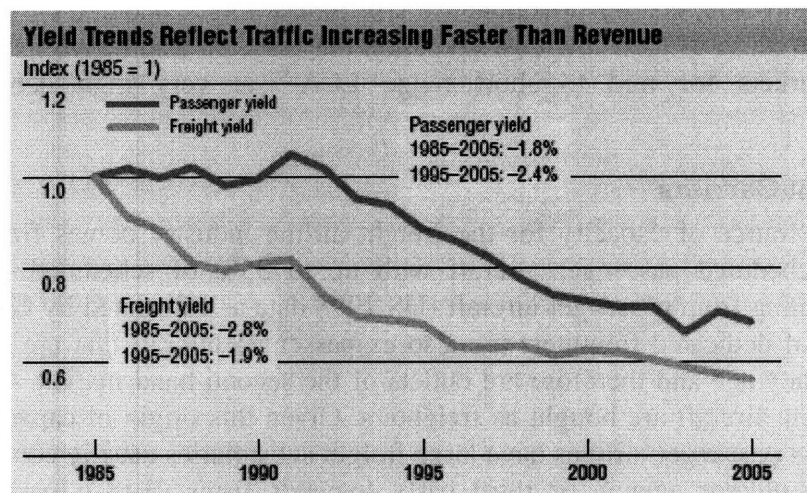


Figure 3-4 Comparison of real yield trends for passenger and freight carriers (Source: Boeing 2006)

²⁷ Korean Air, Lufthansa, Singapore Airlines, Cathay Pacific China Airlines, Air France, Japan Airlines with Federal Express, United Parcel Services, and Eva Airways (a subsidiary of sea shipping firm) being the non-passenger ones in 2004.

Given the similarities in competitive behavior, growth rates, ownership, and capacity that were discussed above, it can be deduced that the market structure in the two segments is very similar. As a result, for the purposes of modeling the industry it is fairly safe to combine the two for an aggregate perspective as we practice in modeling the industry (see Chapters 9 and 10).

3.3.4 Comparisons Among Operators

While there is a great deal of diversity across airlines, in order to be able to model the industry successfully in its current and future states it is important to understand what the real differences between operators are and how they may evolve. In other words, is it reasonable to expect that the structure of the airline industry as a whole will change radically and what impacts would that have for its future performance?

The most apparent effect of airlines competition is the reduction of real yields even in the face of increasing fuel costs. This happens as airlines manage their costs better and rationalize their operations. Charter airlines, with aircraft that have the maximum number of seat configurations that operate only based on demand and on certain routes have by far the least unit costs in the industry as shown in Fig. 3-5.

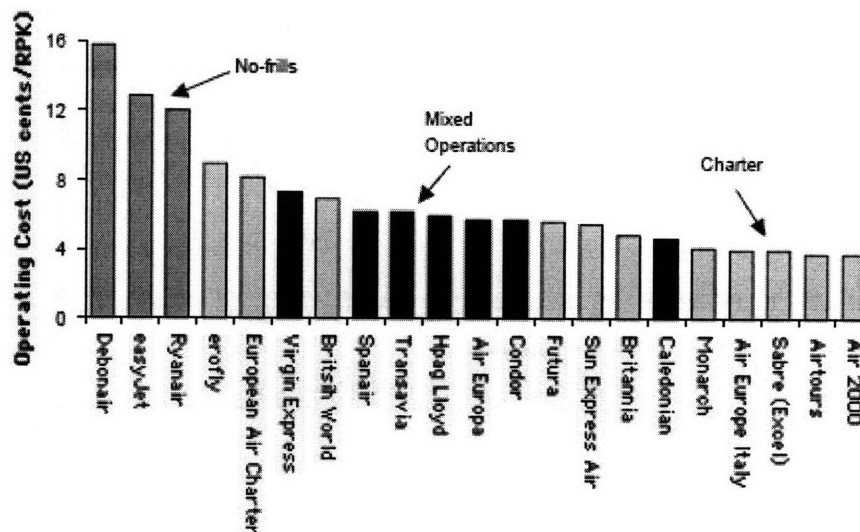


Figure 3-5 Operating costs comparison of LCCs and charter operators (Source: (Button, Haynes et al. 2002))

The same differences can be found between LCCs and legacy carriers as shown in Figure 3-6. LCCs until 2003 managed to retain a significant advantage in unit costs and equipment utilization which in turn translated in better profitability. In later years the cost advantage gap is closing after restructuring and rationalization of services by several legacy carriers while the service levels provided by the two are also equalizing.

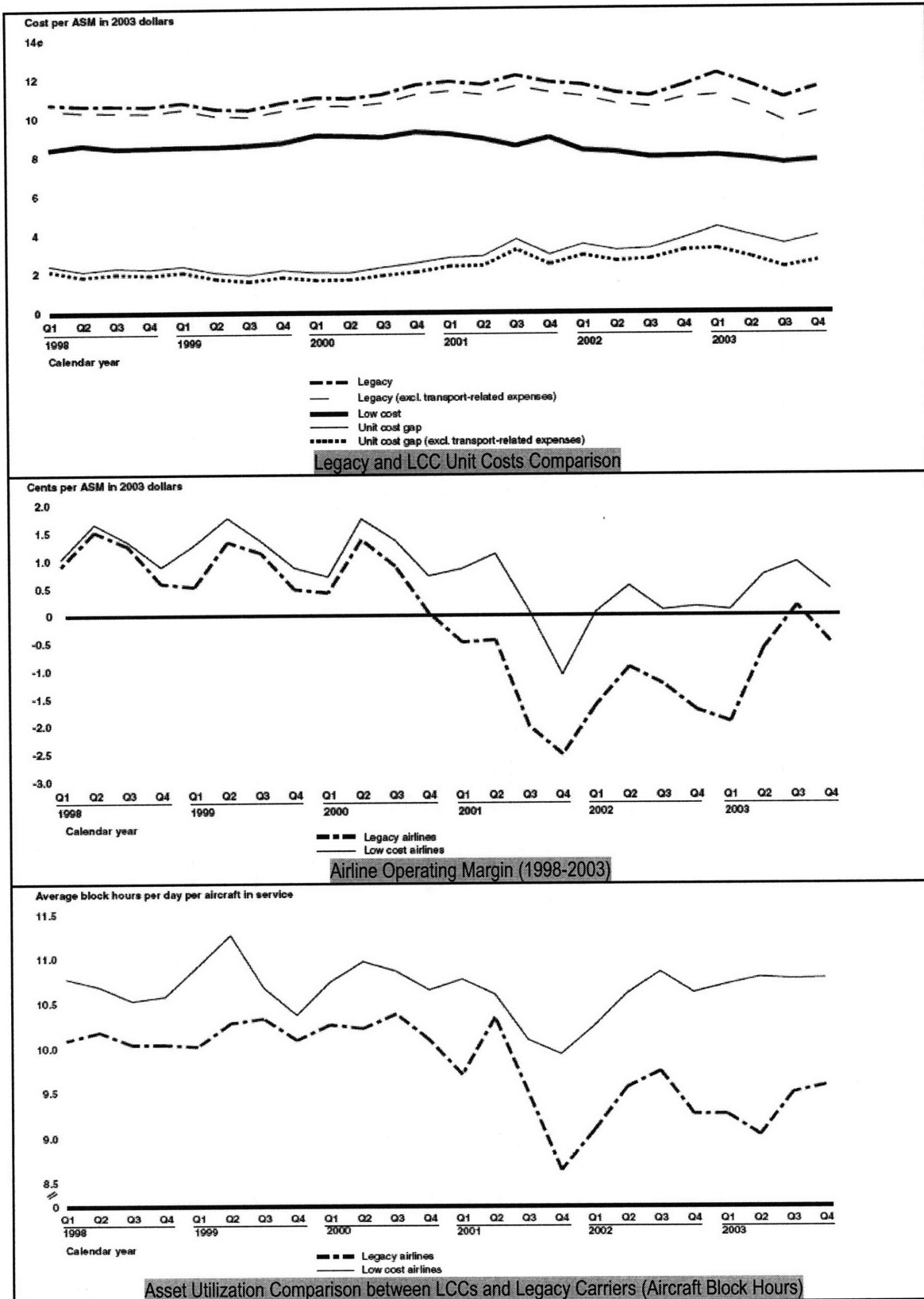


Figure 3-6 Comparisons between LCCs and Legacy Carriers in the US Market for the period 1998-2003 (Source: (GAO 2004))

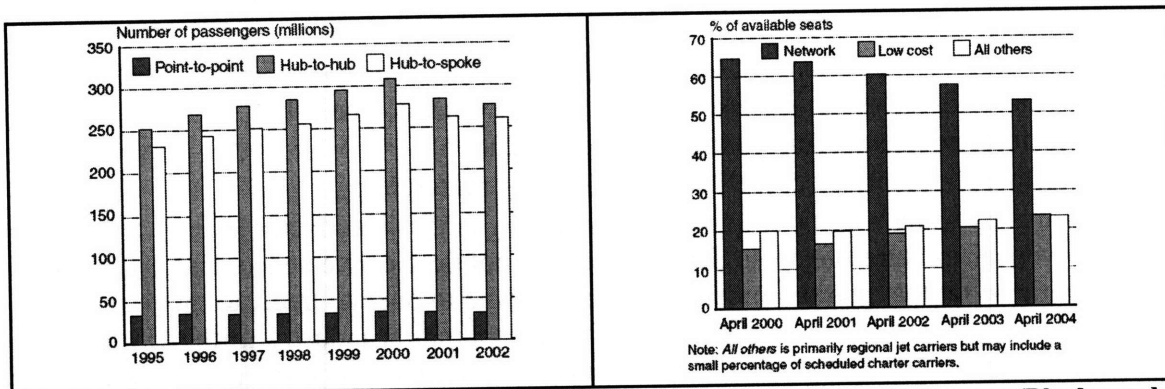


Figure 3-7 Comparisons of Market Share in Emplanements and available seats (source: (Bhadra and Texter 2004))

While the boundaries between the operations of LCCs and network carriers are blurring, the ability of the entire industry to mimic the LCC model entirely is impeded by the difficulty to dispense with the hub-and-spoke network system. Although rationalizing the system through depeaking (or peak-smoothing) is seen as viable total point-to-point network is impractical and inefficient. The network distribution does change (as seen in Figure 3-7) but the trend is slowing and it is likely that it will reach an equilibrium distribution between the types of carriers.

3.4 Airlines and Other Stakeholders

Airlines do not operate in a vacuum. They face competition from other modes, they buy equipment and services from suppliers (airframe and engine manufacturers, airports, air traffic control system), they are regulated by governments in the ways that they can operate and compete, they are financed using capital markets and also make extensive use of financing instruments to help with the acquisition of the increasingly expensive equipment. In this section we will review these connections.

3.4.1 Governments

Taneja (1982) (pg. 112) notes that governments have been wavering in their industrial policies of promotion of a strong air-transport industry. The first types of protections to go were access to markets and government-set fares on the national level, described in Section 3.4.8.1 known as deregulation and later on an international level (see Section 3.4.8.2). Subsidies and state support sometimes persist even in a deregulated environment (Section 3.4.8.3) increasing the barriers to exit which in turn can fuel the industry cycle discussed in detail in Section 3.5, as we discuss in Chapter 6. Governments also provide for infrastructure and they regulate emissions (noise, pollutants, and, recently, greenhouse gases). Other areas of direct government involvement include taxation levels and safety standards but these are not discussed here as they apply universally (independent of the type of carrier) and, at least theoretically, they should not create any kind of competitive advantage between airlines although it is known that increased competitive pressures have an effect on regulatory compliance that needs to be considered (see Perrow (1984)).

3.4.1.1 O-D market as a competitive environment: Contestability theory and deregulation

The Civil Aeronautics Board (CAB) exerted regulatory control over the US airline industry from 1938 to 1978 (Viscusi et al. 2005). The CAB controlled:

- Firm entry rates by controlling airline certification²⁸,
- Airline O-D market competition by allocating routes, and
- Fares by using a cost plus model and assuming a 55% load factor levels.

A controversial mixture of ideological conviction, political convenience, and a genuine technocratic belief that market forces should be allowed to operate freely to the benefit of the consumer led to the first deregulation of a transportation industry in the US (Kahn (1988), Dempsey and Goetz (1992)). The results were dramatic and included substantial operating cost reductions and faster increase in total demand but also increased profit cyclicity (see Section 3.5), labor frictions and a spurred a deterioration of service quality that accompanied the lowering of the fares. Baltagi et al. (1995) estimated that deregulation precipitated cost reductions from 9 to 20%. In the following we discuss how the level of competition can in fact still be limited despite deregulation and examine the barriers to entry and exit present in the airline industry.

Probably the most interesting dynamic that emerges at the micro-level view is the dynamics of O-D competition in a regional market. If the regional market is “regulated” then the markets are not competitive and no additional dynamics emerge: each airline is servicing its assigned routes and without direct competition can charge monopolistic rents as fare-capping permits. This approach was favored not only for the industry to be established but also to prevent ‘destructive competition.’ (Button 2002)(pg.2)

Theoretically, in “deregulated” markets, the barriers to entry are low enough that interested parties, either existing airlines or investors interested in creating one, can enter and exit any given O-D market without difficulty. Such a behavior would lead to competitive pricing close to marginal cost.

While the first deregulation in the U.S. and all subsequent market liberalization exercises in markets across the world²⁹ did in fact lead to greater competition and a proliferation of business models most deregulated markets are still oligopolistic. A perfectly competitive market implies that airlines are price takers and so their decisions on capacity or pricing do not affect the market. As we have seen though, market competition does not reside on the global or regional level but on the local level (O-D market).

Ideally, a deregulated industry would ensure low barriers to entry. Examining one by one the relevant barriers to entry, we mark the factors with (+) if they lower the barriers, (-) if they impede entry, and (=) if the effect is unclear.

- *Entry capital costs*: The necessary capital intensive infrastructure (airports and air traffic control system) is already in place and funded mostly by government

²⁸ Interestingly, an entry to a served market was allowed only if it could be proven by the entrant that the incumbent’s position would not be harmed (Good et al. (1993)).

²⁹ It is estimated that 50% of the world’s O-D markets operate in a deregulated setting.

sources (+). The acquisition of aircraft is capital intensive (-) but the recent availability of leasing contracts attenuates that effect (+).

- *Government policies*: given a deregulated state, they should not be an issue (+). Safety and security requirements are not impediments to free entry as long as ownership and cabotage³⁰ requirements (-) are met. For large markets like the U.S. or E.U. this is unlikely to be a reason for dearth of entrants although it still exerts capital stifling effect. Holloway (1997) contends that government subsidies through state aid or state owned airlines can prevent entrants by retaining an inefficient airline and hence potential oversupply in the market (-). On the other hand, the government's interest of accessibility to non-competitive, remote and underpopulated markets, may justify this in terms of social policy.
- *Economies of scale*: Air transportation has economies of scale with larger aircraft up to the point where load factors cannot keep pace (+). For the same size of airplanes the marginal cost of adding an extra seat should be the same independent of whether a firm owns 2 airplanes or 200 airplanes. There are four caveats in this assertion: the availability (and cost) of landing slots at airports, the **network effects**, the utility advantages from higher frequencies in short haul markets, and the smaller capital costs for large orders (or leasing contracts) of aircraft (-).
- *Economies of scope and Network Effects*: Hub-and-spoke networks, code-sharing and alliances are the primary way for airlines to increase their coverage and hence the utility to potential customers. To the extent that new entrants are precluded from these arrangements, they can offer less value to the potential customers than the competition (-). This is the reason why successful low-cost carriers focus their entry on specific, usually under-utilized routes
- *Distributor agreements*: Travel agents were responsible for the bulk of ticket reservations by passengers until the wide-spread use of online reservation systems. But both reservation systems present similar barriers to entry that include commissions charged, system ownership by incumbent airline competitors, and volume agreements (-).
- *Advertising and Customer Loyalty*: In a safety conscious industry incumbents with a good and sustained safety record have a natural advantage that helps brand recognition. To counter that, new entrants need to invest in advertising substantially to enhance their image; a cost that is irreversible if the market is exited (-). Customer loyalty, especially as enhanced by **frequent flyer programs**, is hard to badge (-). New entrants in a market try to attract customer base through **product differentiation**. While air travel has only limited potential for differentiation, some new entrants with high initial market capitalization did include it successfully in their overall strategy by offering higher service quality than competing products (see Virgin and JetBlue) (+).
- *Predatory pricing*: Incumbent airlines have the market power and financial clout to out-price new entrants by cross-subsidizing their products. If their behavior is uncontestable in courts (predatory pricing cases are notoriously hard to judge ex-

³⁰ Restricting ownership for transportation operators within a country's borders to citizens.

post) and the financial means of the new entrant are limited then usually the outcome favors the incumbent with the competitor withdrawing (-).

- *Infrastructural constraints*: Incumbent airlines have long leases on airport gates and grandfathered schedule slots. This is a critical advantage for busy airports and it is a de-facto exclusion of entrants for the most lucrative markets (-). The emergence and utilization of satellite airports in major urban centers circumvents this problems but does not solve it (+).
- *Market size*: Finally, the size of the O-D market can be an entry deterrent in itself; if the potential size of the market is so small that it cannot justify more than a few flights a day, then a monopoly situation is usually the natural outcome. There simply is not enough revenue to justify a second or third entrant even with the incumbent's rent gains (-). There is a counter effect to this named "Southwest effect" that derived from the observation that significantly lower fares offered by Southwest (and later JetBlue) seemed to increased the overall market. In reality the potential for this effect is limited and it is likely attributed to the attraction of market share from flights that share the same catchment areas (i.e. the increase in flights from A to B come from a similar reduction in flights from A1 to B1 that share the catchment areas of A and B) (see Table 3-2 for an illustration).

From the above overview, the picture that emerges is that regional market deregulation does not guarantee a competitive market on an O-D pair basis. In contrast to this observation, Baumol (1982) argued that the market for air travel between two cities is a "**perfectly contestable market**" based on the assumption that it allows "frictionless reversible entry and equal access to technology"; that is airlines have comparable aircraft and operating processes and can enter and exit the market without incurring substantial sunk costs. An O-D pair, as a contestable market "may support only one airline, but the active airline must price at cost to prevent a price-cutting rival airline from flying in and skimming off customers" as Brock (1983) puts it. That is the threat of competition alone is enough to force competitive behavior even in natural monopoly situations, i.e. low density routes.

While Baumol cites the empirical study of Bailey and Panzar on city pair airline markets, further studies suggest that the applicability of contestability theory on air markets is at best contestable and that "imperfect contestability" is more aptly describing empirical findings (Hurdle, Johnson et al. 1989) and confirmed by the persisting barriers to entry as described by (GAO 1996).

Even if markets are not perfectly contestable and barriers to entry and exit are not low enough to signal a perfectly competitive market and oligopolistic pricing can persist, it is undeniable that market liberalization did change drastically the competitive environment and forced the industry towards commoditization and drastic reduction of their unit costs. On the international front, market liberalization is slower and its effects are probably less dramatic as we discuss in the next section.

3.4.1.2 Market Access Regulations: Freedoms of the Air

Air transportation is a regulated activity because of safety requirements but also because access to a country's airspace and the mobility and accessibility options offered to its citizens (and military) are considered matters of national sovereignty. As a result, establishing national airlines and securing access rights to the national and international markets were subject to international negotiations. Immediately after the end of WWII, the international treaty that established what came to be known as "**freedoms of the air**" was the Convention on International Civil Aviation (**Chicago Convention**) that was ratified into effect in 1947.

There are nine freedoms of the air that progressively allow for increasing liberalization of air transport. The first five freedoms are multilateral, that is they can be ratified by all signatories to the Chicago Convention but the rest are not yet formally recognized in international treaties (referred to as "so-called" by ICAO). The sixth freedom is derivative of the third and fourth and its prohibition cannot really be enforced and therefore is practiced without restrictions. For the rest, bilateral agreements, like the Open Skies agreements promoted by the U.S., may allow them. All nine freedoms are briefly presented in Box 3-1.

As can be inferred by the dearth of examples where the eighth and ninth freedoms are implemented, states still view air transportation as an industry to be protected for the national interest. For this reason, airline **ownership** is restricted in varying degrees to citizens of the country.³¹

The implication of the regulatory environment discussed is that regional markets can be closed to competition for companies that cannot comply with the ownership and cabotage requirements. For geographically small countries this used to mean that the whole market would be served by a **monopolistic airline owned and controlled by the state**, which was usually regulated by fare-setting caps. On the other hand, the U.S., which also happened to encompass the largest domestic market, pioneered the liberalization approach that through **deregulation** lifted some of the domestic market restrictions (fare-setting and route assignment) and allowed for a more competitive environment.

A more important aspect in the difficulty of liberalizing international markets and allowing access to local market for international airlines is that it would do little to change the current cost structure of the long-range flight. The relative unit costs of long-range travel are already quite low. Reducing them further by faster aircraft turn-around, which was a primary tool in the toolkit of LCCs, will not have any significant effect as it is small compared to total travel time. It is more probable that it may effect local markets if the Eight freedom goes into play. This is probably the greatest impact to be expected

³¹ The ongoing struggle (as of October 2006) of the Virgin brand to enter the U.S. market with Virgin America Inc. serves as a case in point. While, as required by U.S. law, 75% of the proposed airline is owned by U.S.-based interests and both CEO and president are American citizens, there was strong opposition raised by incumbent U.S. airlines. If the venture proceeds, it will be the highest capitalization airline start-up in history with \$177M of launch capital.

from the Open Skies agreement between the US and the EU that has been recently ratified.

Box 3-1 Freedoms of the air

First: Right to overfly a country's territory. Necessary for practicable aviation, it is wallowed almost globally as long as it is requested in advance.

Second: Right to stop-over in a country's airport without embarking or disembarking customers and cargo. The reason for it could be scheduled or unscheduled refueling and maintenance requirements. When airliners' range was not adequate, Shannon airport in Ireland and Anchorage airport in Alaska were prime examples of such usage for trans-Atlantic and trans-Pacific flights, respectively. While for passenger traffic this freedom is not used anymore, cargo flights do make use of it.

Third: Right to land and deliver traffic to a country that originated from the home country.

Fourth: Right to receive traffic that originates from one country to be transferred to the home country of the airline.

Fifth: Right to carry traffic from the home country to second country and from there to a third country.

Sixth: Right to transfer traffic, via the home country, from one country to another. Since its prohibition is not enforceable because it derives from the third and fourth freedoms, it is *de facto* exercised.

Seventh: Right to connect traffic between two countries without continuing to the home country. Exercising of this freedom is rare.

Eighth: Right to transport traffic that originates between two points in the same country in a flight that originates or terminates in the home country. Also known as "consecutive cabotage", this is also a rarely exercised freedom. It has been extended to carriers for all European Union member countries showing the need for having very tight interactions between the countries for this freedom to be ratified.

Ninth: Right to transport traffic between points in the same country without needing to connect to the home country. This is known as "stand-alone cabotage."

3.4.1.3 Bankruptcy Protections and Subsidies

One aspect of government intervention with potential significance for the cyclical behavior of the industry is the area of subsidies. In a deregulated market subsidies support can take the form of:

- Distress funding (see the US government response to 9/11 in Figure 3-8)
- Bankruptcy protections
- Pension scheme relief
- National defense funds

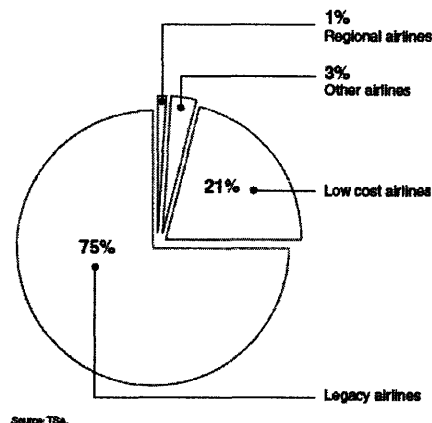


Figure 3-8 Allocation of \$2.3B of Post-9/11 Direct Assistance to US Airlines (Source: (GAO 2004))

All of the above means of support are, at least in principle, geared towards social as opposed to pure market goals but as such they can also be prone to misuse and create dysfunctional markets (government failure). Pure free market advocates would argue that any type of intervention is detrimental. From the business cycle literature (see Ch. 6), it is known that forced retention of capacity for any reason (in this case it takes the form of higher barriers to exit) increases the chances for price wars and the consequent profitability cycle (see Section 3.5). In the case of the airline industry the effect is not as strong because capacity in the form of aircraft would be largely maintained as it can be sold in second hand markets rather than being taken off-market entirely.

3.4.1.4 Mergers, Code-sharing Alliances and Anti-trust Immunity

Another form of government intervention is anti-monopoly regulations that are intended to prevent collusion between companies in any industry. These regulations are intended to provide the benefit to the consumer of the lowest prices and highest levels of service that competitive markets are supposed to offer. As we saw previously, most airline O-D markets are only imperfectly contestable and in many cases there may not be a market core, i.e. the market could not be competitive and efficient as the entry of more than one competitors would create losses for both (Button 2002).

Partially recognizing this, government policies have relaxed anti-monopoly regulation (the Sherman Act in the US) to allow international airline alliances in which airlines that do not compete directly in their markets are allowed (offered anti-trust immunity) to code-share (i.e. sell a flight that is operated by an alliance partner and thus extend their network coverage without extending their capacity) and share price information with their partners. Brueckner (2003) in an empirical study found that the existence of alliances in international airline markets reduces the fare by 8-17% thus supporting the concept of empty-core airline markets.

Consistent with Brueckner, Bilotkach (2005) investigated the effect that anti-trust immunity (sharing price information) can have on alliances and found that immunity is expected to produce benefits for interline passengers and not granting it can discourage consolidation. Porter (1990) considered alliances as “transitional devices” characteristic

of industries under transformation into a more competitive, perhaps commoditized, setting because of management mistrust in their ability to cope with the change. This characterization may not be justifiable for airline alliances as they seem to be well established and may usher an era of mega-carriers.

3.4.1.5 Environmental and Capacity Regulations

The fourth relevant area of government involvement with airlines is the impact of regulations on capacity. Emission and noise control regulations in the form of standards are technology forcing and therefore reduce the risk of innovation required to meet them (Ashford, Ayers et al. 1985). Their existence allowed airlines to plan and conduct their fleet management so as to meet these regulations and in some cases retire the older aircraft prematurely although retrofitting and conversion to freighters maintained some of that fleet in use.

More recently, the concern over the effects of global warming inducing greenhouse gases has instituted regulations in Europe that will start charging some of that externality cost in the form of carbon tax to polluting aircraft. Unlike automobiles or electricity generation, there is no known carbon-free propulsion technology for aircraft and only increased efficiency in engine technology and operations along with no use can curb carbon emissions. The expansion of carbon charges beyond Europe is plausible and in this case, the increases cost of fares could substantially curb future demand.

3.4.2 Capacity Management: Aircraft Manufacturers and Leasing Firms

As shown in Equations 2 and 3 in Section 3-1, the capacity offered by a given carrier in their market is a product of the number of aircraft in active duty, the number of seats per aircraft, the frequency with which they fly, their utilization per day, and the distances that they bridge. As a result the decisions that influence that capacity have both short term and long term horizons. The short term decisions, with a horizon of about a year, include scheduling, routing, aircraft parking, aircraft wet leasing and maintenance planning. The longer term decisions, with a horizon of at least three years³², include aircraft acquisition and long-term leasing, aircraft retirement, long-term route planning, airport slot and infrastructure planning, crew training and hiring.

Aircraft capacity management is therefore not only critical in terms of capacity (and by implication yield based on the supply demand equilibration) it is also responsible for a large fraction of the operating cost since different aircraft allow for different operating cost structures. In this section we discuss the critical attributes of aircraft from the airline operator perspective and the separation of aircraft ownership and operation with the relatively recent growth of aircraft leasing.

³² Anecdotal information from discussions with Boeing officials suggest that airlines do not usually plan for further than 5 years.

3.4.2.1 Commercial Jet Aircraft Attributes Relevant to Airline Business Considerations

Modern aircraft are very complex products that utilize cutting-edge technologies in their design, materials, and systems. The dominant tube and wing basic design has been refined over several decades in the early period of aviation and remained pretty constant since the 1940s. This is not to say that innovation did not take place, but it was incremental rather than radical innovation. The capabilities and prices of aircraft have evolved accordingly.

From the airline perspective, there are different categories of properties that are relevant when an order for aircraft is made: mission-critical performance characteristics, non-mission critical technical and operational characteristics, financial and contractual obligations.

The detailed technical characteristics of even a simple single engine airplane may fill hundreds of pages. This kind of detail refers to aerodynamic and flight characteristics that any certified airplane must have and therefore it is of little value for our purposes. In this description we collect and focus on the characteristics that drastically differentiate aircraft offers and influence buying decisions as described by Downen (2005), Clark (2001), and Holloway (1997).

Mission-critical performance characteristics:

Performance characteristics define the ability of an aircraft to perform a given mission: i.e. the payload it can carry, the range it can reach and the time it needs to complete the trip.

Maximum Take-off Weight (MTOW): The limit of total weight that an aircraft is certified to take-off. When an aircraft type is new, it is common practice to rate the aircraft's structural ability conservatively. Later versions of the plane after it has been shown that there are no unexpected problems are certified higher. This may make the early-launch aircraft of a type somewhat less valuable over time.

Operating Empty Weight (OEW): The weight of the aircraft ready to fly without payload and fuel.

Range: Range cannot be described by a single number. It is limited by fuel tank capacity and is dependent on payload and MTOW. For each aircraft type there are payload-range diagrams like the one shown in Figure 3-9. Some aircraft types allow for extra fuel tank capacity usually at the expense of cargo bay volume. In this work, we tried to be consistent and use maximum range with full payload at cruise speed when available in our sources.

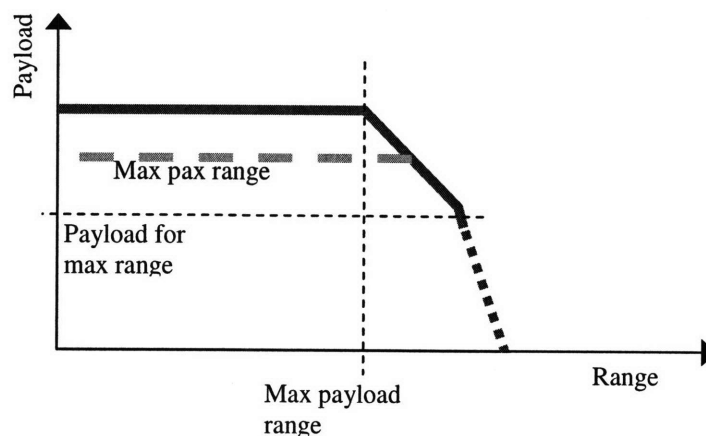


Figure 3-9 A typical Payload-Range diagram

A regulatory and not technical barrier to range consisted of clearances for two engine aircraft to fly over areas without available suitable airports for emergency landings. As jet engines proved their reliability, these requirements were relaxed with the introduction of Extended Twin Operations (ETOPS)³³ regulations in the 80s. ETOPS progressively allowed twin engine aircraft to fly further in airport constrained areas as long as maintenance and safety record requirements were met.

Seating capacity: While the true maximum capacity for a given range can be found by subtracting OEW and the fuel needed for the mission from MTOW, in most cases of passenger LCA the seating arrangement (volumetric payload) is the limiting factor as dictated by service level requirements. As a comparative metric we use the same typical class arrangement.

Speed: A measure for aircraft speed is cruise speed at altitude. For commercial jets, it is usually measured in Mach number but since this metric is dependent on altitude and is not directly related to distance we use km/h as an equivalent proxy. While speed really differentiated jet commercial aircraft from propeller driven ones, it is less of a factor now with most offerings reaching similar cruise speeds. The possible introduction of more fuel efficient propfan planes that cruise at lower speeds may introduce more variability.

Block speed (as defined in Section 3.1, the average speed between door close at origin to door open at destination, also known as chock to chock) also vary operationally, and is higher with longer stage lengths as take-off and landing procedures are time consuming.

Additional performance characteristics:

For fleet planning, other considerations include take-off distance requirements, climbing performance, and runway loading but for the majority of airports and airlines we consider

³³ Before ETOPS, two engine airplanes were not allowed to fly further than one hour from an airfield at their single-engine speed. The ETOPS acronym came to be jokingly known also as standing for “Engines Turn or Passengers Swim.”

them as equivalent across airframe manufacturers and therefore not critical in carrier choice.

Non-mission critical technical characteristics:

For aircraft that meet mission-critical performance characteristics other technical characteristics that may offer cost or operating advantages can become the tipping factor for the choice among them. These technical differences can characterize different generations of aircraft or be dependent on the existing fleet of the operator.

Crew requirements: As shown in Section 3.1.2, flight and cabin crew compensation is usually the greatest relative expense in the carriers' budget. While, the number of pilots required is mandated for redundancy reasons and the number of cabin crew for safety reasons, technical advancements did manage to relax these requirements. As we discuss in the aircraft competition vignettes in Section 4.2.2, the Airbus A300 appeal was enhanced by sporting the first two-man cockpit in a widebody aircraft. Yet, these differences are rare.

Fuel Burn: Fuel burn expresses the mass of fuel used for the specific aircraft to fly for one hour at cruise speed and altitude. Unlike **Specific Fuel Consumption**³⁴ which is dependent only on engine performance, fuel burn accounts for weight and aerodynamic differences³⁵. The fluctuations of fuel prices make this parameter of varying importance to airlines³⁶.

Noise and emissions: Regulatory requirements mandate performance thresholds for these characteristics. As noise requirements were introduced in the North American and European markets, several older models were either retired, sold in other markets, or retrofitted with noise reduction equipment (hash-kitting) based on the availability of new aircraft. New aircraft that anticipate or exceed future requirements presumably are more competitive.

Maintenance requirements: Maintenance is an important cost for airlines. Direct maintenance costs (DMC) are generally lower for newer airplanes and tend to increase over time. Clark (2001) divides maintenance into line (simple tasks performed with the aircraft in duty), airframe maintenance and engine maintenance. Maintenance work is scheduled in advance and due to safety considerations is intended to be preventive.

Airframe maintenance is divided into A, C and D checks which are scheduled for every ~400 hours, ~15 months, and ~5 years correspondingly and are of increasing detail. These checks are done with the aircraft taken off line and therefore incur an additional cost in lost productivity. Engine maintenance is scheduled similarly into overhauls based

³⁴ The amount of fuel consumed to generate one pound of thrust for one hour.

³⁵ Well designed winglets can lower consumption by about 3 to 5%. Retrofitting older jets is an available option as well.

³⁶ But the importance of fuel consumption is expected to solidify in the fleet planning decision makers given (a) the specter of regulating CO2 emissions due to their impact on global climate, and (b) the increasing cost of oil as global capacity is pressed by demand.

on number of take-off cycles and total operating hours. Because of their scheduling, maintenance costs are not spread evenly over time as shown in Figure 3-10. A recent trend is the provision of “flight-by-the-hour” agreements by manufacturers of aircraft and engines that allow for an even spread of maintenance costs and reductions in overhead from the required personnel.

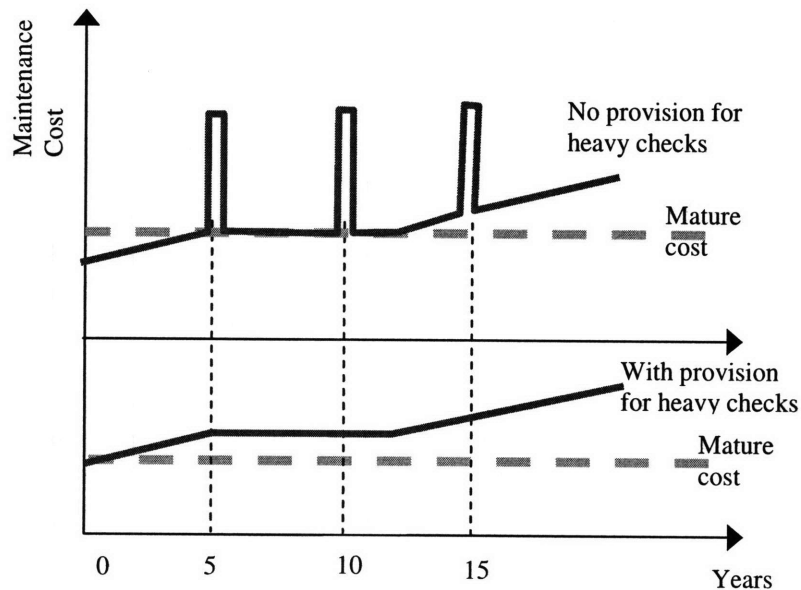


Figure 3-10 Cost structuring for maintenance costs (concept source Clark 2001)

Fleet commonality: Legacy airlines bought and retained large fleets with diverse types of aircraft. The fleet diversity would be exacerbated because of mergers when the aircraft of the two airlines were joined in a single fleet or with impulse buying. With their reduced emphasis on cost-control, the management failed to recognize that such diversity entailed significant costs in maintenance, parts inventory carrying, larger than optimal number of pilots, crews, and mechanics that have appropriate ratings for the different types of aircraft etc. The success of LCCs showed clearly that keeping a single aircraft fleet had benefits in all the above cost areas and legacy carriers were forced by competitive pressures to “rationalize” their fleets.

Of course there is a limit to the types of networks that can be covered with single type fleet as aircraft were optimized for combinations of distance, range and capacity. In that respect commonality by single-sourcing (using one supplier) can have an impact as long as parts are interchangeable. Airbus offered an innovation in that respect by extending commonality to whole aircraft subsystems and allowing for pilot cross-certification thus significantly increasing the advantage of single-sourcing (Stüssel 2003). Bador (2007) discusses limits in the benefits of commonality especially in the area of cockpit arrangements.

Strategies of aircraft purchasing/leasing/selling

Based on the above discussion, the decision to purchase an aircraft should involve long-term planning that balances of performance, maintainability, purchase and resale value. New aircraft have long delivery lead-times as they are complex engineering artifacts that are built on demand. These delivery lead-times make market forecasting necessary for airlines but are also providing an incentive to airlines to place phantom orders (orders that they are unsure if they needs) just to be in the queue. Airframe manufacturers, in their intent to gain market share (see Ch. 4), are not pricing the option for aircraft at its market value. In addition they offer several selling incentives: heavy discounts from list price, financing schemes, performance guarantees, and buy-back agreements. These incentives add to the pressure of airlines fleet planning teams to make a bargain contract.

Very large airlines may follow a dual-sourcing strategy just to ensure that both of the two manufacturing competitors can make credible bids for their orders. Large airlines are also regularly consulted by the manufacturers as to the desired performance of aircraft under development. In earlier years, dominant airlines like Pan Am, were the driving forces behind innovative aircraft (like the development of the Boeing 747 see Section 4.2.2). This is no longer usual although some promising leadership has been shown by Easy Jet (Harrison 2007). Despite the necessity of long-term planning by airlines, anecdotal evidence indicate that their true planning horizon is relatively short even when making these decisions of longer term impact.

Airlines that are in difficult economic position have also been found to be more likely to sell their used aircraft and at lower prices during market downturns (Pulvino 1998).

3.4.2.2 Leasing Companies: Owners vs. Operators

The dichotomy between owners and operators of aircraft is fairly recent as shown in Figure 3-11. Leasing firms buy new aircraft and lease them out using different types of leases³⁷. They regularly sell used aircraft from their fleet and may also manage fleets for airlines that are carriers only. The aircraft leasing industry is quite concentrated with three companies sharing most of the market but several other smaller ones: International Lease Finance Corporation (ILFC) owned by insurance firm AIG, GECAS which is a business unit of GE – which also happens to be a large aircraft engine manufacturer, and AWAS owned by the investment bank Morgan Stanley.³⁸

Morrell (2002) identifies four types of leases:

- *Finance leases.* These are non-cancellable with periods of 10-12 years covering the entire period of the asset's economic life. They are full pay-out leases, in that the lessees usually own the aircraft at the end of the lease. Leveraged leases are a

³⁷ Wet leases are short term offering fully manned aircraft and maintenance in which the lessee has to pay for the fuel and the lease. Dry leasing offers the aircraft only and is usually made for longer periods. Finally, capital leasing is a sort of financing provision in which the airline intends to retain the aircraft for periods longer than five years and generally intends to take ownership of the aircraft.

³⁸ In 2000, GECAS and ILFC owned a little less than 50% of the leased aircraft by value (based on Morell 2002, Table 8-3).

form of finance lease with the difference that they are financed using 60 to 80% debt finance and provided tax advantages to the lessors.

- *Operating leases.* These are more flexible, shorter term leases with duration from one to seven years and average contracts being five years.
- *Wet leases.* Very short period leases for which the lessor provides complete maintenance and cockpit and cabin crew (although the latter is not prerequisite).
- *Sale and leaseback.* This type of lease involves the sale of an aircraft by the airline that owns it and which continues to operate it under lease. They can be used as cash infusion mechanisms for airlines by realizing the aircraft value.

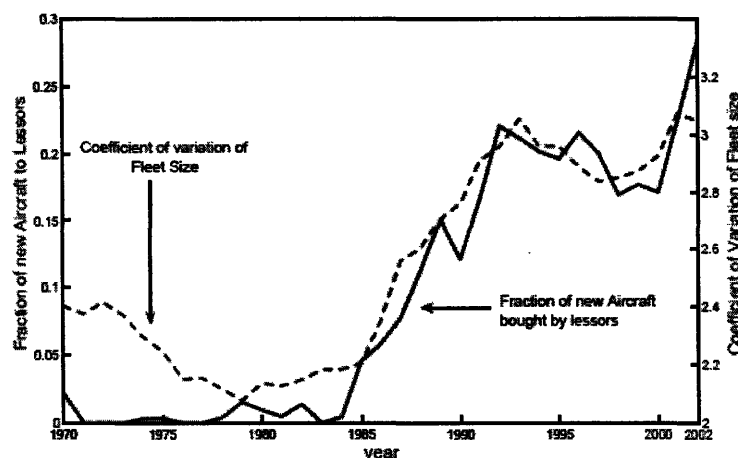


Figure 3-11 Percentage of New Orders by Lessors and coefficient of variation of fleet size (source: (Gavazza 2005))

Leasing, in theory, facilitates a more efficient allocation of capital resources by eliminating (or at least reducing) the friction in decision-making encountered by owners of the resource which is due to the transaction costs involved in trading in secondary markets or the value loss of idling. Gavazza (2005) found empirical evidence in the airline industry that support these expectations. He found that leased aircraft are held 40% on average less than owned aircraft and, more importantly, have 8% higher output than owned aircraft as they are held by airlines that can utilize them better. It should be noted though that lease contracts do not offer full flexibility; many of them are long-term and are not open to renegotiation or opting out.³⁹

Figure 3-11 shows two interesting aspects of leasing firms behavior. First there is high correlation between the increase in the variation of fleet size which implies that the emergence (and demise) of large number of small new entrant carriers was correlated and probably facilitated by the existence of leasing firms. The second aspect is shown more clearly if the fraction of aircraft orders by leasing firms is superimposed on the total

³⁹ Udvar-Hazy founder and CEO of the leasing firm ILFC recently remarked: “Big U.S. carriers, since the dawn of the jet age, act almost like superior beings,” after half his US customers asked for lease renegotiation post 9/11. “They want all the benefits when times are good, but if they are bad, they want you to sacrifice.” He continues: “Our company is stronger than any major U.S. carrier. The day will come when they need I.L.F.C.” (Wayne 2007)

orders as shown in Figure 3-12. There it is shown that although overall the orders of leasing firms follow the market trend they act as a dampening mechanism as they order much more comparatively to other players during order downturns (perhaps partly helped by the strong financial positions of their parent firms) and much less during upturns.

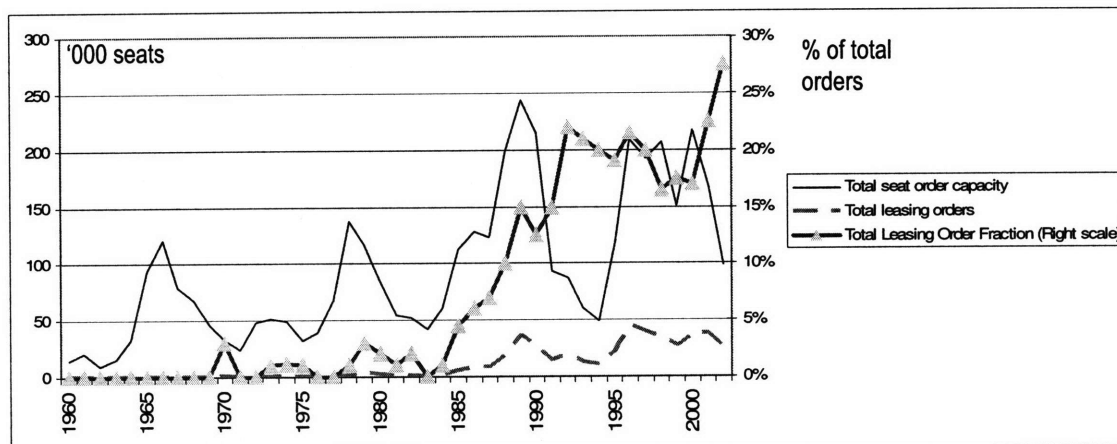


Figure 3-12 The dampening effect of leasing: Comparison of Total Orders to Leasing Orders (data sources: Boeing and Airbus orderbooks and (Gavazza 2005))

3.4.3 Employees and Labor Unions

The airline relationship with their employees has been notorious. As previously mentioned, employees enjoyed protected, well-paying jobs with substantial benefit packages before deregulation. Post-deregulation they were the first to face the brunt of cost-cutting measures to meet the competitive pressures and in some instances agreed to negotiated payment and benefit cuts while in others they engaged in severe strikes. In many cases, the powerful airline unions (pilots, attendants and machinists) did not act concertedly but rather tried to undercut each other generating animosity and partially succumbing to management manipulation to that effect. The tumultuous times peaked in mid-1980s and since then most airlines faced less protracted strikes. Attempts of employee ownership and management have generally been thwarted and were not successful the one time that was actually tried (Petzinger 1995)

At this stage, unionization is not an indicative factor of the management-employee relationship levels. Southwest has the highest level of unionization in the industry but is also know for extremely high levels of employee satisfaction and these are a key part of their business strategy (Gittell 2003). JetBlue, another carrier with high levels of employee satisfaction and stated goal to achieve them, is entirely non-unionized.

3.5 Cycles in the Airline Industry

In the previous sections we alluded to the cyclical behavior of the airline industry but we did not address it directly. In this section we will review the aspects of the industry that are cyclical directly.

Demand itself does fluctuate tracking the GDP (see Fig. 3-13 and Ch. 2) but these fluctuations are relatively benign as shown in Figure 3-14 and if anything they tend to dampen post-deregulation.

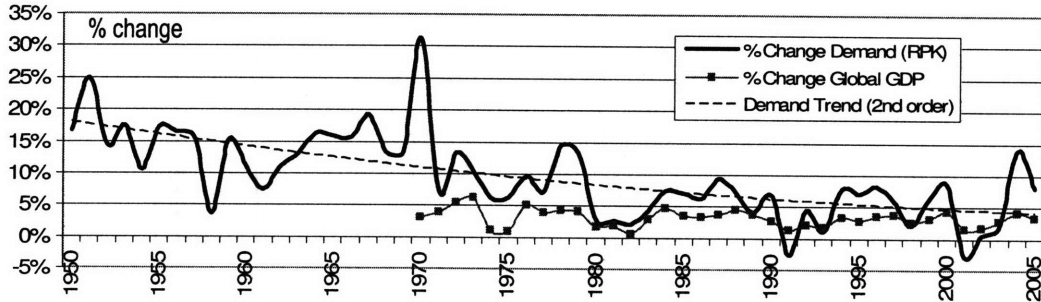


Figure 3-13 Demand change rate compared to GDP

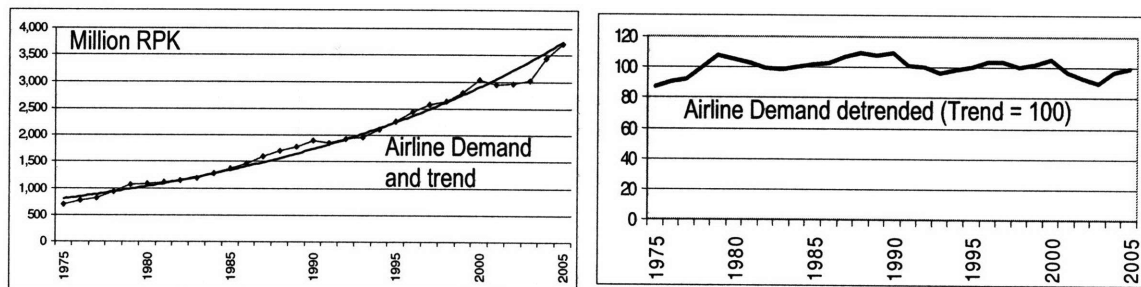


Figure 3-14 Global Airline Demand, Trend (left side), and Detrended Normalized Demand (right side) (data source: (ATA 2006))

This dampening of demand fluctuations is indicative of the increased competition between airlines and the success of yield management systems and price discrimination that tailors fare prices to maximize load factors.

As shown, in Figure 3-15, load factors do indeed increase consistently in the post-deregulation period while the real yield (which is equivalent to average fare price is consistently decreasing).

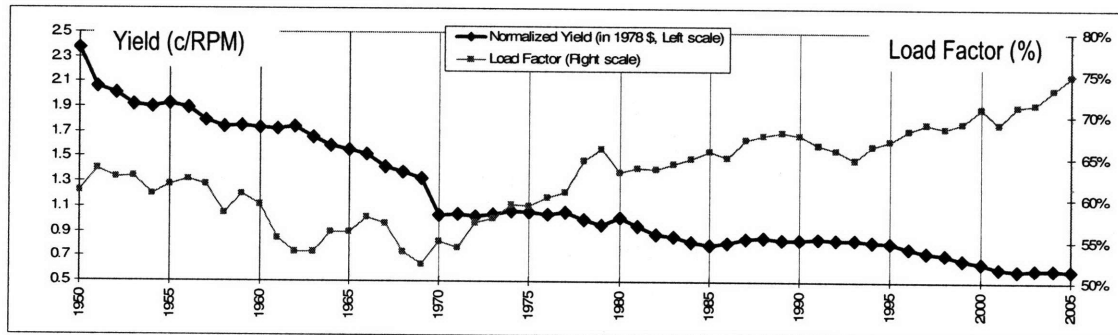


Figure 3-15 Normalized real yield and average load factors

Given this consistent increases in load factors and demand even in the face of changes in economic activity we expect that airlines would alter their fares to achieve this and thus

impact their profitability as the airline cost structure is relatively fixed in the short term. This indeed is the case as shown in Figure 3-16. Jiang and Hansman (2004) modeled this profitability cycle with a seemingly increasing amplitude as a second order undamped oscillatory system with a period of approximately 11 years as shown in Figure 3-17.

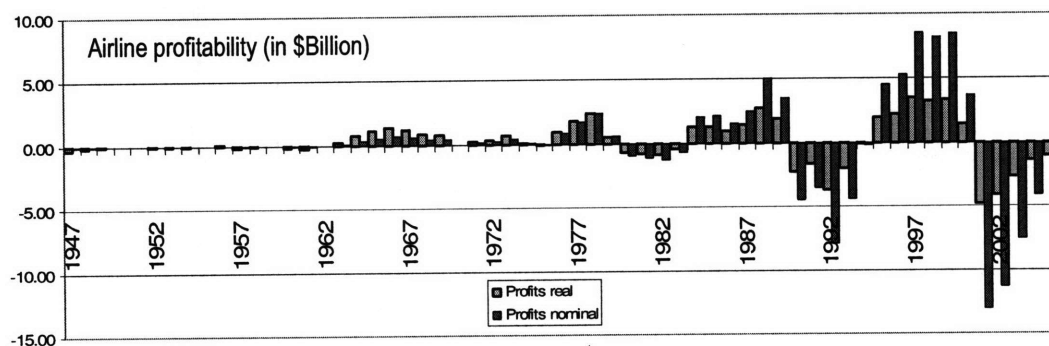


Figure 3-16 Airline net profitability in Real and Nominal \$

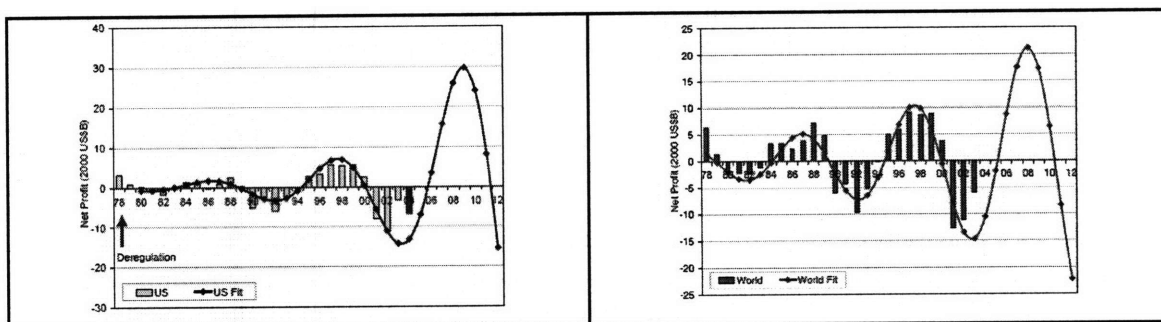


Figure 3-17 Airline oscillatory profitability and 2nd order undamped oscillation fit for the US (left) and global (right) airline market (source: (Jiang and Hansman 2004))

This quite cyclical profitability is not an artifact of one dominant market (US) that supersedes a more normal behavior elsewhere but persists on the same scale in different regions as shown in Figure 3-18.

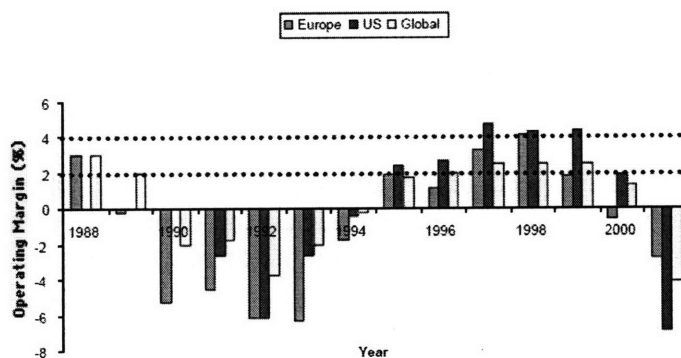


Figure 3-18 Comparison of European, US, and Global airline performance (source: (Button, Haynes et al. 2002))

The effect of cyclical profits in a sector that uses durable goods is expected to propagate up the supply chain amplifying in variance in a phenomenon known as the 'bullwhip

effect' (see Ch. 6 for further discussion). This is indeed the case in the order relationship between airline and airframe manufacturers as shown in Figure 3-19. Where the total orders placed with manufacturers in seats have a phase shift from the profit cycle of the airlines by about a year in the peaks and two years or more in the recessions.

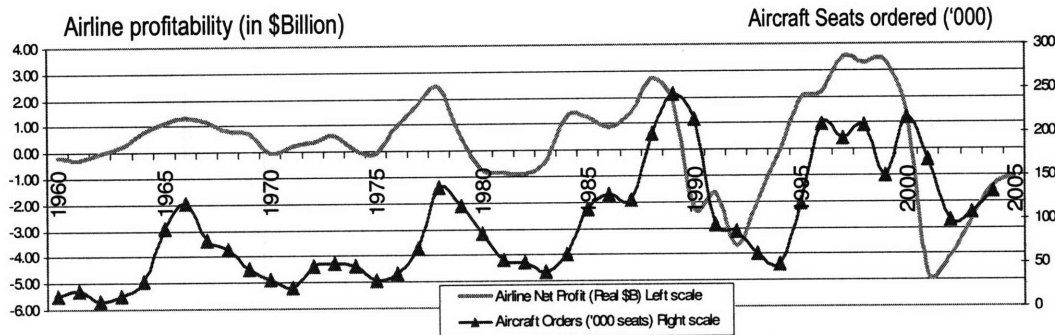


Figure 3-19 Airline profitability and order placements comparison

The mechanisms that feed the strong cyclicity in the airline industry as shown by the indicators in this section will be discussed extensively in Chapter 7.

3.6 Chapter 3 Summary

In this chapter we explored some defining characteristics of the airline industry. We defined the basic metrics used to measure output and performance in the industry. We discussed its cost structure and how different business models and deregulation spurred competition and even price wars in the industry. Even with deregulation though, the setting of fares can be less than competitive for uncontested routes or routes that would not support more than one carrier profitably.

Besides the government-airline connection, we saw the factors that airlines consider when making aircraft purchase decision and how the rise of leasing firms has impacted the industry: (i) leasing allows (relatively) increased flexibility in capacity ownership, (ii) leasing also reduces the barriers to entry for new carriers that do not have to carry the full risk of aircraft ownership, and (iii) while not reacting as fast as airlines in ordering aircraft as conditions change (dampening effect) it provides an additional echelon of decision making that may allow for some duplication of ordering.

Finally, we illustrated the aspects of the industry that are cyclical and aspects that are not. In the next chapter we will present in more detail the immediate upstream suppliers for airlines – aircraft manufacturers. How the manufacturers' competitive environment reacts to the cyclicity in the airline industry and to what extent it reinforces it will be analyzed further in the remainder of this dissertation.

Chapter 4 Airframe Manufacturing: Industrial Evolution

Airframe manufacturers are the next step up after airlines in the value chain of air travel. Traditionally, they design, manufacture, and support the aircraft equipment used for providing air transport services. In this chapter we review the strategic alternatives they face in the context of their industry and its relations to their suppliers, buyers, shareholders and governments. For exploring the dynamics of the industry we use the evolution of aircraft as a base for narrating the technological and organizational changes in the industry.

Airframe manufacturers have to decide on whether to build a new aircraft, what specifications to equip it with, and at what price to sell it. Although, aircraft prices have been steadily increasing in line with the increase of aircraft complexity and performance, the manufacturers have competed aggressively to gain or retain market share. This competition reflects on the substantial discounts offered to launch buyers, volume buyers, and most interested parties that try to pit the airframe manufacturers against their competitors.

The reasons behind such aggressive marketing behavior are summarized in the list below:

- **Economies of scale:** As aircraft production requires significant upfront development costs, the average aircraft production costs are reduced substantially as development costs are allocated over more aircraft produced.⁴⁰
- **Learning curves:** Given the complexity and the number of each production run, it does not come as a surprise that aircraft manufacturing is adhering to strong learning curves. In fact, the aircraft industry has been the focus of case studies on the effect of learning effects since the 1930s ((Wright 1936), (Alchian 1950), (Argote and Epple 1990), (Benkard 2000))
- **Vendor lock-in⁴¹:** The larger the number of aircraft of a given production line that are in use reduces the operating cost of that aircraft type for the airlines. This is due to the relative greater abundance of spare parts, mechanics, and airports that accept that type. This effect is even more pronounced internally for a given airline where commonality in parts and training can allow savings in part inventories, crew training, and higher interoperability. While the lock-in effects have not been studied rigorously for aircraft, there are anecdotal indications for them⁴². (Liebowitz and Margolis 1995) identified three types of lock-in: (i) first degree where there is cost changing but it the choice was efficient because of full

⁴⁰ While this is true for most heavy manufacturing products, LCA are in a category of their own as they run in production lines that range from 200 to 3000. They are produced in higher numbers than large ships which are largely custom-built yet they are not mass produced like automobiles.

⁴¹ While the definition of network effects is usually given as value increasing more than proportionally due to the addition of users, it can be used for aircraft in the inverse: value *decreases* more than proportionally with the addition of aircraft types.

⁴² A GE executive stated that they are in the “razor business” to justify selling aeroengines below cost and aiming to recover their expenses and profit by revenues from the after-sale support and parts sales (the blade aspect of the business).

knowledge; (ii) second degree where the outcome appear inefficient a posteriori due to limitations on knowledge; and (iii) third degree inefficient but remediable outcomes. They note that owners (in our case aircraft manufacturers) can take advantage of lock-in externalities by offering incentives to early adopters.

- **Lifecycle revenues.** Aircraft maintenance during its lifecycle provides sustainable revenue for the manufacturer as a sort of annuity. While such revenues have been instrumental in the marketing of jet engines with revenues that could exceed 90% of the engine price tag over its lifecycle, they are less important for airframes.

The above characteristics offer a potentially long-term and reinforcing advantage to the manufacturer that can gain an edge in the market share on specific families and across the product line.

The nature of the competition and the limited production runs for aircraft, forced industry consolidation to the current point of a competitive duopoly. While in the near term future, no potential entrant to the large commercial aircraft (LCA) market is perceived as viable, manufacturers of smaller aircraft like regional jets and turboprops, governments of large developing world economies, key suppliers of aircraft parts or any combination of the above may eventually provide a credible counteroffer or even introduce a disruptive technology that would render the LCA obsolete.

The sensitivity of the airframe manufacturing industry in issues of national defense and its use of cutting edge technologies with great potential for spillover in other economic sectors, made aircraft manufacturing an attractive sector for government involvement and support. This involvement, direct and indirect, has lead to ongoing legal disputes brought to international adjudication with regard to subsidies provided to Boeing and Airbus by their respective governments. Even more than airlines, aircraft manufacturers are flag carriers of national pride. As no single national market is sufficient, aircraft manufacturing becomes a leading industrial exporter of high value assets. As such, it can mitigate trade imbalances with third countries. All these characteristics combined, make the industry a prime target for industrial policy and government manipulation which some times is brought to the extreme where head of states act practically as sales representatives for the manufacturer of their country.

It is critical to understand the characteristics summarized above in order to understand and meaningfully model the interactions of the airframe industry with the airline industry and the other constituents of the Commercial Aviation Enterprise of Enterprises. In Section 4.1 of this chapter we will review the current state of aircraft manufacturers. We discuss the considerations taken in aircraft development and how these affected competition in Section 4.2. Section 4.3 discusses the manufacturing requirements for a complex aircraft and how competitive pressures shape pricing. Finally, Section 4.4 reviews the effects that the cyclical behavior of the airline industry imposes on the manufacturing industry.

4.1 Large Commercial Aircraft: Industrial Evolution

Limited markets and the size of capital investments needed to compete for the increasingly complex task of producing LCA led to the consolidation of the industry down to a duopoly. Boeing (after its merger with McDonnell Douglas) and Airbus, a combination of a number of European aerospace firms, are the two remaining players as LCA suppliers.⁴³ The aircraft supply chain is completed by four engine manufacturers⁴⁴, a large number of part suppliers and raw material providers. Some key raw materials for aircraft manufacturing like titanium and certain types of composites are production-constrained and therefore access to supply can be critical for aircraft production.

Piepenbrock (2005) used Boeing and Airbus as prototypical examples of his “red vs. blue” enterprise categorization.

“Red” or *integral* companies exhibit a tendency to grow organically in slow but intently sustainable fashion. They form strong relationships with the stakeholders of their extended enterprise that include governments, suppliers, financiers, and suppliers. As these companies emerge during the mature phase of a technology, their product innovation focuses on providing end user value at low cost but usually at the expense of cutting edge innovation or performance.

“Blue” or *modular* companies on the other hand tend to be more insular from the stakeholders of their extended enterprise. As they have a comparatively longer history of engineering excellence, they are usually driven by technical innovation and in some cases sacrifice operating efficiency or manufacturability for technical performance.

The red/blue division integrates several models of enterprise evolution from (Utterback 1994) technological maturation to the stakeholder vs. shareholder model of the corporation as reviewed by (Donaldson and Preston 1995).⁴⁵

No company is purely blue or red based on the above description but their shade of purple may be skewed towards one or the other color. In the following sections, we will identify the overarching characteristics of aircraft manufacturing as an enterprise and where the two primary competitors (Boeing and Airbus) differ starting with an overview of their organizational history.

4.1.1 Early History of US Aircraft Manufacturing: Boeing Commercial Aircraft Origins

Boeing started its career in the second half of 1920’s by selling training aircraft to the U.S. Navy. Boeing founded Boeing Air Transport (BAT) an airline operator for

⁴³ Regional jets have capacities of up to 120 seats that are on the low end of LCA. This market is also duopolistic with Bombardier and Embraer being the two primary manufacturers. This is a more contestable market with ventures from China and Russia intent on entering it.

⁴⁴ GE and Pratt Whitney on the US side. Rolls Royce and Snecma (part of the SAFRAN group) on the European side. Many engines are actually developed in collaboration between two (or more) of the manufacturers to pool the costs and risks of such development.

⁴⁵ See extended discussion in Chapter 5.

passenger flights (1927) and at the same time it engaged into a contract with the U.S. Postal Service to transport mail between Chicago and San Francisco. The U.S. government was involved in the nascent industry through its defense arm by ordering combat planes and with the passage of the Air Commerce Act which established federal regulation over commercial air services and federal funding for establishing the beacon network necessary to guide those flights.

As a builder of planes, Boeing was one among dozens small aircraft companies competing for a relatively small and unpredictable market. Boeing managed to distinguish itself through conglomeration: in 1928, during a booming stock market period, Boeing Airplane and Transport Company absorbed Boeing Airplane Company, BAT, engine maker Pratt & Whitney, a propeller manufacturer and smaller regional airlines becoming “the largest aerospace conglomerate in the world” (Lynn 1997). This conglomerate, known as United, was the essence of vertical integration, controlling almost all aspects of the aerospace business. By 1931 United Airlines had a fleet of 120 planes that flew 32.000 miles a day.

A continuing expansionist drive for market domination fueled the conglomerate. At work was a positive feedback loop shown diagrammatically in Fig. 1: United created demand for aircraft and the manufacturing profits are used for designing bigger and better planes that would in turn attract more passengers generating more profit for both divisions.

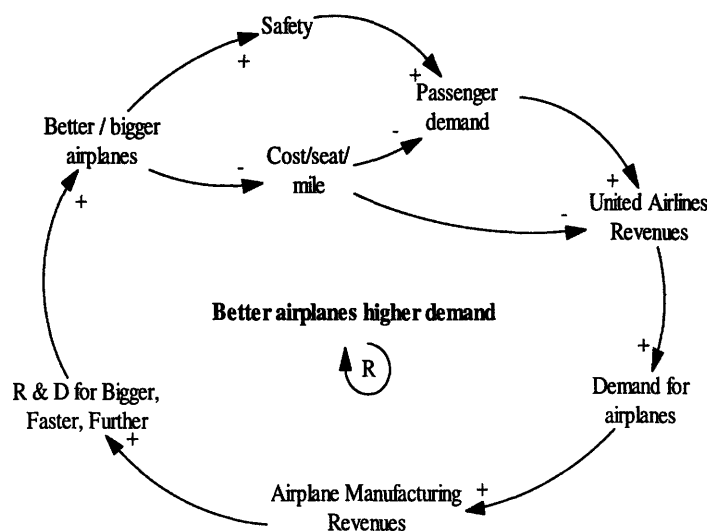


Figure 4-1 A virtuous cycle of demand in a vertically integrated business (Boeing's business strategy in the 1920's)

Boeing's airplane design in fact followed those demand trends: the four-seater mail planes were replaced in 1928 with Model 80, a 12-seater known as the “Pullman of the air.” **Boeing 247**, the “first modern passenger airliner” in 1933 created new standards of comfort and speed with an all-metal construction, 200mph top speed and a cruising altitude of 11,500 feet but still carrying only 10 passengers. At this time Boeing had managed to capture almost fifty percent of a fragmented market.

Ironically, this high point for Boeing, achieved through vertical integration of production, distribution, and retail, created fertile ground for the anti-trust watchdogs to take action. Congressional committees investigated into the award of airmail contracts without bidding and although Boeing's defense indicated that this was done because no competitor bid for them, they lost the case. The legislation enacted prohibited companies with a connection to airframe manufacturers to bid for contracts and this for United meant that its flights could not be sustained since passenger revenue alone was not nearly enough for profitability. Inevitably, the conglomerate broke up to its original constituents and Boeing shrunk back to being a "financially weak airframe manufacturer." (Lynn 1997). In the meantime competition was catching up; Douglas built, at TWA's prompting who wanted a supplier outside the United conglomerate, an all aluminum DC-2 and Lockheed introduced Electra, a 10-seater all-metal plane sporting a series of innovations⁴⁶.

Despite all this, in the mid 1930's Boeing started to gain momentum with the B-17 Flying Fortress project which was ordered experimentally by the Army. Although, this project did not expand until WWII, it gave Boeing the experience needed to introduce large civilian aircraft. In 1936, PanAm ordered a fleet of **Model 314** Clippers (4 engine flying boat seating comfortably 74 passengers) but the flying boat was soon deemed to slow and inefficient by comparison to the next generation of designs. **Model 307** Stratoliners (33 pax capacity) were introduced in 1941 with a significant innovation: pressurized cabins that make them capable of flying at 20,000ft thus providing comfort and speed by avoiding bad weather conditions. Douglas responded by developing the DC-4 (42 pax capacity) which was both faster and roomier and allowed it to capture market share over the 307. This left Boeing just before WWII at the number two position (45 planes flying in the US) significantly lagging behind Douglas (183 planes) and closely followed by Lockheed (42 planes) (Lynn 1997).

WWII changed the landscape radically creating a windfall of revenues from the huge ramp-up of military aircraft production. During the war more than 300,000 planes were built. Boeing's facilities for the production of 307 and 314 were converted for producing B-17s at a rate of over 200 / month at peak period. The improved bomber design, B-29 Superfortress, went into production in 1944.

Expectedly, such levels of production could not be sustained after the end of the war. At this point, the new president of Boeing, Bill Allen, boldly decided to produce 50 Stratocruisers (**Model 377** was a modified B-29 design with an ability to carry up to 100 pax) hoping to attract buyers by taking advantage of scale economies. The strategy proved successful gaining orders from Pan Am, Northwest and other large carriers of the day but even so the program was only marginally profitable after ten years of sales and this margin was achieved primarily due to sales of spare parts (Lynn 1997).

As it happens, for the 1950's Boeing continued to be supported primarily through military contracts due to the Cold war-induced need for long-range strategic bombers.

⁴⁶ Electra featured retractable landing gear, trailing edge flaps and variable-pitch propellers.

Boeing's first jet was B-47 followed by the well known and still in use B-52. Despite this experience, Boeing and the two other major American LCA manufacturers were reluctant to proceed in creating a jet airliner believing that the operational costs would offset the advantages of higher speed, comfort and safety. The fact that De Havilland's **Comet** was under development loomed as a significant threat though (see Section 4.2.2) that mobilized the US Congress into action to pass a bill for the development of a civil jet. The bill ended up being scrapped partly because the manufacturers would not agree on the allocation of the subsidies.

While the U.S. airframe manufacturing industry never reconsolidated with airlines, it did see a strong wave of consolidation as the industry matured in both the commercial and the defense side of the business as shown in Figure 4-2 in accordance with the S-curve industry and technology development framework proposed by Christensen (1997).

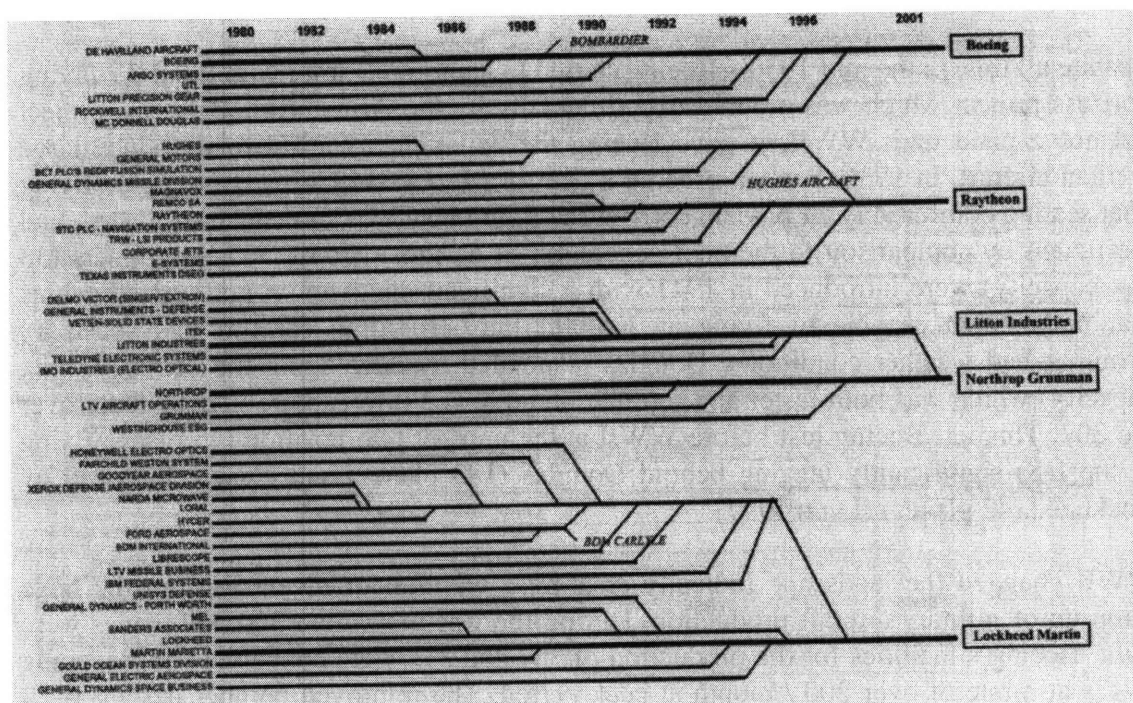


Figure 4-2 Consolidation in the U.S. LCA and Defense Aerospace Industry (Source: Ferreri (2003))

The early years of aircraft manufacturing history demonstrate some themes that are consistent over time: diversification and synergistic development primarily with defense contracts, government support, close collaboration with airlines, and exploitation of economies of scale were instrumental in establishing LCA manufacturers.

These themes are repeated with variations:

- the spillover between military transports and LCAs may have changed direction from the civil to the defense side (the development of the A400M military transport by Airbus or the air refueling tankers KC-135 relied more on civilian-developed technologies and using the economies of scale provided by civil aircraft production)

- airlines were more fragmented and have not instigated the development of a new aircraft type since the time of PanAm. Exceptions to this have only recently appeared.

4.1.2 Airbus Industrie

In the face of the Concorde financial failure (apparent after the 1973 oil crisis) the European industry players were reluctant to commit to another common undertaking. The politics behind it made the birth pains of Airbus quite significant, the British and the French partners were unable to agree on either the size of the proposed aircraft or the amount of financing provided by each partner and more importantly, partner commitment was lukewarm, to say the least. So when in 1970, Roger Beteille as chief executive and Henry Ziegler as chairman of the just formed Airbus Industrie (referred as Airbus) started work for the first A300 to be produced it was the unlikely brew of German assertiveness and an American idea that made it possible (Lynn 1997).

The extensive existing fleet that Airbus needed to compete against was substantial and almost complete as shown in Figure 4-3. Airbus found the niche to enter the market by following the suggestion of Frank Kolk, the technical director of American Airlines, who had tried to lobby the U.S. manufacturers during the mid-1960s to consider a twin-engine wide-body jet that could fly 1500 miles. They all refused to do so for good reasons; Boeing was committed in the development of the 747, and Douglas and Lockheed had 3-engine planes in the making. Furthermore, the FAA "60-minute rule"⁴⁷ was still in effect for twin-engine airplanes and that would render the airplane less useful for certain routes. Yet, the idea of such an airplane had appeal for the airlines since it could significantly reduce their operational costs per available seat-mile. As we discuss in Section 4.2.2, the resulting A300 became a relative success after intense marketing and lobbying efforts that allowed for generous terms of development and initial production financing supported by the European government of the consortium.

The initial Franco-British consortium was stabilized by the German involvement at its most vulnerable moment, when the British government decided to withdraw their support. The issue was not only financial but a technical one since no one else in the nascent consortium had readily available the expertise to build wing-structures of such scale (Lynn 1997).

⁴⁷ This rule prohibited flight of twin-engine aircraft for more than 60 minutes over water or from the closest airport. The reliability and thrust of turbofan engines allowed for a relaxation of the rule for tri-engine airplanes like the 727, Lockheed L-1011, and Douglas DC-10. The equivalent International Civil Aviation Organization (ICAO) regulations are known as ETOPS (that stands for Extended-range Twin-engine Operation Performance Standards or as it is jokingly referred to Engines Turn or Passengers Swim). With the advent of A300 and the proven safety record of high by-pass turbofan engines the ETOPS regulations were extended to 180 minutes to allow for trans-pacific flights of twin-engine airplanes like the Boeing 777 given the operation of emergency runways in the Aleutian Islands.

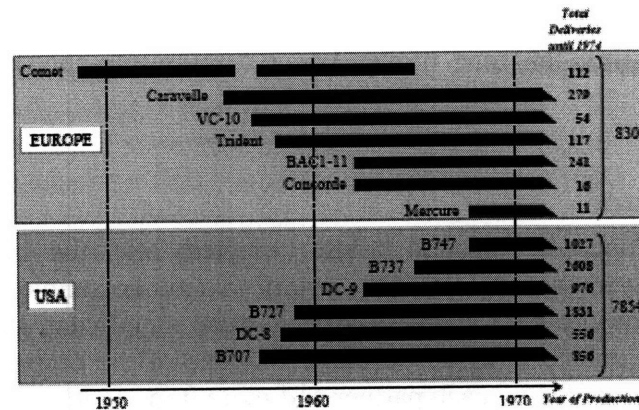


Figure 4-3 Pre-Airbus Jet Aircraft in Production (Source: (Stüssel 2003)).

Airbus was created as a special corporate partnership known as Groupement d'Interet Economique (GIE) under French law. At that stage, the partners were responsible against third party obligations and not Airbus which had no capital of its own. The stabilized participation of the partners was France's Aerospatiale S.A. (37.9 percent ownership), Germany's Daimler-Benz Aerospace (37.9 percent), British Aerospace PLC (20 percent) rejoined in 1979⁴⁸, and Construcciones Aeronauticas S.A. of Spain (4.2 percent) (Stüssel 2003).

While this structure arguably provided unintended advantages to Airbus by forcing a just-in-time (JIT) production pattern and a less aggressive growth strategy based on consensus decision-making, it seemed that it would not be able to sustain the growth of the consortium indefinitely. That became apparent after the merger of Boeing and MDD in 1997 which was the year that negotiations started for forming an integrated European aerospace entity. After complex negotiations detailed extensively by (Schmitt 2000), the European Aeronautic Defense and Space Company (EADS) was formed with activities in helicopters, space launch, missiles, military aircraft, avionics in addition to LCA manufacturing. Compromises were made to allow public shareholders against the wishes of the German partners (Schmitt 2000) (pg. 44).

4.2 Aircraft Design: Performance and Decision-making

Commercial aircraft have shown tremendous gains in performance which have been accompanied by increases in the cost of their design and manufacturing. The aircraft of today are highly complicated systems that have in excess of 100,000 primary parts. Their design requires the coordination of engineers across several disciplines and presents a formidable systems integration problem. Even a successful aircraft design is produced in very low quantities (break-even point is usually around 600 aircraft) compared to other manufactured products like cars or microchips. The low number runs coupled with the high complexity of the design make aircraft manufacturing subject to strong learning

⁴⁸ BAe sold their EADS 20% share in 2006 after a strategic decision to focus entirely on defense.

curve effects ((Wright 1936), (Alchian 1950), (Argote and Epple 1990), (Benkart 2000)).⁴⁹

As we saw in the beginning of this chapter, the learning curve coupled with very high initial R&D costs make aircraft particularly prone to economies of scale as the average cost per aircraft is significantly reduced by each additional aircraft produced. Adding to the economies of scale of production, are vendor lock-in effects that are exhibited after the aircraft are deployed: the higher the number of aircraft of a given family deployed (or if there is sufficient commonality across product families of the entire fleet) then the costs of maintenance and inventory parts are reduced.

The increasing cost of complexity in the design is reflected in the price paid by the airlines, which has been steadily increasing as shown in Figures 4-4. The capital ownership costs for airlines follow the same trends as shown in Figure 4-5. Since these do not include interest expenses (they do include leasing expenses), the true ownership costs are higher than indicated in the chart. While this price increases could be attributed to market power of the manufacturers, they are more correlated to an increase in complexity and the related development costs as we discuss in the next section.

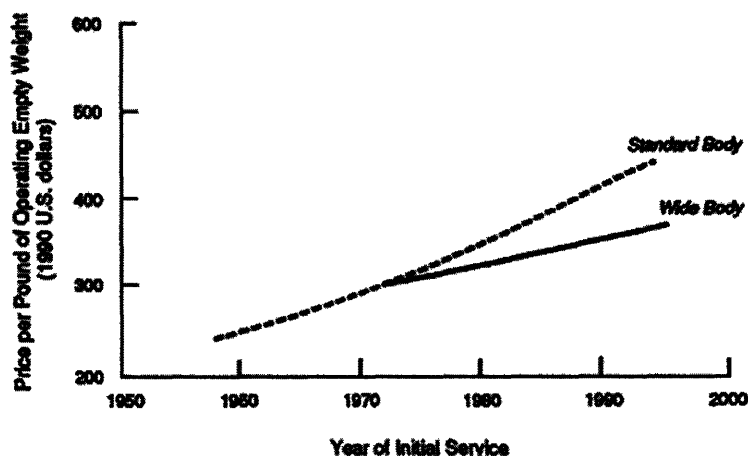


Figure 4-4 Aircraft Price Trends (Source:(NRC 1992))

Even the pressure of the discounts did not hinder the steady climb of ownership costs as declared by US airlines.

Impact of aircraft capital costs on airlines

These costs allocated over a large number of aircraft and over the aircraft's usually long life cycle (~25 years) may seem to lose their importance for the airlines. As we saw in Chapter 3, the aircraft ownership costs as a percentage of total airline costs can range from 5% to 13% (10% to 25% of direct operating costs) depending on the estimation. These calculations are fleet wide and specifically do not take interest into account while they depend on depreciation method. That range can be as high as an average of 50% of

⁴⁹ Studies calculated this effect to a 20% reduction of manufacturing costs for every doubling of production.

direct operating cost when interest is included for specific aircraft rather than fleet wide (see Table 4-1).

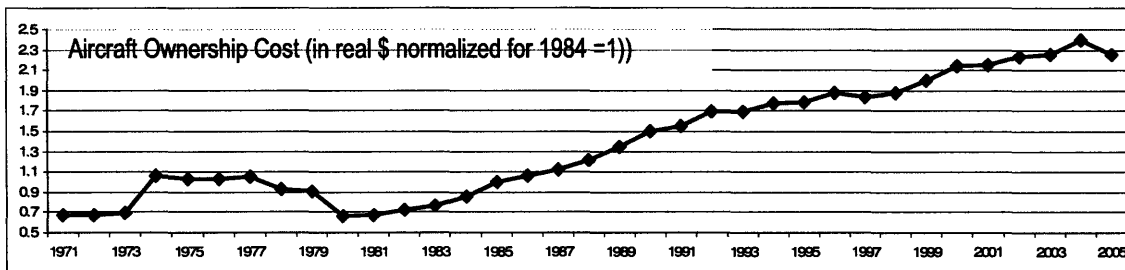


Figure 4-5 Inflation Adjusted Normalized ownership costs for US Airlines (Data source: (ATA 2006))

Table 4-1 Airline Direct Operating Cost (Source: (NRC 1992) pg. 45)

	\$0.63 Fuel (1990 Level)		\$1.20 Fuel	
	DOC BREAKDOWN (%)	IMPACT ON DOC OF 25% CHANGE (%)	DOC BREAKDOWN (%)	IMPACT ON DOC OF 25% CHANGE (%)
Crew	13.3	3.3	11.4	2.9
Maintenance	14.4	3.6	12.3	3.1
Insurance	1.5	0.4	1.3	0.3
Fuel	18.6	4.7	30.3	7.6
Ownership	52.2	13.1	44.7	11.2

(Average for B737-400, B757-500, B747-400 for ranges 500, 1000, 2000 nautical miles respectively).

So for airlines the decision to buy the right aircraft at the right time can be critical for survival as their actual costs are dependent heavily on the type. Two among the many anecdotal examples that show how critical this decision can be are (i) Pan Am and its strong push to acquire B747s that were delivered on the height of recession in 1971 and were flying at a loss with less than 60% load factors weakening the company (Petzinger 1995) and (ii) the decision by Eastern airlines to order new and fuel efficient B757s during the second oil crises in 1978 only to find that when delivered in the early 1980s oil prices were back to pre-crisis levels, the aircraft were larger than needed for the markets they were serving that meant less frequency. This fleet choice created a strong vulnerability that People Express and New York Air exploited by deploying cheap, small, old technology, gas-guzzling planes and offering the right frequency at the right price (Petzinger 1995).

Aircraft performance improvement

Decreasing operating expenses and increased performance is the necessary *quid pro quo* for making new aircraft appealing to airlines. The evolution of aircraft has seen a consistent decrease in the operating costs involved as exhibited dramatically in Figure 4-6. The only exception to the rule was the introduction of the jet engine which, being a disruptive innovation, was not refined to the point of piston engines. While the initial jet engines offered dramatic improvements in speed it took a few years until their fuel efficiency and maintenance costs matched the older technology. The advance in the relative operating cost per seat mile spanning the total life of the industry can be seen in Fig. 4-6.

Anecdotal narratives of the state of aircraft pre 1960 give an even better sense of the disparity between feasible and ideal aircraft designs (Gann 1961).⁵⁰

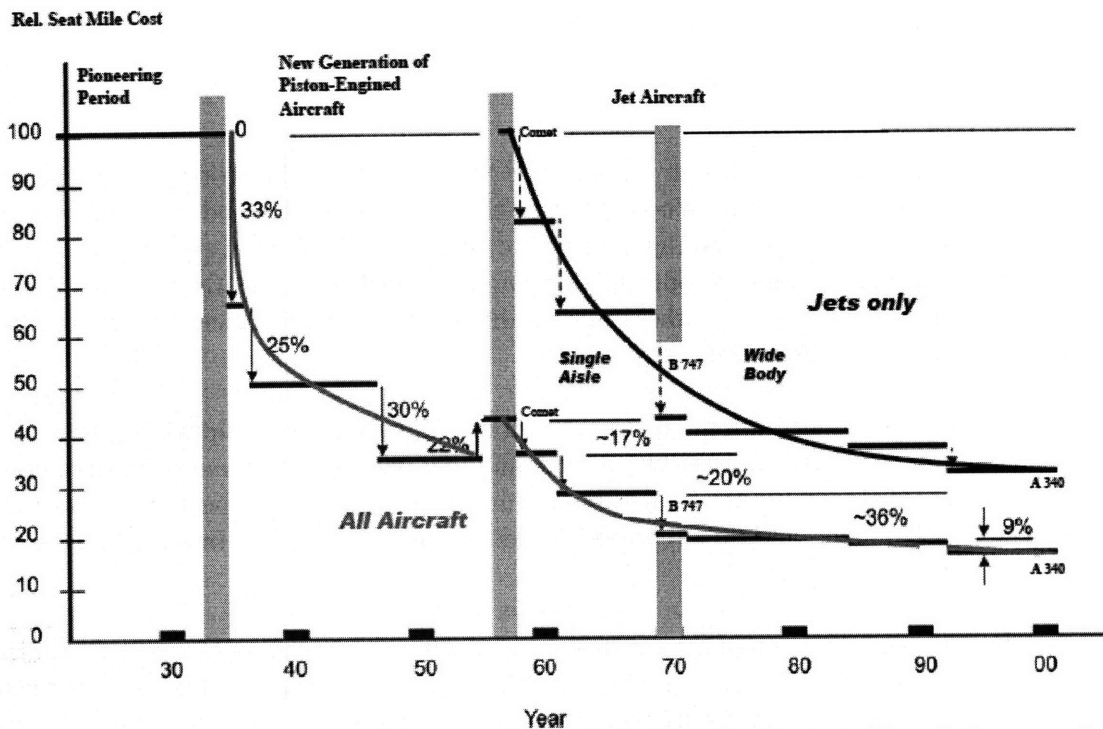


Figure 4-6 A maturing industry: Advances of the technical frontier illustrated by relative operating cost per seat mile (Source: (Stüssel 2003))

These improvements were made possible by a combination of advances in technology and of consultation and push-back from the customers. Any successful aircraft design when it enters the market is the product of extensive consultations with the dominant buyers and users (Stüssel 2003) (pg. 6). Being able to achieve the right balance of performance, size and economics to fill the different market segments as those have formed and perhaps create new niches is not trivial.

The irreversible sunk costs involved make aircraft development a risky proposition and as airlines can be critically threatened by erroneous aircraft acquisition, so do aircraft manufacturers if they develop an aircraft that is not right for the market even if technically excellent. Commensurately, if the aircraft designed has technical issues that compromise safety or performance then the costs to the manufacturers can extend far beyond the specific aircraft and tarnish the image of both the user and the producer.

⁵⁰ For a vivid illustration of the handicaps faced by pilots that had to tame, live (and not infrequently) die with such "beast[s] of an aircraft" in the dawn of the commercial airline aviation industry see the book "*Fate is the hunter*" by Ernest Gann. The legendary DC-2s, DC-3s, and DC-4s play protagonistic roles with their quirks and abilities as they fly their unpressurized cabins across mountain passes, through blizzards and over oceans. Stories of icing on the wings' leading edges, of backfiring engines and auxiliary rubber fuel tanks fitted in the cabin to increase range are spread throughout the book. For a story that combines the urge to improve performance with technical miscalculations and a closely avoided disaster, see the chapter "A certain embarrassment" pg. 337.

To exhibit the effects of aircraft decisions on the manufacturers we use the ‘vignettes’ that follow. Each vignette compares key commercial aircraft and discusses the decisions that led to them and how they affected the current competitive status.

4.2.2 V1: The Early Jet Years

For our first juxtaposition we choose the aircrafts that introduced the world to the jet-age and a piston-engined competitor. We summarize their characteristics and relative market success in Table 4-2. The first commercial jet airliner was the Comet produced by the British firm DeHavilland and introduced into service in 1952⁵¹. The British used their expertise on jet engines to bridge the gap in altitude and therefore speed⁵² that piston-engine powered aircraft could not reach.

The Comet presented a technological leap that could have been a disruptive innovation: the new technology was incorporated by a company that was not dominant in the existing market for piston-engined LCAs. A disruptive innovation would be expected to give the first mover an advantage, and this appeared to be the case in the years immediately after the introduction of the Comet.

Designing the Comet was a challenge with the low thrust the available jet engines⁵³ could produce. This had three design ramifications: (i) create a small plane (36 seats) intended for the high-end market, (ii) use a thinner sheet of metal for the fuselage skin in order to reduce weight, and (iii) position the engines inside the base of the wing to reduce drag rather than in pods as would be the prevalent design in most LCAs to come. As a way to improve customer satisfaction, the Comet also sported wide rectangular windows that would offer views comparable to those of the competition.

From the three compromises described above, the second proved fateful; after multiple compression decompression cycles in the plane’s normal life, metal fatigue concentrated around the corners of the rectangular windows caused skin failure and as a result explosive decompression that led to consecutive accidents and the grounding of the Comet fleet. Investigations eventually pinpointed the cause of the failures and all subsequent Comet models resolved the problem of metal fatigue by strengthening the skin, incorporating the then available more powerful engines, and re-adopting round windows. Yet, the reputation of the Comet was tarnished and was never able to regain market share.





Given the high stakes in the industry, it appears that the choice to proceed with innovation is risky. Certification and testing becomes more expensive and if a problem is discovered after causing accidents, demand will vanish favoring the competition.

⁵¹ Maiden flight in 1949. Testing and certification for commercial use took three years.

⁵² Turbulence and

⁵³ The Comet was initially fitted with the DH Ghost engines, and later with Rolls Royce Avon and Spey engines.

Table 4-2 Early Jets Technical and Market Comparison

	Mfg.	Year/Sales	Pax.	Range	Speed	MTOW
	Designation	(first delivery)	Typical config.	Typical in km	Cruise in Km/h	Metric tons
	Lockheed L-1049 Constellation	1950	95	8700	530	65.8
	DeHavilland Comet 2	1952 Sales: 112	36	2400	725	47.6
	Boeing 707	1958 Civil Sales: 1010 Mil. Sales: 820	110	6820	884	116.6
	DC-10	1959 Sales: 556	124	7410	946	140.6
Image credits: Wikipedia, Boeing		Source credits: Wikipedia, Janes, Boeing				

That was the case with the Boeing 707. Despite being second, its entry timing allowed for incorporating the lessons from the Comet failure and also take advantage of the rapid technological advancement of jet engines.

The established technology was represented by three aircraft: the Lockheed Constellation, the Boeing Stratocruiser, and the Douglas DC-6. DeHavilland was selling as many Comets as it could produce until the accidents but after that their first mover advantage proved elusive in the introduction of a disruptive technology. Boeing with the 707 design captured the technology at a slightly more mature stage and avoiding the pitfalls of their European competitor.

The competition between Boeing 707 and the Douglas DC-8 was not played on the technological level though. There are rather two other dominant aspects in the relative failure of the Douglas aircraft: complacency and government.

Douglas behaved in the textbook way that Christensen (1997) describes. As most successful firms producing a mature technology, Douglas was expecting a slow transition to jets and did not want to cannibalize their current and profitable product line. It took the pressure of customers (in this case Juan Trippe of Pan Am) who wanted an alternative to the Boeing design (Lawrence and Thornton 2005) (pg. 34). Even with Trippe's urge, Douglas would not have proceeded if not for competing for the parallel market generated by U.S. Air Force's expressed desire to acquire a large fleet of military tankers. With the Air Force's decision to purchase solely from Boeing KC-135s which were modified B707s. In that Boeing capitalized both on their long held relationship with the U.S Air Force but also on their demonstrated experience in building jet bombers like the B-47 Stratojet and the B-52 Stratofortress.

Perhaps, this early handicap was the first blow that shape the fate of Douglas aircraft which although it had to offer a better⁵⁴ product it did not have the economies of scale, learning and risk reduction provided to Boeing by their defense contract.

4.2.3 V2: The Wide-body Contenders

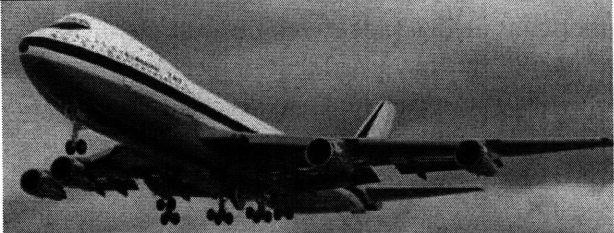



After the success of the 707 and 727, Boeing had a substantial cash reserve (Lawrence and Thornton 2005) (pg. 51). With the support and urging of Pan Am, Boeing went ahead to create one of the most successful aircraft in history while betting the company's survival at the same time. The characteristics of the resulting Boeing 747 and the aircraft that followed its wide-body design but never became direct competitors are summarized in Table 4-3.

The potential for a military contract of a heavy transport eased initial research and development costs but far from enough. Cost overruns and the huge infrastructure costs involved in building the factory floor space drained Boeing finances while revenue influx from the rest of the product line was substantially reduced due to the recession. Critics were expecting the supersonic transport to change yet again the face of the industry and make the Boeing leviathan obsolete in a few years.

The combination of a recession and a major aircraft development undertaking lead Boeing to the first of its great cost-cutting layoffs moving from 100000 employees in Seattle plants in 1968 to 37000 in 1971 (Newhouse 1982) (pg. 169).

⁵⁴ DC-8s being designed later were given a larger fuselage and more powerful engines that allowed it to travel transatlantic and transcontinental non-stop. (Lawrence and Thornton 2003, pg 35). Incidentally the first airliner to exceed the speed of sound was a DC-8 in a shallow dive.

Table 4-3 Competing Wide-Body LCA

	Mfg.	Year/Sales	Pax.	Range	Speed	MTOW
	Designation	(first delivery)	Typical config.	Typical in km	Cruise in Km/h	Metric tons
	Boeing 747	1969 Sales: 1382	366	10000	895	377
	Douglas DC-10	1971 Sales: 646 (incl. 200 MD-11)	290	7010	965	206
	Lockheed L-1011 Tristar	1972 Sales: 250 (incl. ~50 military)	263	7419	940	209
	Airbus A300	1974 Sales: 772 (incl. 255 A310)	266	6670	830	165
Image credits: Wikipedia, Boeing		Source credits: Wikipedia, Janes, Boeing				

The competitive situation worsened by the effort of the two other major aircraft manufacturer in the U.S. to stay in the game by developing their own version of a widebody jet: DC-10 by Douglas and L-1011 by Lockheed. Their products used a slightly smaller tri-jet design and also targeted the medium-long range markets. Both aircraft proved technologically superb (despite DC-10s teething problems) and airlines had use for an aircraft of this type for markets that were thinner than a 747 would support. But two aircraft in the same league divided the already small market in a way that made neither project viable.

Lockheed's effort especially showed how the lack of a supporting product family would make a single aircraft (even a good one) an economic failure by never making a profit (Benkard 2004).

Airbus on the other hand, with its debut aircraft managed to capture the niche for a large aircraft on short-medium range routes which American airline executives desired (Lynn 1997). Having two engines and being cheaper A300 fit the profile of an economic alternative to the tri-jets from which it captured the European and slowly the North American market. In the widebody market, two big bets paid off in some ways largely due to luck.

4.2.4 V3: Competition and Incremental Innovation: The 1980s Generation

Despite, the slow success of its first offering, Airbus would not have been established without providing a complete product range starting from the A320 workhorse on the low end, to the A330/A340 in the mini-jumbo area and most recently the A380 superjumbo. Similarly to how Boeing established itself in the jet age over Douglas, Airbus fought with Boeing when the latter commanded the largest market share and a successful and complete product line.

Airbus's second aircraft, the A320 was introduced in order to capture the need of airlines to replace their first generation narrow body jets (DC-9s, 727, 737) (Clark 1997(pg. 7). Airbus went for incremental improvements to a proven design. It offered a wider and therefore more comfortable fuselage. More importantly it provided fly-by-wire as opposed to the hydro-mechanical systems in use, saving space, weight and allowing for easy crew cross-training across the product line (Stüssel 2003).

Boeing, after a harrowing decade that allowed the development of a series of successful aircraft became reluctant to continue investing in innovative products. Their next aircrafts, the 757 narrow body and 767 wide body twin engine jets that were partially competing with the A300 family did not continue the innovation legacy of their predecessors. The 757 was a narrow body aircraft using the same diameter fuselage as the 737 and did not follow the increased width provided by the A320. More importantly, unlike A320, neither of the two aircraft used fly-by-wire technology which was already developed for Boeing's military aircraft citing pilot concerns as the primary reason -- a system which Airbus had to develop from scratch. On the same vein, the 767 was designed with a narrower fuselage than the A300 and was therefore unable to accommodate 2-4-2 seating arrangements or the LD3 type containers used by the 747 thus being at a disadvantage compared to the Airbus offerings.

Interestingly, the development of the 757 in its current configuration could have been precipitated by Boeing's strategic objectives. British Aerospace (BAe), a key partner in Airbus formative years, left the coalition in 1977 (Lynn 1997) and Boeing could ensure a weakened Airbus if BAe stayed out. To do so, Lawrence and Thornton (2003) (pg 79) allege, Boeing offered to BAe the design and construction of 757 wing and the engines to Rolls-Royce. It also designed the aircraft to specifications aligned with the needs of

British Airways. This offer was enticing for BAe and it was quite significant at the time as the outsourcing of key parts of a new aircraft was far from commonplace. Still it was not a partnership of equals and BAe opted for returning to the Airbus fold.

Boeing's conservatism in the design field, "flight from innovation" Lawrence and Thornton (2003) (pg. 87) characterize it, was also observed when the 777 development. Initial designs that were shown to airlines were based on a redesigned 767 leaving potential customers dissatisfied – in a very similar fashion to the recent A350 saga discussed in the next vignette. Boeing was content in developing derivatives of their existing product line if by making marginal improvements of their product line they could match the competition at less than half the cost of developing a new aircraft.

Arguably this policy delivered value to the shareholders as it allowed relatively high profit margins, strong learning curve effects over long product life times and continuous revenue from maintenance and training requirements that can be more than 10% of the aircraft value over its lifecycle. These cash flows accumulated cash reserves that could be used to create the next breakthrough aircraft were used instead for stock buybacks (\$8 B in 1999 to 2001). The disadvantage lay with the fact that Airbus had slightly better products to offer as a whole at slightly better prices given the, also, newer manufacturing processes.

Overall, Airbus with its more modern and innovative A320 was capturing significant market share in the low end of the market. Their product line, augmented by the medium-long range A330/340 family started filling every niche that Boeing had besides the jumbo. More than that, Airbus strengthened the commonality value proposition by providing greater number of interchangeable parts across the product line and, equally significant, the ability to interchange crews across the product line with minimal training requirements as the cockpits and aircraft flight characteristics were designed to be very similar. In the case of incremental innovation, the first mover seemed to gain an advantage in this case.

4.2.5 V4: Next Generation Widebodies

Airbus offered the A330/340 family as a replacement for the aging medium-long range DC-10s and L-1011. They designed their long-range A340 with four engines to comply with ETOPS⁵⁵ for intercontinental flights. They also used a common wing platform for aircraft with two and four engines (Stussel 2003) – a first that saved upfront R&D costs but penalized slightly the performance of the two aircraft as a compromise rather than optimization of the characteristics of each.

With Boeing's 767X plans being rejected by the airlines, an entirely new aircraft was finally designed. The Boeing 777 utilized the two engine configuration with its advantages in maintenance and fuel efficiency and the relaxation of ETOPS regulation for a highly successful aircraft. Airline consultation for the desired aircraft characteristics was extensive. The new aircraft was successful and started outselling the cheaper Airbus

⁵⁵ Extended-range Twin-engine Operations. See Section 3.4.2 for details.

offerings primarily due to its fuel efficiency with a world stage of highly volatile oil prices.

The quest for efficiency and range led the development of the next generation of aircraft. The Airbus A380, the largest passenger airliner with 555 passengers in a 3-class configuration, after 30+ years provides a direct competitor to the Boeing 747. The 747 by being virtually unchallenged offered a monopoly niche to Boeing and the opportunity to charge a premium in its price. Thus the 747 with the development costs long amortized was justifiably characterized as Boeing's "cash cow." (Esty and Ghemawat 2002) characterize Boeing's efforts to thwart the A3XX project as a "case of failed preemption." Boeing attempted to win time by first collaborating with Airbus on a super jumbo feasibility study. When it became apparent that the Boeing side was stalling for time Airbus announced their A3XX project. To this Boeing countered a different design as an alternative. This vaporware product was enough to delay decisions by airlines to order the Airbus aircraft. While Esty and Ghemawat argued that Boeing's efforts lacked credibility, it is arguable that the time delays they gained meant additional sales for their 747 and could be considered far from failed.

While Airbus promoted the A380 as a fuel efficient aircraft that would allow the infrastructure congestion at key hub airports to be alleviated, Boeing went on to design and produce the 7E7, later designated 787. Because of the extensive use of composite materials⁵⁶ in both the wing and the fuselage, the 787 is expected to offer a more comfortable flying experience through higher cabin pressurization, 20% higher fuel efficiency than competing aircraft with 15% attributed to the new engine design and 5% to the reduced weight, and less maintenance requirements. This proposition has been very well accepted by the airlines who have ordered 500 787s as of this writing (April 2007).

The success of the 787 design was underscored by Airbus's inertia to offer a credible alternative. Overextended by the enormous task of designing and building the A380 and plagued by budget overruns due to production glitches, Airbus's strategy was to offer a redesigned A330, designated A350, that would require about half the development cost of an entirely new aircraft (approximately US \$6B) while not sacrificing much in terms of performance. The airline customers seemed to disagree with that assessment as they made clear through order cancellations that they prefer an offering that would compete on an equal footing with the 787. This pressure forced Airbus to announce the A350XWB, for extra wide body. The A350XWB ups the ante of fuselage width compared to the 787 while it would be utilizing full composite technology. The downside of course is that the planned first delivery was pushed back to 2013 and the development costs raised to US \$13B.

4.2.6 V5: 3rd Gen Narrobody and the (near) future of LCA manufacturing

The question of whether the first or second mover in the 787 A350 rivalry will be the winner depends on many unknowns and will not be clear until well into the next decade. Boeing's moves managed to halt Airbus market share intrusion. The next strategic moves

⁵⁶ The first LCA to sport composite wings and fuselage with total participation of composites reaching 50% vs. 11% for the Boeing 777 (Pritchard MacPherson 2004, pg. 65)

between the two companies could be critical as they involve the replacements for the very popular 737NG and A320 narrow body planes. As neither company has provided a design and is not scheduled to do so for the next few years, a slight door of opportunity is opened because of this uncertainty.

We have seen that in the past there were several instances where the established manufacturers missed the opportunity to gain an advantage in a promising niche. Airbus gained its foothold by exploiting the short-medium range widebody niche. Bombardier and later Embraer exploited the need for small regional jets of 50-100 seats – a market that no large jet manufacture considered possible. Similarly at this stage, there are several aspiring players that could potentially threaten the domination of Boeing and Airbus in the large commercial aircraft market with a product targeting the narrowbody 100-200 seat aircraft. The possible challengers include Bombardier and Embraer, who already offer aircraft in the 100 seat range, along with companies from Russia, China, and Japan. All of these stakeholders have some experience with building and integrating large systems. The Japanese heavies are already invested in their partnership with Boeing. Chinese are still nascent in the large aircraft industry and expect to gain expertise from the A320 final assembly line recently established in China by Airbus. The Russian aircraft manufacturing industry has been set back during the country's recession and has not yet recovered. The trend of outsourcing and offset agreements is enabling the knowledge and manufacturing base of these potential competitors. (MacPherson and Pritchard 2003) (pg 230) and (Newhouse 2007) have pointed to the same effect. Given the complexity of the technologies required, none of the above stakeholders have either the resources or the expertise to provide a credible new generation LCA. A clever strategic partnership between them is a possibility but political issues and the strategic moves taken preemptively by Boeing and Airbus make the initiation of such a venture unlikely but still not impossible.

Besides who will build the first 3rd generation narrow-body aircraft, its dominant characteristics are also unknown. With a drive towards more fuel efficient, lighter aircraft, the options open up to more radical airframe and engine designs. Designs that have lower cruise speeds and utilize a turbofan engines may be preferred especially for short range trips in which the economics of lower speeds will outweigh the loss in productivity due to the lower speed. Another potential design that involves the use of reduced drag flying wing fuselage known as a Blended-Wing Body (BWB) has the fuel conservation potential in larger configurations.

While the airlines may be conservative about the desired design, technology forcing by regulation may be a strong driver of change especially as the CO₂ reduction measures to counter global warming come into effect for aviation. Even if that is not the case and airlines succeed in deferring this burden, the erratic cost of fuel itself may be a sufficient incentive to look into more radical designs.

Decision-making influences: A Summary

From the overview of LCA product lines above, we can draw some generalized conclusions of the type of influences that play a role in the decision to launch a new aircraft family.

- **Performance characteristics:** in the developing years of aviation these were technology-driven. Many new aircraft types were built more because the technology for pushing the envelope was available and less because of market considerations. This trend has been inverted in recent years, when the technology has matured. Innovation is market-driven and results from close consultation with the clients.
- **Airline involvement:** While in the early years customer airlines were big enough as to dictate and support certain designs, their market power of single airlines has waned. Many airlines are consulted now and the commitment of solvent launch customers is still crucial for the success of a new design. In the current state, airlines vote with their orders as their primary means of exerting influence over a design. Since their orders depend on overall financial expectations than absolute performance, the market-driven design emerges. On that realm, the market power of leasing firms has been continuously increasing in recent years but their influence is still limited to their primary lessors' recommendations. Yet, as resale value and reusability become of greater importance, the ease of reconfigurability (flexibility) and the expected resale value will start driving most of the manufacturing.
- **Government involvement:** The influence of governments will be discussed in greater detail but it is certainly significant primarily in the economic support realm (risk-free launch loans) and technology. Launching a new aircraft product line as Boeing did in the 1950s and as Airbus did in the 1970s against established manufacturers would have been all but impossible without some sort of state guarantees.
- **Derivation vs. launching:** Using an aircraft design as a product family platform by stretching (or less commonly shortening) the fuselage, providing more powerful engines, adding range through extra tanks has been a common and successful practice. Airframe manufacturers in the absence of competition, and sometimes in the face of it, prefer to defer the large costs associated with launching a new aircraft. Boeing pulled this off successfully with the 747-400 which has been left unchanged for 20 years (from 1985 to 2005) and responded with the upgraded 747-8 only when the A380 came to the market.
- **Disruptive vs. incremental innovation:** The introduction of jet engines, which can be considered a radical innovation, became a success by the second mover (Boeing). Incremental change rather benefited the first mover although the record is not clear. In some cases the second mover can benchmark against and exceed a clearly set goal and then the outcome depends on whether the economies of scale and the network effects enjoyed by the first mover are sufficient to let them retain the market share. Recently, both airlines and airframe manufacturers have been averse to radical designs as innovation efforts have been focused solely on providing marginally better operating economies to the user. Regulatory

compliance is another form of innovation pressure as the effects of ETOPS, or noise and emission regulations have shown.

- **Product development and commonality:** Boeing imbued by its strong engineering culture reengineered each aircraft family they produced optimizing primarily on performance. Airbus, faced with the challenge of developing a fleet portfolio in a much shorter timeframe, focused on engineering re-use and part commonality to provide aircraft that are usually cheaper to design, manufacture, and operate even if not highly optimized in their performance characteristics (see Bador (2007) and McConnell (2007)).

4.3 Aircraft Manufacturing: Production and Sales (the Business Case)

4.3.1 Revenue Structure

As a business, commercial aircraft manufacturing relies on revenues from aircraft deliveries, interest from financing (for the leasing/financing arm of the enterprise⁵⁷), sales of used aircraft from lease and buyback agreements, and aircraft services and modifications. Although the exact figures are proprietary, the strong correlation between aircraft deliveries and revenues shown in Figure 4-7 for Boeing, indicates that direct aircraft sales currently dominate as source of revenue.

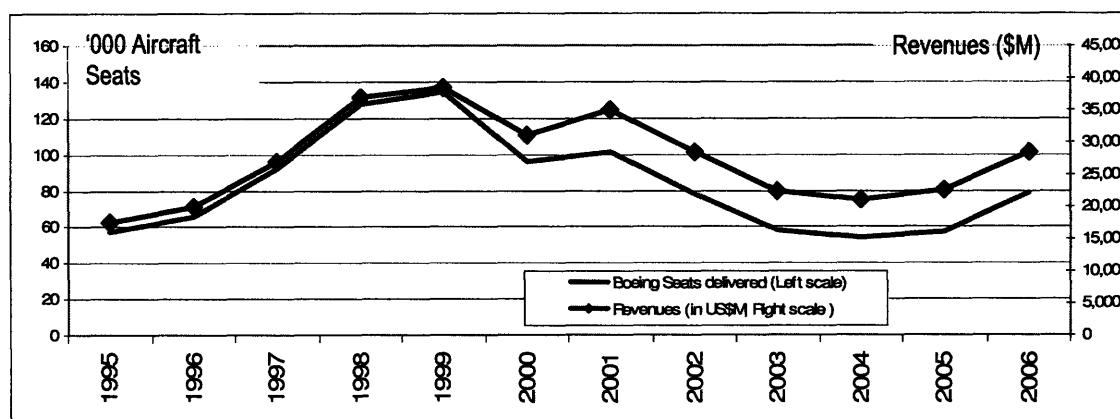


Figure 4-7 Correlation of Seats Delivered and Revenues (Data source: Boeing Annual Reports)

Price Setting

Revenues are a function of price and volume. Aircraft list prices are more or less linearly correlated with capacity as shown in Figure 4-8 and appreciate at varying rates based on inflation and demand but with an average of around 4% (based on (Greenslet 2003)).

⁵⁷ According to the 2006 Boeing Annual Report, Boeing had US\$1,025M revenues with an operating margin of 28% not including depreciation or interest.

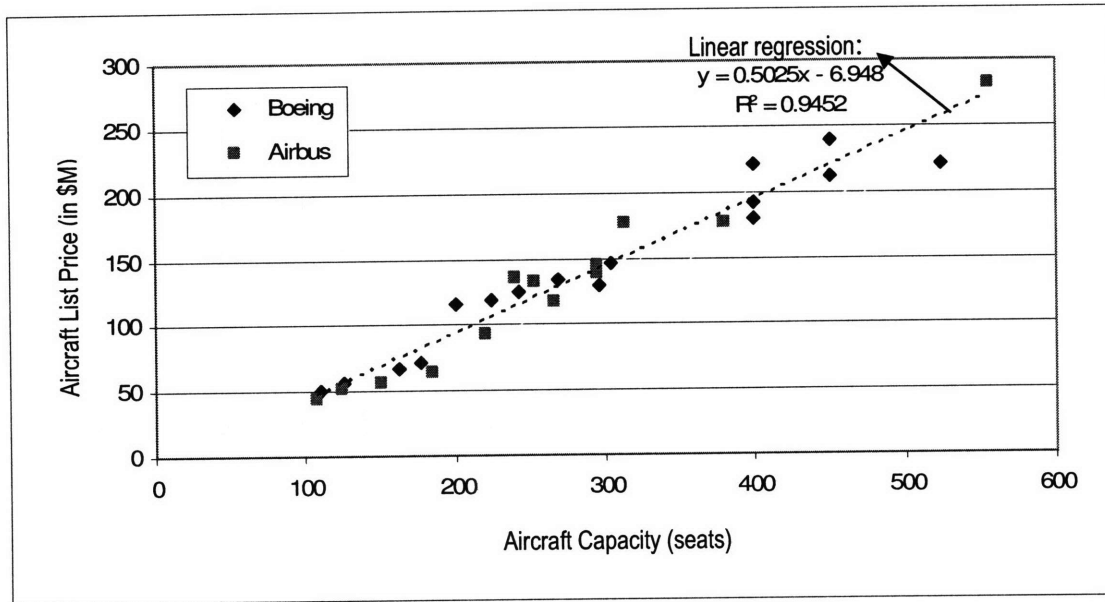


Figure 4-8 Correlation of Price and Capacity for LCA (2004 Data Source: Boeing and Airbus websites)

While the list prices are pretty straight forward, the actual prices at which aircraft are sold are not publicized and all available data are estimates. Manufacturers offer significant discounts over list prices to launch customers or bulk orders in hopes of harnessing the economies of scale in manufacturing discussed in the next section. The negotiations between the airlines and the manufacturers are usually multi-round, as airlines evaluate the aircraft characteristics versus the contract characteristics (Newhouse 1982).

Benkard (2004) and Irwin and Pavcnik (2001) have attempted to model the mark-ups set by airframe manufacturers in their competitive behavior. Benkard (pg. 588) leaned towards quantity setting for describing the dynamics of the industry; i.e. in short term pricing decisions, airframe manufacturers are constrained by their production rate. This is assuming that their decision is depending on backlog size which may not necessarily be the case. Irwin and Pavnick (pg. 13) concur that price competition is paramount and, citing (Tyson 1992), that for most of the industry's history production capacity was not constraining.

Beside the tag price, aircraft ownership has lifecycle costs and risks. Manufacturers offer reductions in these costs as a marketing device in their intensifying competitive situation to make their products more attractive to buyers. As a result, they providing in addition to discounts, easier financing terms, performance and delivery guarantees, and buyback agreements. Offering these additional terms makes manufacturers increasingly *risk-sharing* partners in the businesses of their airline clients.

Just on the discount levels, the average percentage off list prices is currently reaching up to 40% as shown in the 2006 estimates of Table 4-4.

Table 4-4 Discount Estimates for 2006 Deliveries (Source: Gates (2007))

Boeing	Number delivered	List Value (in \$B)	Estimated Sale Value (in \$B)	Av. Discount
717	5	0.19	0.12	36.8%
737	302	19.74	12.55	36.4%
767	12	1.68	0.98	41.7%
777	65	15.09	9	40.4%
747	14	3.27	1.97	39.8%
Total	398	39.97	24.62	38.4%
Airbus				
A320	339	22.49	13.82	38.6%
A300	71	11.77	6.67	43.3%
A340	24	5.34	2.96	44.6%
Total	434	39.6	23.45	40.8%

According to Greenslet (2003), as yields decrease, airlines pressure all the stakeholders that contribute to their factors of production. Their employees have been a prime target, as we saw in Chapter 3, but their capital costs are another one as evidenced by the continual increase in the discounts off list prices negotiated by airlines. That price pressure is of course facilitated by the level of competitive behavior in the duopoly situation which can spiral towards the Bertrand equilibrium⁵⁸. Figure 4-9 shows the discounts increasing. Unsurprisingly the traditionally unchallenged 747 saw its margins erode as discounts shot from 5% in 1990 to 35% in 2003 to close to 40% in 2006.

It is not clear what part of the steep discount can be attributed to competition and what part to the pressure by airlines. The two airframe manufacturers though appear to offer very comparable discounts. As the negotiation with airlines focuses on selling aircraft characteristics for a given price, it is interesting to see whether aircraft that provide operating advantage can command a premium and what the market share spread can be.

For this reason we focus our comparison to the competition between the A320 and the 737 family (-300 and -700NG). As shown in Figure 4-10, the A320 advantages discussed in the previous section, allowed it to command 25% of the market in 1990 at a premium of 25%. As the A320 was established into a reliable and cost-effective aircraft and before the next generation 737 became available, at the same premium it commanded 50% of the market. With the advent of the 737 next generation that premium was gradually reduced to 13% although market share reached above 55%.

⁵⁸ A Bertrand equilibrium implies that firms in a duopoly compete to charge prices equal to that of a perfectly competitive market. In applying it to the aircraft manufacturing competition, the ability to differentiate products and the fact that competition is a multi-stage game make Bertrand equilibrium outcomes less likely. The alternative Cournot equilibrium creates an outcome that resembles tacit collusion in a two firm game where capacity is more restricted than a fully competitive market but not at monopoly levels. Both competitive games are theoretical constructs with fairly restrictive assumptions that are not directly applicable to real world situations.

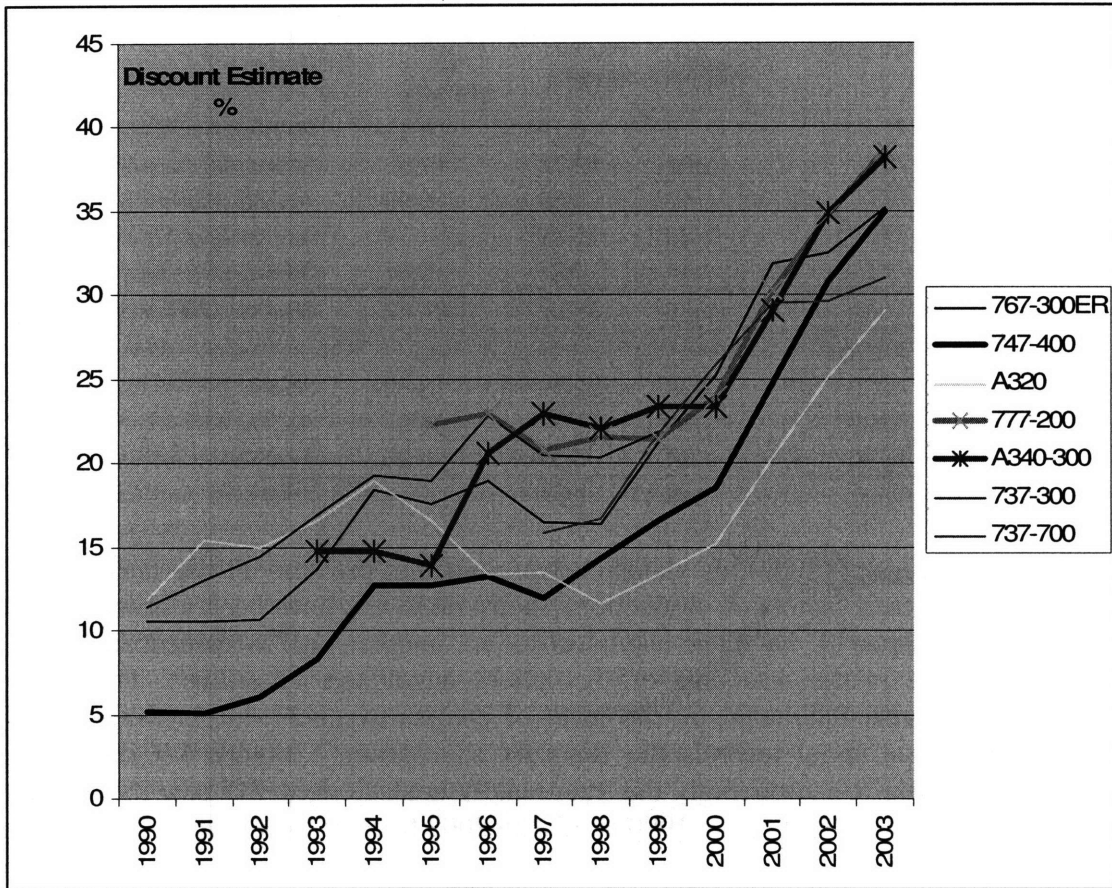


Figure 4-9 Estimated discount evolution (Data source: Greenslet 2003)

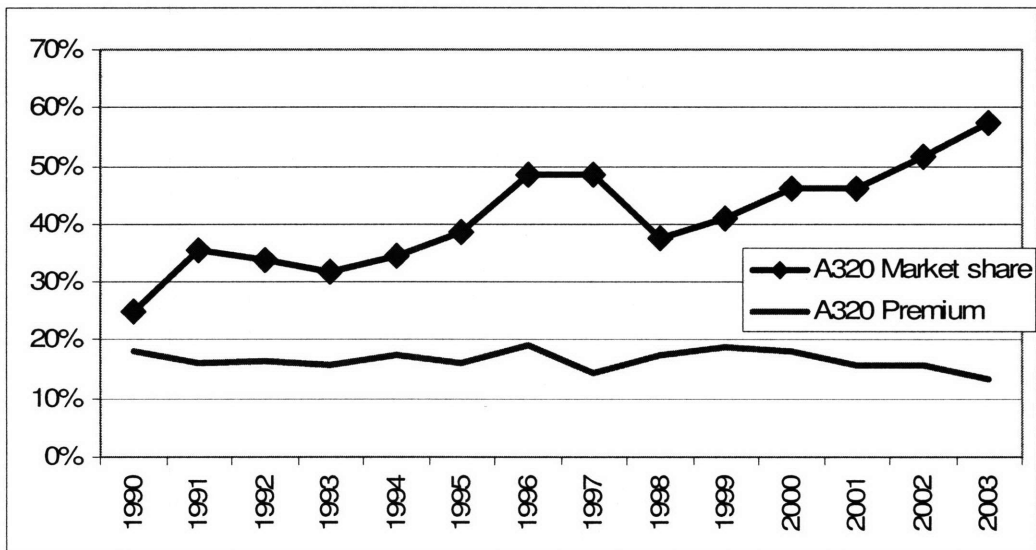


Figure 4-10 A320 Family market share and corresponding estimated premium in percentage as compared to the 737 family (Data source: Greenslet 2003)

At the extreme, this type of massive discounts led airlines to buying aircraft as a means for “receiv[ing] the huge checks reflecting the discounts on offer” according to Newhouse (2007) (pg 113) *to be used as collateral for further loans to cover operating expenses.*

4.3.2 Cost Structure

In order to understand the effect of revenue fluctuations for the airframe manufacturers, we need to understand their cost structure.

The primary costs of aircraft production can be broken down into:

- Research and Development (R&D)
- Manufacturing facilities and tooling
- Employees (shop-floor and supervisors)

4.3.2.1 Research and Development

Table 4-5 shows the increasing real costs of R&D that are caused by the increasing complexity of airframes and engines as they struggle for stretching the performance goals.

The aggregated R&D costs for Boeing commercial are shown in Figure 4-11. Based on this figure, it can be seen that in recent years when Boeing is developing a new aircraft its R&D expenditures come close to 10% of its revenues (1995 was the end of the development of the 777 and 2006 has been critical in the development of the 787). When derivatives and exploratory research is taking place then the R&D costs can be as low as 2% of revenues.

Table 4-5 Commercial Aircraft Development Costs

Aircraft	Year entered service	Development costs (millions of 1991 dollars)	Development costs per seat (millions of 1991 dollars)
DC-3	1936	3	0.1
DC-6	1947	90	1.7
DC-8	1959	600	3.8
B747	1970	3,300	7.3
B777	1995*	4,300	14.0
A380	2007*	10500	18.9
B787	2009*	9800	32.7
A350XWB	2012*	10850	36.2

*Estimates

Sources (DC-3 to B777: (Hayward 1994) (pg. 7), compiled by author A380 – A350XWB from press releases)

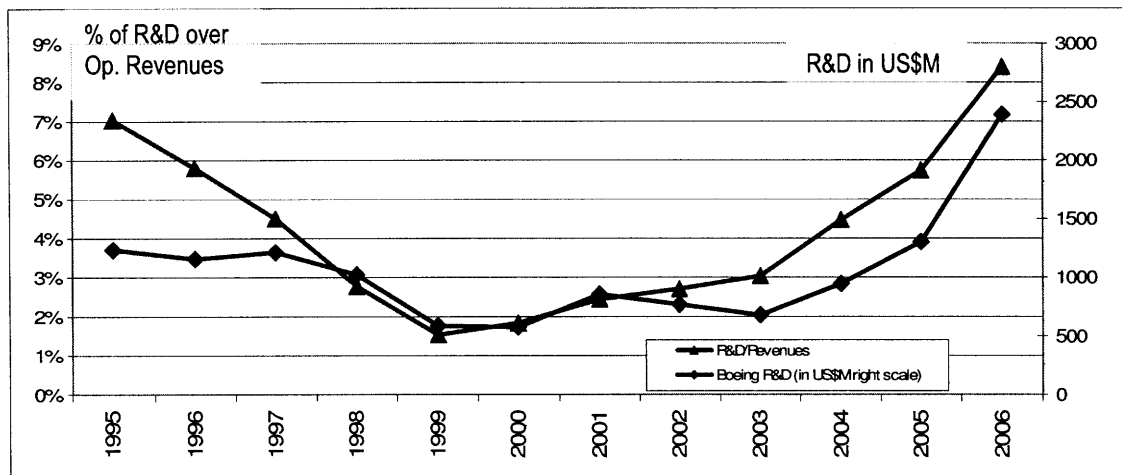


Figure 4-11 Boeing Commercial R&D Spending (Data source: Boeing Annual Reports)

There is anecdotal evidence that suggests deeply rooted differences in the engineering mentality of Boeing and Airbus which is reflected in the characteristics of their product lines. While Boeing is enthralled with engineering optimization of each individual aircraft or product family (Piepenbrock 2005), Airbus' attitude was focused towards optimizing across the product lines with emphasis on re-use and commonality for parts that reduces the costs of aircraft design but also its manufacturing and operating costs (Bador 2007).

Whether Airbus management came to this approach deliberately or if they made a virtue out of necessity is unclear. By the economics of the industry their hand was forced to design and build a complete product line to could compete offering by offering to Boeing's product line in as little time as possible.

4.3.2.2 Manufacturing: Learning Curve Effect

Aircraft production by itself has long been used as a case study of the effect of learning curves. Wright (1936) was the first to document the effects of the learning curve in aircraft production. Archial (1950) developed models to predict the man-hours necessary for completion of different types of airframes based on the number of aircraft produced and type of airframe. He points that no evidence of cessation of the decline in man-hour per airframe needed was observed based on his data (pg. 6). A typical learning curve in aircraft production is shown in Figure 4-12.

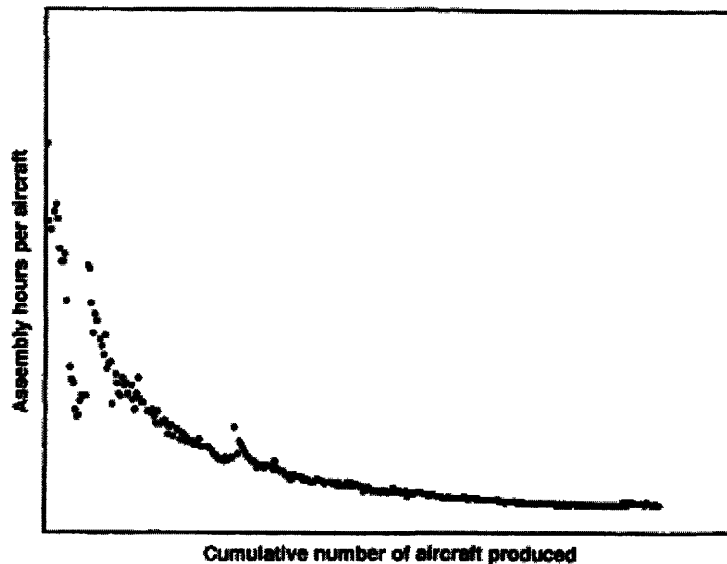


Figure 4-12 Assembly hours per aircraft vs. cumulative output with omitted scale. (Source: (Argote and Epple 1990))

Argote and Epple (1990) pointed that there is in fact a level of organizational forgetting as evidenced in the data released on Lockheed's Tristar program. In other words, the improvements due to learning curves depreciate and as a result, recent production rates are more indicative of the actual learning curve effect rather than cumulative output in the face of production disruptions. Figures 4-13 and 4-14, based on the Lockheed Tristar data, show that indeed average costs rose significantly even as cumulative production was increasing. When cumulative production reaches 138 there is a slow down in production rates which immediately reflects on the average costs. The trend is not reversed until the production rates resume at the 176 point. Besides knowledge, capital costs that include the manufacturing facilities and dedicated tooling is also part of the large upfront investment for starting a new product family. For the same reasons, ramping up production rates or closing down facilities also imposes significant sunk costs.

Cabral and Riordan (1994) review the strategic implications of such strong learning curve effects. They developed a model to indicate the "increasing dominance (ID)" offered to first movers and the "increasing increasing dominance (IID)" of their advantage aided by the positive reinforcing feedback that it offer to them. Competitors in this situation have an incentive to engage in seemingly predatory pricing using their expectations of going down the learning curves as production ramps up which can be thought of as a subsidy from the future. In one of their conclusions, they propose that the seemingly predatory pricing that ensues due to the learning curve future expectations of reduced productions costs which then incentivizes two competitors to undercut each other creates potentially socially beneficial outcomes.

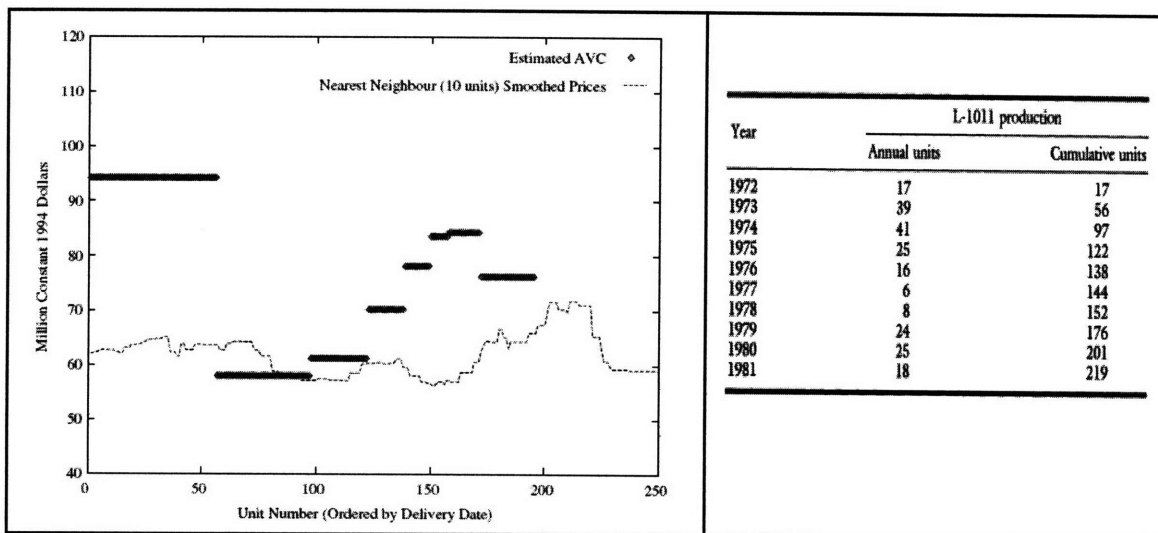


Figure 4-13 Cost vs. price for the Lockheed L1011 Tristar (Source: Benkard 2004) and Production Rates (Source: Argotte and Epple 1980)

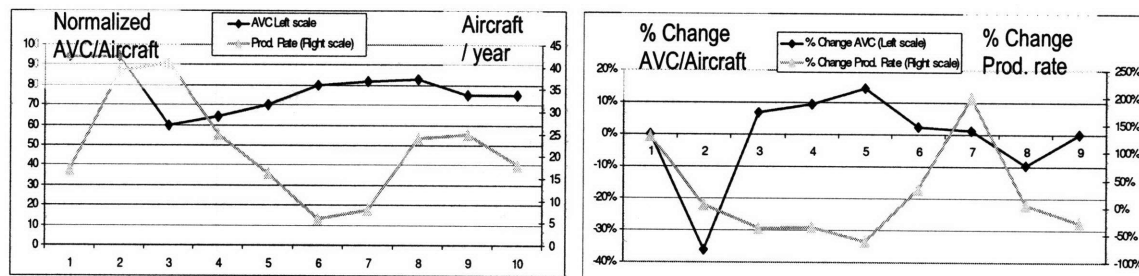


Figure 4-14 Lockheed L1011 Tristar comparison of estimated average costs (AVC) and production rates / production rate changes (right scale)

Scherer and Ross (1990, p. 372 as quoted by Cabral and Riordan) suggest that firms that are close to the bottom of their learning curve would have less of an incentive to price aggressively and would prefer instead to increase their profits. Cabral and Riordan counter that this would not be the case if aggressive pricing would inhibit competitors from reaching the same point.

4.3.2.3 Manufacturing: Production and Supply Chain

As mentioned in Section 4.3.2.1, the different outlook of product vs. product line optimization affects not only the development budgets but the manufacturing of the aircraft as well.

MacPherson and Pritchard (2003) point that Airbus, by virtue of being a latecomer, used state-of-the-art manufacturing processes for its plants that reduce overall production costs. They give as an example the older riveting tools used for the 737 and 767 fuselages compared to laser welding and greater use of composites in the Airbus products. Boeing with the 777 and 787 production line has bridged that gap. (see Table 4-6)

Table 4-6 Boeing Machinery Capital Stock by Period of Installation. Source: (Pritchard 2002) (p56)

Boeing Aircraft Model	737	747	757	767	777
Wing Assembly Riveters	1960s	1960s	1970s	1970s	1990s
Wing Spar Assembly Tool	1990s	N/A	N/A	1980's	1990s
Fuselage Assembly Riveters	1990s	1960s	1970s	1970s	1990s
Body Assembly Tool	1990s	N/A	N/A	N/A	N/A

Lean Manufacturing

Murman et al. (2002) point to a potentially greater significance cost reduction measure for aircraft manufacturing: lean. Inspired by applications in the automotive industry as pioneered by Toyota and popularized by Womack, Jones et al. (1991), lean production systems have been successfully implemented in a variety of industries. Figure 4-15 shows the potential effect of lean practices in manufacturing and design can result in major savings. Cook and Graser (2001) provide a detailed review of how lean manufacturing was implemented in the defense side of aerospace.

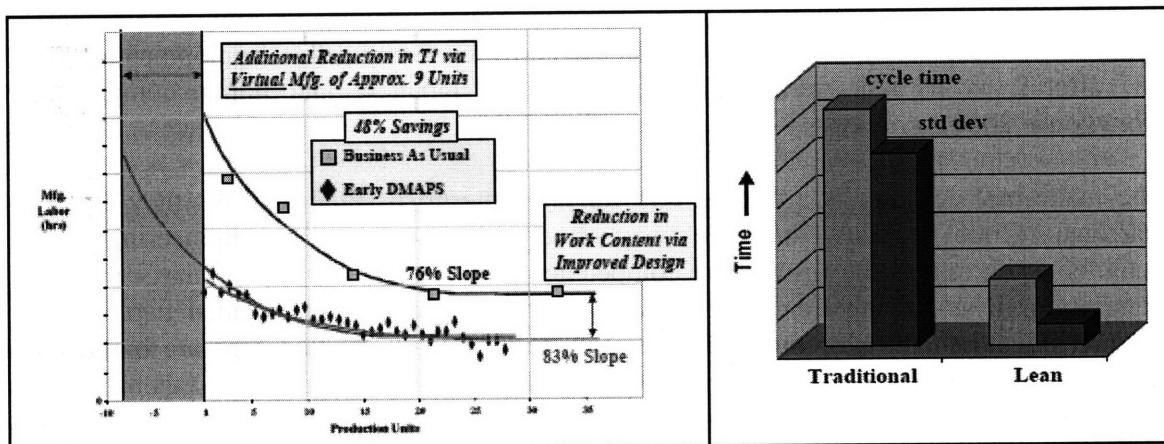


Figure 4-15 Estimated Cost savings by implementing lean practices in manufacturing (left) and design (right) of aircraft (Source: Murman et. al. (2001))

Boeing moved from lean manufacturing to the “Lean Global Enterprise” strategy in an effort to align its suppliers and address the issues that were revealed in the 1997 crisis (see Box 4-2). Alderman (2002) reports that for the B737 line, “Boeing has achieved 44% reduction in flow time, 64% reduction in inventory, and 44% reduction in work in process” and in parallel reduced its supplier base from more than 3,500 to about 1,500. This effort, Alderman claims, led to an increase in Boeing’s operating margin from 3.6% in 1998 to 8.4% in 2001. Airbus has not yet implemented lean manufacturing explicitly but its newer facilities and cross-border corporate structure that forced it to move towards a version of lean with just-in-time deliveries of aircraft sections allowed Airbus to have an employee to aircraft ratio of 143 compared to Boeing’s 220 in 1999 (Olienyk and Carbaugh 1999).

From the above, it can be deduced that the supplier strategy is critical. MacPherson and Pritchard (2003) point to the importance of offset agreements with strategically significant country partners in securing market share. Offset manufacturing agreements stipulate the outsourcing of certain parts of an aircraft to another country in return for higher orders of that aircraft type from the domestic carriers. Enforcement can be either direct (state-controlled airlines) or indirect (subsidies of the price for the aircraft). Participating countries benefit by establishing their manufacturing base in a high technology sector with potential spill over to other sectors while the manufacturer gains from the security in future orders and potentially from lower manufacturing costs due to differential wages or hosting government subsidies.

Douglas exercised this advantage by outsourcing to Canada and Italy in the 1960s (MacPherson and Pritchard 2003) and later China (Newhouse 2007). Boeing followed this trend by outsourcing to Japan in the 1970s reluctantly, being unwilling to lose core competencies. This shift accelerated as can be seen in the Table 4-7, where the 30% of critical parts for the 777 were foreign sourced.

This accelerating trend was subsequently enforced by the need to distribute the risk of upfront investment to partners less jittery than the capital markets. Foreign governments could fill that gap as shown by the external subsidies received for the development of the 787 aircraft by its risk-sharing partners, especially Japanese and Italian companies. (Newhouse 2007).

The make-buy decision is a critical one for any enterprise (Fine and Whitney 1996). Harrigan (2006) argues that the way Boeing outsources its engineering and manufacturing retains the firm's core competence proposition which lies in large system integration. Risk-sharing agreements⁵⁹ and R&D support provide needed capital for product development. Moreover, collaborative supply chain relationships are based on trust and thrive because of the symbiotic benefit that the partners gain out of them. Their enforcement is implicit, as a breach of trust could mean the loss of future collaborations. An additional argument in favor of outsourcing is as a way to transfer the requirement for a flexible workforce generated by the cyclical orders to the partner/suppliers, assuming that they would be better equipped to provide it.

In outsourcing Airbus holds development and manufacturing of the latest generation of aircraft in-house and only offers older generation aircraft for offset production (MacPherson and Pritchard 2004 referencing (Smith 2001)).

⁵⁹ Whether the 787 risk-sharing partnership is true risk-sharing is questionable. There appears to be no additional upside accommodation from the Boeing side in the event of good product performance. Similar to government loans to Airbus the risk is shared asymmetrically: if things turn badly risk is shared but if not then benefits do not exceed the contractual obligations.

Table 4-7 Domestic and Foreign Sourcing for Critical Airframe Parts by Boeing (Source: Pritchards (2002))

Launch year:	1963	1966	1969	1981	1982	1994
Aircraft model	727	737	747	757	767	777
Wings	D	D	D	D	D	D
Inboard flaps	D	F	F	F	F	D
Outboard flaps	D	F	F	F	F	F
Engine nacelles	D	D	D	D	D	D
Nose	D	D	D	D	D	D
Engine strut	D	D	F	D	D	D
Front fuselage	D	D	D	F/D	F	F
Center fuselage	D	D	D	F/D	F	F
Center wing box	D	D	F	D	D	F
Keel beam	D	D	D	D	D	F
Aft fuselage	D	D	D	D	F	F
Stabiliser	D	F/D	D	D	F	D
Dorsal fin	D	D	D	F	F	F
Vertical fin	D	F/D	D	D	F	D
Elevators	D	F	D	F	F	F
Rudder	D	F	D	F	F	F
Passenger doors	D	D	D	D	F	F
Cargo doors	D	D	F	F	F	F
Section 48	D	F/D	F/D	D	F	F
# of major parts from foreign sources	0	7	6	8	13	12

4.3.2.4 Employment

As with the airlines, employee numbers and compensation are also critical parameters in the cost structure of airframe manufacturers. Given the complexity of the tasks involved, it is not surprising that the workforce is highly skilled with a little less than 50% of the employees having at least college education (88,000 out of 198,000 for Boeing – (Boeing 2000)). Engineers, assembly line workers, and floor managers all build tacit knowledge in their tenure in the company. In the recent past, Boeing commercial responded to crises by drastically cutting its workforce and then rehiring when manufacturing levels required it, as shown in Box 4-1.

Arguably, the cost of firing employees is not confined to severance packages, though they can be substantial. Governments on the local or federal level also face social costs in the form of unemployment and lack of insurance coverage. For the 2001 layoffs, the government support that was estimated as needed reached US\$3.75B for two years (Cantwell 2001) but only a fraction of this amount was eventually included in the Air Transportation Stabilization Act.

Box 4-1 Boeing Employment Cycles in Washington State (Source: Pope and Nyhan (2001))**Boeing Layoff History:**

1967-1971:	95,000
1992:	28,000 (20% of workforce, Source Newhouse 2006 pg. 48)
1995:	7,500
1997:	50,000
2001:	35,000

1967: Boeing employment hits a 1960s peak with a companywide total of 148,480, with 100,874 in the Puget Sound region.

1971: After the cancellation of the supersonic transport and other federal projects, Boeing employment crashes to a low of 53,300 companywide, 37,200 locally.

1980: After four years of steady job growth, Boeing employment hits a peak of 81,392 locally, 113,972 companywide.

1981: Because of a slowdown in jetliner production Boeing begins three years of employment cuts, bottoming out in 1983 with 57,823 jobs locally, 88,181 companywide.

1989: Boeing employment reaches a peak at 165,787 companywide, 106,670 statewide, ending a six-year run of years with employment gains.

1990: January: Boeing announces it will end its seven-year hiring binge and will cut 5,000 production jobs from its local payroll. Boeing had hired 50,000 workers in the Puget Sound area since 1983. Military budget cuts are partly cited.

1992: February: Boeing announces a cut of 6,500 jobs from its local payroll, the largest drop in a decade, citing cutbacks in the B-2 Bomber and reduction of 737 production.

1994: Boeing ends five years of cuts with total employment of 117,331 as a result of four bad years posted by airlines.

1995: February: Boeing announces deeper cuts, reducing employment rolls by 6,500.

2000: May: Boeing ends two years of job cuts, reducing companywide payroll from 238,400 in February 1998, to 191,500.

2001: March 12: After 85 years in the Seattle area, The Boeing Company announces it is moving its headquarters to another city, affecting 1,000 headquarters jobs. Boeing announces that it is moving fuselage work to Kansas.

2001: Sept. 19: Boeing announces layoffs of 20 percent to 30 percent of its commercial airline work force, by as many as 30,000 employees.

On a systemic level, these employees had developed tacit knowledge of the procedures for the complex task of aircraft manufacturing. If their expertise is not transferable, and a part of it is certainly not, then the cost of coming down the learning curve at the next boom is higher due to organizational forgetting.

While the numbers may not be exact, the history of layoff hiring cycles in the aviation industry has been pronounced and follows the boom and bust cycle (procyclical). While the U.S. based manufacturers fit this pattern of following the cycle, their European competitors managed to cope with a higher employment cost structure and more inelastic hiring/layoff cycles due to the labor relations regulatory regime. In fact Airbus, despite

several rough spots in its history was constrained by a combination of regulatory dynamics and different management practices from mimicking the layoff cycles of its overseas competitors. It was not until the 2006 A380 production glitches that layoffs on a large scale have been proposed in the Power 8 restructuring plan (Airbus press release) that still were targeted towards part-time employees with the full-time ones planned for reduction through attrition and a freeze in hiring. Even so, this proposal was followed by strong reactions by both employee unions and local governments.

Box 4-2 Costs of following the cycle: Boeing Production in the 1997 Crisis

Following the success of cost reductions due to lean implementation and advanced design and manufacturing techniques for the 777 aircraft, Boeing was confident that it could reproduce the savings in the older product families. This initial success and the strategic desire to not concede market share to Airbus led Boeing's sales department to aggressively seek orders in the peak of the mid-nineties.

As a result of the ensuing price war with Airbus, discounts that ranged at around 10% were increased to 20% and even 30% in an effort to maintain market share and drain Airbus's orderbook (Newhouse 2007, pg. 125). This effort on regaining market share, essentially selling aircraft at cost, it backfired in two ways: first revenues were significantly reduced and more importantly precipitated a production crisis in 1997.

Between 1995 and 1997, Boeing adds 38000 employees (about the number that was laid off since 1989) incurring training costs as well as errors. Trailing back the learning curve while increasing production rates left both internal and external manufacturing facilities wanting. Delays in the production and delivery of parts led to production stoppages and errors to expensive overtime that increases labor costs by 30% according to one account (Harrigan 2006) (pg. 24).

As if these issues were not enough, the Asian currency crisis and the resulting recession in the Asian tiger economies led to cutbacks in orders from the airline market with the greatest growth rate.

Airbus was better positioned to weather the price war as evidenced by internal Boeing studies that showed Airbus having a cost advantage of 12-15% in production and tooling (Newhouse, pg. 126). Equally important, Boeing's skilled workforce was reduced by voluntary retirements and strikes had forced Boeing to hire new and untrained employees. (Newhouse pg. 127). The steep increases in production rates could not be matched internally but also externally as the Boeing supply chain was not set to anticipate such increases eventually leading to a *US\$2.6B write-off* and an overnight drop of share value by 8%.

These problems coincided with the merger with MacDonnell Douglas that led to accusations of stock manipulation as the problems were not officially disclosed until after the completion of the merger maintaining an artificially high stock price that facilitated the buyout of MDD. This behavior resulted in lawsuits by shareholders and a *US\$92.5M settlement* in 2001. (Newhouse pg. 129).

4.3.2.5 Financing: The Subsidy Arguments

The sunk costs required to develop and build commercial aircraft is one reason that make government involvement, direct or otherwise, practically necessary, as the capital markets would not accept the level of risks and returns involved. Spencer (1986) suggested six criteria for targeting prime candidate strategic industries. These were:

- i. *Entry barriers faced by new entrants.*
- ii. *Significant foreign competition.*
- iii. *High domestic and international industry concentration..*

- iv. *Factor prices would be inelastic to domestic targeting.*
- v. *Economies of scale and learning in production.*
- vi. *Targeting would minimize technological spillovers to competitors and/or maximize domestic access to foreign technology.*

The fact that airframe manufacturing easily meets all of the criteria partially explains the interest of governments in supporting this industry. More generally, government involvement is driven by several objectives spanning a wide range that can be categorized in the following areas:

- **Transportation:** ensuring that their citizens can have access to affordable air transport.
- **Market:** discouraging monopolistic pricing for commercial aircraft.
- **Technology:** given the technical complexity of aircraft, the technological spillovers that occur to other sectors can provide significant positive externalities.
- **Economic:**
 - **Employment:** aircraft manufacturing as high-skilled employer
 - **Trade balance:** aircraft can be a high value export item that balances trade deficits with developing countries.
 - **Prestige:** aircraft manufacturing with all its implications provides credibility and prestige for the host country.
- **Defense:** as aircraft have military applications, the developing and retention of skills and technological capacities in the production of civil aircraft provides a serious strategic advantage to countries that do not have to rely on aircraft imports.

Given the above potential advantages, governments have the incentive to provide for and retain commercial aircraft related industries. This occurs in direct or indirect fashion and has over time evolved in a very contentious dispute between Boeing and Airbus on the issue of government subsidies.

Government involvement and support for domestic airframe manufacturers can take any of the following forms:

- Financing guarantees and risk-sharing
- Marketing support through international relations and indirect offsets
- Basic R&D support
- Military/commercial cross-subsidies
 - Financial support over the cycle
 - Commonality in R&D, parts, tooling,
 - Indirect risk reduction by moving down learning curve faster.

Financing support provided to Airbus in its formative years has been the most visible and contentious subsidy leading from accusations to settlements under the General Agreement on Tariffs and Trade (GATT)⁶⁰ agreement to active cases (as of 2007) with

⁶⁰ In 1992 the US and EU representatives agreed in a bilateral reduction of government subsidies which would be limited to 33% of development costs and prohibited production subsidies (Irwin and Pavnick

World Trade Organization (WTO), GATT successor. Obviously the subject is still contended with a number of articles and reports supporting one or the other side but although the level and nature of subsidies may be disputed, it is undisputable that both industries were recipients of government support and continue to be so. In Box 4-3, we discuss a few examples of the types government support categorized above.

Box 4-3 Government Involvement in Airframe Manufacturers

Financing

Stussel (2003) clarifies that Airbus received government guarantees for repayable loans. While these loans could not have been supportable in market terms, Airbus would not have existed if not for this support (Olienycck and Carbaugh 1999). More recently, Boeing, using its partners and state governments has arguably received similar levels of the same kind of development support that could be a little less than 50% of the total development costs of the 787 (Pritchard and MacPherson 2004, Table 2 pg. 65).

Marketing

Much of anecdotal evidence exists to support the political influence on national airline decisions. An illustrative example is chronicled by Lynn (1997) and others and details the pressure exerted by delegations of the Clinton and Mitterand administrations on Saudi Arabia with regard to the choice of the supplier for a large aircraft order from Saudia, the flag airline of the country. The order at the time was valued at US\$2Billion and after intense back and forth went finally to Boeing allegedly as a result of the U.S.-led intervention in Bosnia in support of its Muslim population. Similarly politicized decisions have been reported for China with orders awarded to European or U.S. manufacturers pending on which party favored Chinese interests (Lynn 1997).

Basic R&D support

This is a rather straight forward involvement and has primarily involved NASA research and the availability of its facilities to conduct Boeing sponsored research at below cost rates. The argument involves the timing of the release of the results which otherwise become publicly available ((Pritchard and MacPherson 2004)).

Military/Commercial Cross Subsidies

We described examples of this type of ties in the vignettes on the Boeing 707 and 747 ((Ruttan 2006) Ch. 3 pg. 68). In these cases, some of the initial development costs for the commercial versions of these airliners differed because of the similarities to the military versions. The production lines gain experience from the military versions of similar aircraft like the air refueling tankers KC-135 (modified 707) and the controversial KC-767 (modified 767 for the US Air Force KC-X program). Similarly, Airbus could benefit from its push to develop the A-400M military transport aircraft with technologies that may spillover in its next generation narrow body aircraft.

Lawrence and Thornton (2003) (pg. 40-41) underscore this relationship in the following quotes. One came from a congressional report of the, now defunct, Office of Technology Assessment:

"The single greatest means by which US government policy has affected the competitiveness of the commercial aircraft industry is in the procurement of military aircraft and funding of the related R&D. [...] In some cases whole systems developed for the military have been 'spun off' to commercial applications, reducing development costs and risks to the commercial users."

The other from (Hardy 1982) related to the development of the Boeing 707:

"Without the huge KC-135A programme there would almost certainly have been no Model 707."

2003). The dispute reemerged with the development of the A380 which U.S. officials contended that violated the agreement. The EU side responded with a counter case with regard to subsidies for the 787. Both cases are pending at the World Trade Organization.

Profitability

The revenue and cost structure of the industry in the end defines the profitability and margins. The published results from Boeing Commercial in Figure 4-16 show generally positive operating margins that do fluctuate with the cycle but not as strongly as the equivalent metric for the airlines, at least for the limited span of this time series.

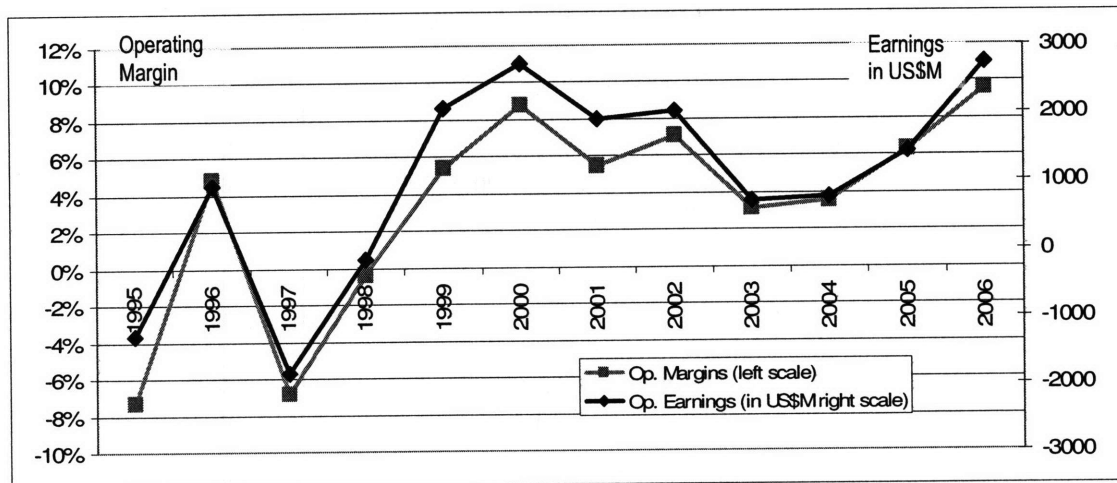


Figure 4-16 Boeing Commercial Operating Earnings and Margins (Data source: Boeing Annual reports 1997-2006).

Of course operating margins do not equal economic return as they do not account for the cost of capital.

4.4 Cycles in LCA Manufacturing

In Section 3.5 we showed how small variations in demand are amplified by airlines orders in very close correlation to airline profitability.

Unsurprisingly, the manufacturers need time to gear up and produce the deluge of orders they receive after a trough and this results in a dampening of the cycle between orders and deliveries as shown in Figures 4-17 and 4-18. Although dampened the delivery divergence from the trend is an order of magnitude greater than the divergence of the detrended demand (see Fig. 4-21).⁶¹

⁶¹ The coefficient of variation for the detrended demand is 0.06, while the equivalent value for detrended orders and deliveries is 0.55 and 0.41 respectively.

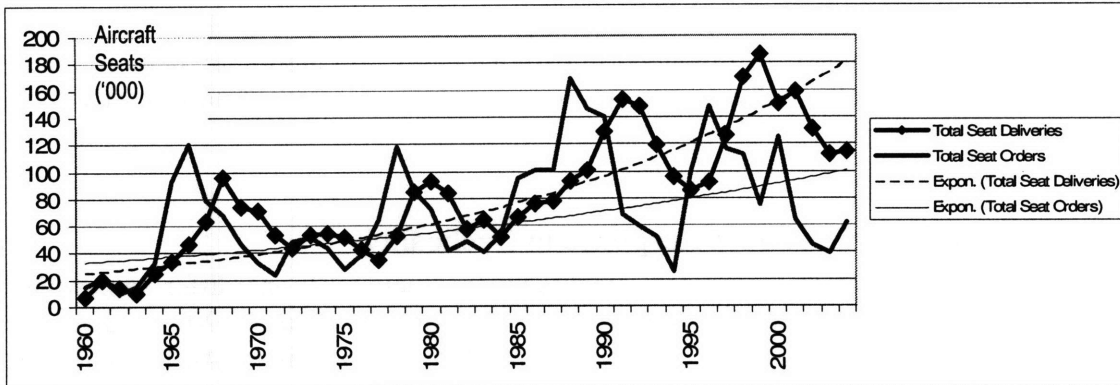


Figure 4-17 Comparison of Aircraft Orders and Deliveries

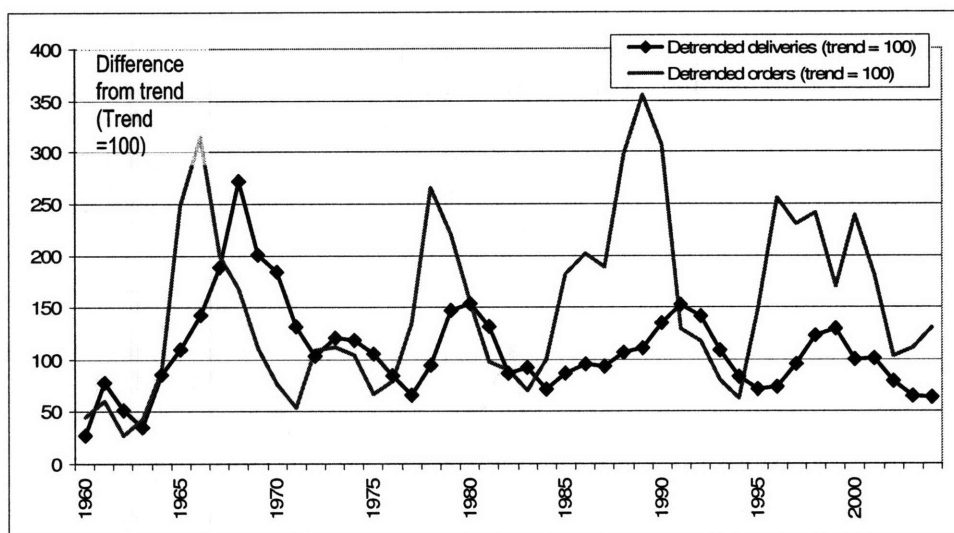


Figure 4-18 Detrended aircraft orders and deliveries

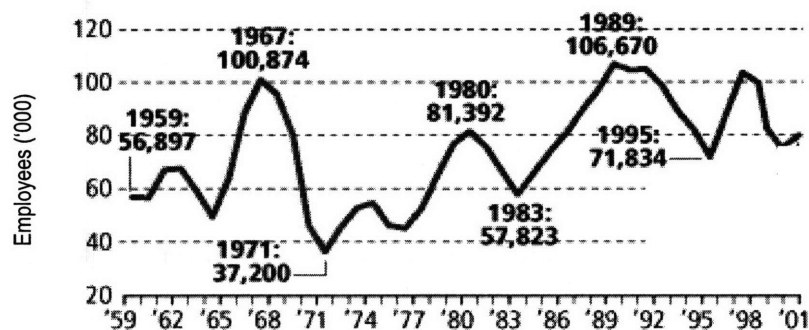


Figure 4-19 Employment by Boeing in Washington State (Source: Pope and Nyhan 2002)

The natural response of the manufacturers to use backlogs as a way to dampen the oscillation of their production rate is not enough to really stabilize production rates. This creates the fluctuations in employment discussed in Box 4-1 and also shown in Fig. 4-19 which tracks very closely and with a delay the order variation. As we discussed in Section 4.3.2.2, production rate variation does not allow for a full exploitation of the learning curve due to the 'forgetting' effect that can be partially attributed to loss of

organizational competencies as a side effect of the hire-fire cycle but also to a lack of coordination with the upstream suppliers. In extreme cases, as empirically demonstrated in Box 4-2, the effect of a sudden surge in production rates can even lead to costly shut downs of production lines.

4.4.1 Airframe Manufacturers Response to Cyclicality

From the perspective of the individual manufacturers, their reactions differ somewhat. While Airbus has been receiving a greater order variation (see Figure 4-20), its delivery rates are shown to be substantially less varied than Boeing's in Figure 4-21. Table 4-8 makes the comparison using coefficient of variation of the detrended time series (see Figure 4-22) as a measure for volatility.

Similarly, European labor regulations dictate a less pronounced variation in employment in Airbus compared to Boeing. This is illustrated by the difficulty that Airbus faces because of labor union reactions in implementing the planned 10,000 job cuts over five years under its Power 8 restructuring program compared to triple that number for Boeing only in the post-9/11 period. This inflexibility, when managed correctly, may be a blessing in disguise given the discussion above.

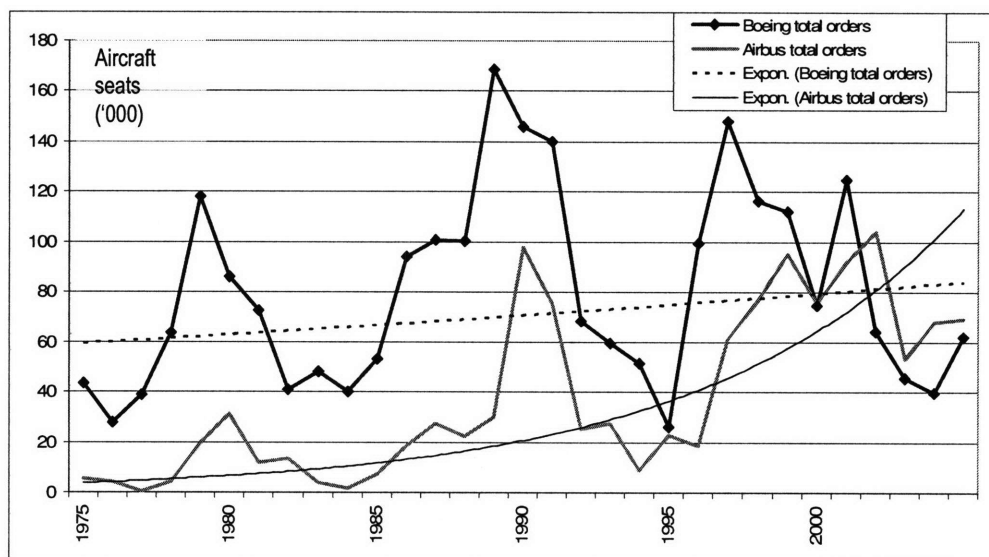


Figure 4-20 Comparative Boeing and Airbus Orders in Total Seats (Data sources: Boeing and Airbus websites)

All the above indicate that the extended enterprises represented by Boeing and Airbus deal with the cyclicality in the orders received differently. What the differences in the backlog years data series in Fig 4-23 make prominent is that Airbus appears less 'coupled' or more insulated from the cycle than the Boeing extended enterprise which attempts to maintain a lower level of backlog. While the data on volatility in Table 4-8 seem that they contradict this (Airbus volatility seems higher) there are three observations that mitigate this: (i) the volatility of orders received by Airbus is much greater while the volatility of deliveries is equal, (ii) the latter equality is deceptive in that it does not

capture the dampening trend shown in Figure 4-22, and (iii) Airbus has a shorter history and volatility for a start-up is expectedly higher than for an established firm.

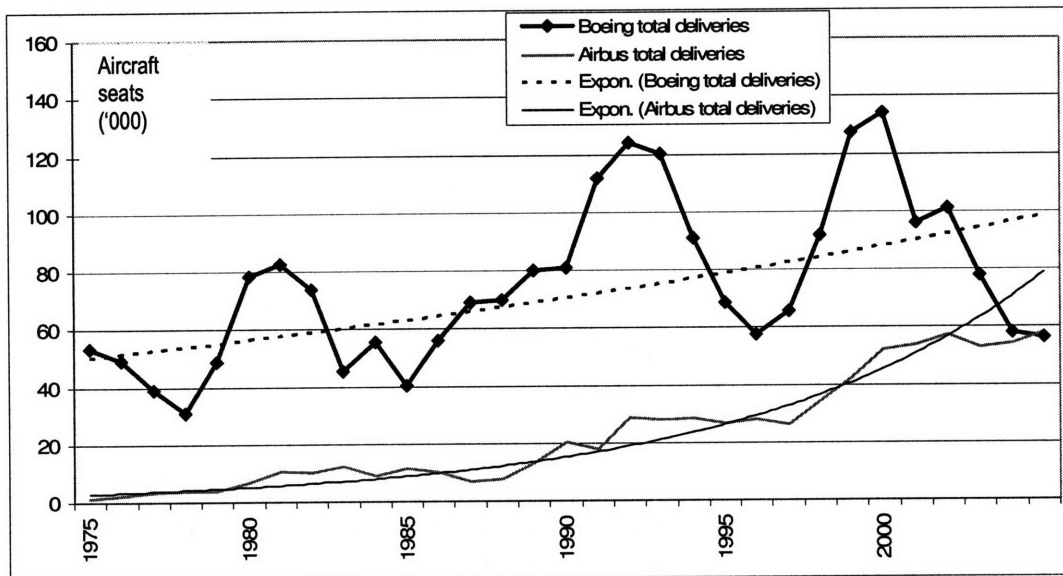


Figure 4-21 Comparative Boeing and Airbus Deliveries in Total Seats (Data sources: Boeing and Airbus websites)

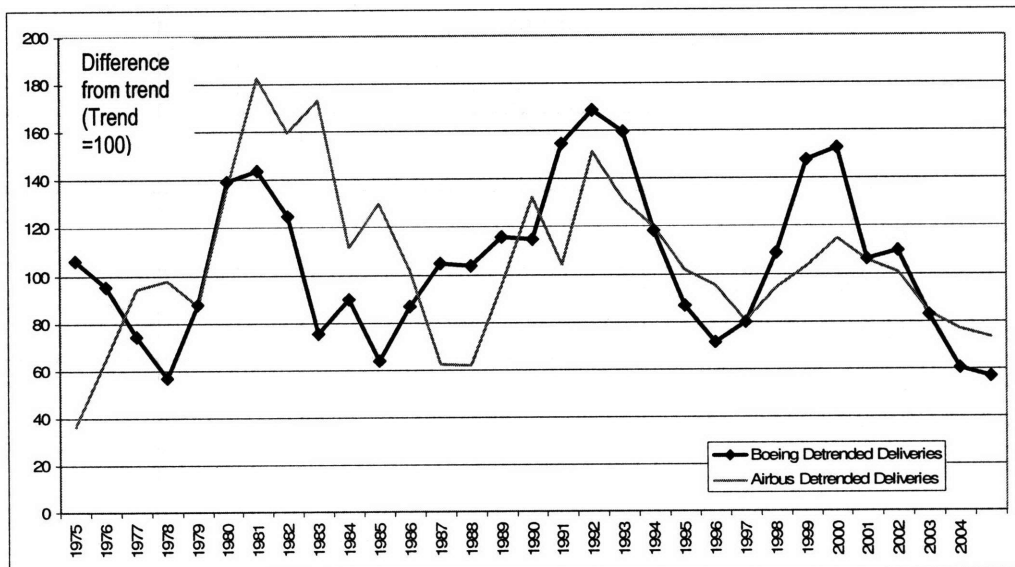


Figure 4-22 Comparative Boeing and Airbus Deliveries Detrended (Basis: 100)

These findings are aligned to Piepenbrock's (2005) theory of the enterprise. Airbus seems more bound by the "integral" architecture of its extended enterprise to respond more slowly to the demand variation while Boeing appears intent to maintain a responsive production rate. Boeing's behavior comes at a cost which is intent on reducing by employing lean manufacturing principles.

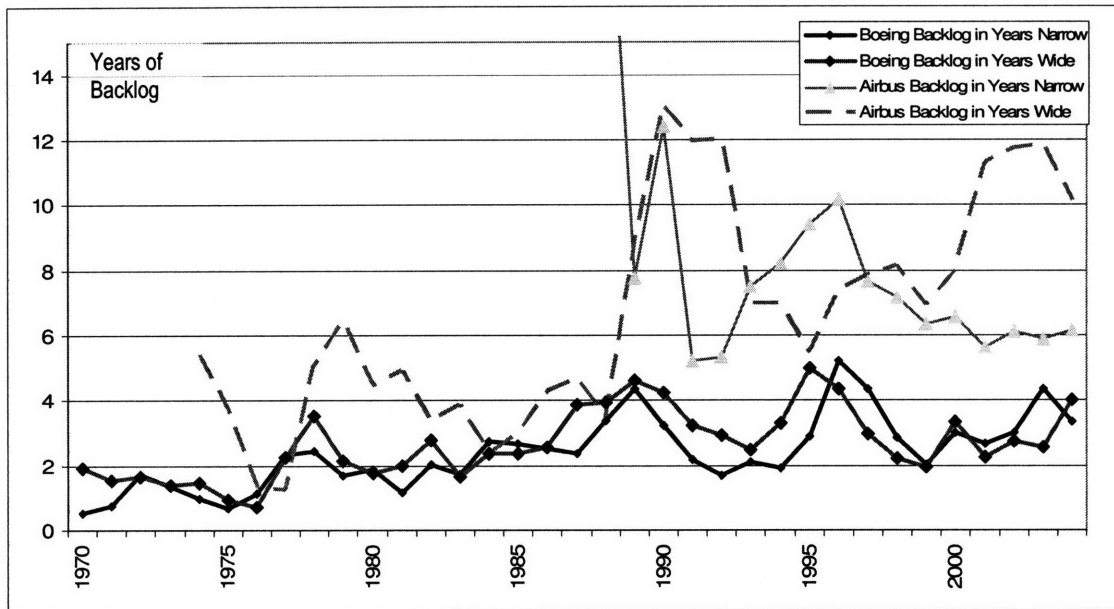


Figure 4-23 Backlog in Years of Production Rate Comparison between Airbus and Boeing (includes MDC pre-1997 data)

Table 4-8 Comparison of Volatility for Airbus and Boeing (includes MDC data pre-1997)
Coefficient of Variation

	Boeing	Airbus
Order rates (1974-2004 data)	0.48	0.83
Delivery rates (1974-2004)	0.31	0.31
Backlog in years of production (for narrow body aircraft 1988-2004)	1.00	1.95*
Backlog in years of production (for wide body aircraft 1974-2004)	0.92	1.94

*Excluding first year of delivery for the A320 which skews the results to a much higher number

4.5 Chapter 4 Summary

In this chapter we reviewed some key aspects of the airframe manufacturing industry: its history, product characteristics, manufacturing performance and pricing strategies. We also discussed why these led to a consolidation of the industry into a duopoly in the current market for large commercial aircraft and why, even under such consolidation, the manufacturers remain competitive and how they respond to cyclical signals from their customers (aircraft orders). Cyclical order variation induces significant costs when trying to respond to them. Empirical evidence, namely the length of historical order backlog, supported the concept of differences in the institutional architecture of the extended

enterprise between the two competitors. In any case, both manufacturers are closely related to and supported by the governments of the countries they are located in.

This chapter concludes the overview of the three primary stakeholders in the commercial air transportation system: the customers (Chapter 2), the airlines and owners of aircraft (Chapter 3), and the manufacturers of aircraft (Chapter 4). While until now the connection between them has been implicit, in Chapter 5 we make these connections explicit by developing them under the Enterprise of Enterprises framework.

Chapter 5 Commercial Aviation as an Enterprise-of-Enterprises: An Integrative Framework for Cross-Industry Analysis

In the previous chapters we discussed several aspects of the commercial aviation value chain. Chapter 2 investigated how passengers and shippers are served and what they value in terms of service. Chapter 3 gave an overview of the types and structure of airlines and how they compete in providing air transportation services; Finally, Chapter 4 reviewed the currently duopolistic LCA manufacturing industry and the technical characteristics of aircraft that they developed in their effort to gain competitive advantage. Where applicable, we discussed their relationships and interactions with other key stakeholders.

A broad view of the stakeholders directly involved in the commercial air transportation system is shown in Figure 5-1.

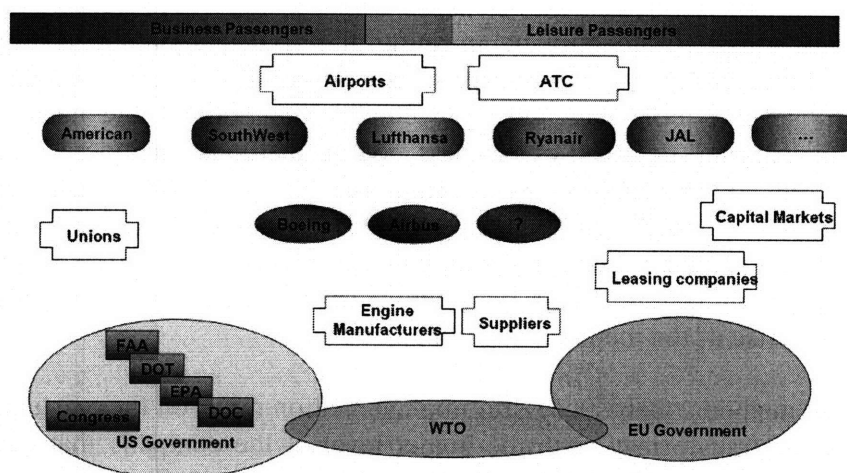


Figure 5-1 Broad View of the Stakeholders in the Commercial Air Transportation System

These stakeholders form the core of an interdependent value chain which, as we saw in Chapters 3 and 4 and further discuss here, is subject to a severe boom and bust cycle with all the negative repercussions that this entails. On top of that, the cyclical behavior is an emergent property of the system of interactions among these stakeholders. Instead of being solely a result of external shocks, the system dynamics are set up in a way that induces and amplifies this oscillation. As a result one needs a holistic perspective of how each component stakeholder contributes to the oscillation and what strategies could be used to prevent this from happening which is our intention as stated in Chapter 1.

Given the variety in value contribution and value perception across the stakeholders in that global air transportation system, it was necessary to devise a conceptual framework that would standardize the interactions and value functions of the diverse stakeholders and facilitate the modeling and experimentation of such a complex system. In this chapter we develop the concept of Enterprise of Enterprises as a framework for studying and

prescribing system-wide policies for systems that require coordination across multiple industries.

5.1 Enterprises and Systems: the need for an Integrative Framework for Enterprise of Enterprises

Rouse (2005) defines an enterprise as “*a goal-directed organization of resources—human, information, financial, and physical—and activities, usually of significant operational scope, complication, risk, and duration.*”⁶² Based on this definition he identifies as potential enterprises corporations, supply chains, markets, governments and economies. In a footnote he states that supply chains can be considered extended enterprises and markets as further extensions involving several supply chains. According to the basic tenets of systems thinking, the design and management of the enterprise functions independently, fails to account for the strong level of interactions among them and therefore leads to suboptimal performance which, in turn, leads to the natural conclusion that the enterprise needs to be viewed holistically.

Enterprise transformation can only be meaningful if pursued on the enterprise level (Womack and Jones 1996). For the enterprise as a corporation or an extended enterprise (supply chain) several tools have been developed that address the need of holistic approach with varying degrees of success. Such methods include: Total Quality Management (see Powel (1995)), Six Sigma (see Harry (1998)), Business Process Reengineering (see Hammer and Champy (1993)), and Lean Transformation (see Womack and Jones (1996)). Lean has been constantly evolving since its inception from the Toyota Production System (Liker 2004) and is arguably the most encompassing in its view of the enterprise of the methods mentioned above.

In each of these methods, their successful implementation relies on the existence of a few **champions** of the transformation in the higher level of the company that can push the change and allow the, also necessary, bottom up initiatives to flourish. In the case of extended enterprises, the lean transformation occurs through the lead of one company which is usually the primary integrator and has significant influence over its suppliers. Toyota’s ongoing lean transformation of its supply chain demonstrates the best practice in that arena. Unlike traditional value chain-inspired strategies in which the dominant organization in each echelon attempts to maximize the value it can capture (Porter 1985), Toyota shared the benefits of transformation with its suppliers expecting that the value generated by the whole chain through this incentivized cooperation to exceed the value Toyota could extract if it acted with a short-term zero-sum outlook (Liker 2004).

In these examples of transformation, independent of outcome, the identification of a lead stakeholder with defined objectives played a key role. When one considers the larger

⁶² Another definition for an enterprise is the following: “An enterprise is *a purposeful socio-technical system organized to create value for its multiple stakeholders by performing its defined core missions, functions or businesses serving societal ends.*” (as defined by Kirk Bozdogan in the Lean Aerospace initiative at MIT)

scope enterprises identified by Rouse, i.e. markets and economies, then the methodologies outlined above are not applicable directly as even the identification of a lead stakeholder or the definition of widely acceptable objectives are not straightforward.

By developing the concept of Enterprise of Enterprises (EoE) we take the first steps towards bridging the gap of transformation from hierarchical to non-hierarchical enterprises. The ultimate goal is to create a framework that could allow the “architecting” and purposeful transformation of such systems.

Hitchins (1994,2005) used a hierarchy of five layers to categorize where systems engineering can be applied as shown in Table 5-1. These layers form a “nesting” model in which “*many products make a project, many projects make a business, many businesses make an industry and many industries make a socio-economic system.*”

Table 5-1 Categories of Systems according to Hitchins (1994) (2005)

Layer 5	<i>Socio-economic.</i> Principal lever of control is regulation.
Layer 4	<i>Industry.</i> Complete and competitive supply chains.
Layer 3	<i>Business.</i> Controlled optimization independent of competitor/partner performance.
Layer 2	<i>Project.</i> The making of complex artifacts.
Layer 1	<i>Product.</i> The making of tangible artifacts.

While some of the differences may need further clarification as the categories are not complete, e.g. the socio-economic layer is comprised by more than industries, it is a useful starting point.

Traditional systems engineering has focused on Layers 1 and 2. Management science has focused on Layer 3 and political scientists and economists have struggled with Layer 5. Layer 4, the industry and multi-industry interactions is not virgin territory but the scope of work on that level has been focused on competitive strategies and strategic dominance when approached from Layer 3 and from the end customer and individual industry perspective when approached from Level 5 while the holistic system approach has been lacking.⁶³

This lack may be the result of the characteristic lack of centralized control that Layer 4 enterprises exhibit. Ackoff (1971) defined organizations in the systems terminology as “a

⁶³ For the air transportation industry, layer 4 has been looked in business school case studies focused on airline strategies for expansion or on the competitive behavior of manufacturers but not on how the two interact. It has also been looked at as a system from a regulatory perspective in which the interests of certain stakeholders are emphasized e.g. passengers and deregulation or specific airlines and antitrust (see Viscuzi et al. pg 554).

*purposeful system*⁶⁴ that contains at least two purposeful elements which have a common purpose; ... its functionally distinct subset can respond to each other's behavior ... and at least one subset has a system-control function." The Layer 4 systems do not meet the requirement that at least one purposeful element has a system control function and in that respect, closely match the characteristics of "loosely-coupled system of systems." In the next section we introduce the concepts of system of systems (SoS), how loosely-coupled SoS are defined, and then extend this to define the Enterprise of Enterprises.

5.2 Enterprise Views: From Systems of Systems (SoS) to Enterprises of Enterprises (EoE)

5.2.1 Enterprises as Systems and their Representation: a Literature Overview

The definitions cited in Section 5.1 do not clarify what forms enterprises can take. The most common organizational form identified as an enterprise is the incorporated organization (belongs to Level 3 under Hitchin's categories). Enterprises are fairly cohesive with identifiable strategies and hierarchical decision-making process at least on the macro-level. This is the type of organization that the term "enterprise" will refer to when used without any qualifier.

The term "extended enterprise" is referring to the part of the value chain in which an enterprise is involved, has interests in, and potential influence over. An extended enterprise is smaller than an industry as it usually does not include competitors.

The view of enterprises has been evolving and continues to evolve. It moved from a mechanistic reductionist closed-system view to one where emergent behavior necessitates a holistic open-system view. Both views are valid in different settings. (Ackoff 1994) (pg. 3) noted that the enterprise was conceptualized progressively as a machine, an organism, and as a social system. The latter conceptualization, as a social system, enables the stakeholder view of the firm which we discuss later in this section.

Closed-system view of the Enterprise

Taylorism and the scientific organization of labor has been the most widely known result of the "organization as machine" worldview. The hierarchical centralized bureaucracy is necessary for deciding on organizational planning and execution via budgeting and objectives. The control structure is provided through punishment and reward primarily via financial incentives. Taylor's scientific approach met with great resistance from the shop floor workers (Kanigel 2005)(pg. 179-180)⁶⁵.

⁶⁴ A Purposeful system according to Ackoff "can produce the same outcome in different ways and ... different outcomes in the same and different states... [I]t selects ends as well as means and thus display will."

⁶⁵ "The greatest obstacle faced by the experimenter was *the blind [] prejudice on the part of most machinists to any improvement or change. [The experimenter] upon entering such an undertaking must bid good-bye to all ideas of personal popularity among his fellow workmen.*"

Toyota improved on that paradigm by instilling a scientific hypothesis testing via trial and error culture from management appointed organizational scientists to the workers themselves as part of a broader company culture by using “Kaizen” events to reveal the tacit knowledge and creativity of its workforce in a participatory fashion (Liker 2004). Companies operating in fast clock-speed environments also adapted their approaches from top-down hierarchy to a matrix structure (functional on one dimension and project-related on the other) and delegating decision-making (Burns and Stalker ref. by Katz and Kahn (1978) (pg. 133), Fine (1998)).

Open-system views of the Enterprise

On a larger scale though, the reductionist paradigm starts to break down as Katz and Kahn (1978) (pg. 30-33) are quick to point out. Organizations observe and adapt to their environment. Organizations compete for resources and information and they survive if they adapt successfully. (Dooley 1997) considers them as complex adaptive systems with potentially chaotic behavior that can move between dynamic states either motivated by crises or leadership. He classifies organizational change into (i) improving the performance of current functions (first-order change), (ii) changing functions (second-order change), and surviving or dying-off (third-order change). When they change they do so for a reason (teleological view) and the way the change is determined by the understanding of the existing environment and the ingrained organizational knowledge, culture, and core principles called DNA by Spear and Bowen (1999).

Zott (2003) considers two primary ways in which enterprise change is achieved: (a) imitation and (b) experimentation. Competitors can choose to experiment and gain competitive advantage through their ability to generate and operationalize innovation while other may imitate and adapt innovation. Of course, more traditional modes of competition like quantity and price setting exist. Milgrom and Roberts (1995) used an abstract model of the firm that defined quantity, product innovation and process innovation as basis to study the complementarity between certain firm functions.

Although the biological metaphor has been used widely to describe enterprises, Katz and Kahn (1974 pg. 37) caution its use because organizations are social structures, and as such they do not have a physical “anatomy” once they cease to exist. Another difference stems from the ability of organizations to grow continuously and at will. This ability which Katz and Kahn called the “maximization principle” overrides the maintenance dynamics⁶⁶ either as a natural result of proficiency or as means for alleviating internal and external threats (pg. 97). As they are applied successfully, these impulses become ingrained in the organizational DNA of a successful growing organization but they may be ill-serving when the organization and its environment encounter limits to growth resulting in the overshoot and collapse pattern of boom-bust cycles. This is besides the inherent problems of growth that Katz and Kahn list (harder integration, loss of core motivation, communication breakdowns, misalignment of incentives pg. 108).

⁶⁶ They define maintenance dynamics as the tendency of biological systems to retain the status-quo (homeostasis).

Strategic Objectives of the Enterprise: Stakeholder vs. Shareholder View

According to Katz and Kahn, productive or economic enterprises have as primary motivator the creation of wealth through material extraction, transformation, and service rendering (pg. 153). The motivator of “creation of wealth” or value is not equated to economic profit. Economic profit is in fact the value to the owners but there is value distributed to employees (wages), financiers (interest), government (taxes), society (consumer surplus, employment), suppliers (their products needed the added value to be sold) etc. These entities are *stakeholders* of the enterprise and their interests may or may not be aligned.

In defining stakeholders more formally, (Freeman 1984) simply classifies any group that impacts or is affected by an enterprise’s performance as a stakeholder. Kochan and Rubinstein (2000) are more specific and use three criteria to characterize the relative influence of stakeholder groups:

- (1) possession of resources key to the enterprise’s success;
- (2) level of risk that their assets are exposed in the enterprise;
- (3) formal and informal power they wield over the enterprise.

Based on the involvement of stakeholders, two corporate traditions have evolved successfully each with long history: *shareholder capitalism* in English speaking countries and *stakeholder capitalism* in continental Europe and Asia. In stakeholder capitalism, the enterprise strives to balance the, often conflicting, interests of all major stakeholders while in shareholder capitalism the interests of the owners have precedence. (Grant 2005) (pg. 39) illustrates this difference in legal terms; while in the US, Canada, UK, and Australia company boards are legally expected to act in the interest of the shareholders, French boards are mandated to act according to national interests, Dutch boards to guarantee the continuity of the enterprise, and German boards are required to have employee representatives in their members. Similarly, the Japanese *Keiretsus*, horizontal and vertical families of industrial and financial companies, are strong embodiments of the stakeholder view of the enterprise and are thus recognized by law.

Piepenbrock (2005) observed that the two models (stakeholder vs. shareholder) also exhibit their advantages best at different stages of industrial and technologic maturity. By combining Utterback’s (1994) innovation s-curves and the stakeholder model of the enterprise, he postulated that integral enterprises (managed with a stakeholder view) are advantaged during the initial phase of a disruptive technology where the need for stable financing and customer integration is significant. As the disruptive technology leaves its initial product innovation stage only a few designs have the potential to emerge as dominant. At this stage, a modular enterprise (shareholder centric with arm’s length relationships with their stakeholders) is better poised to push the technology frontier and innovate faster than the other ‘slower’ stakeholder-centric enterprise. Once the dominant design emerges and product starts being commoditized, the competitive advantage is provided by process innovation and the ability to reduce marginal production costs hence prices and improve operational efficiencies. At this stage, the integral firms regain the advantage as they can better focus their energies to satisfying their customers.

If the two enterprise views are archetypes of black and white then most real-world enterprises would be painted in shades of gray; that is the two views have influenced each other but the two practices are still distinguishable. An illustration of the two contrasting views is given in Table 5-2. While the input-output model depicts only those stakeholders with a financial interest in the firm and the relationship is primarily one way, the stakeholder model is far richer and considers the inputs and benefits expected to them. Donaldson and Preston (1995) reviewed the arguments for and against the stakeholder theory. Specifically they tried to verify whether (i) the stakeholder model describes the reality of the enterprise more accurately, (ii) enterprises that follow the model are relatively more successful in conventional performance terms, (iii) the interests of all stakeholders are of intrinsic value, and (iv) the stakeholder model prescribes specific managerial actions. While they do not find a conclusive proof for the second thesis, they do find a consensus in that the alternative shareholder theory in its pure form is “morally untenable” even for its proponents.

Table 5-2 Contrasting models of the enterprise: Shareholder vs. Stakeholder Model (Source: Donaldson and Preston (1995) and Kochan and Rubinstein (2000), adapted)

	Shareholder-centric/modular Enterprise	Stakeholder-centric/integral Enterprise
View		
Goals	Maximize shareholder wealth	Pursue multiple objectives of parties with different interests
Governance	Principal-Agent Model: Managers are agents of stakeholders. Control is the key task.	Team production model: Coordination, cooperation, & conflict resolution are the key tasks.
Performance metrics	Shareholder value	Fair distribution of value

The strategic objectives of enterprises under the two archetypes would be expected to diverge along with the incentives provided to the managers. Indeed, as shown under ‘goals’ in Table 5-2, for a shareholder enterprise the economic return is the primary metric and the incentive structure for management is similarly aligned. A side-effect of this structure is that the time horizon of strategic decision also varies between the two archetypes. For shareholder-centric enterprises, the ratio of institutional stockholders against high-turnover high-return seeking stockholders may determine the length of investment horizon (Keynes 1936). When managers are judged by short-term economic performance then long-term strategic investments expectedly take the back-seat to short-term profit maximization (Stiglitz 1985) (pg. 146).

Capital Markets as Stakeholders

As capital markets become more actively involved in the management of firms due to their status as shareholders in shaping the management decisions it is useful to briefly review their structure.

Financial institutions as stakeholders can be broadly categorized into banks, stock-markets, and private investors (equity). All three of them are substitutes as sources of financing for enterprises. Stiglitz (1985) summarizes the functions of capital markets as threefold: (i) allocation of limited capital to competing users, (ii) provision of indicators to managers and (iii) control of capital.

According to Stiglitz, banks and lenders rather than shareholders provide greater control of the corporate decision-making as the banks can better control the principal-agent dynamic to their interests. Stiglitz recommended that institutional reforms where labor unions, as one of the primary long-term interest stakeholders, should play a more active role in management decisions.

His analysis did not include the ascend of fiduciary capitalism which saw an increase in the size of mutual and pension funds and other investor pooling mechanisms that concentrate the power of the shareholders to the fund managers from 5% in 1945 to more than 50% of corporate equity in 2000 (Hawley and Williams 2000)(pg 55). Hawley and Williams identify three waves of corporate control: corporate entrepreneurial management (owners manage the firms they started, 1890-1920), managerial capitalism (control goes to professional managers with diffuse shareholders exerting weak influence, 1920-1970), fiduciary capitalism (investor fund managers concentrated the power of shareholders, 1970-).

According to Hawley and Williams, fiduciary capitalism is characterized by *universal owners* (institutional owners with highly diversified portfolios that are usually held for the long term). *Universal owners, with their large portfolio of assets, have the potential to capture spillover externalities; that is positive effects of actions of one firm that do not benefit that specific firm but others in the value chain which are included in the broad portfolio of a fund.* The case is similar for negative externalities generated by one firm but which burden another. While this is in theory possible, in practice the short-term focus and competition among funds to generate large short-term returns along with the inability to measure externalities has blurred if not entirely eliminated the long-term focus and potential.

Simplified assumptions on the representation of strategic objectives

Using short-term profit maximization as the primary metric for managing an enterprise can have adverse consequences that range from corruption and illegal activities (financial statement manipulation, market fixing, product adulteration etc. with abundant examples in each case), to disregard for the adverse externalities generated (e.g. environmental damage, inequality), to short-sighted decisions that endanger long-term strategy and competitive advantage. While these are real problems when actively managing an

enterprise, the metric of economic value added remains valid in judging and comparing enterprise performance if the factors mentioned above are accounted for.

Grant (2004) (pg. 40-41) argues that for analytical purposes on strategy the use of long-term profit maximization as performance metric is a valid, albeit simplifying, assumption for the following reasons:

1. Companies in competitive markets face survival threats due to competition and in many cases earn returns that do not cover their capital costs – a fundamentally unsustainable situation.
2. Management control can be wrested over from underperforming companies by either their shareholders or private investment firms.
3. Sustained long-term profitability is more likely to require a stakeholder-centric management approach.
4. It allows for a simple metric when comparing systematically and analyzing between companies.

Given the absence of clear alternative metrics, the above arguments are compelling. In our analysis, we will use relative economic profit as one metric for identifying successful strategies without endorsing it as a criterion for short-term management tactics.

Enterprises and Extended Enterprises: symbiosis and competition

The vertical value chain from suppliers, to the enterprise, to the customers has been considered as an extended enterprise. We already mentioned the efforts by Toyota in affect lean transformation across their value chain in Section 5.1. Stakeholder-centric managed companies create an extended enterprise as a competitive advantage. They tend to have a smaller number of suppliers with which they nurture a trust-based relationship. Illustrative examples of the risk and rewards of such relationships are given by (Sheffi 2005). Risks may include the vulnerability of a single-sourcing strategy but the advantages outweigh the costs as a close relationship with a single supplier provides: shared R&D, ability to co-optimize production and logistics as a system, better understanding of their cost structure, better integrated products due to shared R&D etc.

The boundaries of the extended enterprise though, understandably, do not extend to include competitors⁶⁷ – stakeholders in the overall system but not in the enterprise per se. These competitors have their own value functions but also share a stake in the performance of the industry they participate in and are influenced by the results of their collective decisions.

5.2.2 Systems of Systems

(Maier 1998) defines systems of systems or “collaborative systems” if (i) the component systems operate with different purposes and (ii) “are managed (at least in part) for their own purposes.” This definition matches the difference between Layer 4 and other layers in Hitchin’s categorization. For Maier, systems of systems are a composite of systems

⁶⁷ Ackoff (1994) echoed this, by not extending the boundaries of his enterprise view to competitors either.

that have operational and managerial independence among other distinguishing properties. Shah (2007, forthcoming) points out that these systems have localized value functions but are also influenced by a global value function. Maier describes the principal characteristics that distinguish “*true systems-of-systems*” from “*very large and complex but monolithic systems*” as shown in Box 5-1.

Maier (1998) uses three examples to demonstrate systems of systems and their characteristic architecture: wide area networks like the Internet, integrated air defense systems, and Intelligent Transportation Systems. Maier’s is focused on how these systems of systems can be architected and thus he concludes with four heuristics:

1. **Stable intermediate forms:** The systems of systems are expected to form dynamically and not centrally directed and as such their design should try to ensure that they can function in intermediate phases.
2. **Policy triage.** As the designer does not have “coercive” control, he or she needs to prioritize the points of leverage.
3. **Leverage at the interfaces.** “*Interfaces are the architecture.*” The interfaces between components (e.g. data standards and protocols for networks) are the critical areas through which the designer can control the system of systems.
4. **Ensuring cooperation:** The designer should enforce the reasons that the components choose to collaborate.

Box 5-1 Loosely-coupled System-of-Systems Characteristics (Sources Sage and Cuppan (2001), Maier (1998))

Operational Independence of the Elements: If the system-of-systems is disassembled into its component systems the component systems must be able to usefully operate independently. The system-of-systems is composed of systems which are independent and useful in their own right.

Managerial Independence of the Elements: The component systems not only can operate independently, they do operate independently. The component systems are separately acquired and integrated but maintain a continuing operational existence independent of the system-of- systems.

Evolutionary Development: The system-of-systems does not appear fully formed. Its development and existence is evolutionary with functions and purposes added, removed, and modified with experience.

Emergent Behavior: The system-of-systems performs functions and carries out purposes that do not reside in any component system. These behaviors are emergent properties of the entire system-of-systems and cannot be localized to any component system. The principal purposes of the systems-of-systems are fulfilled by these behaviors.

Geographic Distribution: The geographic extent of the component systems is large. Large is a nebulous and relative concept as communication capabilities increase, but at a minimum it means that the components can readily exchange only information and not substantial quantities of mass or energy.

SOS have emergent properties as the behavior of the SOS cannot be deduced from the behavior of component systems and because of their interdependency of the components a “*new set of mechanisms must emerge to guarantee the integration.*” (Correa and Keating 2003).

SoS Related Methodologies

Having identified what systems have been considered SoS, we will discuss the methodologies developed to address the challenges they present.

Jackson and Keys (1984) classified the problems encountered by SoS designers into *mechanical-unitary*, *systemic-unitary*, *mechanical-pluralist*, and *systemic-pluralist* (see Figure 5-2). Following Ackoff's (1971) reference to "machine-age" and "system's age," mechanical are systems that are "closed [with] passive parts and [] understood through reductionism" while systemic are "open, with purposeful parts, [] only partially observable and [] not understood by reductionism." The second attribute refers to system control; unitary systems have a single set of decision-makers and conversely pluralist exhibit multiple sets of decision makers.

Jackson and Keys consider operations research (OR), systems engineering (SE) and systems analysis (SA) as methodologies developed to address problems that are primarily systemic-unitary. SoS, on the other hand, based on the prevalent examples used to demonstrate the concept, would fall under the mechanical-pluralist category in which while there are multiple stakeholders managing the component systems (pluralist) the systems themselves have well known engineered responses (mechanical). They argue that Churchman's (Churchman 1979) methodology of synthesis of decision-makers' positions towards consensus (later formalized by Mitroff, Emshoff et al. (1979)) may be well suited to such systems when addressing the pluralist component. They assert though that "every formulation of a wicked problem corresponds to a statement of solutions and vice versa" which seems to underestimate the systemic aspect of their behavior.

Complexity	<i>Socio-Technical (systemic)</i>	Focus of: OR SE SA	EoE
	<i>Technical/ Mechanical</i>	Traditional Engineering	SoS
		<i>Unitary</i>	<i>Pluralist</i>
		Authority	

Figure 5-2 Classification of Systems (based on Jackson and Keys (1984))

Jackson and Keys describe the environment prone to systemic-pluralist problems thus: "**organizations are purposeful systems which contain purposeful parts and which are themselves part of larger purposeful systems. Hence organizations have responsibilities to their own purposes, to the purposes of their parts, and to the purposes of the larger systems of which they are part.**" As a result of these characteristics, they assert that the task of the manager of such systems is to remove the conflicts among these levels of purpose.

The methodology that they recommend for such a task derives from Checkland (1981) and revolves around three principles for the problem solving strategies:

- Participative: participation of all stakeholders in the planning process.
- Continuous: continuous adaptation of the strategies to address the changes of the evolving system.

- Holistic: address and consider as many layers of the system as possible simultaneously.

In keeping with these principles, (Ackoff 1981) proposed a structured planning process that consists of five iterative steps:

1. Formulating the mess
2. Ends planning
3. Means planning
4. Resource planning, and
5. Implementation and control

Participatory and interactive planning is key for such systems as is the second step of the planning process – ends planning – which is intended to eliminate petty differences among the stakeholders by focusing on the desired end state. The approach outlined by Jackson and Keys is still concentrated on systems that despite having multiple stakeholders, their purposes can be aligned – i.e. conflicts of interest can be held to a minimum. Layer 4 systems, or industries, may or may not satisfy that requirement.

Wojcik and Hoffman (2007) point to the need for accounting of interactions between stakeholders with different objectives when modeling enterprises on the strategic level. They also note that equilibrium seeking methods rather than optimization are more appropriate for these systems. Even if the equilibrium is not reachable in practice, it can act as an “attractor” of enterprise behavior that is sufficient to inform strategic decisions. They also stress the importance of the human factor and organizational context that seems to be missing from applications of SoS engineering. In order to address that shortcoming they suggest that Highly Optimized Tolerances (HOT) could be a methodology that is applicable at the highest level of the hierarchy of the modeled SoS. Their approach is demonstrated by a simple model of a system of cost equations that is solved for game theoretic equilibrium. The HOT approach reliance on analytical systems of equations may prove to be limiting in accurately representing systemic aspects and as a result could be more appropriate for mechanical-pluralist SoS but it follows the same trajectory of thought that we combine in the EoE representation (this chapter) and modeling (Chapters 9-10).

Kasser (2002) suggests that managing an SoS⁶⁸ could become easier if abstracted as an information management problem and use a methodology similar to those used for configuration management. He points that the difficulties in managing an SoS stem from the loose coupling of self-regulated systems and therefore he expects that finding and adding the organizational elements that would interface between the component systems as shown in Fig. 5-3 would allow for the better management of the SoS. While his suggestions make sense for unitary systems they may not be practicable for pluralist decentralized ones.

⁶⁸ Kasser uses a slightly different definition of SoS as a set of interdependent systems that evolve at different rates.

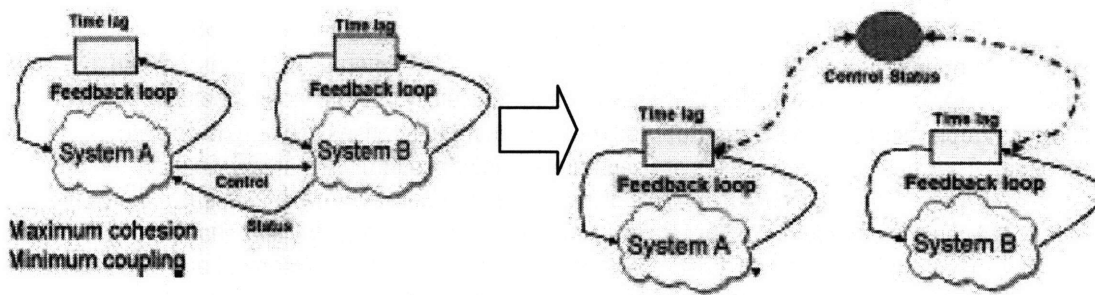


Figure 5-3 Adding control to self-regulating systems as a way for solving SoS problems (Source: Kasser 2004)

Transportation Domain Applications

DeLaurentis (2005) presents the U.S national transportation system (NTS) as an example of SoS. He views the NTS as a mechanical-pluralist system with individual stakeholders operating parts of the system while connected in a network of interactions on both the business and the physical levels. His view does not extend to the supply chain issues (i.e. the cross-industry supply chain connections). Crossley and Mane (2005) develop a more specific application by using the SoS framework for developing the aircraft choice and future sizing as a multidisciplinary optimization problem. Rebentisch, Crawley et al. (2005) also used the SoS framework from a stakeholder value perspective to develop sustainable space exploration. Based on the integrated system-of-systems approach, Taylor and deWeck (2007) demonstrated a way for concurrent optimization of the aircraft design and the network structure that the aircraft will operate in.

5.2.3 Enterprise of Enterprises (EoE)

5.2.3.1 The Characteristics of EoEs: Need and Definitions

The discussion above illustrated that while the SoS framework encompasses systems with systemic-pluralist problems, the bulk of applications of SoS have been reserved for mechanical-pluralist problems. Even when systemic-pluralist problems are considered, for example by Jackson and Keys (1984), consensus and tight-coupling of the stakeholders is implied. Similarly, Kasser's solution to challenges faced by loosely-coupled self-regulating SoS is to add a centralized control mechanism. But neither approach is generally feasible for Level 4 systems. The difficulty to assert centralized control and the divergence of interests among the constituents are the distinguishing characteristics of EoEs. Box 5-2 translates the characteristics of loosely coupled SoS from Box 5-1 to address the characteristics of EoEs.

As a concept, EoE bridges the gap between the between industry and enterprise as it considers the a set of related industries as a purposeful system with the implicit assumption that it can be modified towards optimizing its performance across stakeholders. This is done by using terms, methods and heuristics from literature on System of Systems, Enterprise Architecture, and management science.

Box 5-2 Characteristics of an Enterprise of Enterprises based on SoS

Operational Independence of the Constituents: If the Enterprise-of-Enterprises is disassembled into its constituent enterprises, the constituent enterprises are able to usefully operate independently.

Managerial Independence of the Constituents: The constituent enterprises can and do operate independently. The constituent enterprises are separate and interface through material, financial, or regulatory exchanges. *There are strong conflicts of interests (especially short-term) present in the value functions of the constituent enterprises that instill a zero-sum game mentality in their behavior.*

Evolutionary Development: The enterprise-of-enterprises is not static. Its development and existence is evolutionary with functions and interactions added, removed, and modified by the volition of the constituent stakeholders responding to market forces.

Emergent Behavior: The system performs functions and carries out purposes that do not reside in any component system. These behaviors are emergent properties of the entire enterprise-of-enterprises and cannot be localized to any component system. The principal purposes of the enterprise-of-enterprises are fulfilled by these behaviors.

Diversity of Interfaces: The constituent enterprises interface with each other through a variety of ways: material, financial, and regulatory. Information exchanges still occur but are relegated a supporting rather than primary role.

Following the classic systems approach for EoEs may not be possible for the following reasons:

- *No obvious architect.* The need for systemic change may be recognized by several stakeholders in the system and yet either because of their relative size or because of difficulties to see beyond the short-term, the option of rearchitecting the EoE may not even be considered.
- *No obvious points of leverage.* Even if there are stakeholders that recognize the need for change and have the will to do so, there may not be any *obvious* point of leverage given the magnitude and complexity of the system. The usual point of leverage considered is regulatory intervention and hence lobbying towards that end but the objective is usually still guided by short-term self-interest and is expected to cause reaction and counter-lobbying efforts by stakeholders that are adversely impacted. Cooperation may also be considered but it is not an obvious leverage point due to the competitive nature of the relationships and because of the legal implications introduced by anti-trust regulations.
- *Divergent value functions.* The local and the global value functions are usually at odds with each other especially in the short-term.
- *Large system inertia.* The nature and magnitude of EoEs make them difficult to change compared to regular SoS examples. Even when intentional changes occur their results are rarely immediate and often hidden by the compound effect of multiple actions.

In response to these differences, we reformulate Maier's four heuristics or architecting principles to represent the specific characteristics of EoEs:

- **Leverage at the interfaces:** Interfaces for EoEs can include price signals, delivery and order rate signals, product characteristics, information etc. Interfaces are still prime leverage points.

- **Policy triage:** Even more than other SoS, standardization will not always be possible and the leverage points not readily identifiable. Effort will be required on the part of the architect to find them and decide where to use limited resources to affect them.
- **Stable intermediate forms:** Because of their independence, parts of the EoE may separate from the whole and function entirely independently. This can happen dynamically and unexpectedly but with all its disadvantages it gives a reassurance as well: the system is resilient and will continue to operate even if change fails.
- **Ensuring collaboration:** The value delivered to the component systems needs to be considered in order to maintain long term participation. The value functions and culture of the constituent enterprises of the EoE become of equal importance to the interfaces in affecting change as they are expected to be conflicting more often than not. While arguably these may be one of the hardest elements of an enterprise to change, they do evolve over time.

The definitions and heuristics that were presented here in the abstract will be used to define the air transportation related industries as an Enterprise of Enterprises in the next section.

5.2.3.2 Building Blocks/Components of an EoE

In order to provide a common terminology for referring to EoEs, we define the common building blocks of EoEs based on the conceptual abstraction of the EoE concept:

- Constituent enterprises and stakeholders,
- Value functions, and
- Interfaces.

EoEs are comprised of enterprises which we call **constituent enterprises**. EoEs can also have non-enterprise **stakeholders**. In some cases there is an overlap of stakeholders and enterprises but there can be stakeholder groups that are not tightly organized enough to be considered an enterprise (for example, passengers are stakeholders in the commercial aviation EoE as they cannot be considered constituent enterprises).

Enterprises are defined by their value functions and exert control/authority over *components* internal to the enterprise in the desire to fulfill their value functions. Enterprise components can be *physical capacities* (e.g. capital equipment, contracts, liquid assets, etc) or *functions* (e.g. business units, marketing, operations etc.).

Value functions represent the needs, expectations and objectives of constituent enterprises and stakeholders. They are the fundamental aspects of the enterprise which are targeted by the driving policies and strategies followed by the enterprise's managers. They are not always quantifiable and in many cases they may not even be clearly articulated by managers. For the purpose of this thesis, we follow Grant's simplification of the strategic objectives of a private enterprise and the stakeholders directly involved with it (labor, capital markets, owners) which is the maximization of its long-term economic return (see Grant (2004) and Section 7.3 for further discussion).

The primary **interface** within an enterprise is authority that is the strongest level of coupling is assumed for interfaces within an enterprise. (Authority in our definition includes the notion of contractual obligations and team inputs and so account for the objection raised by Alchian and Demsetz (1972) that the primary governance of activities within the firm is not authority).

Interfaces between constituent enterprises of an EoE cannot be authoritative. Enterprises are **coupled** with stronger (tight) or weaker ties (loose). In the generic form, EoEs can have variations of loosely- and tightly- coupled interfaces but not of authority. An extended enterprise, referred to as an EoE by Nightingale (2004) can be considered as a tightly coupled EoE according to our definition above.

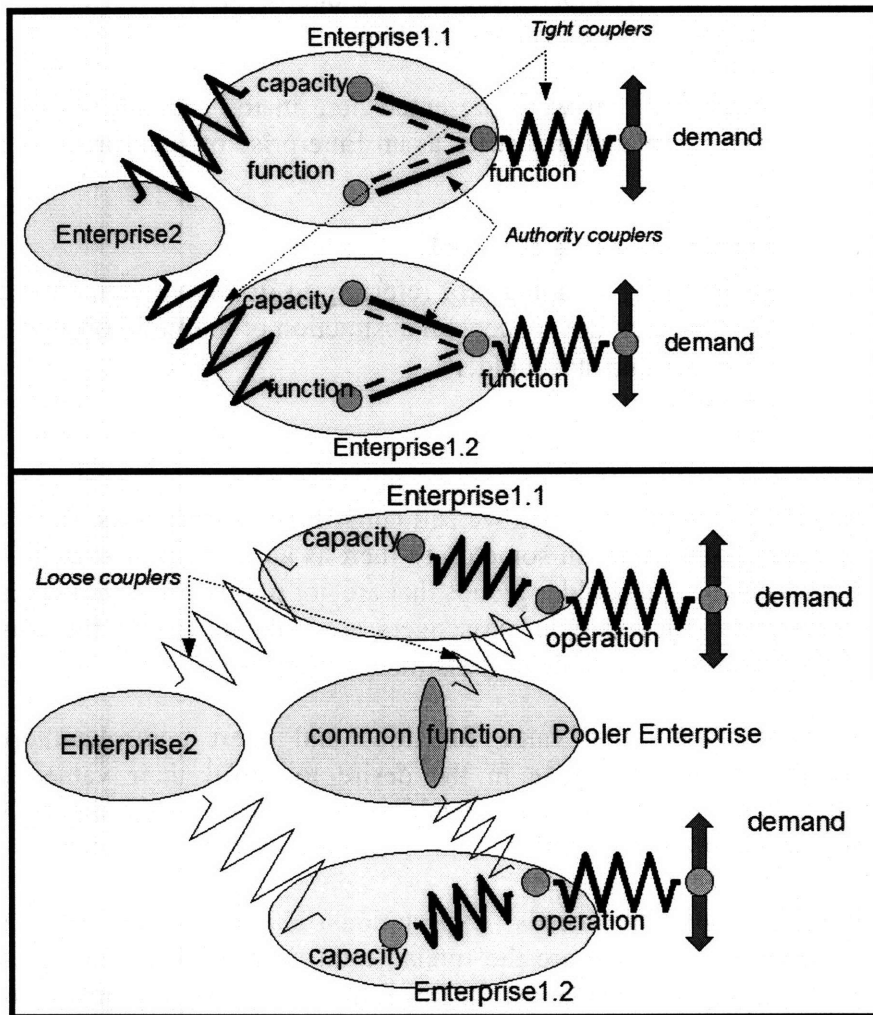


Figure 5-4 Demonstration of the EoE mechanical analogy view in two different EoEs

Transcribing the notation above into a mechanistic analogy, the EoE could be presented as shown in Fig. 5-4.

A note on the Figure 5-4 of the graphical EoE view mechanical analogy:

- Capital first letter and overarching ovals were used to represent enterprises.
- Double lines, one dotted the other continuous, indicate control (authority coupler) from an enterprise.
- Lower case first letter and small circle denote capacity or function.
- Small oval represents pooled capacity or function.
- Spring indicates interface/coupler, with the wider/bolder lines denoting a tighter coupling than thinner ones.

5.2.3.3 Architecting Heuristics for the CA EoE and Cyclicity

The distinction between a supply chain and an EoE is that the latter is substantially more pluralist. The prevailing view of supply chains is based on the ability of one stakeholder to exert control over the choices and behavior of their upstream and downstream partners. This implies that the level of managerial independence (and therefore value functions) in supply chains is less than an EoE, in which each echelon can be populated by competing enterprises that may or may not be able to control their supply chains as extended enterprises.

In order to connect though cyclical behavior in an EoE, we will borrow the conceptual understandings of the cycles in supply chains (and to a lesser extent macroeconomic theories) which are reviewed and summarized in Ch. 6. In this section we will simply define *strategy heuristics* on architecting an EoE to be less prone to cycles based on the insights from the aforementioned literatures (which we name cyclicity moderation strategy heuristics CM-SH). We will further discuss and apply these strategy heuristics in the experimental modeling section in Ch. 10.

CM-SH.1(pooling strategy): Cyclicity in an EoE can be reduced by delegating control of a function that is internal to a number of enterprises to another enterprise that can pool that capacity and function and thus reduce overcapacity.

For supply chains, this heuristic is applied for example in supplier-managed inventory. I.e. the retailer delegates the authority/control over inventory to the supplier who can control it better across several other retailers.

CM-SH.2 (JIT strategy): Cyclicity in an EoE can be reduced by tighter coupling of one or more enterprises

For supply chains this is equivalent to just-in-time (JIT) inventory control or a pull supply chain strategy. Tighter coupling to downstream demand, i.e. as close to immediate as possible gratification or completion of the downstream orders, reduces the lead times and the associated forecasting errors, therefore reducing the amplification of order variation upstream. Womack and Jones suggested the JIT production can eliminate the business cycles which we introduced as the Womack and Jones hypothesis in Ch. 1.

CM-SH.3. (capacity decoupler strategy): Cyclicity in an EoE can be reduced by delegating control of a key interface capacity that is common across the EoE.

This is a variation of the CS-SH.1 but for capacity.

These heuristics and the relative effectiveness when applied to commercial aviation as an enterprise of enterprises will be the subject of Section 10.3. In the next section we will define how commercial aviation can be viewed as an EoE.

5.3 Commercial Aviation as an Enterprise of Enterprises

Having described the need and the theoretical basis for an Enterprise of Enterprises analysis, in this section we will consolidate the key aspects of the commercial aviation related industries, as discussed in Chapters 2-4, using the EoE lens. Section 5.3.1 identifies the objectives and the constituents of the CA EoE. Section 5.3.2, summarizes the costs (and benefits) incurred by the EoE constituents and stakeholders, discusses the key interrelationships between the constituent enterprises and directs to potential points of leverage based on these interfaces.

5.3.1 Purposeful Commercial Aviation

Commercial aviation as an EoE is purposeful in the sense of purpose that Keynes (1936) (pg. 158) called “social purpose. Arguably its primary social purpose is to produce transportation services for the customer class of stakeholders (primary value) and in the process provide value to the other classes of stakeholders (incidental value). Going one level lower, corporations as constituent enterprises are also purposeful in providing their services and meeting their obligations to their shareholders, employees, and society.

Objective of Analysis

As with any type of system representation and analysis, ours is motivated by specific objectives. Our motivation is to identify ways to mitigate the cyclical behavior of the related industries.

Constituent Enterprises of the Commercial Aviation EoE

The multitudes of stakeholders shown in Figure 5-1 are interdependent but not all interactions are direct. Interactions are directed and the constituents can be aggregated based on their position in the system and their behavior. A schematic is shown in Figure 5-5.

In our analysis, the NTS that DeLaurentis (2005) describes as an SoS is confined by the triangle of demand (passengers and shippers), service providers (aircraft owners/operators) and infrastructure (airport and ATC capacity) with the other modes being implicitly included as moderating demand through competition. The airport and air traffic control (ATC) systems are considered here only to the extent that they become constraining factors in the expansion of air travel. Therefore, the commercial aviation EoE (CA EoE) includes the aspects of the NTS described previously in addition to the aircraft supply chain (airframe and engine manufacturers and their suppliers), and the relevant parts of governmental and capital market constituents.

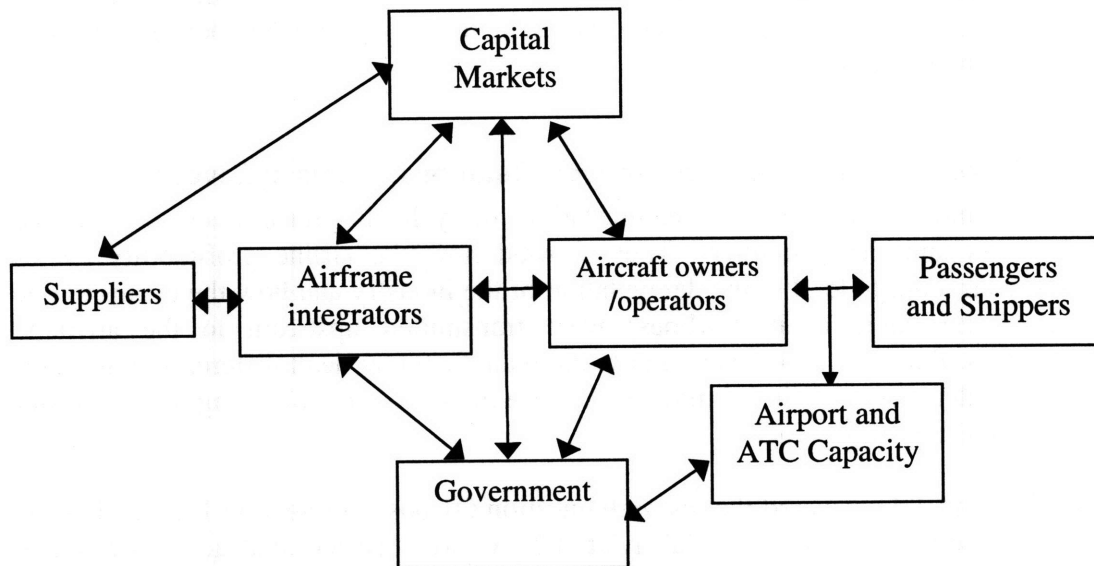


Figure 5-5 Constituent view of the EoE and their interactions in the Commercial Aviation EoE

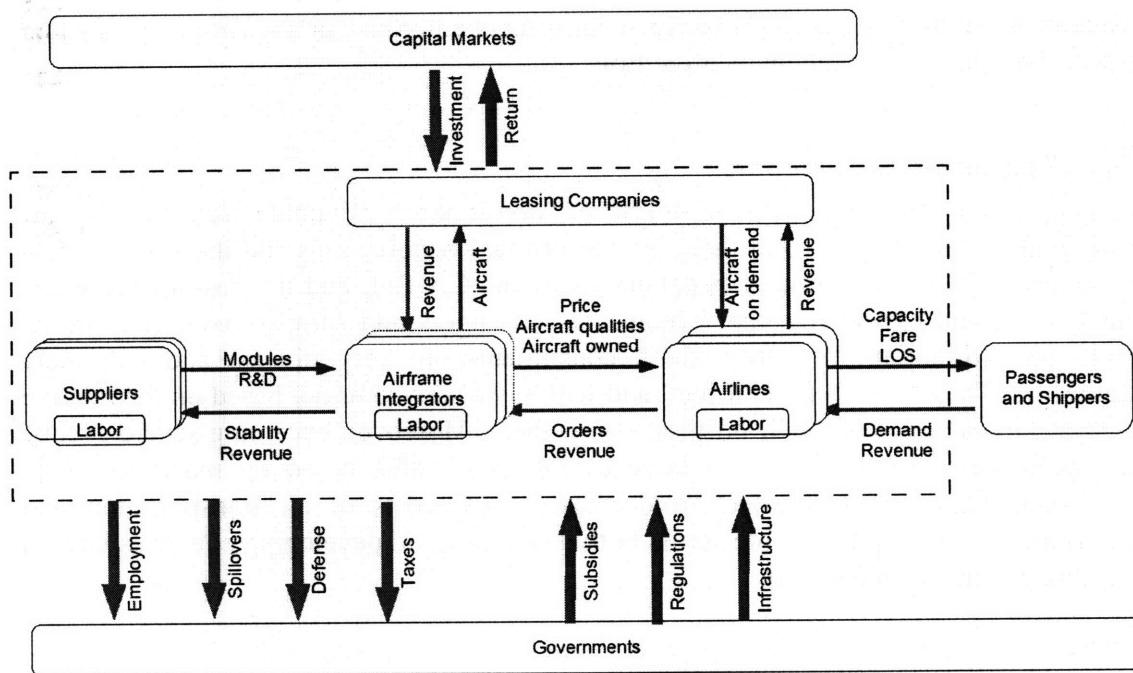


Figure 5-6 Interface and Constituent View of the CA EoE

The representation in Figure 5-5 simplifies the system significantly and it does not include the potential differences in the constituent enterprises structure and culture (e.g., Piepenbrock's stylized "red" vs. "blue" distinction) and the nature of the interactions between them. In order to accurately portray the type of managerial independence in the constituents of the EoE the differences of enterprise structure and culture need to be

considered at least on a broad scale. Furthermore, given the importance of interfaces in SoS analysis discussed in the previous section, they would need to be represented as well in any high level view of an EoE. The representation of Figure 5-6 portrays the key interfaces of the CA EoE.

5.3.2 CA EoE Constituents: Perspectives, Relations, Points of Leverage

Sections 3.5 and 4.4 illustrated the manifestations of cyclicity for airlines and airframe manufacturers and their suppliers. They showed how the airline profitability cycles increased their amplitude after the deregulation of the industry and how the cycles in one echelon of the value chain (airlines) were transmitted upstream to the airframe manufacturers. Finally we also hinted how the manufacturers dealt differently with their backlog of orders allowing it to build (in the case of Airbus) or following a much faster response in the case of Boeing.

Sections 3.5 and 4.4 answered the research question Q1 posed in Section 1.2 i.e. “How is cyclicity manifested in commercial aviation?” Various aspects that address research question Q2, i.e. “What are the impacts of cyclicity in commercial aviation?” have been hinted at previously, namely employment hire/fire cycles and direct and indirect government-funded subsidization for airlines and manufacturers. In this section we formulate a concise answer to Q2 for each constituent enterprise or stakeholder group and discuss their potential leverage over the EoE.

5.3.2.1 Passengers and Shippers

Passengers and shippers are the ultimate “consumers” or final users of the air transportation service good and therefore the primary beneficiaries and the *raison d'être* of the CA EoE. As the primary beneficiaries of the CA EoE and the base of the value chain, one could expect that the leverage of passengers and shippers over the system would be substantial. In reality, these constituents are very diverse and extremely fragmented. They ‘vote with their feet’ and will buy a service or not based on the relative benefits they perceive but their influence stops there. Moreover, excepting severe events, their behavior is stable and, to a large extent, predictable based on macroeconomic conditions. The combined effect of decreasing real costs of air transportation and increasing real per capita income across both developed and developing countries has led to a steady increase in demand.

Impacts of Cyclicity on Passengers and Shippers

It can be argued that passengers and shippers are potential beneficiaries of the boom-bust cycle (Gross 2007)(see Ch. 6); as increases in aircraft capacity orders during a boom further reduce fares during the trough. Therefore they may have neither the incentive nor the power to affect the system behavior.

This argument assumes that the liberalization of air transportation markets that could arguably be credited with reductions in fare prices due to higher competition invites more cyclical market behavior *by necessity*. In reality though, as shown in Figure 3-15,

normalized real fare prices have been downward trending continuously long before deregulation and the technical changes brought on by deregulation (primarily the hub-and-spoke network system) were credited for more than 50% of the cost savings attributed to deregulation in the U.S. market (Baltagi et al. 1995).

More importantly for the final users, cyclicalities brings unpredictability in air transportation fares and levels of service. Overinvestment during the upcycle may indeed create a capacity glut during the downcycle and bring down prices but it also sets the stage for a period where when demand recovers there is a lack of capacity at which point both the fare prices are high but also the levels of service deteriorate; aircraft load factors are high and delays are more frequent.

5.3.2.2 Capacity providers

Airports and air-traffic control systems were traditionally government owned and operated as basic infrastructure. Airline deregulation was followed by airport privatization in the form of public-private partnerships with varying degrees of government involvement (De Neufville and Odoni 2003)(pg. 107). While the rapid growth of aviation and the sometimes incommensurate investment in the infrastructure created bottlenecks, especially in the congested metropolitan airports, these were either resolved or worked around (e.g. by using airport systems⁶⁹ to serve a metropolitan area or introducing new technologies for air traffic management).

Impacts of Cyclicalities on Capacity Providers

For airports, the volatility associated with the boom-bust cycles is significant and *increases the risk* involved to investments in new facilities and dictates a more flexible approach to planning and leasing (ibid., pg. 113). While airport authorities usually have close to monopoly power over their area (local monopoly ibid. pg. 101), they are very fragmented as stakeholders on a national and, even more so, on a global level. Moreover, the competition among airports to attract hub traffic is adding to the inherent volatility that they face (ibid. pg. 125). This influence depends on the relative importance of hubs in the future.

Given the above, the possibility that either airports or ATCs would act as a constituent stakeholder with common interests and in a concerted fashion impact the CA EoE cycles is unlikely. Rather, their impact revolves around the de facto ability of these public-private partnerships to provide the capacity requested by the airlines while managing these volatility risks especially if these requirements continue at historic growth rates. If the volatility associated with the cyclicalities of the CA EoE subsides then the effort and costs associated with managing the infrastructure risks are reduced substantially and as a consequence these constituents have a strong incentive to facilitate their reduction.

⁶⁹ Multiple airports that serve the same metropolitan area therefore sharing a large part of their catchment areas. For example, the Boston MA metro area can be served by the Logan airport, but also by Manchester NH, and Providence RI primary airports as well as by smaller airports that can be used by regional or charter carriers and air taxi services (e.g. Hanscom field).

5.3.2.3 Airlines

Airlines went through periods of consolidation and fragmentation. On a global scale, airlines, as a constituent of the CA EoE, are fragmented. One level down, the industry remains fragmented in most deregulated national markets (including the EU) with significant competition in most notable routes and very few remaining uncontested monopolies. There is a strong trend for consolidation in the passenger market which, unless stopped by antitrust legislation, can result in a small number of mega-carriers as the evolution of the existing legacy carriers and a fairly large number of small niche and regional carriers. The successful low-cost carriers will be among these mega-carriers even if they do not expand into international long-haul routes.

Airlines are primary agents in introducing cyclical behavior in the CA EoE and also recipients of a large share of the related costs. Fragmentation, commoditization, and the economies of scale derived by size have led to intense and occasionally destructive competition. While competition fueled demand by lowering the prices and facilitating the reduction of operating costs by process innovation, it also led to conditions that generate significant costs for the airline enterprises and the whole value chain.

The primary interfaces that airlines control in relation to other constituents of the CA EoE are:

- fare prices and capacity (strongly correlated in free markets) with the demand constituents, and
- order patterns with the airframe manufacturers constituents

As airlines consolidate, the ability to form partnerships with an airframe manufacturer and stabilize the ordering pattern may be a significant point of leverage for attenuating the cycles. Other than that possibility, a fragmented and commoditized airline industry may be incapable of exerting enough control on the CA EoE by itself to do this.

Impact of cyclical on Airlines

Airline profitability is the archetypical symptom of cyclical in commercial aviation. In nominal terms, as seen in Figure 3-16, there were two times in which the nominal losses of the industry practically wiped all its cumulative profits (this occurred between 1990-1995 and between 2001-2005). During protracted low profitability periods airlines slow investments in new capacity to a near halt (transferring the cycle upstream). In addition they furlough employees or radically reduce their benefits to a point which labor-management tensions can lead to strikes, loss of confidence, and a demoralized workforce whose productivity suffers. These pressure conditions may lead to compromises of safety especially in regions where regulatory oversight is laxer.

5.3.2.4 Airframe manufacturers and Suppliers

We have seen that as the aircraft industry matured the number of competitors was reduced to a duopoly. This kind of concentration has the potential of exerting significant control on the industry cycles through the aircraft delivery and aircraft type interfaces. As economies of scale forced the duopolists into fierce head-on competition, they fueled the cyclical of the industry by accepting and even inducing orders larger than prudent on

an industry-wide level. Additionally, the level of customization of aircraft to meet customer requirements that made them incompatible without heavy modifications across fleets reduced the attractiveness of the second market.

Aircraft manufacturers, in their quest for market share, have increasingly and willingly accepted a greater share of the ownership risk born by airlines (Section 4.3). These risks compound the risks of development of new, increasingly complex, aircraft and the costs associated with variability in production rates (Section 4.3). As a result, aircraft manufacturers have both the incentive and the potential leverage to work towards attenuating the cycle.

Their suppliers are also very fragmented and have far less control over delivery rates than manufacturers although they share in both the risks and costs associated to volatility described above. Given these, they are an unlikely constituent for affecting change as they do not share a direct interface to major dynamics.

Impacts of Cyclicalities on Airframe Manufacturers

The primary negative aspect of cyclicalities that airframe manufacturers have to contend with is the cyclical aircraft orders that are highly correlated with the airline industry profitability as shown in Figure 3-19. This creates three related problems; (i) a manufacturing slow-down followed by a production ramp-up which, as manufacturing is labor constrained, leads to a hire/fire cycle with problems similar to those faced by airlines. In Box 4-2 we showed how an attempt by Boeing to rapidly increase production in 1997 cost Boeing a \$2.6B write-off and an 8% drop in their stock price in a single day; (ii) the hire/fire cycle reduces the effectiveness of the learning curve and at least in the Lockheed Tristar case led to increases in per unit production costs reversal (Benkard 2004); (iii) increased risk with regard to the return in the substantial upfront costs in new aircraft development. In their efforts to command greater market share, manufacturers may also take underpriced risks in aircraft options and repurchase agreements offered as incentives to airlines.

5.3.2.5 Leasing Firms

Similarly to airline manufacturers, the leasing companies also have both the incentive and the consolidated position necessary for becoming change agents. As owners of expensive, depreciating assets whose value fluctuates dramatically with the industry cycle and on which operation and efficiency have little if any leverage, leasing firms carry a substantial share of the industry risk (Section 3.4). As an increasing share of the total industry orders go through some form of lease, they are in the position of moderating this ordering pattern. Like the other industries though, leasing firms have to compete in offering better terms to their clients and surge of entrants in booming periods can diminish this type of leverage. In addition, their sophistication on the industry needs is deferred to the clients and a broader view of the system as a whole is usually not pursued.

5.3.2.6 Capital Markets

As we saw in Section 5.2.1, capital markets as constituents are quite diverse. Large banks and lenders are relatively consolidated while the stock-markets have been consolidating their diffuse power. The interests of financial institutions with broad portfolios and long-term hold strategies would be aligned with the combined improvement of all their holdings. While in countries with stakeholder capitalism tradition like Europe and Japan, the ties of financial institutions with the industry are part of the existing model, the full potential of a portfolio system that actively pursues the synergies generated by it is not yet realized.

Capital markets in the form of universal owners, in the Hawley and Williams nomenclature (see Section 5.2.1), have both the incentive and the power to work towards creating more stable and long-term profitable value chains, and this could apply to the CA EoE as all the enterprises involved are publicly traded companies. The practical effect though is currently the opposite. Institutional investor managers are currently rewarded for generating higher return rates than their competitors in the *short*-term. The kind of returns that are achieved in that fashion (usually significantly exceeding market index rates) are not sustainable and therefore implicitly require the existence of asset bubbles with their high albeit temporary returns. In the troughs, as long as the institutional managers do not do worse than their peers, the repercussions for them are limited (not to mention some positive as downcycle actions, like loan renegotiations or mergers, can generate additional fee income). Overall, the current structure of expectations high short-term return provides perverse incentives against long-term sustainable growth and portfolio-wide synergistic optimization.

Impacts of Cyclicity on Capital Markets

While capital markets are inherently volatile, investors receive significant hits when airlines default or airline and aircraft manufacturer stock prices plummet as a result of the cyclicity in their returns. The volatility of economic return of these enterprises pretty much captures the impact borne by capital markets.

5.3.2.7 Labor

Stiglitz's insight (Stiglitz 1985) that because workers "collectively have the largest undiversified stake in the [enterprise]," they along with banks have the incentive to monitor and control enterprise management. Like banks, employees have an interest in the long-term survival of the enterprise but unlike banks they are not impelled to be as risk-averse. In order for labor unions to take such a role, the adversarial relationship between employees and managers would need to be ameliorated and become a mutual realization that their interaction is not a zero-sum game. The pension funds of said employees would also be prime candidates in realizing the synergies alluded to in the capital markets section.

Several enterprises have demonstrated the benefits from active participation of employers in improving workplace conditions and cutting operating costs using Kaizen events and other methods. Prominent examples of such integral companies come from the aviation sector (e.g. Southwest) and manufacturing (e.g. Toyota). In the U.S. airline industry,

employees have attempted to actively engage in the ownership and management of the company in the late 80s and early 90s with relatively poor results (e.g. United, see Petzinger (1995)). Airbus labor unions have similarly obstructed drastic management measures and precipitated a leadership change as members of a stakeholder coalition (recent example... reference). In all cases though, labor unions do not reach out across the value chain and lack the big picture system view necessary for managing a long term system change. Their incentives could make them significant members of a coalition that attempts to bring stability in the boom-bust cycle but they have neither the power, nor the capacity to bring this change single-handedly.

5.3.2.8 Governments

Governments as constituents of the CA EoE are connected, much like capital markets, to all other constituents and therefore have great potential leverage over the system. Furthermore, assuming that stabilizing the boom-bust cycle creates tangible economic benefits and better meets the intangible needs of their citizens; governments have the incentive to facilitate long-term stabilization. Governments can exert control indirectly through regulations and selective subsidies and directly by their control over the infrastructure. Government action that does not directly target any of the other constituents could also have significant impact on the CA EoE (e.g. monetary policies to stabilize macroeconomic cycles and ameliorate recessions or environmental regulations in the form of carbon caps or taxes).

While theoretically governments have incentives and the power to dampen the cycles, their policy making process is highly fragmented and disproportionately responsive to selective interests. On the airline industry side, it could reasonably be argued that it was a government action in the form of deregulation that destabilized the system and deepened the troughs of the cycle. As the benefits of deregulation to the consumer are also quite clear, a reversion to the previously regulated environment is highly unlikely. On the airframe manufacturing side, the governments involved expectedly support, protect, and promote their domestic industry champion. There are plenty of anecdotal examples where international policy and aircraft marketing were tightly coupled (see Box 4-3) as well as formal support as is the case of the recent WTO case (see Section 4.3.2.5).

Impacts of Cyclicity on Governments

We saw that governments carry a significant proportion of the societal costs of cyclicity directly. To use a recent example, the post-9/11 layoffs from airlines and aircraft manufacturers induced federal and state support for retraining and health care coverage for the 30,000 laid-off employees in addition to the \$20B in direct and indirect assistance U.S. airlines received under the Airline Stabilization Act (GAO 2004). Other types of support include subsidies for flag carriers, bankruptcy protections and pension relief. *This support when aimed at the enterprises, rather than directly to the furloughed employees, may perversely exacerbate cyclicity in the long-run as it increases the barriers to exit and retains capacity in the industry.*

5.3.2.9 Comparative Return on Investment

Another view of the constituents of the CA EoE can be based on their relative margins. This view is shown in Figure 5-8. Airlines are shown as *the* most competitive industry while aircraft manufacturers and leasing firms are shown to have greater margins. This is simply indicative and does not track long term performance and year to year changes though.

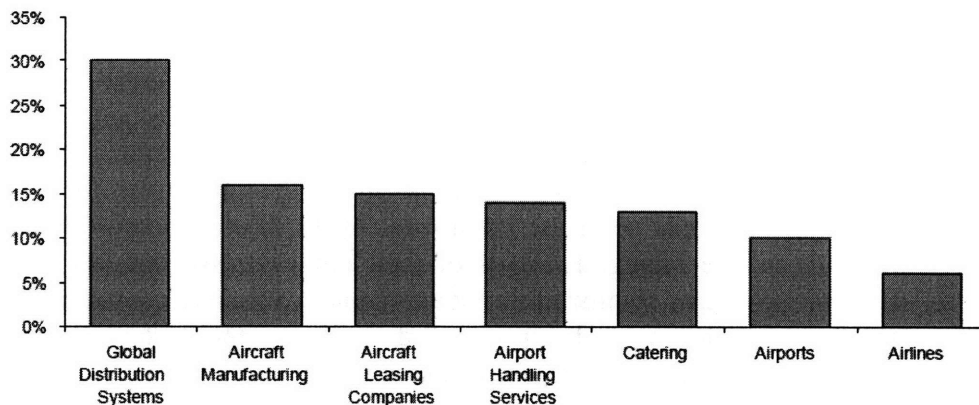


Figure 5-7 Estimated return on capital invested by European aviation industry sector for the 1992-1996 period (source: (Button, Haynes et al. 2002))

Table 5-3 The Constituent Value Functions of the CA EoE

Constituent Enterprise/ Stakeholder	Values	Metrics
Passengers/ Shippers	Availability of air travel	ASK / year
	Affordability of air travel	Average fares
	Level of Service	Frequency, reliability, amenities (load factors as proxy)
Carriers	Economic Return	Economic Value Added (EVA: Op. Profit – Taxes – Cost of Capital) Discounted to NPV
	Stability of Return	Coefficient of variation (CV)
	Downturn time	Average time with negative returns
Airframe Manufacturers	Economic Return	Economic Value Added (EVA: Op. Profit – Taxes – Cost of Capital) Discounted to NPV
	Stability of Aircraft Deliveries	Coefficient of variation (CV)
	Downturn time	Average time with negative returns
Capital Markets	Return on investment	Combination of airlines and airframe manufacturers returns
	Defaults avoidance	Economic losses due to defaults
Governments	Availability of air travel	ASK/year
	Returns of domestic industries	EVA
	Min. subsidies	Amount of assistance in support of airlines and aircraft manufacturers
	Employment stability	Employment numbers

Value Functions of the CA EoE

The type and relative importance of value functions of the constituent enterprises in an EoE can be subjective. In Table 5-3, we present in summary form a choice of value functions and metrics for the different constituents of the CA EoE. As discussed in Section 5.2.1, long-term economic value can be a metric of choice for both the stakeholder and the shareholder view of the firm. In addition to this, we used the stability of economic value as a way to gauge cyclical behavior and as a tie-breaker in the analysis between situations that yield approximately the same total returns.

The content and specific formulations of Table 5-3 are controversial as they embody subjective definitions of value and, more importantly, aggregate the fractious interests present in most enterprises as we discussed in Section 5.2.1.

5.4 Chapter 5 Summary

From the discussion in this section, it is apparent that none of the CA EoE constituents have a strong incentive to retain the status quo with the prevailing cyclical behavior with the potential exception of some capital market stakeholders. On the other hand, there are few constituents with a full view of the value chain and with power to significantly influence its behavior. Private sector constituents with power include the two airframe manufacturers, a duopoly, the similarly concentrated leasing firms, potentially some of the larger airlines after further consolidation, and universal owners in capital markets that have a portfolio extending over the entire CA EoE. Governments and labor unions are also significant constituents as they are necessary but not sufficient in and of themselves to make practical changes.

While these institutions have the potential power to change system behavior and dampen the cyclicity, they do need to do so in some collaborative fashion as the individual incentives within the respective industries and across the value chain are competitively set and favoring short-term results – a behavior for which the capital market constituents had a significant part in promoting.

The CA EoE can be simplistically seen as a large scale ‘prisoner’s dilemma’ game, in which the collaborative outcome provides substantial benefits for all stakeholders but the incentive structures that are in place reward “defection.”

Stiglitz’s (1985) observation about the enterprise represents even better the situation faced by any constituent interesting in changing the CA EoE as it “*is not appropriately modeled as a single-principal/multiple-agent problem, for which the Nash equilibrium is almost invariably inefficient. [All] participants (or classes of participants) pursuing [their] own interests, given the set of controls at [their] disposal, results in resource allocations that are not Pareto efficient. The actions of each group have important consequences for all other groups [].*” He goes on to state that as good management is a public good, in a version of a tragedy of the commons, no small group has the incentive to devote enough resources to push for the right management especially as it would be unlikely to capture the positive spillovers from such action.

In considering the solution he states that the “*problem is to design institutional structures that serve to internalize some of these externalities, that take advantage of those who are in the best position to obtain information and exercise control [], and that can ameliorate [] some of the free-rider problems which are inherent in the maintenance of good management.*”

In this chapter we have established a conceptual framework for enterprise ecosystems. In the next chapter, we will review how enterprises, forming ecosystems like the ones presented here, can create and amplify cyclical behavior.

Chapter 6 Manifestations of Cyclicity in Industries and Supply Chains

“Cycles are not, like tonsils, separable things that might be treated by themselves, but are, like the beat of the heart, of the essence of the organism that displays them.”

J. Schumpeter (1939)

With this chapter we transition from an examination of the CA EoE as a system in Chapters 2-5 to exploring the specific causes of the cyclical behavior we identified in such systems.

Cyclical or periodic behavior of natural systems has accompanied mankind since pre-history. The alternation of day and night, of seasons, of tides, of sowing and harvesting, and even of life and death are all manifestations of natural cycles. Any break in this periodicity like an eclipse or a particularly prolonged drought could wreak havoc to the psychological, social, and economic structures of ancient societies. Social cycles with longer and uneven periods like the rise and fall of empires and civilizations were also identified as soon as historical records were introduced. Yet despite the fact that 100% hindsight was available, foresight was and, unfortunately, remains elusive.

With the development of social sciences and economics and the quantification of socioeconomic interactions that they introduced, it soon became apparent that several measures of economic activity also appeared to follow synchronized cycles. While these cycles involve aggregate economic activity and monetary policy similar patterns were revealed on smaller scales by the study of supply chains. Evidence of similar industry-level cyclical behavior in the commercial aviation world is readily available as we discussed in Chapters 3 and 4.

Like natural cycles, these socioeconomic cycles may have benefits in their ability to force a Darwinian selection process for enterprises and technologies and also, as suggested by (Gross 2007), provide ample infrastructure during the boom periods on which innovative uses of technology can build upon. But they also entail significant economic costs in the form of production inefficiencies and, more importantly, social costs due to pro-cyclical labor policies that entail hire/fire cycles with costs for enterprises as they lose both talent and trust and for the workers themselves that face uncertainty and loss of benefits. These costs are pronounced in the high amplitude oscillations experienced by most enterprises involved in the commercial aviation world.

If the intent of organized society is to ameliorate the effect of unpredictable swings on its more vulnerable members, a similar argument can be made in the context of commercial aviation world. In order to provide effective policies to mitigate negative impacts an understanding of the underlying causes of the phenomenon is necessary. This chapter explores the literature on the business cycle and particularly as it is manifested in specific industries rather than the macroeconomy. In Chapter 7 we review different hypotheses on the causes of cyclical behavior as they apply specifically in the CA EoE while Chapter 8

matches causes and strategies that can potentially counter these effects in the form of plausible scenarios.

Our stated objective is to understand the costly cyclical behaviors that are observed in the aviation world and develop strategies to mitigate their effects. Since, similar cyclical patterns have been observed in many industries and supply chains of capitalist industrial systems and a thriving research literature exists about them. This chapter reviews the literature on business cyclicity on the macroeconomic (business cycles) and microeconomic/supply chain level (bullwhip effect) to introduce the existing theories, terminology, and tools to understand and interpret business cycles.

The Business of Cycles

There is evidence of cyclicity in capitalist economies since their establishment. The traditional definition of the business cycle given by (Burns and Mitchell 1946) characterizes them as: *“a type of fluctuation found in the aggregate activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions [,] recessions, contractions and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic...”*

While the frequency of extreme cycles and their impact has seemingly been moderated, regional economies are still prone to them. Although the cycles are not periodic⁷⁰ they seem to involve similar sequences of events and reactions as indicated by the identified macroeconomic indicators. The economists and practitioners that developed theories on the business cycle were interested in aggregate economic behaviors but they did recognize these as results of seemingly rational actions of agents.

Based on this definition, the business cycle is an aggregate phenomenon and as such we, interested in a specific industry, should only consider it as an exogenous factor. Yet, our interest is deeper than this because the terms used to describe macroeconomic cycles and the models developed to dampen them provide insights for more focused applications. This is especially the case for theories that review the micro foundations of the business cycle.

Early recognition of greater volatility of inventories, prices of durable goods, and business profitability predated the conclusions reached by research on the microeconomic and supply chain side although the specificity of the tools developed by the latter does not have counterpart in macroeconomic theories of the business cycle. We discuss the macroeconomic theories on business cycles in Section 6.1 and the supply chain research on the bullwhip effect in Section 6.2.

⁷⁰ The use of the term “cycle” is controversial because it implies regularity in the period and intensity of the fluctuation which is generally not the case as the inability to accurately predict future cycles shows. Despite this shortcoming, the alternative “economic fluctuations” is not as evoking or recognizable.

6.1 Macroeconomic Business Cycles

The existence of business cycles is widely acknowledged as an economic phenomenon. Economic activity in national, regional, and, more recently, global scale is correlated and tends to synchronize into periods of stronger and weaker growth or contraction. Business cycles, like waves, can be analyzed into periods of **expansion, recession or contraction, and recovery** and they have a peak at the end of the expansion period and a trough at the end of the recession.

The business cycles had been recognized early on in the history of capitalist economies. Characteristically, Lord Overton, a successful English banker, described the phases of a cycle more graphically, and expressing the personal aspect of cycles, as: “**quiescence, improvement, confidence, prosperity, excitement, overtrading, convulsion, pressure, stagnation, [] quiescence.**” He was quoted by Walther Bagehot, chief editor of the Economist, after a crash in the British economy in 1847 with global repercussions (Tvede 2001) (pp. 50).

Schumpeter (1939)⁷¹ categorized business cycles based on their observed period and named after those who first proposed them into:

- Kitchin inventory cycles – (3-5 years)
- Juglar fixed investment cycles – (7-11 years)
- Kuznets infrastructural investment cycles – (15-25 years)
- Kondratiev waves – (45-60 years)

While there is a vast literature on the business cycles as it relates to monetary policy and public investments and their effect on business cycles in this review we focused on those aspects of the cycles that deal with consumption and infrastructure investments and the theories dealing with them.

6.1.1 Manifestations and Causes of Industrial Business Cycles

“The only cause of depression is prosperity.”

Clement Juglar

Keynes: “[] where should a crisis come from?”

Somary⁷²: “From the difference between expectations and reality...”

1927. Quoted by Tvede pg. 108

An early, although quickly discredited, theory of the causes of business cycles had been proposed by Jevons in the late 19th century and came to be known as the sunspot theory. Starting from the assumption that markets systems are inherently stable, Jevons looked for external shocks that would coincide with the observed cycles and indeed he found these in the sunspot cycle; as agriculture productivity would vary based on the intensity

⁷¹ Three years before introducing the creative destruction concept as a force of capitalism.

⁷² Felix Somary. Investment banker in Zurich.

of sunlight this variation would feed and amplify in the economy hence creating the observed cycles (Tvede 2001), (Morgan 1990). While the actual cycle correlation was soon found to be incorrect, the idea that external shocks may be the cause of at least some of the cyclical behavior is still perfectly valid.

Neoclassical “real business cycle theories” suggested that technical (Schumpeterian creative destruction), societal (political events like wars, revolutions, regime changes), and natural (epidemics, climate changing supply of labor or raw materials) shocks could create and propagate cycles by generating external events to which the market economies responded *while remaining in equilibrium*. Lucas (1975) proposed that while markets keep clearing based on **rational** decisions, **imperfect information** about the market and the external shocks lead to **forecast errors** which cumulatively in the economy create the **accelerator effect**, a precursor of the bullwhip effect in the supply chain literature that we discuss in Section 5.2. These shocks are relevant for aviation, as we shall see in Chapter 7, given it can be influenced from weather related events and fuel fluctuations in the short term and from economic and health events in the longer term but other researchers probed what they considered as endogenous instabilities of markets.

Despite the acknowledged importance of external shocks in precipitating business cycles, the real business cycle theories failed to account for a number of endogenous economic mechanisms that had been described as cycle inducing. Tvede (2001) categorizes the endogenous factors of cyclical movements in capital markets into:

- Positive feedback loops (non-linearity)
- Echoes (Durable goods and reinvestment cycles)
- Cascade reactions (network effects and mass psychology events)
- Lags (Time delays inherent in system performance that are not perceived by multiple players), and
- Negative Feedback Loops (Disinhibitors).

In the rest of the section we will highlight the theories that present those endogenous aspects of the business cycles as documented in the literature.

Pigou (1929), cited by Tvede (2001) (pg. 76), like Jevons, noted the importance of external shocks, but he also assigned importance to the **psychological factors** that make errors of optimism and also create subsequent errors of pessimism thus feeding cyclical behavior. He noted that bankruptcies are not very effective in destroying capital, as the capital investments simply changes owners⁷³, but instead instill fear for new investments. Price changes created profits for some and losses for others. As remedies to these effects he advocated for **transparency** and dissemination of market information by regulators as well as **stabilization of prices**.

⁷³ This is true for assets like ships and aircraft as well as manufacturing plants and land. Arguably, the reintroduction of the former in the productive economy is faster.

Delays, the Cobweb Theorem and Commodity Cycles

Aside from psychological factors, the micro foundations of cycles were seeded early with the concept of **imperfect information** and its effects on inventory cycles. Reminiscent of the recent bullwhip supply chain theories, (Metzler 1941) and later (Abramovitz 1950) stressed the impact of the firms' **inability to forecast the cycle** in the generation of procyclical inventory fluctuations.

Metzler's point of inaccurate forecasting makes the assumptions of perfect knowledge in classical economic models hard to justify. This lack of perfect knowledge has repercussions in the actions of multiple agents making simultaneous decisions to enter or exit a market. This phenomenon named **cobweb theorem**⁷⁴ by Kaldor (Ezekiel 1938) was first identified in commodities markets and therefore was also known as the 'hog-cycle.' Farmers and commodity manufacturers, the theorem went, could only perceive the prices in the market but lacking coordination they rushed to the "opportunity" synchronized. As there was a **delay** between them starting the effort, e.g. planting crops, and their selling them, the market ended up flooded and the prices for the previously scarce commodity dropped precipitously.

Shipping and Durable Goods Cycles

Similar cycles though were also identified in non-commodity products. Tinbergen was the first to describe the "**durable goods**" cycle in the shipping industry in 1931. According to (Tvedt 2003), he attributed the cyclicity in the orders to delayed feedback between orders and rates. When freight rates increased orders followed, yet as the delay of construction intervened, freight rates could reach very high levels triggering even more orders for ships. Expectedly,⁷⁵ when the orders materialized they could create a glut and even a depression in cycles.

What complicates the behavior of durable goods compared to the commodity cycles is the need to replace them when they reach their useful life. Most machines produced for the same purpose and at the same period have approximately the same useful life span; therefore a spike of orders should be replicated when the machines reach their useful life in what was named the **reinvestment cycle**.

Continuing research in the shipping industry, Einarsen (1938) observed the **reinvestment cycle** but he also noted that since the useful life of machinery can be extended through repairs capital replacement should be elastic. This would imply the existence of what he called the *secondary reinvestment cycle*. These cycles "*owe their existence to the fact that the replacement of the machinery, which during depression becomes ripe for renewal, will to a great extent be neglected or postponed. During revival and prosperity, there will consequently take place a concentration of replacement.*"

Assuming that manufacturers have adequate capacity to respond and do not smooth their orders, this mechanism can **synchronize** the reinvestment cycle and the macroeconomic

⁷⁴ The name comes from the cobweb-like image if the behavior is mapped on a supply demand graph.

⁷⁵ Similar type of cycle causality is at work in the aviation industry as well, as we see in Chapter 7.

cycle and potentially increase the amplification in the industry cycle magnitude due to resonance between the two cycles. In other words, the need to replace and the need to invest in new capacity could synchronize and their effects add.

Einarsen's work was based on the time series of shipbuilding construction from 1883 to 1932 as shown in Figure 6-1. The peaks in the diagram exhibit a period of about 5 years and in almost every cycle, the replacements in that time series preceded the new investment orders. This could be an artifact of how Einarsen defined replacements – he could not look for equivalence between ship types – but is also reasonable as the least performing ships in the fleet would need to be replaced first by the better performing ones before newer additions are made.

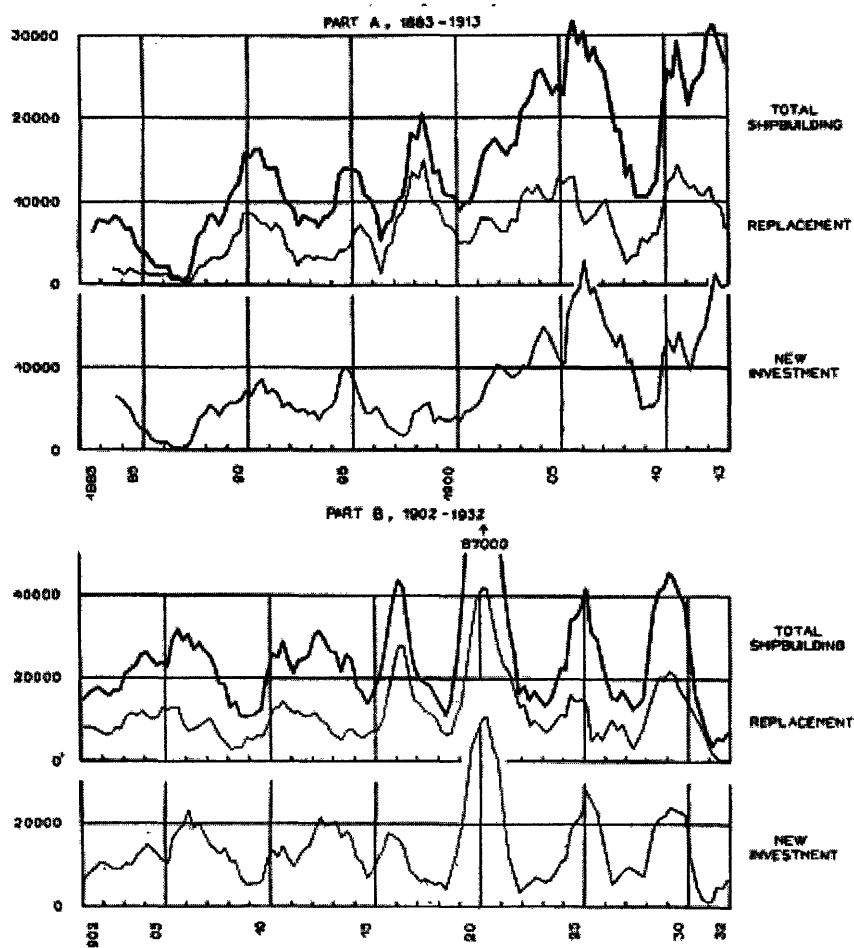


Figure 6-1 Shipbuilding for Norwegian Shipowners, 1883 – 1932 in gross tons (Source: Einarsen 1938)

Another set of interesting observations can be made based on the age distribution of ships when they are sold or replaced as shown in Figure 6-2. There are two fairly clear peaks: one in 20-year time which coincides with the productivity vs. maintenance and technological change trade-off point and another at about 10 years for which Einarsen does not give an explanation. If these were aircraft, the explanation would be the sharp

increase in maintenance costs due to the requirement for complete overhaul. Assuming that no such requirement existed for ships at that time, and given that during prosperity this peak is lost, a plausible hypothesis could be that it reflects the need of ship owners to unload capacity and the newer ships are the only ones that can be sold reasonably as demand contracts.

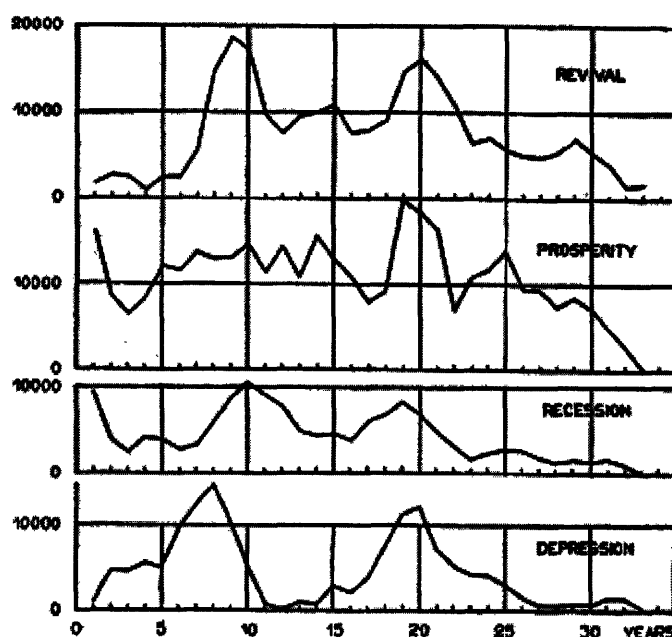


Figure 6-2 Age Distribution of Ships Sold and Replaced between 1884 and 1932 based on the Cycle Phase when the Transaction Occurred. (in tons. Source: Einarsen 1938)

Supporting the view that durable good industries are highly cyclical, Petersen and Strongin (1996) found that durable-goods industries are on average three times more cyclical compared to non-durable goods industries. They used an empirical study of disaggregated industry data to answer the question of why some industries are more cyclical than others. They found that “quasi-fixed” factor inputs, market concentration, and “labor hoarding”⁷⁶ are key determinants of cyclical industry behavior. They also noted that energy intensity is an indicator of cyclical behavior when energy costs fluctuate more than GDP.

Infrastructures, Rational Investment, Stock Market and Mass Psychology

While the reinvestment cycle is a more or less deterministic artifact of the underlying technology that is used as producing capital, there is another factor of production

⁷⁶ Petersen and Strongin notes: “If firms retain workers in periods of low demand, their economic incentive to cut output is lower than for firms or industries that do not hoard labor. Likewise, if firms are reluctant to hire new workers in boom periods, their incentive to increase output is also less than for firms that do not hoard labor. Other things equal, the more labor hoarding an industry engages in, the less cyclical its fluctuations in output should be.” A consequence of that is that their profitability may be sacrificed during the downturns.

investment that is used for acquiring the capital assets. The development of stock markets and public financing made this aspect of the business cycle far less predictable and more prone to effects of mass psychology.

It is at the intersection of capital markets and industries that the effects of business cycles are most heavily felt. As shown in Table 6-1, the level of investment as reflected in the stock prices is quite volatile, procyclical, and a leading indicator of the business cycle. It has been observed that increased financial liquidity and a capital glut that allows for speculative investment with higher potential returns but also more exposed to risk may precede heavy crashes as investors rush to protect their positions. Whether this is a causal relationship, i.e. if stock market rallies actually precipitate the cycles, is controversial. What is certain is that it affects the industry's ability to finance infrastructure expansion. There have been cases where the two were intricately linked as shown in Box 6-1 for railways in the late 19th century but similar scenarios played later in the aviation sectors as well.

Box 6-1 Infrastructure the Stock Market: Railways and the crash of 1873 (Source: Lubben (2004) (pg. 1428))

While financial fraud, mismanagement, and cartelization were not unusual railroad stock prices were booming. Fueled by the bullish performance of railway equities, new companies and incumbents raced to provide railway services. Overcapacity started ensuing in 1868 and onwards as new railway construction soared.

The inevitable price wars allowed even more traffic demand to use the railroad network though at a loss for the providers and their balance sheets.

The inevitable crash landing occurred 1873 and the sparking event was the failure of the investment bank heading up the financing of Northern Pacific Railroad. That precipitated widespread stock market panic and the collapse of the New York Stock Exchange value (in the accompanying figure the event is shown starting in August of 1873 and culminating in November 1873 with the railroad index (_SPRAILD) closely followed by the SP500 (_SPXD)). Eventually, 89 railroads defaulted on their bonds and the effects of that collapse were still felt a decade after.

As a side note, railroads did recover and continued expanding until the geographical limits for expansion were reached just before the turn of the century. The cut rate competition that prevailed and continued mismanagement led to another crash and even greater number of defaults in 1893.

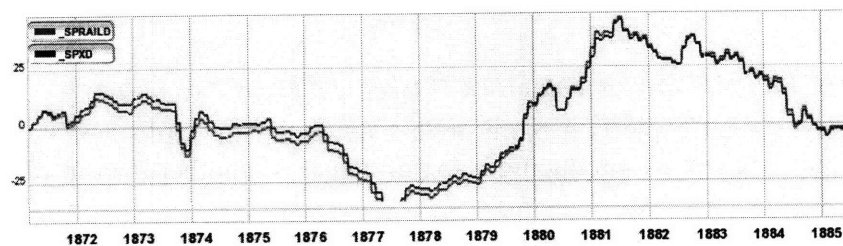


Figure source: www.globalinfdata.com

What this anecdotal evidence brings into question is the relationship between the market valuation of firms (their equity) and their fundamentals (assets). Lucas (1975), as we saw

earlier, suggested a model where investors made rational decisions based on expected returns of a given market and he developed a model of overinvestment based on this assumption, that is the cycle was actually generated by the traders and the financial market as opposed to any change in the real production and valuation of the market. This connection of financial markets and business cycles and more specifically how operating decisions over *output, pricing, inventories, and working capital investment* are influenced by financing decisions is investigated by (Krainer 2003).

Krainer (pg. 6) suggests that “*the higher (or lower) the market valuations investors place in equity shares as a result of a reduction (or increase) in risk aversion, the more (or less) operating risk managers will accept in the implementation of their operating strategies.*” This model explains why, as shown in Table 6-1, stocks are leading indicators of business cycles: changes of the valuation of equity by investors precipitates the cycle in the economy. As a simplification, Krainer distinguishes investors into more risk averse bondholders and less risk-averse stockholders (“buy and hold” investors) but his model does not consider the more aggressive traders. Krainer favors the sharing of firm’s decision between stockholders (operating) and bondholders (financing).

Bernanke and Getler (1989) formalize the intuitive understanding of the reinforcing feedback loop that in “*good times when profits are high and balance sheets are healthy, it is easier for firms to obtain [investor] funds. This stimulates investment and propagates the good times. Conversely, poor financial health in bad times reduces investment and stimulates the decline in output.*” (pg. 27). Jensen and Meckling (1976) provide an additional reinforcing feedback to this cycle by noting that equity holders prefer activities that raise payoffs in good states even at the expense of lowering payoffs at bad states. The two models differ in their perspective of what can start the cycle, as Krainer (2003) (pg. 66) notes, in the Bernanke Getler model a change in the net worth or value of the firms is necessary while in Krainer’s model a change in investors risk-aversion is sufficient. More recently, (Jaimovich and Rebelo 2007), going back to Pigou’s psychological factors develop a model that generates cycles without the need of an external productivity change but just a change in the future expectations of investors that can be rational optimistic or overconfident. In practice, these models can operate side by side reinforcing each other’s effect.

Along the same lines, (Blanchard, Rhee et al. 1993) discuss the case when there is an apparent contradiction between the equity market’s valuation of an investment and the expectations of its managers based on their knowledge of ‘fundamentals’. In discussing prior literature he notes that there are two diametrically opposing theoretical recommendations: ignoring the market (Bosworth 1975), or following the market (Fischer and Merton 1984). Their empirical analysis indicated that in practice market valuation did influence operating decisions, given fundamentals, but on a limited basis.

Going from external finance to internal finance, the firm’s cheapest access to funds, Carpenter, Fazzari et al. (1994) found that fluctuations of internal financing due to changes in profitability are quickly reflected on their inventory holdings that is being correspondingly depleted. By extrapolation, they argue that for firms where inventory is

not a primary factor, airlines and airframe manufacturers for our case fit in that category, the internal financing fluctuations would be expected to be reflected on capital investment, that would be made more cyclical.

The Random Models

Examining the behavior of prices or other indicators during the business cycle, some researchers instead of examining causality focused on the statistical properties of the those indicators. Bachelier first postulated that the observed behavior could be approximated as a random walk based on a Gaussian distribution (Bachelier, Davis et al. 2006). As Tvedt (2003) observes after affirming the random walk property in freight rates in the dry bulk shipping markets, the random walk means high prices are not necessarily followed by lower prices and vice versa. In other words it confirms the traditional market models in which high prices stimulate demand and low prices increase scrapping.

While mathematically elegant, this model failed to allow for the frequency of extreme fluctuations that was actually observed. Mandelbrot suggested that different probability functions with “fatter tails” would be more accurate (Mandelbrot and Hudson 2004). He also noted fractal properties, primarily self-similarity, in the time-series of economic indicators at different scales. In other words the time series of stock fluctuations within a day could not be distinguished by the time series of stock fluctuations within a year based on the properties of their plots.

In the next section we review some of the economic indicators that are more referenced in the business cycle literature.

6.1.2 Measures and Indicators of the Business Cycle

Business cycles reflect the aggregate state of the economy; therefore the measures used to define them are also aggregate. Gross Domestic Product (GDP) is the primary indicator but personal income, employment, industrial production, and industrial and wholesale-retail sales are also considered in identifying the U.S. economic cycle according to National Bureau for Economic Research (NBER, Hall et al. 2003).

For forecasting and modeling purposes, economists categorize the macroeconomic variables with regard to how synchronized their behavior is with the cycle into:

- *Procyclical* for variables that have approximately similar phase to that of the cycle
- *Countercyclical* for variables that oscillate against the cycle, and
- *Acyclical* for variables that do not oscillate.

Similarly, they were categorized based on their phase into:

- *Leading*,
- *Coincident*, and
- *Lagging*

Identifying the indicators of business cycle, especially the leading ones, has been the objective for a number of researchers. While there is consensus on most of the primary variables, observation of change in one leading indicator does not provide sufficient

proof that a cycle change is under way. Economists rely on a number of these in order to forecast or identify recessions ex post facto. A partial list of primary indicators is given in Table 6-1 which summarizes the findings from several sources that based the direction and phase of the indicators on historical datasets derived from observations of the U.S. and European economies.

Table 6-1 Classification of Macroeconomic Variables (Sources: (Roubini 2003), (Forni, Hallin et al. 2001), (Zink 1993), (Ralf 2000))

Variable	Direction	Phase
<i>Industrial production</i>	Procyclical	Coincident
<i>Corporate profits</i>	Procyclical (volatile)	Coincident
<i>Orders</i>	Procyclical	Leading
<i>Mark-ups and prices</i>	Countercyclical	
<i>Consumption</i>	Procyclical	
<i>Investment and stocks</i>	Procyclical (volatile)	Leading*
<i>Capacity utilization</i>	Procyclical	Leading
<i>Employment</i>	Procyclical	Coincident, Lagging**
<i>Labor productivity</i>	Procyclical	Leading
<i>Unemployment rate</i>	Countercyclical	
<i>Inflation rate</i>	Procyclical	Lagging
<i>Short-term nominal interest rate</i>	Procyclical	Lagging

* Stock market performance can provide false signals⁷⁷

** Employment found as lagging by Forni et al. (2001)

Forni et al. (2001) make similar observations from EU datasets but, expectedly due to the more rigid EU labor laws, find that employment is generally a lagging rather than a coincident indicator.

Figure 6-3 reproduces three of the graphs used by Roubini (industrial production, corporate profits, and employment) that exhibit the relative sensitivity of the corporate profitability compared to the other variables. This sensitivity is similar to the one exhibited in the commercial aviation industry as shown in Ch. 3.

While the indicators can be useful for forecasting the business cycle, their explanatory power is limited as they can just as well be reactive measures taken by individuals (investment), firms (orders, employment), and governments (interest rates) to dampen the effects of the cycle as perceived by each stakeholder.

The macroeconomic cycles aggregate the behavior of individual firms. As we saw, Metzler and Abramovitz, among others, had identified the importance of inventories for the higher frequency business cycles.

⁷⁷ Stock market is considered as reflecting the best knowledge of market conditions and therefore theoretically investors should be able to anticipate recessions. Yet, as Roubini cautions, "the stock market has predicted **twelve** of the last **eight** recessions"!

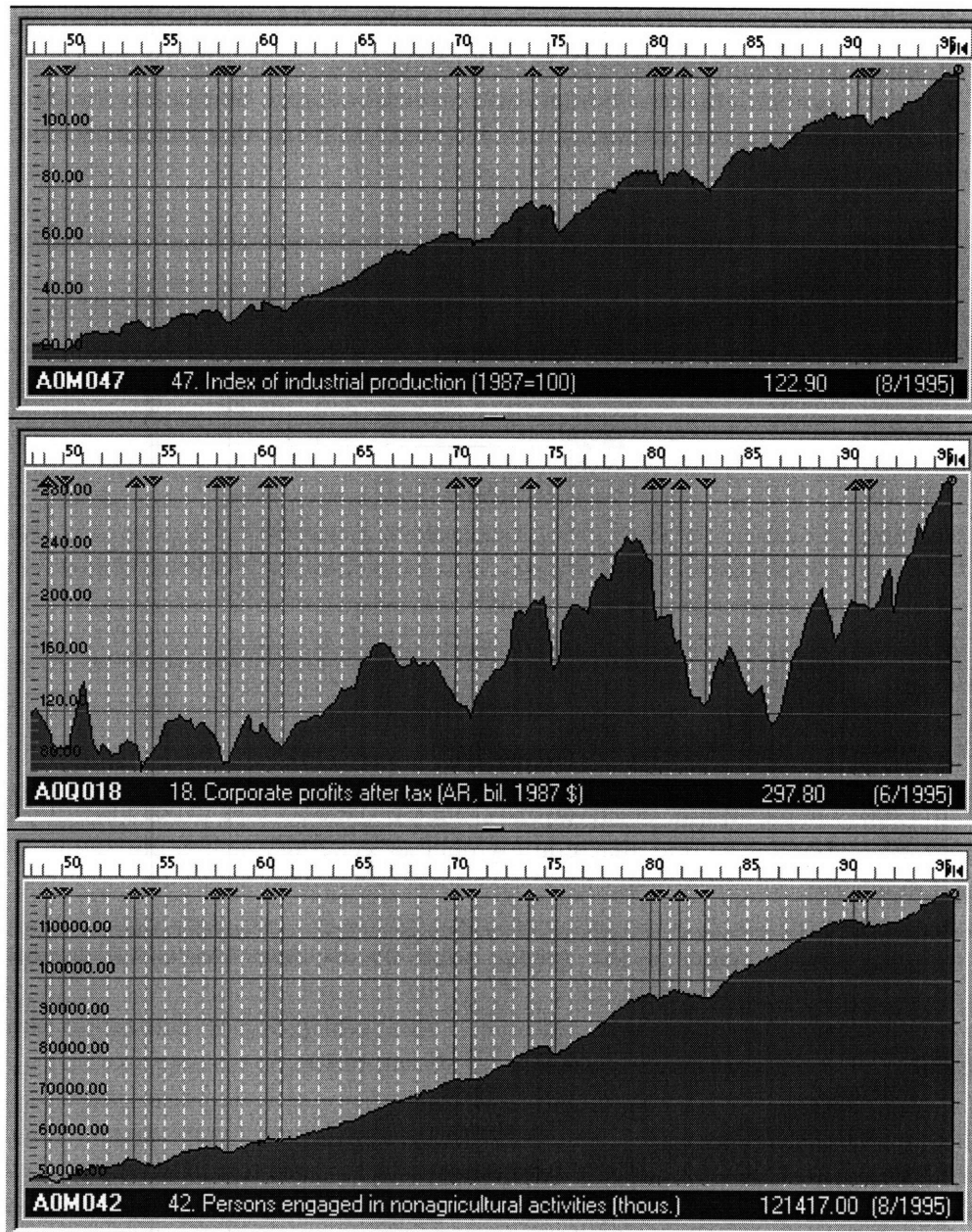


Figure 6-3 Industrial production, corporate profits, and employment indices for the U.S. from 1950 to 1995. (Source: Roubini 2001)

(Note: Up arrow indicates peak and down arrow trough of business cycle)

More recent, business-oriented literature using operations research homed in independently on what practitioners called the bullwhip effect and developed models to help managers avoid its repercussions. The bullwhip cycles can have even shorter periods although the described mechanisms for their occurrence may sound similar to the inventory, or infrastructure cycles as discussed previously. In fact the bullwhip effect can just as well be an inventory cycle as industries evolved to produce at faster pace and the clockspeed of production development shortened. Another point of connection between the cycles is the potential of the macroeconomic cycles to create the changes in demand growth rate that can spawn bullwhip effects in multiple industries.

6.2 Supply Chain specific cycles and the “bullwhip effect”

The stylized narrative of Box 6-2 presents the basic workings of what was named by industrial logistic experts who first witnessed it “the bullwhip effect.” It was later defined as *the amplification of order variation moving upstream in the supply chain*. (Forrester 1961) initially pointed to this phenomenon without actually naming it and research has been actively conducted to analyze, explain, mitigate, or even deny it ever since.

Box 6-2 Stylized Description of a Bullwhip Cycle

An upward trend of the macroeconomic cycle creates a robust demand growth for product X. The retailers of product X did not anticipate that growth of demand and being in a competitive industry their ability to manage demand by increasing prices is limited. They are concerned that their competitors will have the ability to capture the spill over demand and therefore gain a foothold in the opportunities presented by this market surge.

Their remaining option is for every competitor to increase safety inventories and order rates. Yet the manufacturers for product X and their suppliers did not anticipate this surge in demand either and their spare production capacity is not sufficient to cover it. If their monopoly power is also constrained and their forecasters advise them that the surge will continue apace then their viable option is similar to that of their downstream counterparts; increase capacity. For them this is a longer term investment, as factories need to be built and manned and in the meantime orders keep pouring in.

Some of orders are ‘phantom’ placed in multiples by exasperated retailers vying to see which manufacturer can clear their backlog first. As all these processes rely on forecasting, overshooting in one or more echelons is almost a certainty and suddenly supply can exceed demand or the demand for the product starts trending downward, following the exogenous macroeconomic cycle. Suddenly inventories lose their value as retailers slash their prices to get rid of them and cancel their orders while the extra capacities built upstream become redundant and underutilized. That is until the baseline demand growth rate catches up and supply shortages make the cycle start over.⁷⁸

Industries where bullwhip effect behavior has been reported are diverse based on the examples in the literature. Lee, Padmanabhan et al. (1997) based on their work with Procter & Gamble report it in a three echelon supply chain of **baby diapers**, which surprisingly is a product with a stable base demand. In that case it involved retailers, the manufacturer, and its suppliers as distinct firms. Hammond (1994) describes it in the **pasta** industry. Lee, Padmanabhan et al. (1997) also report the bullwhip effect in the electronics industry for **printers**. In that case the supply chain was also multi-echelon (retailers, wholesaler, manufacturer, parts manufacturer) but the bullwhip effect was existent even at the last two sites that belonged in the same firm. Svensson (2003) reports that the seeds of the effect can be found even within a single echelon as the levels of inbound inventories are found to be higher than those outbound inventories within a site.

While the examples cited above are firm specific, the bullwhip effect has been identified on the industry level as well. (Blanchard 1983) reported higher variance in production

⁷⁸ The period of the cycle described here can be a few years but the same patterns can apply for shorter period variations but with different mechanisms dominating as we see later in the section.

than in sales in the **automotive industry**. (Anderson, Fine et al. 2000) report evidence that point to the bullwhip in the **machine tool industry** and (Terwiesch, Ren et al. 2005) in the **electronics industry** (order volatility was found higher for semiconductors than for personal computers). In fact, on an industry level the bullwhip effect had been observed and described by classical economists (Tvede 2003) (pg 155) and dubbed the “*acceleration principle*” since the beginning of the 20th century (Clark 1917). They observed that stabilization of growth in one industry could create a shock in the supplier industries and (Samuelson 1939) conducted a sensitivity analysis using a simple model economy to identify the relationship between the parameters that led to four possible outcomes: stability, dampened cycles, accelerating cycles, and extreme growth.

However, Cachon, Randall et al. (2005) conducted an aggregate industry study and report that they did not find the bullwhip amplification signature universally on aggregate industry level production and sales data. They conclude that a majority of industries *do* production smooth and therefore the bullwhip effect is not as prevalent as originally thought. Some drawbacks of their methodology though make their results far from conclusive (firstly they were able to compare the variance of demand and production on individual echelons only and as a result the multi echelon view critical for observing the bullwhip effect is missing and secondly the data aggregate behavior of all firms and of all products in an industry which by averaging may hide areas where the bullwhip is occurring). The aircraft manufacturing industry is included in the Transportation Equipment North American Industrial Classification System (NAICS) group which is found to production smooth⁷⁹.

6.2.1 Costs of the Bullwhip Effect

“The bullwhip effect has been viewed as one of the forces that paralyze supply chains.”
(Lee, Padmanabhan et al. 2004)

The costs of the bullwhip effect stem from the inefficiencies generated by sub-optimization. In fact, after the system delays and feedbacks run their course, the result may be actually harmful to the interests of both the acting party and the supply chain as a whole. One of the most dramatic examples of the effects of the bullwhip effect is the write-off of \$2.1B inventory by Cisco in 2001. Overoptimistic forecasting by Cisco and shortage gaming by its customers⁸⁰ who placed multiple orders conspired to create that huge almost catastrophic outcome for the company (Lee et al. 2004).

Inventory write-offs are extreme manifestations of the bullwhip effect inefficiencies. Less visible inefficiencies but in aggregate more costly due to their pervasiveness are identified by Hugos (2003) (Ch. 4) to exist into the following areas:

- **Manufacturing:** the manufacturing side copes with the large swings in demand by maintaining reserve capacity that is underutilized for periods of time

⁷⁹ The average ratio of variance of production over variance of demand is found to be 0.57 for the years 1993 to 2004. (Cachon et. al. 2005 Table 1).

⁸⁰ See next section for cause explanations.

- **Inventory:** Inventory stocks at all points of the supply chain are kept higher than optimal as insurance against the variability. In extreme cases write-offs may be required.
- **Transportation:** Overcapacity in the transportation side of logistics operations to cope with the excesses.
- **Labor:** High demand periods may require expensive overtime while idle time or even lay-offs may be required during troughs.
- **Sales:** Sales can be lost at the beginning of the bullwhip cycle.

The actual relative costs of these inefficiencies are hard to quantify even having access to proprietary company data. Sancar (2003) using modeling, estimated the benefits from addressing the bullwhip effect inefficiencies caused by seasonality in production and forecasting error to range between 15 to 30 percent of the supply chain profitability but did not define the beneficiary.

6.2.2 Identified Causes of the Bullwhip Effect

Having strong empirical evidence on each existence researchers focused on the causes of the bullwhip effect and ways to mitigate it given the inefficiencies it caused in the affected supply chains. Initial perceptions of the bullwhip effect attributed its roots to exogenous shocks but later research strongly suggested that it is an endogenous phenomenon.

Towill (1996) characterizes the bullwhip effect as highly undesirable and gives as a rule of thumb an amplification ratio of 2:1 upstream the supply chain and attributes it to overordering by each echelon of the supply chain as guard against uncertainties in their market and supply chain (see Fig. 6-4).

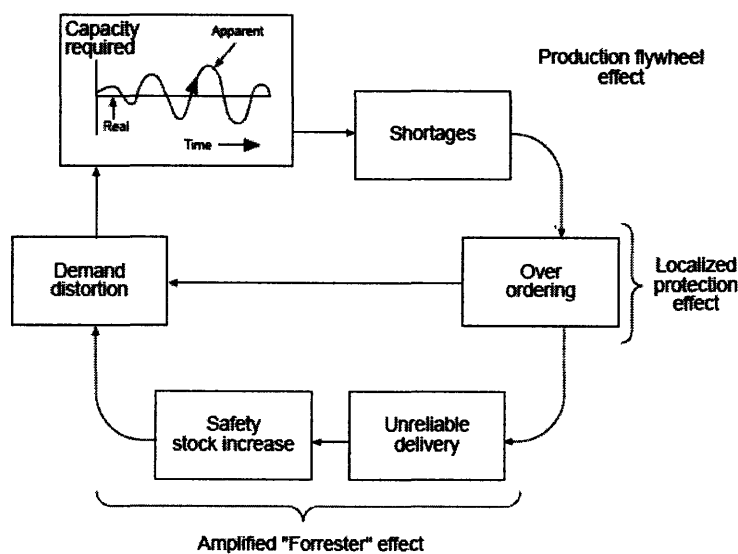


Figure 6-4 The "Forrester Flywheel Effect" (Source: Towill (1996))

Croson, Donohue et al. (2004) recognize two categories of causes for the bullwhip effect: *operational* and *behavioral*.

On the *operational* side, Lee et al. (1997) in their seminal paper identified four primary causes for the bullwhip effect:

1. Demand forecast updating (Demand signal processing)

Supply chain managers base their forecasts on historical patterns of the orders they received and adjust their upstream orders to maintain adequate safety stock and satisfy the forecasted demand. The longer the lead times the greater the safety stock and the variation in the output orders. As this function is repeated in multi-echelon supply chains the amplification in the variation becomes significant.

2. Order Batching

While retailers receive a constant stream of orders usually with small variability, the cost of processing orders creates incentives for batching orders over longer periods. Order batching reduces the visible costs to both parties and allows for more cost-efficient shipping (truck-load and less-than-truck load rates are significantly different. On the negative side though, it requires significant inventory accumulation and accentuates the bullwhip effect since the receiving supplier sees an erratic series of orders that often coincide with orders from the rest of its customers.

3. Price Variations

Often suppliers may try to promote their products by offering discounts that induce their customers into forward-buying, i.e. before the demand for the product materializes. While these types of promotions may help some supply chains by evening out their seasonal demand or by increasing the penetration of products that rely on network effects, it may wreak havoc to others when not implemented correctly. Inventories can surge and the market forecasts can be distorted. If shareholders are not informed properly changes in the realized versus forecasted sales can also reduce the value of the stock.

4. Rationing and shortage gaming

When supply of a product is constrained compared to demand, manufacturers will ration their product. A common rationing scheme involves allocating the existing supply proportionally to the orders, i.e. if supply is only 75 percent then each customer will receive 75 percent of their placed orders. In such cases, the customers may try to game the order system by artificially increasing their orders beyond their forecasts. This way, the manufacturers receive a false signal of demand and when they eventually adjust their supply to order cancellations pour in.

Simchi-Levi, Kaminsky et al. (2003) (pg. 104) added lead time to the list as for longer lead times, even a small change in variability of the demand impacts the calculations of safety stocks and order levels.

The *behavioral* causes of the bullwhip effect were first investigated experimentally by Sterman (1989) with the introduction of the beer game. Croson and Donohue (2006) replicated the beer game experiments but removed all the identified operational causes of the bullwhip effect except lead time and still found significant amplification of the order variance for about half the teams that participated in their experiments.

Anderson, Fine et al. (2000) proposed that the amplification of cyclical volatility faced by tool manufacturers can be attributed primarily to the investment accelerator. It should be noted that in their system dynamics model they excluded the “irrational” supply chain discounting discussed by Sterman above and also used a single supply chain with no competitors.⁸¹

The bounded rationality of the participants gives them insufficient intuition of the prevailing feedback loops and time delays of their actions. The, so called, supply line **underweighting** (supply chain discounting) effect, i.e. the inclination of decision makers to place orders based on current inventory and demand without appropriately accounting for orders in transit, is the more prominently identified behavioral cause. As Croson et al. (2004) note this choice can be a result of ‘rational’ behavior in anticipation of non-optimal behavior from the other participants in the supply chain – what is known as **coordination risk**. The latter may also be implicated in the shortage gaming behavior discussed previously.

6.2.3 Measures of the Bullwhip effect and Recommended Solutions

The bullwhip effect consists of an amplification of the volatility of downstream demand when it translates to upstream orders. Hence a reduction in volatility is one measure for identifying a successful implementation of a countercyclical strategy. This is a rather indirect performance measure as it is not directly related to the performance of the enterprise. Beamon (1998) in her literature survey summarized the performance measures used in supply chain analyses in the following:

- Cost minimization,
- Sales maximization,
- Profit maximization
- Inventory investment minimization,
- Return of investment (ROI) maximization
- Product demand variance minimization
- Stockout probability minimization
- System capacity maximization

Having seen the relevant performance measures, we move back to connecting the causes of the bullwhip effect and corresponding strategies. The discussion in Section 6.2.4 indicates that there is a strong interdependency among the echelons of the supply chain. As Swaminathan, Smith et al. (1998) recognize, “*performance of any entity in a supply chain depends on the performance of others and their willingness and ability to coordinate activities within the supply chain.*” Therefore cooperative solutions dominate those suggested in the literature.

The solutions proposed by researchers ranged across a wide spectrum and included among others measures to:

- increase transparency,

⁸¹ These assumptions differ substantially from the assumptions we used in the system dynamics model that we developed for the CA EoE as described in Ch. 9.

- reduce lead times,
- integrate supply chain echelons,
- refine and automate ordering practices,
- introduce price stability,
- improve forecasting.

Some of those measures were adopted and tested in practice while others that had been in use by few pioneering firms were widely disseminated.

Central inventory control had been found to be better than site specific inventory control by (Clark and Scarf 1960). Three practices allowing for differing degrees of integration flourished in response: distribution of **point-of-sale** (POS) data across the supply chain, **vendor managed inventory** (VMI), and **direct-to-consumer** marketing (Dell and Apple are good examples). **Strategic partnerships**, by increasing the level of trust in the supply chain, may make the adoption of the measures discussed easier for companies.

Addressing the long lead times and the costs of inventories, **just-in-time** (JIT) manufacturing as pioneered by Toyota became an industry norm. This was enabled by **logistics innovations** that allowed shipment consolidation and LTL shipping at reasonable rates.

More importantly, Womack and Jones (1996) (Ch. 3 & 4) emphasize that enterprise innovations that foster **lean production and pull principles** in supply chains can be instrumental in gaining the most out of JIT applications. The difference is between JIT-supply that simply transfers the need for inventory upstream and JIT-production that allows for real single batch, on-demand production in an economic fashion. In some cases, inventories may continue to provide the safety cushion against unexpected supply chain disruptions Sheffi (2005) without jeopardizing the benefits of JIT.

In dealing with rationing scheming and order gaming the proposed solutions are geared towards making the retailers to commit to their forecasts by making it **harder to cancel orders** or return products. In a competitive environment this may be difficult to institutionalize if competitors can provide this 'service' and use it as a competitive advantage to gain market share.

Order batching behaviors can be abated by cheaper LTL services as mentioned above, but also if the transaction costs of orders can be reduced. Electronic systems for ordering like business-to-business network solutions enabled by electronic data interchange (**EDI**) based standards. Many of these solutions come bundled with **automated ordering systems** that further reduce the transaction costs of ordering and alleviate some of the behavioral causes of the bullwhip effect if properly calibrated with forecasting and ordering algorithms like those proposed by (Dejonckheere, Disney et al. 2003) and the forecast control algorithms that (Ingalls, Foote et al. 2005) recommend as a way to overcome the assertion by Dejonckheere et al. that order-up-to policies will always result to a bullwhip amplification.

Stabilizing demand can happen by offering stable pricing on the retail level or what many retailers call **value-pricing** or “everyday low prices” that avoids the surges in demand by offers and promotions.

6.3 Intersecting and Overlapping Cycles

Womack and Jones (1996) (pg. 88) suggest that stabilizing inventories on an individual firm level with just-in-time production and pull operations can have a “*damping effect on the traditional business cycle.*” They claim that if inventory buildup can be moderated by pull production then the optimistic overproduction that fuels the inventory cycle will be ameliorated. Although they probably refer to the Kitchin cycle they do not discuss what impact that would have to the longer period cycles.

As we saw, Cachon et al. (2005) showed that the aggregate volatility data do not support such an assertion and (Zarnowitz 1999) concurs with his observation that : “*business inventory investment in constant dollars was about as volatile and as cyclical in the 1990s as it had been in the past.*” Womack and Jones (1996) preempt this argument pointing that the critical mass of businesses that have adopted JIT-production as opposed to JIT-supply is not there and therefore visible changes on aggregate indicators are not to be expected.

This means in looking for cyclical behavior in the aviation environment we need to look both on the aggregate as well as on the individual firm level.

Why some industries are apparently more prone to cycles than others is a worthwhile question. The railroad industry in the U.S. exhibited the very strong boom-bust cycles that precipitated a financial market crash as we saw in Box 6-1 but its more recent behavior is far more benign. The airline industry itself had been less cyclical during the pre-deregulation period as we saw in Ch. 3. The sea shipping industry has been consistently cyclical with no signs of easing out since the 19th century as we saw with Einarsen’s and Timbergen’s work.

6.4 Chapter Summary

In scanning the literature on business cycles that covered both economic and supply chain operations research, we identified a series of factors that were thought to be contributing to their creation, propagation. Corresponding to the factors there are broad policies that have been proposed to address them. We summarize and distill them in the list below. While not all characteristics are necessary and neither is sufficient for a supply chain to exhibit the strong cyclicity it is a useful reference.

Triggers. These are factors exogenous to the industry or industries considered and they cannot be directly impacted from within the industry.

- *Macroeconomic cycle.* the effect of the larger economic cycle spilling over to specific industries

- *Final demand and Input variability.* If the cost and availability of critical inputs to the industry considered (fuel, raw materials, etc.) is volatile chances are that the profitability of the industry will be subject to cyclical pressures.

Psychological Factors. Influences caused by the human characteristics of the decision makers in a supply chain.

- *Bounded rationality.* The inability of the human brain to meaningfully process all available information even if complete information was available.
- *Supply chain discounting.* Human subjects were shown to ‘forget’ or underweight the orders that are placed in backlog even in quite simple supply chain settings (beer game).
- *Investment exuberance and strategic optimism.* Related to availability of financing and new entrants. During market upswings, managers and participants tend to extrapolate positive trends expecting them to last into the future and discounting previous recession experiences.

Industry Structure. These are endogenous characteristics of the supply chain that promote cyclical volatility or bullwhip volatility.

- *Imperfect financing and capital market volatility.* The ability, or lack thereof, to obtain financial means for investment is subject to the whims of investors whose appetites for risk and perceptions of acceptable return change with the markets. As a result, firms may try to expand more than optimal when funding is available during an expansion or peak.
- *Investment irreversibility and intertemporal substitution.* large capital investments can be deferred into the future (causing reinvestment cycles) and conversely when they are made they are relatively irreversible and commit the enterprise into using them.
- *Underutilized capacity and labor ‘hoarding’.* Similar to investment irreversibility, the difficulty in training new employees (and labor regulations) make existing capacity inflexible and can force the firms to produce more than optimal.
- *Inventories.* Existence of inventories in the supply chains is an indicator that replenishment ordering strategies would more likely than not increase volatility.
- *Long lead times.* When delivery times are stretched the effects of psychological factors (discussed above) are pronounced.
- *Technological change.* It includes the Schumpeterian idea of creative destruction but can be extended to more benign forms of product improvements. Making the previous technology obsolete can trigger a wave of demand that will saturate some time in the future until the next technologic breakthrough appears.
- *Low barriers to entry, high barriers to exit.* Overly competitive industries generated by low barriers to entry but higher barriers to exit are expected to have low profit margins.

Supply chain characteristics. Imprecise forecasting and planning due to

- lack of transparency of downstream demand
- Order batching
- Order gaming due to constrained supply
- Price fluctuations (promotions, bulk discounts)
- Strong seasonality or network effects

- Multiple supply chain echelons

In Chapter 7, we look at the CA EoE cyclicalities more specifically to identify its potential causes based on the generic causes identified here.

Chapter 7 Cyclicity: Causes and Cures. Cyclical Scenarios for Commercial Aviation and Symbiotic strategies

“[A] review of the last twelve [sea shipping] cycles demonstrates that the same explanations of cyclical peaks and troughs appear again and again. Economic conditions, the ‘business cycle’, trade growth and the ordering and scrapping of ships are the fundamental variables which can be analyzed, modeled, and extrapolated”

(Stopford 1997) (pg. 62)

Chapter 6 scanned the literature on business cycles from an economic and supply chain perspective. Chapters 3 and 4 (Sections 3.5 and 4.4 respectively) discussed how cyclicity is manifested in the CA EoE. In this Chapter, we combine the views and understanding of cyclicity gained from Chapter 6 with the specific characteristics of the CA EoE to produce plausible narratives that explain the cyclicity in the related industries and their interaction (Section 7.1) and then distill the industry specific causes in Section 7.2. Finally, in Sections 7.3 and 7.4 we generate strategies that correspond to these causes. We will use these strategies to develop and test strategic alternatives via modeling in Ch. 10.

The multifaceted evidence of cyclical behavior in the commercial aviation EoE, which as we have shown in Chapter 7 affects the entire value chain and carries significant social costs, can be caused by an overlapping set of drivers. In order to achieve our goal of elaborating countercyclical strategies in the CA EoE, we need to answer the following questions:

- a. Is the cycle amplified and delayed as the bullwhip effect would have us expect?
- b. Do individual firms fare differently in different parts of the cycle (the Piepenbrock hypothesis) and can this behavior alter the cycle as whole?
- c. What are possible causal relationships that impact how the cycle wave is transmitted upstream the supply chain and what is their relative impact?
- d. What are potential strategies to for dampening that transmission? How can they be investigated?

The next section describes, in a narrative form, the plausible causal relationships that trigger cycles in the industry drawing from the narrative representations. Researchers that focused on modeling the commercial aviation business cycles using system dynamics appear to also have a consensus on a number of factors that apply to the industry which we summarize in Chapter 8.

7.1 A Short History of Waves: Pre- and Post- Deregulation Interactions in the Commercial Aviation

This narrative is based on the U.S. deregulation experience (post-1978) but similar behaviors to the ones we describe have been prevalent to airline market liberalization in Europe (mid-1990s) and Asia (ongoing).

7.1.1 Ripples: Pre-deregulation status-quo

Passenger travel is growing steadily but slowly. No new airlines have commenced long-range operations for several years due to regulatory barriers and the few newcomers are limited to regional markets. The incumbent carriers have divided their primary markets by being assigned to them in consultation with the Civil Aviation Board (CAB) and they coexist in a relatively stable semi-collusive equilibrium. Given that fare prices are capped and adjust based on a cost-plus basis, unit costs have been allowed to creep up and the primary competitive advantage (where there are competing routes) is considered to be differentiation in service. Employees are given generous benefits especially for their pension plans. While in the U.S. airlines were privately owned even before deregulation, in the smaller European and Asian markets, flag-carriers were government-owned but their ability to pass their costs on to consumers was preserved via the government sanctioned monopoly.

Along the lines of providing high level of service, point-to-point connections become the network structure of choice and widebody aircraft are used for most flights longer than 2000 miles. While relatively inefficient, the service levels provided to passengers are very high as this is the only means of competition available given the caps on fares

Causes of cyclicality under the status-quo

This relatively stable situation has still been subject to smaller cycles caused by:

- changes in demand growth rates,
- increases in operating costs due to fuel surges,
- occasional intensification of the competition among incumbents in their attempt to grow market share, and
- introduction of disruptive technologies like the jet engine and the resulting premature fleet retirements and consequent Einarsen reinvestment cycles.

Stakeholder Status

Overall, the system was able to reach equilibrium quickly and the stakeholders (carriers and airframe manufacturers) would prosper with profit margins comparable to other industries.

The customers were satisfied with the service and the sense of privilege from flying but affordability was not part of their expectations and consequently the extent of personal travel was limited even for the relatively affluent society. The business model of the dominant airlines revolved around the business and first class travelers and the load factors were expected to hover around 60% on average. The reliance on travel agents and the difficulty of monitoring and adjusting prices due to the limitations in technology made demand management hard.

On the supply side, the relationship with airframe and engine manufacturers is one in which the big airlines have significant leverage. Their overall healthy balance sheets allow them in certain instances to support the heavy upfront costs of aircraft development by early commitments and generous front payments. This is particularly the case for

ground-breaking aircraft that were made to fit to the dominant airlines' business models (see aircraft vignettes in Sections 4.2.3 and 4.2.4).

7.1.2 The Deregulation Wave

The period of relative stability described in the previous section reached its closure for the US market when fuel price surges accompanied by global and regional recession pushed tickets prices to being even less affordable. At the same time, the liberalization of traditionally regulated market was gaining traction in theory and practice. In that setting, constraints on airline launching, market assignment by the CAB, and price capping are abandoned. While this regulatory change does not immediately raise all significant barriers to entry, access to infrastructure like airport gates and slots being a prominent one, it allows for the gradual increase in the intensity of the competition and the reluctant entrance of nascent airlines that brought diversified business models.

As funding an airline is expensive, new airline entrants are fueled by an increase in economic output. This has the direct effect of raising the demand for air travel and the indirect effect of increasing the availability of investment capital and willing investors. In addition, airline entrants were helped by the emergence of aircraft leasing as a viable way to obtain and operate new aircraft.

The newcomers

In the view of the potential entrants, their ability to start without the obligations of the legacy carriers provided an advantage on their unit costs and hence the prices they could offer but their primary selling point was the difference in business models. In some cases, the competition was not considered to be other airlines but the *automobile* (a more detailed discussion of the low cost carries (LCCs) business model see Section 3.3.1). The targeted customer base expanded significantly.

The managers and investors of the newcomers and incumbents could have faced a short-term payoff matrix where their lower unit costs would give them an advantage over the incumbents in any scenario and therefore the incumbents feeling that they are not threatened enough they would accommodate the entry. For a visualization using game theory, we present the above in the short-term payoff matrix in Fig. 7-1 where the outcome is depicted using token representative payoffs. The first number in each cell is the expected payoff for the incumbent and the second number the expected payoff of the new entrant.

Similarly for the expected long-term payoff matrix, the Nash equilibrium is at an area where both competitors accommodate and a sort of reversion to the pre-deregulation status ensues which may be sporadically threatened by price wars but quickly reaches equilibrium. These mental attitudes to the results of entry are shown in the payoff matrices in Figure 7-1.

Short-term Payoff Matrix (expected)

Newcomer	Incumbent	
	Compete	Accommodate
Enter	-1, -2	1, 2
Refrain	0, 1	0, 3

Long-term Payoff Matrix (expected)

Newcomer	Incumbent	
	Compete	Accommodate
Compete	-2, -3	1, -2
Accommodate	-1, 1	4, 2

Short-term Payoff Matrix (post entry)

Newcomer	Incumbent	
	Compete	Accommodate
Compete	-1, -2	-2, 3
Accommodate	2, -2	1, 0

Figure 7-1 Anticipated and post-entry payoff-matrices for incumbent and new-entrant airlines (illustrative payoffs)

What the above analysis does not take into account is the uncoordinated simultaneous decision making of several investors eyeing the same market in a textbook application of the cobweb theorem (see Ch. 6). The simultaneous investment, aided by investors ready to supply the industry with capital, creates very different dynamics with overcapacity being a distinct consequence. Faced with overcapacity, competition becomes a fight for survival; LCCs are seen as having potentially weaker resources and the incumbents see that they will lose if they accommodate as their competitors need to compete for survival; they need to reach a critical mass of frequency and network to be sustainable. This is depicted in the third payoff matrix. The result of this fight, as discussed later is that most LCCs are wiped out by the end of the competition but with significantly weakened if not broken legacy carriers that cannot reenact the same game for the second wave of entrant a few years later.

Overcapacity and competitive situation

For the new entrants, a fast growth rate and an expanding market share is considered necessary to counter the advantage of scale and network economies enjoyed by their established competitors. Their cumulative projections thus translate in an ordering rate of aircraft that exceeds, by far, the historic one.

In their eagerness to penetrate new markets and establish market share the primary short-term objective of the new entrants is to fill their existing capacity by reducing their prices. The realization that the marginal cost of offering an additional empty seat on a scheduled flight is considered to be zero generates interest for algorithms that can automatically calculate the optimal fare under these assumptions and given demand. As a

result, profit margins are sacrificed in pursue of higher utilization rates and market share penetration.

A second order effect of the price wars is the strong stimulus that they provide to demand. Passengers can now travel by air almost as casually as they travel by car. A warming economy adds to that demand growth and as result the overly optimistic aircraft order rates on a systemic level become a self-fulfilling prophesy once the objective of profitability is relegated to the future.

While the incumbent carriers might have initially dismissed one or two new entrants as niche players and accommodated, their sheer number and aggressive strategies make this a matter of survival for the incumbents.

The ensuing price wars become more severe and protracted than what the 2-player games above would have suggested fueled as they are by a slowing economy and the accumulation of debt create unsustainable conditions for the new entrants. Another second order effect of the price wars is that in a slowing economy they are fueled by liquidity constraints as much as by competition; fares sold at giveaway prices become the last resort before Chapter 11. Nevertheless, this situation along with flawed business models becomes unsustainable and leads to the bankruptcy or merger of the majority of the first wave new entrants with the notable exception of Southwest.

The incumbent carriers have several advantages that allow them to sustain the price wars: accumulated capital, established network of distributors, dominance in their hub operations, and international routes – a market segment with relatively higher barriers to entry as it requires bilateral agreements. Since competition now focuses on price, the pressure to reduce costs leads to a new network structure that becomes dominant. Hub and spoke operations consolidate demand across several markets and allow for high frequencies – probably the highest element of service after price for passengers. In addition, the generous in-flight services that gave flying its glamour are severely cut back especially for the economy fares. Yield management systems, enabled by technology, create potentially huge fare disparities for the same seats in the same flight. The pendulum for demand consolidation and yield management swings somewhat too far for travelers as the reliability and cost of their travel take on significant variance.

While the incumbents can rely on their extensive international routes for a positive cash flow, aggressively expanding them to compensate for the deficits on domestic flights creates competitive tensions there as well. This makes positive flows elusive and far from being adequate to sustain the incumbent carriers. The incumbents' victory is pyrrhic. Most of the incumbent airlines are staggering under accumulated debt and their pension funds are drained as they were used to supply needed cash. An economy slow down on the domestic front and a war on the international scene reduces demand in both markets. The increasing pressure to honor the pension responsibilities and the extent of red ink in the airlines' balance sheets diminishes their access to cash necessary for wages, capital and interest payments, maintenance, leases etc. creating an additional pressure for

reducing the prices and gaining that short term increase in market share before their competitors react.

Under these conditions, the wave of bankruptcies that follows is not surprising. Chapter 11 relatively generous protections help the majority of the weak incumbent airlines reorganize while a few previous giants are forced to succumb to hostile takeovers and mergers. In either case, capacity is not correspondingly retracted from the market as the aircraft continue to operate under a different brand or helped by bankruptcy proceedings. An expansion of the economy and a decrease in fuel prices allows profitability to return but also encourages a second wave of new entrants. These new entrants try to reverse the pendulum of cost and service variance by reintroducing point-to-point networks and simpler fare structures. They also start using their cheaper one or two aircraft type fleet for longer domestic and even international trips challenging the conventional wisdom that passengers will not be comfortable in single aisle aircraft for longer flights.

Stakeholder Status

In these turbulent times, passengers and freight consolidators witnessed ambivalent effects: overall they benefited from the increased competition and the expansion of networks but the losses in level of service and reliability were substantial.

The aircraft manufacturing side also saw benefits in that period. Some of the benefits were partly attributed of stricter noise and emissions regulation that forced a partial renewal of older fleets. Increases in fuel prices created a similar effect by increasing the financial strains of airlines that had insufficient leverage in hedged fuel. Newer, more fuel efficient aircraft presented an advantage and a further incentive for fleet renewal. The legacy airlines tried to reduce the size of their fleets and following the lead of LCCs homogenize it with varying success. The dearth of aircraft orders during industry consolidation generated an additional price war among the aircraft manufacturers. The ascendancy of a new player (Airbus) was by the necessity of economies of scale forcing it to reduce prices and try to lure buyers by offering additional operating efficiencies based on the commonality features of their product architecture.

Lower aircraft prices due to competition and the introduction of an additional stakeholder in the form of aircraft leasing companies offered greater flexibility for the airlines in the planning and optimization of their fleet. At the same time, the expanding set of decision makers created another source of potential overcapacity through overoptimistic forecasts and the limited liability that airlines faced when ordering planes through a leasing firm.

Causes of cyclicity post-deregulation

In addition to the causes of cyclicity effective in the pre-deregulation period the following effects created destabilizing forces after deregulation:

- A large number of new entrants with lower operating costs were suddenly allowed to enter and were free to order far more capacity than the market could absorb.
- The new entrants focus on gaining market share and utilizing their capacity rather than profitability. This behavior although rational in the short-term for a single

player, created the illusion that even more capacity is needed as the lowered prices boosted demand; this was exacerbated by a growing economy.

- Airframe manufacturers and, later, leasing firms were happy to oblige in offering that capacity as that also helped them reduce their unit costs faster and compete for market share in a duopolistic market.
- Airframe manufacturers were engulfed in their own price war further inducing demand and adding another source of overcapacity.
- Airline bailouts, subsidies, mergers, and Chapter 11 protections create barriers to exit thus retaining a level of overcapacity and allowing for a continuation of the high unit cost practices by the legacy carriers.
- Airlines have difficulties in adjusting their capacity flexibly as their operations face significant fixed costs:
 - Highly trained employees have to be “hoarded” rather than fired if the airline can remain competitive at the next market upturn and furloughs have only limited effectiveness.
 - Costs for long-term leases, owned equipment and gate leases are all fixed in the medium-term.

High fixed costs made the prospect of price wars more palatable to decision-makers as at least these would ensure a source of badly needed short-term liquidity even at the expense of profitability and long-term viability.

7.1.3 Post post-deregulation and the Future: Ripples or Tsunami?

The second wave of LCCs along with a set of successful full service carriers that use hub airports to connect international markets became established. The economic boom of the 90s allowed both the newcomers and the previously ailing legacy airlines to recover and post strong profits. Utilization rates for both types of carriers were increasing and aircraft orders pouring in. The ascendant manufacturer (Airbus) aided by a lack of commitment by MDD, demonstrated in their incomplete product line, became established as the largest manufacturer after Boeing and in a way precipitates the merger of the two American manufacturers, Boeing and MDD. Orders to the two remaining manufacturers are issued with renewed vigor aided by liquidity and smaller debt constraints. This necessitated increases in manufacturing capacity that end up being costly and poorly managed for Boeing to the point of halting production and reorganizing its operations right after the merger with MDD.

The Asian financial crisis in 1997 that exposed the accumulation of capacity in that region was a prelude for the more far reaching crisis in 2000/2001. The latter mini-recession created a sharp drop in demand for air travel with obvious repercussions in the airline industry. Compounded by the tragic terrorist attacks of 9/11, consequent active wars, and a potential pandemic (SARS) deepened the predicament of the airlines even further by further reducing the actual demand for air travel in the more lucrative international routes. Furthermore, as the world oil production capacity reached closer to the inevitable peak and spare capacity is not as readily available, the volatility of fuel prices increases even with relatively minor disruption events.

In estimating their capacity, it is possible that some airlines failed to see that the increase in leisure travel was accompanied by an increase in the elasticity of demand – these travelers are more sensitive to price and income fluctuations. Airlines facing this sharply reduced demand and increased fuel prices respond with cutbacks in prices, fleet reductions, and aircraft order cancellations. In 2001, the airlines ended up parking a significant percentage of the global fleet mainly older and less efficient aircraft faced with a weak secondary aircraft market. With orders from the previous boom now arriving, airlines face a dilemma on whether they should start parking even younger aircraft and some have instead opted for mothballing the newly delivered aircraft instead in the hope of preserving their resale value when the market warms up again.

Aircraft manufacturers, faced with the wave of order cancellations, responded in a typical supply chain bullwhip effect reaction. Boeing opted for drastically reducing production capacity through painful layoffs and closure of manufacturing facilities in the pursuit of continuity in short-term financial performance while Airbus simply slowed capacity expansion given that their backlog was significantly more extensive. Boeing's seeming overreaction could make the transition to the next boom period harder and create the potential for a future expansion that may be faster than warranted in order to reduce an accumulating backlog.

Further cyclical inducing effects

The additional parameters that induce cyclical behavior as illustrated in this subsection, can be summarized into the following:

- External events especially if they coincide with economic downturns can deepen the cycle.
- Airframe manufacturers can be prone to react in a bullwhip fashion as the establishment of production facilities, employee training, and introduction of new aircraft types entail long-term investments.
- Airlines can also order in a bullwhip fashion as they may order more aircraft than they need even assuming their forecasts being correct. In an attempt to preempt competition, they order more than warranted during good times and when backlogs are long in a form of order gaming.
- Timing of deliveries may be out of sync with real demand in capacity and instead coincide with downturns thus fueling price wars to fill this excess capacity.
- Capital markets, to the extent that they influence the decision making of publicly traded companies, may force some managers to react with a short-term strategy dismissing the long-term implications of their actions. Loan provisions are also a direct way in which financial institutions can impact capacity.

Outlook

The development of the CA EoE in the future can take different twists. The growth rates projected for the sector depend on the one hand on external factors:

- Economic growth and income distribution in the dominant domestic markets in North America and Europe but also in the potentially vast markets of fast growing Asian economies.

- The increase in unit costs stemming from regulations that intend to internalize the costs of greenhouse gas emissions and their impact on global climate change.
- The potentially devastating effects of escalation in Middle East conflicts or the appearance of pandemics.
- The effects of disruptive technologies that change customer segments and operating parameters drastically.

Whether these potentially destabilizing effects will be amplified due to the internal dynamics of the industry or if the sector will learn from the history of cycles and dampen their effects remains to be seen.

On the technology side, airlines seem to have reversed from technology lead adopters to a semi-technophobic outlook. They seem content with the current level of technology and are very reluctant to embrace technological innovation that changes the dominant aircraft design. Instead, they push for further process or cost-cutting incremental innovations to the current design which are unlikely to be able to continue in the face of hard technical limits. Given these tendencies, the emergence of a breakthrough that that would create a technology-induced spike in new aircraft orders similar to the one faced in the transition from turboprop to jet is rather unlikely in the twenty year horizon of this dissertation.

In the next section we summarize and codify the causes we identified above and form our working hypothesis as to which are primary causes. This in turn allows us to draft potential strategies for managing them.

7.2 Codifying the specific cyclicity causes for Commercial Aviation

Using the causal relationships indications from the previous section, the generic causes of cyclicity identified in Chapter 6, and the conclusions of the system dynamics researchers presented in Section 8.3.8 we generated the following list of working hypotheses as to the causes of cyclical behavior in CA EoE.

1. There is endogenous cyclicity in the current EoE architecture which can be triggered by and reinforce the impact of external events.
2. The following aspects of the CA EoE are shown to be exhibit cyclical behavior:
 - 2.1. The **average profitability** of the airline industry and their supply chain (aircraft manufacturers and suppliers). Other constituents of the EoE may see cyclical fluctuations but their margins are higher and their profitability remains positive throughout the cycle.
 - 2.1.1. The cycle in airline profitability is caused by capacity that cannot be adjusted rapidly enough to the changing demand environment.
 - 2.2. The **aircraft orders** are highly correlated to airline profitability. The factors that influence the ordering cycle are:
 - 2.2.1. Multiple decision-makers:
 - 2.2.1.1. Large number of competitive and start-up airlines that compete for market share.

- 2.2.1.2. Leasing firms that project capacity based on orders from their clients.
- 2.2.1.3. Capacity retention of unprofitable airlines because of barriers to exit due to bankruptcy protections
- 2.2.2. Long manufacturing lead times and large backlogs.
- 2.2.3. Irrational exuberance of investors and airline decision-makers.
 - 2.2.3.1. Start-ups and cash-strapped legacy airlines defer profitability expectations.
 - 2.2.3.2. In good times most decisions yield good returns reinforcing confidence.
 - 2.2.3.3. Short-term management perspective. Short-term gains are rewarded while long-term losses are not sufficiently penalized.
- 2.2.4. Order gaming by airlines simply to stay abreast of competition enabled by:
 - 2.2.4.1. Cost of aircraft options and cancellations below real value ((Butler and Keller 1999) (Ch. 17)).
 - 2.2.4.2. These low costs are provided by manufacturers eager to be competitive in their own industries as aircraft production is a volume game due to the great economies of scale, scope, and network afforded to an early winner.
- 2.2.5. Expectations that as demand increases the passengers attracted maintain their demand elasticity behavior while in fact they exhibit more elastic behavior.
- 2.3. **Employment levels** in the industries involved.
- 2.4. **Aircraft manufacturing capacity:**
 - 2.4.1. Manufacturers go into a hire/fire cycle that is increasing the costs of the cycle to them as they are regressing in their learning curve (forgetting).
- 3. Events that can trigger, moderate, or exacerbate the cycle:
 - 3.1. External demand fluctuations based on global/regional economy and global events (terrorism, pandemics)
 - 3.2. External input factors like fuel prices, and costs of commodity raw materials (e.g. aluminum, copper, titanium, carbon fiber)
 - 3.3. Regulatory changes
 - 3.3.1. Regulatory technology forcing (noise and emissions regulations)
 - 3.3.2. Competitive environment (regulations on consolidation, anti-trust, and operations e.g. Open Skies)
 - 3.3.3. Carbon caps or taxes
 - 3.4. Technology changes and product obsolescence (e.g. transition to jet)

Expanding on the previous hypotheses we observe the following:

- There is a cycle induced by macroeconomic factors (and/or external events like wars and pandemics) that can drastically change (i) the baseline demand by shifting the demand curve and (ii) the **elasticity** of demand for air travel. At an economic downturn passengers (and to lesser extend firms) are still willing to

travel if the price is right (demand is elastic downwards) while at an upturn even high prices may not deter demand (demand is inelastic upwards).

- Like any market that tends to clear, airlines respond to those changes by changing their prices. Because their supply is inelastic in the short-term due to capacity commitments revenue management systems allow them to change the fares in order to maximize load factors since the marginal cost of serving an economy-class passenger is close to zero.⁸²
- Revenue management systems may create an illusion for airlines that are bent on meeting their load factor targets but at the expense of profitability with break-even load factors in cases becoming greater than 1. If wrong metrics are applied, full planes may provide a justification for further expansion of capacity forming a vicious circle of reduced profitability.
- The lead time between order and delivery of new planes may also amplify the cycle if the airlines do not anticipate the market growth and the actions of the other airlines on global scale correctly or otherwise discount the supply chain.
- Anticipating market growth is a hard task because of the uncertainty in the factors affecting demand and production costs (fuel) that establish the break-even point. Strategic behavior exacerbates this uncertainty because competing carriers may wish to secure the capacity in the face of competition. The fact that aircraft production capacity is limited creates the pressure to order capacity for the sake of having a position in the waitlist.
- While the capital cost of the aircraft is a known parameter for the airlines after signing the contract for purchase or lease, the airframe manufacturers need to clear their market as well. This means that they may charge different prices based on the demand for their products as the cycle evolves. While it can be proven that a collusive price-setting outcome is a Nash equilibrium for duopoly suppliers, there are strong incentives to underbid the competition and prevent that outcome:
 - **Economies of scale and learning effects favor large production runs.** Aircraft are very capital intensive upfront with very strong economies of scale (large production runs spread the upfront cost to a larger number of products) and a strong learning effect.⁸³
 - **Legacy and vendor lock-in effects.** A fleet composed by uniform or single-sourced aircraft is cheaper to operate and maintain (primarily due to crew and mechanics training and common parts inventory). So the incumbent supplier of a carrier has an advantage over a potential entrant.
 - **Bandwagon effect.** If an aircraft type that, on paper, offers significant competitive advantages to the operator over the competition is announced it still needs to demonstrate its merits. The more airline customers it attracts the more likely their competitors would be to make firm orders for it. The reason for this is that aircraft production capacity is difficult to scale according to demand and therefore airframe manufacturers prefer to keep a backlog of aircraft in their pipelines which in turn it means that airlines that order late will have to wait a substantial time that may reach

⁸² This is disputable if the costs of the reservation system, flight service, etc are accounted for.

⁸³ See Section 4.3.2 for a discussion of the cost structure of airframe manufacturers.

up to six years or more until they finally receive their orders. This effect is worsened by the customization required by many airline buyers that would make a change in ownership a more expensive proposition due to modifications compared to a standardized aircraft.

- **Production scaling.** The difficulty to scale production capacity can create underpricing in the reverse way; aircraft product lines that are faced with scarce demand either because of failing in their initial attraction (e.g. the B747 in their initial years as discussed in the vignette in Section 4.2.3) or because of weak market may still need to remain operating and thus aircraft may need to be sold at discounts or even produced without a firm buyer (white tails). This may happen because of company strategy or government policy (intent to retain tacit knowledge, intent to reach further down in the learning curve that offers cost advantages, or simply inelastic labor laws).
- When a product is a virtual monopoly (like the Boeing 747 before the A380) then pricing allows for more leeway as long as it does not entice a competitor to enter.

To summarize the effects discussed in the two previous sections, we use the procyclical factors as identified in Section 6.4 and define how they are applicable to the CA EoE setting in Table 7-1, which the majority of them is shown to be present.

Table 7-1 Procyclical factors and their presence in the CA EoE

Triggers
<i>Macroeconomic cycle and Final Demand.</i> Airlines face a shifting demand and elasticity of demand curve that may change in parallel with the economy or due to external events (wars and pandemics).
<i>Input variability.</i> The major procyclical input for airlines, given their energy intensity, would be the cost of fuel but exchange rates volatility can also affect international operations. For airframe manufactures the prices of raw material like aluminum, titanium and composites are volatile but their influence would be much less than the order volatility that they face.
Psychological Factors
<i>Bounded rationality.</i> <i>Supply chain discounting.</i> <i>Investment exuberance and strategic optimism.</i> All CA EoE constituent enterprises are to an extent subject to these
Industry Structure
<i>Imperfect financing and capital market volatility.</i> It was already mentioned that airlines face uncertain and procyclical financing.
<i>Investment irreversibility and intertemporal substitution.</i> For airlines, jetliners are expensive capital assets and the decision to purchase one has risks involved and a mid-term commitment to the asset. Airlines have various means of maintaining capacity without purchases of new aircraft: postpone the retirement date of their older aircraft, leasing, order deferment and cancellation. For airframe manufacturers the full development of a new aircraft family is certainly an irreversible investment decision that at times came close to threatening the survival of the firm.

<p><i>-Table 7-1 Continued</i></p> <p><i>Underutilized capacity and labor 'hoarding'.</i> Both of these can be found in airline operations and aircraft manufacturing. Airline crews and airframe designers and assembly workers are highly specialized with years of training. Firing and hiring cycles exist as a way of adjusting capacity (with a delay) but different firms follow divergent strategies on this area.</p>
<p><i>Inventories.</i> Inventory risk is not a primary characteristic of the CA EoE. Airline products (i.e. seats) are by definition perishable while their means of production (i.e. aircraft) are capital intensive durables. Airframe manufacturing is based on build-to-order rather than build-to-stock (with the exception of Airbus for a short period of its early history).</p>
<p><i>Long lead times.</i> LCA delivery lead times can range from one year to eight years making them rather long and close to the period of the cycle itself. As a result the effects of psychological factors can be exacerbated.</p>
<p><i>Technological change.</i> <i>Low barriers to entry, high barriers to exit.</i> Airline operations have relatively low barriers to entry after deregulation (with secondary aircraft markets and leasing reducing ownership risks) but barriers to exit with Chapter 11 protections and subsidies for flag carriers are still extant.</p>
<p>Supply chain characteristics</p>
<p><i>Lack of transparency of downstream demand.</i> Final customer demand is relatively transparent on the aggregate. Incentives for taking it into account are not lined up properly for airframe manufacturers and leasing firms. <i>Order batching. Order gaming due to constrained supply. Price fluctuations (promotions, bulk discounts)</i> All three are present in aircraft ordering and deliveries. Manufacturers offer additional discounts for large orders and the long lead times create an incentive for phantom ordering especially given that the penalties for cancellations are not priced correctly. <i>Strong seasonality. Network effects</i> Both effects are present in airline industry. For the airframe manufacturers, seasonality is absent but there are significant vendor lock-in effects.</p>

7.3 Definitions: Strategic Alternatives, Symbiosis, Stakeholders, Goals, and Implementability

In the previous sections we discussed how cyclical factors are present in the CA EoE and set the stage for identifying corresponding solutions. Transitioning to this, we need to define the terms that we use to characterize these solutions.

On Strategy and Symbiosis

Strategy is the choice of means to achieve an objective. Grant (2005) (pg. 22) defines the goal of strategy in a firm as “to ensure [the firm’s] survival and prosperity.” He differentiates between *corporate strategy*, i.e. deciding on the scope of the firm and the industries in which to compete, and *business strategy*, i.e. the ways the firm competes in a particular industry through business units. Business strategies are competitive strategies and are usually envisioned as zero sum games but corporate strategies may take a larger longer term view. Corporate and business strategies as such are overarching directions and plans for the future of enterprises that – ideally – have been derived by analyzing the internal competencies of the enterprise as they relate to its external environment.

Corporate and business strategies require by definition a central authority to be conceived and implemented. As we saw in Ch. 5, for an EoE such authority is not defined. Instead, there is rather disparate leadership over the different constituent enterprises that pursue their respective value functions. As a result, a single overarching plan that would qualify as strategy on the EoE level is hard to envision. For complex sociotechnical systems, the terms *strategic alternative* and *bundle of strategic alternatives* proposed by Dodder et al. (2006) can be used as substitutes for strategy when multiple stakeholders are involved. A strategic alternative in that case is an action taken by one or more stakeholders with the objective of affecting system-wide change. Even when implementable, a single strategic alternative is seldom effective in and of itself. It is more common to require a number of strategic alternatives (called bundles) that interact synergistically with one another to achieve the desired objectives of the EoE system.

In order to be implementable, strategic alternatives in the EoE-level should align with the acting constituents internal strategies. In order to meet EoE-level objectives, we propose that *symbiotic* business and corporate strategies can exist. Deriving from the Greek words “syn” (together) + “bios” (life) it originally meant communal life and is used in biological systems to describe organisms that live codependently.⁸⁴

In an enterprise ecosystem, firms compete for limited resources and for limited markets; therefore the dominant business strategies are expected to be competitive. Yet, there are several actions (strategic alternatives) that achieve outcomes and create value further than the narrow short-term self interest of the actor would dictate. These symbiotic strategic alternatives may not always be economically optimal in the short-term, as the actors do not necessarily receive the full rent of their actions, but are usually Pareto efficient. Therefore, the characterization of a strategic alternative as symbiotic is *outcome-dependent* for that particular system.

More formally, we define **symbiotic strategic alternative** implemented by an actor in an enterprise ecosystem as an action that improves total system performance by (a) increasing the probability of survival for a majority of the EoE constituents; and (b) without significantly compromising the long-term value delivered to any single constituent.

The definition of system performance may not be straightforward and may exist in the eye of the beholder. We suggest quantitative formulations of performance and formal definitions of symbiotic strategies specific to the CA EoE context in Chapter 10 based on Section 7.4 and the stakeholder analysis presented in Chapter 5.

⁸⁴ When it refers to two organisms it can take different flavors: **mutualism**, in which both parties benefit, **commensalism**, when one party benefits while the other is not harmed, and **parasitism**, when one party is negatively impacted and the other gains. In an ecosystem where cohabitation rather than dependency defines symbiosis, there is also **amensalism** when one party is unaffected but the other is harmed, **neutralism**, when both parties are unaffected and **competition** when both parties are harmed. [Source: Wikipedia entry referencing the Penguin Reference Dictionary of Biology 11th Edition – 2004].

Symbiotic strategic alternative can be further classified into:

Competitive

These are actions aiming to gain competitive advantage over an existing or potential competitor. Their symbiotic effect is based on leveraging evolutionary adaptation and in the extreme it can take the form of creative destruction processes as described by Schumpeter and the technology S-curves of (Christensen 1997). After the implementation of the strategy which introduces efficiencies to one of the competitors, the rest are required to adopt the efficient innovation, adapt to a new niche, or expire. Examples:

- introduction and spread of efficient production processes (e.g. lean manufacturing, supply chain management),
- or products (e.g. digital vs. analog media).

Cooperative,

Coordinated actions taken by a group of constituents that provide a competitive advantage to the members of the specific group. It is a behavior that is potentially collusive but manages or avoids potential market failures like the tragedy of the commons, natural monopolies etc. Examples:

- alliances,
- mergers,
- vertical integration,
- cartels etc.

Pareto efficient (non-zero sum games)

Actions that improves parameters of the system e.g. market size, performance, etc. without disenfranchising any stakeholder. Examples:

- creating a new market niche,
- infrastructure improvements

Top-down

Actions initiated by stakeholders with an interest in total system performance like government regulators or financial institutions. Examples:

- deregulation,
- subsidies for network coverage,
- targeted control of complete portfolio value chains by universal owners (see Chapter 5), etc.

Implementability is just as important a consideration as theoretical effectiveness when comparing strategies. Strategic alternatives that are competitive or top down are more straightforward to implement. As long as corporate strategic goals of a constituent enterprise and the proposed symbiotic strategic alternative align, then the leadership of that enterprise would be more easily be persuaded in implementing it than a strategic alternative that might seem to compromise short term performance or accommodate competitors. In the latter case, convincing demonstrations of the long-term advantage and pilot test projects combined with strong leadership skills would be necessary.

Having thus defined the necessary terms, we proceed in describing the range of strategic alternatives and bundles that would be applicable in an effort to reduce the extent of the cyclical behavior in the CA EoE and hence, the costs associated to it.

7.4 Br(e)aking the Cycle: Symbiotic Strategies as Potential Remedies for Cyclicity

7.4.1 Existing research

Several researchers, based on their understanding of the causes of the CA EoE cyclicity, made recommendations on ways to reduce the effects of the cycle in the CA EoE.

Neidl (1999) asserts that the airline industry will remain cyclical. He believes that as the structure of the industry changes, the causes of recession and therefore the necessary remedies change. In Neidl's view the cyclical downturn in 1980s triggered by the economic recession found the airlines threatened after deregulation: high levels of debt, strong and contrarian labor unions, and competition from start-ups. The stronger players added too much capacity subsequently. The milder but longer recession in the 1990s found the industry with overcapacity. He argues that managerial experience along with strong balance sheets, and greater *fleet flexibility* prepare the airlines better to weather the cycle. Capacity expansion is less aggressive and costs are better controlled. The flexibility trend could potentially continue towards "asset-less" or "virtual airlines" with *outsourcing* of non-core functions and greater percentage of leased aircraft.

Gallagher (1999) discusses the impact of the 1997 Asian financial crisis on aviation. The generous infusion of capital through foreign direct investment to the rising markets allowed Asian airlines to overextend and then equally fast to collapse as jittery investors withdrew whatever funds they could and demand for air travel weakened as well. While he does not offer a specific solution, he clearly points to *transparency* as means of rationalizing capital market decisions.

The system dynamicists that studied commercial aviation, as presented in Section 8.3.8, reached similar conclusions as to the causes of the boom/bust cycle and the proposed ways to moderate it. They were essentially in agreement that the combination of delivery lags, over-estimation of market size due to large number of market entrants and financial support for these choices, and forecasting errors contributes to the cycle. This conclusion is in accordance with the views of Neidl and Galagher cited previously and with the supply chain literature of the bullwhip effect and the observations of cycles in severely simpler systems like the beer game.

While there is general consensus about the causes of the cycle, there is no clear ranking that shows which of the causes are dominant and which secondary. What combinations of alleviating propositions are effective for countering the cycle industry-wide and what efforts would be simply undermined as another cyclical dynamic becomes dominant? Is the space of available strategic alternatives systematically covered? Are there synergies among strategic alternatives and stakeholders that justify symbiotic collaborative

strategies towards long term performance? What level of risk do the different stakeholders carry and how does this affect their positions under different scenarios? How is this level of risk affected by symbiosis? Is risk shared equally and if not what kind of compensatory exchange would make sense? These are some of the questions that we will focus on in the rest of the dissertation in devising workable strategic alternatives for moderating the CA EoE boom bust cycle. We will then test them using a system dynamics model developed for this purpose and discuss their implementation potential.

7.4.2 Complexity and synergies of available strategic alternatives

Based on the indications from the discussion above, the desired strategic alternatives could focus on:

- Reduce the delays in the system. Aircraft delivery lead times depend on production times and backlog accumulation
- Rationalize capacity ordering
- Add flexible capacity
- Improve forecasting

Of course there is a possibility that external influences may even out and in that case the CA EoE would not need to be restructured to avoid deep cyclical recessions but that is an unlikely proposition.

In either case, for achieving the above effects there are numerous avenues to explore. For example, a more rational aircraft ordering pattern can be a result of any of the following three strategic alternatives:

- Consolidation in the airline industry
- Transformation of airlines to pure operators – asset-less entities that depend on leasing firms for their capacity. Implicitly this action consolidates the decision-makers for aircraft ordering to fewer players (the leasing firms) that can better control risk.
- Establish strong market signals from the manufacturers to guide the market towards more optimal buying behaviors.

The first strategic alternative can be a natural outcome in a commoditizing industry but for the highly regulated airline environment, it would require the approval of government stakeholders as it may violate anti-trust regulations and, for international markets, intergovernmental agreements. Consolidated enterprises can start facing internal challenges stemming from the inability to integrate different cultures, fleets, and executive personalities (common features of airline mergers as described by (Petzinger 1995)) and even when successful they may end up being complacent in a comfortable oligopoly and allow unit cost inflation.

The second strategic alternative in the list would require a coordinated transition that would provide real competitive advantage to the firms implementing it vs. those that do not. In order to occur successfully, airlines would need to trust the upstream echelons of the value chain to supply them with the right amount of aircraft capacity at the right time and at the right price. The risk of owning the aircraft will be held by different entities

(either manufacturers or lessors) that could presumably pool it more efficiently but would not ask exorbitant premiums for doing so.

Similarly, for the third strategic alternative to be viable, a single manufacturer would need to see some guarantee for taking such action that could be costly in market share and potentially reduce the hard to gain learning economies.

The discussion above illustrates that the design and implementation of strategic alternatives in the CA EoE is complex on both the institutional and operational fronts. In the last part of this chapter we chart a set of the plausible strategic alternatives segmented by stakeholder. These will be used to construct the bundles of strategic alternatives that are tested in Chapter 10.

7.4.3 Exploring the range of strategic alternatives

7.4.3.1 Airlines

We start by summarizing the strategic alternatives that airlines can take to ensure their future growth and in response to competitive pressures as discussed in Chapter 3. Airlines can change their competitive position primarily by affecting their pricing, network/frequencies, and capacity. This involves the whole planning continuum from operating to network to fleet decisions to alliances.

The specific areas where strategic action can be taken are:

- Pricing
- Operating Cost
- Network
- Fleet
- Organizational structure
- Alliances
- Mergers and acquisitions
- Marketing
- Distribution systems

Obviously, these actions have to be consistent with the business models of the airlines involved. Some airlines will be more successful in implementing one business model over another simply because of the capacity of their management and the effectiveness of their overall strategies. In practice any changes to be successful need to be oriented towards a specific objective. Airlines cannot haphazardly implement one strategic action in one area and a contradictory one in another.

To further develop the available strategic alternatives for the airline players we will separate them into market, capacity, and cost management categories.

Market management

Once the decision to enter a specific O-D market with a given frequency is made, the primary market management strategy is **pricing**. Pricing can range within a spectrum from demand-based on one extreme which disregards costs and only considers market share as driver for pricing schemes and cost-based on the other extreme which anchors price to a predefined profit margin. Pricing strategies are usually hybrids and are also highly dependent on the capacity and frequency strategies.

Demand-based pricing focuses on fully utilizing the offered capacity and can lead to price wars between airlines at industry downturns. Cash-strapped airlines have the incentive to use their full active capacity and reduce prices to gain cash and the yield management systems can facilitate this choice. Cost-based pricing offers an advantage to low-cost carriers for expanding their market shares.

Other market management strategies include **entering new geographic markets, offering new products, and entering an alliance or merging with competitors.**

Capacity management

Capacity can be adjusted by strategies that affect:

- Aircraft orders on the longer term,
- Aircraft retirements,
- Secondary market acquisitions or sales,
- Leasing,
- Mothballing/parking, and
- Level aircraft of utilization (this is dependent on fleet scheduling as it is a function of the hours per day an aircraft flies and its average speed).

Available capacity impacts service levels by changing the frequency and load factors offered by an airline. Assuming rational yield management practices, capacity is very closely correlated to market share.

In the peak of the cycle, available spare capacity is usually scarce and order backlogs make delivery lead times reach beyond five years. If orders have not been placed in time, losing market share is a possible outcome.

Strategic decisions involve the rates of orders (e.g. procyclical vs. countercyclical or steady ordering), the rates of retirements (e.g. age to sell aircraft), the available flexibility in capacity (percent of short-term leases, reductions in utilization, and mothballing, second-hand market involvement).

Cost management

Strategic alternatives in this category impact the cost structure of the airlines and can be very diverse. In devising cost management strategies we separate costs into fixed and variable. Airlines that can reduce the ratio of fixed to variable costs have the flexibility to adjust their capacity without considering significant sunk costs. For example, short-term leasing and fly-by-the-hour agreements make the capital investment into aircraft a

variable rather than a fixed cost and reduce the incentive to utilize “underutilized” capital. The same is true for employee compensation when based on profit-sharing agreements, outsourcing airport services like baggage handling, or promoting sales over the internet as opposed to dedicated sales personnel. In changing variable costs, the decisions may range from using more fuel efficient aircraft, to reducing and homogenizing in-flight services.

Table 7-2 summarizes the strategic alternatives available to airlines.

Table 7-2 Possible Strategic Alternatives for Airlines

Strategy	Advantages*	Disadvantages	Type
Extensive use of leasing / fractional ownership?	Reduction of fixed costs allows greater flexibility in capacity utilization	Competitive advantage through differentiation of aircraft is reduced if not lost entirely.	Competitive
Capacity time arbitrage (buy low, sell high). Airlines with healthier balance-sheets can take advantage of downcycles to obtain cheap capacity (and have the option to sell it or utilize it in the upcycle).	Evens out the aircraft order swings and allows for exit of aircraft from unprofitable markets by maintaining secondary market prices.		Competitive
Moderated capacity ordering	Constrains capacity and offsets the effect of supply chain discounting	The practicing airline may be short on capacity during a market upswing.	Cooperative
Retirement patterns for capacity management	Old amortized aircraft can be retired or parked without penalty of ownership costs.	Requires the maintenance of older inefficient aircraft in the fleet	Competitive
Less aggressive revenue management	Pricing seats considering that marginal costs are not zero can ease price wars.	It could mean market share loss if the airline implementing it has higher unit costs or competitor airlines do not follow	Competitive / Cooperative
Consolidation through alliances or mergers	-Consolidating capacity will increase market power and reduce excessive capacity. -Profit-based rather than market-share based planning Improved forecasting	If unregulated, monopolistic inefficiencies may arise.	Cooperative
Increasing the flexibility of capacity utilization (by-product of consolidation)	Reduces the pressure of filling up airliners for during demand recession.	Requires industry consolidation (if lead by airlines). It is a fairly inefficient utilization of aircraft resources.	
Mono sourcing vs. dual-sourcing for aircraft	Strong relationship with aircraft manufacturer and potential to strengthen final demand information transparency	Potential loss of bargaining power	
Profit-sharing programs and outsourcing of non-core services	Transforming some mid-term fixed costs to variable costs	Premium paid for the added flexibility	

* Advantages and disadvantages refer to the actor and the effect on stabilization.

7.4.3.2 Airframe Manufacturers

Similarly, airframe manufacturers have control over their (i) market access based on the product families they introduce, (ii) capacity production rates and by implication the manufacturing facilities and labor necessary to achieve those rates, and (iii) the ability to manage their demand based on pricing, delivery lead times, and relative operating costs. We saw in Ch. 4, that for aircraft manufacturers the ability to spread the very big initial R&D investment over large production runs allows them to have better margins per aircraft sold but this is separate from the ability to substantially reduce actual production costs.

Based on this, we can categorize the strategic alternatives available to airframe manufacturers into the following:

- Production capacity policies (including production rate adjustments)
- Production cost policies (primarily lean production although costs are also impacted by production rate changes)
- Aircraft pricing and promotion policies
- Aircraft characteristics adjustments (including aircraft performance, commonality, and standardization)
- Business model transformation:
 - Focusing on service provision
 - Pursuing vertical integration or alliances

Specific strategic alternatives with a brief view of the pros and cons that expand on these categories are shown in Table 7-3.

Table 7-3 Possible Strategic Alternatives for Aircraft Manufacturers

Strategy	Advantages*	Disadvantages	Type
Pro-cyclical pricing (pricing floating on demand)	Maintain steadier order backlog during downturns. Competitive.	Excess orders during downturns to take advantage of the cycle.	Competitive
Stable pricing.	Strong signaling prevents airframe price wars. Avoids speculative ordering.	In theory competitor can undercut slightly to increase market share but aircraft attributes sway decisions.	Cooperative / Competitive
Value-based pricing of aircraft options Order cancellation penalties.	Makes the cost of risk-sharing explicit in the manufacturer/airline relationship. Airlines "own" their decisions. Family option delays specification of size later in time.	Payment if buyer is in danger of bankruptcy may be unforthcoming. Requires collaborative agreements and transparency to avoid capacity inflation that precipitates a downturn for airlines.	Competitive
Long-term contracts.	Spreading capacity more evenly over time.	Increase chances of cancellations.	
Prioritize supply by auctioning delivery dates.	"Market" value placed to delivery can be established.	If one competitor does not implement then the other may lose orders. Increases cost of aircraft.	Competitive

- Table 7-3 continued Strategy	Advantages*	Disadvantages	Type
Standardize aircraft. Facilitate quick post-manufacture customization.	Enables second hand markets. Enables fly-by-hour services. Increases resale value of aircraft.	A more active secondary market potentially reduces demand for new builds.	Competitive
Transformation from aircraft manufacturer to service provider: Fly-by-the-hour aircraft services.	Reduction of fixed costs to airlines.	Requires contract provisions to ensure minimum utilization.	Competitive / Cooperative
Establish closer ties with key customers. Extensive, risk-sharing supply chain partnership	Gain customer loyalty and influence over them.		Cooperative
Order vetting. Refuse unrealistic orders.		Competitor gain in market opportunities.	Cooperative
Introduce paradigm shifting technologies in sync with the reinvestment cycle.	Avoids a shift in the reinvestment cycle which makes current fleets obsolete.	Reduces the potential revenues from increasing a disruptive technology early. Competitor may act first.	Cooperative
Constrain production rate fluctuations. Allow backlogs to build before production rate change is required.	Stabilizes total capacity inflow rate to the system if adhered to by both manufacturers. Reduces the costs related to production rate fluctuations (hire/fire cycle, reverse learning curve progress, loss of trust for supplier/employee relations)	Competitors can capture greater market share in the upcycle or gain economic advantage in the downcycle. Potentially postpones the learning curve benefits for new aircraft families.	Competitive
Reduce capacity delivery lead times (just-in-time (JIT) delivery)	Tighter deliveries usually reduce the bullwhip effect as capacity enters the market more or less on demand.	Has not been achieved before for similarly large complex artifacts.	Competitive
Reduce production and development costs by operations and lean improvement.	Better profit margins. Lower cost of aircraft.	May exacerbate overcapacity by making aircraft cheaper to own.	Competitive
Strategic aircraft introduction timing. Introduce paradigm shifting aircraft before airlines express interest but timed with the expected reinvestment peak. E.g. low-cost, lower-speed, high-efficiency aircraft (the Prius of the skies)	Creates an answer and a market for the need to adjust to a carbon limited world. Gaining market share.	Risky proposition due to R&D costs.	Competitive

* Advantages and disadvantages refer to the actor and the effect on stabilization.

7.4.3.3 Leasing Firms

The leasing firms already partially perform some of the strategic alternatives proposed for manufacturers (i.e. offering flexible capacity) but at a limited basis as the usual lease terms extend about half the average period of a cycle. The current relationship between the manufacturers and leasing firms is considered symbiotic (Galagher 1999) but that may change if airframe manufacturers decide to take a more active role as lessors/ service providers. As we saw in Ch. 3, leasing firms have gained market share after the 1990s and their size became significant in the overall market for aircraft capacity after the latest trough. As a result, their reactions and potential effect on stabilizing the next down cycle is speculative. For this reason, we test the relevant strategies in Chapter 10 and discuss how they would be performed if either a manufacturer or a leasing firm took the lead in implementing them.

7.4.3.4 Capital Markets

As we saw in Chapter 5, the capital markets as a constituent of the CA EoE are quite fragmented. While their power is concentrating in larger agglomerations like pension funds and hedge funds, the incentives to their managers are skewed towards short-term return sometimes perversely so (e.g. pension funds should be expected to have a long-term stable return). For these reasons, the only potential of the capital markets playing an active role is by becoming universal owners in a specific value chain with large percentages of shares outstanding in their portfolio from these firms. That position could theoretically give them a position to benefit from EoE-wide returns that could allow for underperformance or losses in a specific echelon of the chain if that would optimize the whole chain performance. While the possibility of such entities developing is real, their appearance is not imminent. We will however consider these stakeholders' value functions as representative of the capital markets in Chapter 10.

7.4.3.5 Government

Finally, governments as constituents play very important roles in the CA EoE. They can regulate their domestic markets and collaborate in regulating the international markets. As governments have direct or indirect vested interests in their national (and flag) carriers and their domestic aircraft manufacturers, they have a competitive international outlook. At the same time, low cost, extensive network access, and reliable air transportation service to their citizens and businesses is vital to their economic development prospects and their political prospects. The political inertia along with the large scale impacts create often conflicting dynamics that make radical change on the government level a difficult proposition to implement.

Table 7-4 summarizes the leverage areas available to governments for potentially affecting the cyclical structure of the CA EoE.

Table 7-4 Potential Strategic Alternatives for Government Policy

Strategy	Advantages*	Disadvantages	Type
Incentive-based subsidies	Subsidies can be useful for retaining capacity during extreme events if accompanied by performance-based incentives.	If excessive, firms at competitive disadvantage will continue to operate furthering the capacity crises.	Cooperative
Antitrust regulation reconsideration	Reducing the number of players can allow for more rational decision making	Loss of consumer surplus	Competitive
Full deregulation	Reducing barriers to exit thus allowing more adaptive capacity	Exacerbation of cyclical behavior by increasing the number of entrants. Capacity is retained in the system through second hand markets counter to expectations	Competitive
Re-regulation	Returning to government sanctioned monopolies would reduce competitive pressures and innovation. Service levels would probably increase.	Loss of consumer surplus.	
Matching demand increases with airport and ATC capacity	Avoids one cause of the network-related delays faced by airlines and reduces flight risks. Effect on cyclicity is uncertain		
Reducing perceived volatility of fuel prices through carbon caps and taxes	Increasing but stabilizing the price of fuel volatility would force the airlines to account for a given level of costs and adjust accordingly. Reduces uncertainty	Increases cost of air travel across the board.	
Macroeconomic stability	Renders most other strategic alternatives obsolete	Still in the realm of economic wishful thinking	

7.5 Chapter Summary

In this chapter, we presented our basic hypotheses for the causes of the cycle in the form of a narrative which we then distilled into a list that summarized them explicitly. Our hypotheses about the cycle are slightly richer than those described by Stopford in the quote at the beginning of the chapter, but they boil down to the same approximately categories:

- Macroeconomic cycle (plus other exogenous shocks)
- Competitive behavior of airlines and aircraft manufacturers, and
- Capacity management

These hypotheses provided the backbone concepts on which a system dynamics model of the CA EoE was built in order to measure their relative importance as discussed in Chapters 9 and 10.

Subsequent to these hypotheses with regard to the cycle, we developed strategic alternatives aimed at addressing those causal connections shaped on the potential action space of each constituent enterprise in the CA EoE. A second, and more important, function of the system dynamics model was to test their relative effectiveness. As the strategic alternatives discussed here may have synergies if implemented as bundles – in parallel or sequentially – and improve on their individual performance, we also considered bundles of strategic alternatives when testing them quantitatively.

Chapter 8 Models of the enterprise of enterprises: quantitative and qualitative tools for understanding and architecting large collaborative systems

“All models are wrong, some are useful”
(Box 1979)

“All models are wrong, that is why they are useful”
(Hines 2005)

“[We need to develop] mathematics which is suitable to social systems, which the sort of 18th-century mathematics that we use is not.”
(Boulding 1991)

“My confident prediction (made without a computer) is that progress in computer hardware will produce a much greater improvement in weather prediction than in the prediction of economic fluctuations.”
(Simon 1982) (pg. 105)

In Chapter 5 we consolidated our knowledge of the commercial aviation system using the EoE framework in order to identify the salient characteristics of this system, the value functions of its constituent enterprises, and the leverage points they have in affecting the system. In Chapters 2-4 we saw that the CA EoE exhibits a strongly cyclical behavior which is enabled and amplified by the specific dynamics and interactions of the industry.

Even after simplifying and standardizing, the different types, number, time-dependence, and dynamism of these interactions make it difficult to predict the patterns of behavior that would emerge when this system becomes exposed to novel (as opposed to historic) actions and inputs. For this reason, we needed to develop a model of the system on which to test our hypotheses.

While models for “technical/mechanical” systems (see Chapter 5) have been well established and proven, the techniques for developing models for enterprises with acceptable predictive power are more limited and still nascent. In this chapter, Section 8.2 reviews the available methodologies and characteristic applications after a brief introduction to models and their desirable characteristics in Section 8.1. Section 8.3 discusses the models and applications relevant to commercial aviation that have already been developed in the literature and sketches what additional characteristics would be required for our purposes.

8.1 Models as executable representations and characteristics of a good model

Any attempt to intentionally transform a complex system, on which direct experimentation is prohibitive or impossible, requires some sort of model that provides

the change agent with means to represent the system at its current state and a projection of future states with and without the intervention. Implicit in this use of the word model is that models are *executable*. That is the model accepts certain inputs and provides results based on them that are used to evaluate a policy.

By far the most common models that adhere to this definition are “*mental models*”; the understanding of how a given system works based on human experience or as (Senge 1994) (pg. 6) defines as “internal pictures of the world”. For more complex systems the average mind’s carrying capacity cannot retain the number of interacting parts in a phenomenon that is known as “bounded rationality” ((Simon 1982), (Sterman 2000), pg 26). The number of variables and time iterations a human mind can compute consistently ranges from three to eight ((Geus 1988), (Lyons, Adjali et al. 2003)). Therefore the use of “*cognitive artifacts*” (Clemens 2004) supplement mind’s cognitive capacity. The most widely used cognitive artifacts are *representational* models like text, descriptive speech, diagrams, graphs and images. These artifacts require a mental model in order to be used – executed –and hence their output is subjective. On the other hand, there are *functional* models based on algorithms and equations like mathematical models and simulations that that can be executed and provide consistent outputs for a given set of inputs independent of the user. The interpretation of results from these models can still be subjective when filtered through the mental models of the model users.

Clemens (2004) provides a useful visualization of models and their desirable characteristics in Table 8-1.

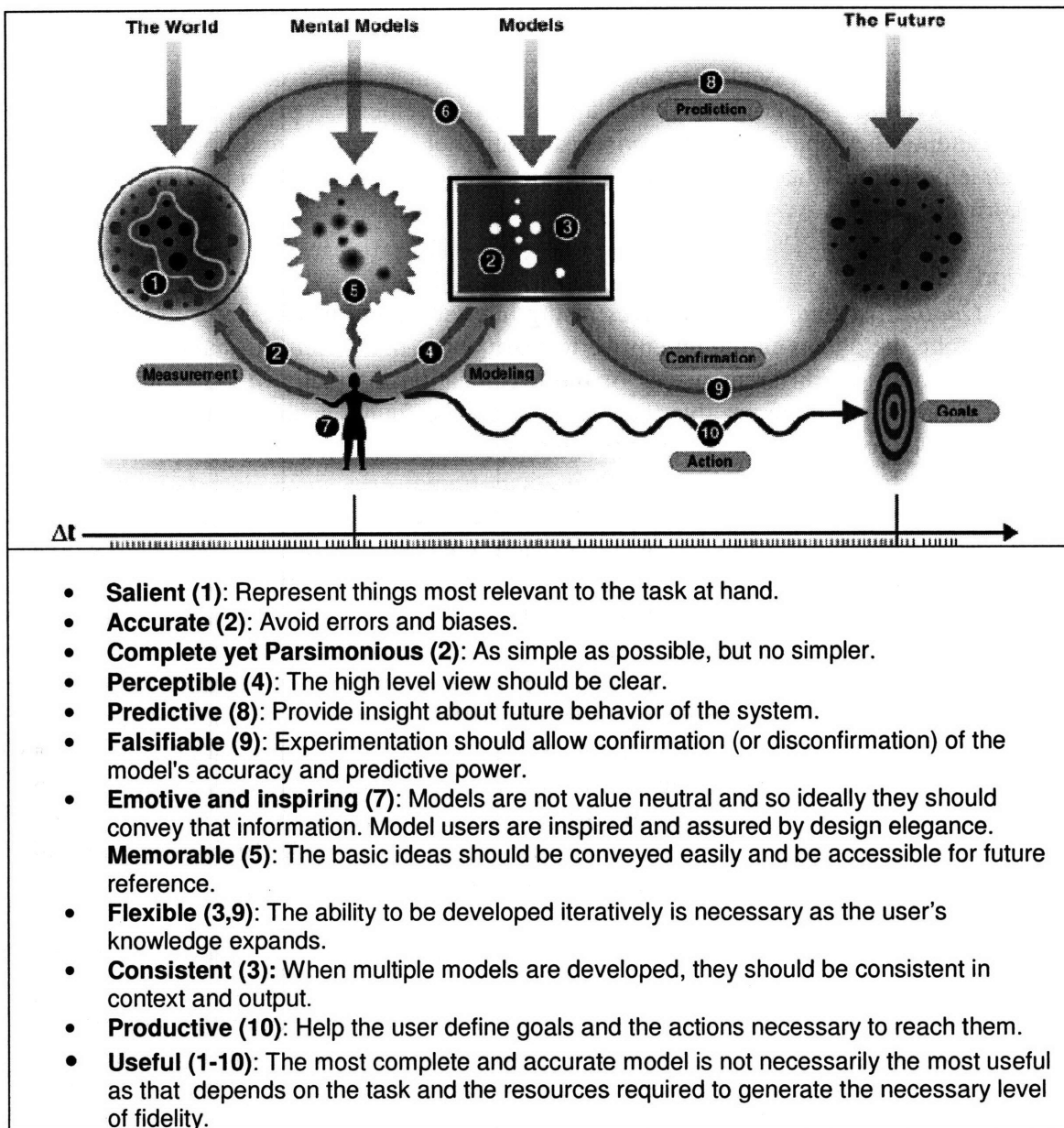
All models as they are constructed need to somehow establish that they fit the purpose for which they were generated. For most formal models this process has three phases (Law and Kelton 2000) (pp 264-267):

- **Validation:** determining whether the model is an accurate representation of the system *for the specific goals of the study*.
- **Verification:** assuring that the model’s actual implementation is error-free (this can be trivial for some mathematical models but it certainly is non-trivial for complex simulations).
- **Accreditation:** gaining buy-in (credibility) from the ultimate users of the model’s output.

Forrester (1961) (pg. 122) and Sterman (2004) (pg. 890)⁸⁵ caution that validation and verification do not mean that the model is objectively true. At best they mean that the model fits the purpose for which it was built and can gain buy-in from the users but at worse “*claims that models are ‘valid’ [] are usually part of a rhetorical strategy the modeler[s] us[e] to legitimate [their] analysis, get their policies adopted, or gain other advantage.*” As a result, system dynamics practitioners do not consider validation as a step function that moves between two states, valid and invalid, but rather as an iterative process that slowly builds confidence in the model.

⁸⁵ The same point on validation is made by Forrester (1961) p.. 122.

Table 8-1 Desirable characteristics of a model (Source: Clemens (2004) modified)



In the final analysis, all models are wrong as the well known quote in the beginning states but the reason some are useful is precisely because they are wrong; they take a complex situation and simplify for our understanding. The art of model making is in striking the correct balance between the assumptions and the level of abstraction that reduces the resources needed to build the model while still achieving the purpose of its use. In the next section we review different modeling methods that have been used to model complex systems with technical and social components akin to an enterprise of enterprises.

8.2 Models for Enterprises

Enterprises are a quintessential example of a system that cannot be experimented with (aside from “natural experiments”) or scaled due to the emergent properties they exhibit. Understanding the behavior of enterprises structured of enterprises and how they operate in their environment has been done using methodologies that fall under the following categories:

Enterprise level:

- *Qualitative empirical narratives*: using interviews and insider access, researchers probe the agents in the enterprise to learn about their decision-making processes and how the different pieces of the organization interact. Although in business management literature this type of work can be found as simply a narrative, it is usually accompanied by a theoretical framework.
- *Theoretical frameworks*: The theoretical frameworks generalize how the firm operates. Strategic frameworks, for example Porter’s five forces (Porter 1985) aim to identify how firms compete in their environment. Other frameworks like Christensen’s innovator’s dilemma (Christensen 1997) or Utterback’s dynamics of innovation (Utterback 1994) provide a broader view of the way an industry evolves over time. Other theories of the firm use different organizational views and psychology to describe why decision-makers faced with uncertainty and incomplete information do not conform to the assumption of rational decision-making with complete information. Firms in theory have the resources to make rational decisions under uncertainty and incomplete information by using decision analysis tools and having as an objective not optimizing but rather satisficing their value functions. Simon (Simon 1991) cautions not to reify the organization but rather consider that it is constituted of human beings that make decisions (and learn) based on heuristics.
- *Architecture representations*: These models use standardized representation tools for describing an enterprise. Fox and Gruninger (1998) review computational enterprise architecture models. The DoDAF architecture framework is one of the most comprehensive tools currently in use but it still lacks both in completeness and methodology (Bartolomei 2007). Research at MIT is conducted to develop more complete representations like the Enterprise Structure Matrix (ESM) (Bartolomei 2007) and the enterprise views framework (ongoing research by D. Nightingale, D. Rhodes and C. Glazner).
- *Game-theoretic and economic models (industrial organization)*: Industrial organization evaluates the strategic choices of enterprises based on game theory and using economic assumptions (rational decision-making, perfect information etc.) Econometric models can also be used to facilitate historic analysis and future projections. Demand models can be used to analyze consumer choices (Ben-Akiva and Lerman 1985). Real options methods can also be used to evaluate the outcomes of enterprise strategies (McConnell 2007).

- *Simulation models*: The most common simulation models for enterprises are developed on the operations side and involve microsimulations that use discrete event modeling to represent manufacturing and assembly procedures. On the whole enterprise level, applications are scarcer and this is the area where the “new type of mathematics” referred to by Boulding in one of the opening quotes of this chapter is more relevant. Arguably this new mathematic language can simply be the fusion of differential equations and a symbolic/diagrammatic language of stocks, flows and causal loops that is known as system dynamics. The most common simulation models of entire enterprises have been based on the branch of system dynamics known as industrial dynamics (Forrester 1961), (Lyneis 1980), (Sterman 2000)). Ilgen and Hulin (2000) note that computational modeling has moved a long way to be accepted as a “third scientific research discipline.” System dynamics models are continuous in time and aggregate. With increasing computational resources, agent-based models have started to tackle these problems seeking to simulate enterprises, presumably more realistically, at a microscopic, i.e. as collection of agents that respond and interact with each other (Lomi and Larsen 2001).

Besides enterprise-level models, far more prevalent are models of specific functions of the enterprise which have been developed primarily under the field of Operations Research. Such sub-enterprise models and decision-making tools include:

- Organization theory
- Mathematical optimization models (e.g. linear programming)
- Simulation models (e.g. discrete event simulation of production processes)

Models for Enterprise of Enterprises

The appropriateness of the model depends on the goal of the research. If that goal requires EoE level interactions then an EoE level model would be desirable. No single model could be complete in providing this understanding but rather a hierarchy of models developed in an iterative fashion based on whether the modeler’s needs were met.

A logical sequence would start from developing qualitative understanding through primary research using interviews with representatives from key constituent enterprises. If the industries are well researched already then secondary research in the literature could provide the basis for building the researcher’s mental models of the system’s basic behavior. Mapping this knowledge of the system on the EoE framework can generate a rudimentary architecture that includes all the important constituents and the ways they interact. Mental models assisted by the architectural representations should allow the modeler to generate hypothesis about the causes of the undesirable behaviors that triggered the study in the first place and the types of strategic alternatives that would be appropriate to fix them.

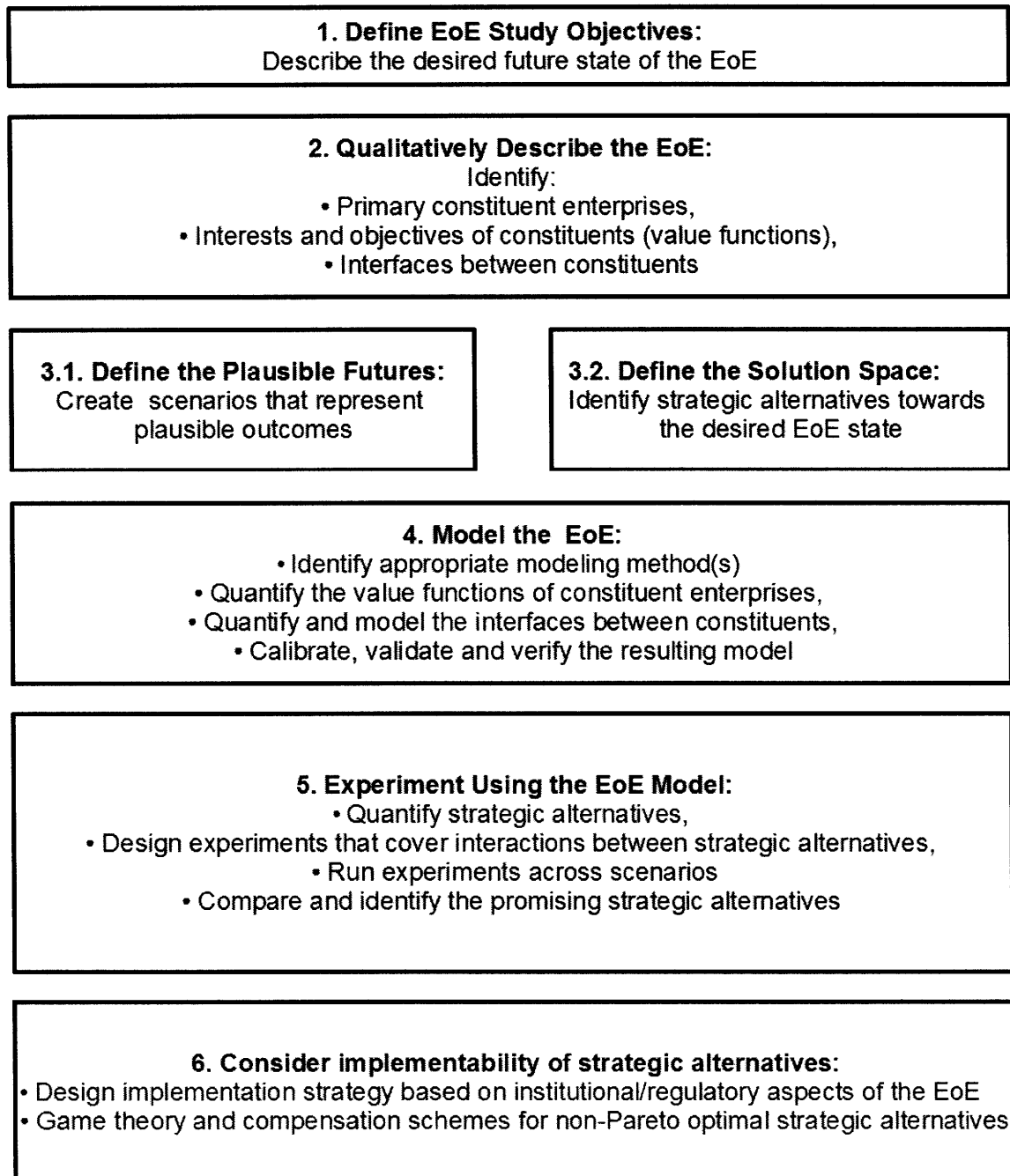


Figure 8-1 EoE Modeling Framework

An EoE, unlike a corporation, is by definition non-hierarchical and the control structure necessary to implement any strategy that involves multiple stakeholders may not be there. Even if the strategies involve only a single constituent enterprise, its actions would have repercussions across the system by triggering responses from the other constituents. The modeler needs to identify the winners and losers under each strategic alternative. For understanding the kind of responses to be expected and for devising the appropriate

implementation strategies, a quantitative assessment of the stakes involved and how individual constituents would be impacted along with their responses would be sought.

The quantification and dynamic responses of the EoE system can be modeled by using mathematical formulas to approximate the value functions of each constituent enterprise and their response spectra. Such a model could theoretically be analytical and solved at key time points but in most cases would require a dynamic simulation environment to be modeled effectively. In any case, a game theoretic framework that defines the responses of one constituent against the actions of the others would need to be explicitly or implicitly incorporated either for informing the simulation or for weeding out the simulation runs that generate “infeasible” outcomes. Lyons, Adjali et al. (2003) showcase how the supplementation of ABM by game theory could work.

Figure 8-1 shows graphically one approach for modeling EoEs based on the above discussion. This dissertation was structured based on this framework.

A natural area for the development of enterprise of enterprises models is supply chain integration. We reviewed a large part of this literature in Chapter 6 in conjunction with the efforts to mitigate the bullwhip effect. Beamon (1998) also provides a wide overview of the modeling approaches used in supply chain integration.

On the economic literature front, Pyka and Fagiolo (2005) concur and note the following developments in economic thought towards increasingly more complex structures:

- Moving from atomistic competition to monopolistic and oligopolistic competition (Scherer and Ross 1990).
- Recognizing the impact of innovation in generating positive feedback effects and increasing returns to scale (Romer 1990).
- Introduction of micro-founded macroeconomic models as representations of “dynamic decentralized economies” composed of agents that make autonomous decisions. In order to solve these formulations analytically, strong assumptions (e.g. interactions among agents are either non-existent or complete – all agents with all agents, rationality, no information asymmetry) (Sargent 1987).
- Anderson, Arrow et al. (1988) view of the economy as a complex adaptive system which could borrow from the study of physics tools for complex system understanding. They broke economic phenomena and the relevant tools into: “*Cycles*” as represented by dynamic behavior of non-linear deterministic systems, “*Webs*”: large numbers of agents that interact with the environment and evolve, and “*Patterns*”: theories based on homeostasis in non-homogeneous systems that maintain and expand differences between agents.
- Evidence from cognitive psychology and experimental economics that the common economic assumptions are not actually observed in practice (Kagel and Roth 1995).
- Need of heterogeneous agents that interact with a network of other agents and learn based on experience is key to accurate representations of economic systems. (Kirman 1997)

Radzicki (2004) argues that system dynamics combined with recent institutional economics is better suited than (neo)classical economics for modeling socioeconomic systems that are characterized by non-linear, dynamic, feedback and bounded rationality which is not amenable to modeling with simple linear economic models based on rational expectations. Whether he is right, is not proven yet although the economic literature cited previously points to that direction. In any case, both approaches use different means but work towards the same goals of understanding complex socioeconomic systems.

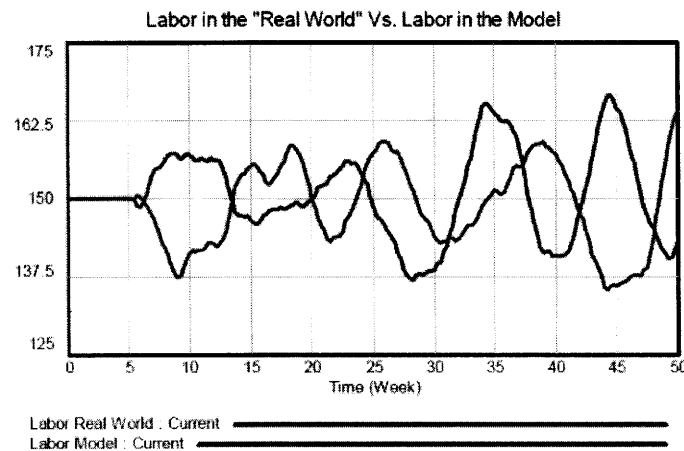


Figure 8-2 Divergent behavior of structurally identical models due to non-linear dynamics (Source: Radzicki (2004))

As far as their ability to forecast future behavior, Forrester (1961), Lyneis (1980), Radzicki (2004) and others caution that system dynamics models even with their superior handling of complexity can only be calibrated to be used as predictors for the very short term. Long term future cannot be accurately forecasted even with very precise models. Taking an insight by Forrester, he demonstrates this by comparing two runs of a single model – one representing the “real world” and the other the perfectly specified model. Although structurally the “real world” and the model are precisely the same, even a small variation in the seed of input variables in the model generate diverging albeit comparable behavior as shown in Fig. 8-2⁸⁶.

The complexity of an EoE level system makes it a daunting challenge for modeling. The right balance in aggregation (macroscopic view) and independent agency of the constituents needs to be reached so that adequate modeling resources exist but the results are both credible and useful.

In the next section we review the types of models that have been built around commercial aviation interests as well as some characteristic examples from other industries. In discussing their characteristics, strengths and weaknesses we gradually develop what the

⁸⁶ Although this phenomenon may resemble the “butterfly effect” in chaos theory (sensitivity to initial conditions), it differs from it in the sense that the generated behavior (characteristic attractor) is stable (i.e. these models do not diverge into radically different ways but they rather present the similar overall behavior (same variance, amplitude of oscillation and period) but with a phase shift).

desirable characteristics of a model of the CA EoE should be and how these characteristics could be adapted for use in CA EoE-level modeling. Thus by showing the weaknesses of existing models when used on the CA EoE level we define the desirable characteristics for the model that aimed to develop and which are summarized in Section 8.4.

8.3 Model Applications for Enterprises with Emphasis on Commercial Aviation

Qualitative empirical representations of aspects of the CA EoE formed the backbone of our understanding of this system and were used extensively in writing the background Chapters 2, 3 and 4 of this dissertation. In this section we will focus selectively on representative formal models that either relate to aspects of the CA EoE or illuminate different modeling methodologies for enterprises.

8.3.1 System Dynamics in Enterprises: Non-aviation industry examples

One of the more prevalent quantitative modeling methodologies for enterprise applications has been systems dynamics. With a long history that includes Forrester's (Forrester 1961) seminal *Industrial Dynamics*, the number of applications is large. Three recent applications are presented here that showcase the versatility of the methodology:

- Weil and Utterback (2005) present a basic theory of the dynamics of innovation using a system dynamics model. The firm entry and exit, experimentation with new technologies, and technology diffusion from early adopters to saturation, among others are represented.
- Tang (2006) uses a system dynamics model of a corporation (ADI) as a surrogate model to test decisions for firm value maximization.
- Finally, Dikos (2004) used a system dynamics model of the tanker shipping market in combination with econometric models to study optimal shipping investment decisions.

8.3.2 ABM and Game theory application for Telecommunications

Lyons et al. (2000) used an interactive business game with human subjects as participants to identify potential strategic outcomes for telecoms. They suggest that the human agents be substituted for by software agents that could "play" a much larger set of possible configurations of strategies (the human game had only limited time to explore the number of possible permutations) at the cost of richness in the strategies themselves. They propose that the agents use evolutionary as opposed to 'classical' game theory in which agents attempt to maximize their objective function with perfect information. A schema of evolutionary game theory allows for mistakes and adaptation.

In their model, Lyons et al. used four agents that represented a market leader, a market follower, a potential entrant and a regulator. Each had specified strategic alternatives which could be chosen based on their "knowledge" of their environment, previous outcomes, and their objectives. This ABM model exhibited a cyclical behavior if the

memory of the agents was restricted but reached equilibrium if their memory was extended.

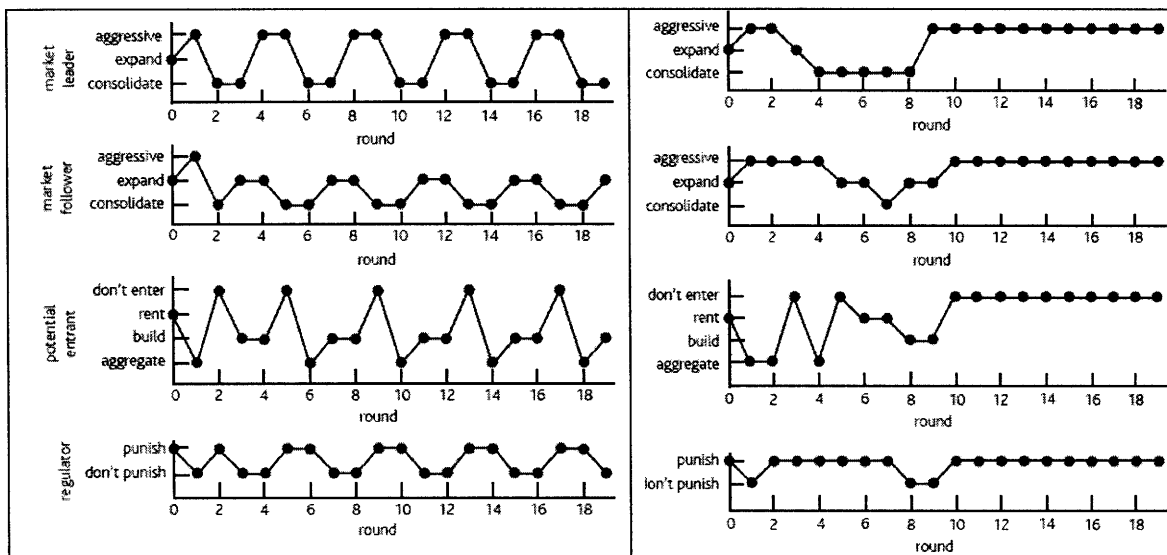


Figure 8-3 Cyclical and stable equilibrium behavior for an agent-based industry model with four agents (Source: Lyons et al. 2000)

8.3.3 ABM and Enterprise Architecture

Lin et al. (1999) developed a formal architecture notation with the intention to be transferable into an agent-based model. The primary components in their architecture were:

- Business units: participant in an enterprise or at industry level an organization.
- Relation interaction: interactions across business units
- Physical facilities
- Processes: every enterprise activity
- Input/output as results of processes
- Information flows
- Decision/strategy
- Knowledge sources: the agents from which information emanates
- Performance measures

They then developed classes of agent types (e.g. inventory management agent, production planning agent, manufacturing agent etc.) which they combined to represent parallel supply chains and investigate different supply chain strategies like make-to-stock (aka push) and make-to-order (aka pull). They found that in the modeled chain, combination strategies of make-to-order policies for downstream echelons and make-to-stock or assembly-to-order strategies for upstream suppliers were the most effective. In a similar vein, Fox and Gruninger (1998) discuss a standardized representation of the enterprise – an enterprise ontology.

Pyka (2003) observes that ABM provide insight into evolutionary processes where the structure of the system can change qualitatively rather than only quantitatively (Tsfatsion 2001) and can be used as laboratories to test institutional arrangements. According to Wooldridge and Jennings (1995) agents should exhibit:

- **Autonomy:** each agent operates without direct control from other agents,
- **Social ability,** agents interact either competitively or cooperatively
- **Reactivity:** agents perceive and respond to their environment
- **Proactivity:** agents forecast expected future and take appropriate actions to achieve their goals.
- **Adaptivity:** Pyka (2003) adds to the list by observing that in order to achieve more realistic behavior and avoid biasing the results of the simulation by the set of rules that are chosen, rules should themselves be evolving (“*endogenously changing objects*”).

Building on the idea of enterprises as agents sharing specific rules, Swaminathan et al. (1998) proposed an agent-based modeling framework as a way to standardize and facilitate supply chain modeling. They constructed a “library” of supply chain modules that could be customized to fit the requirements of specific applications.

Another line of research, reviewed extensively by Chang and Harrington (2005), is interested in modeling enterprises as being constituted by agents rather than being agents.

8.3.4 Hybrid Agent-Based System Dynamic Models

System dynamics and agent-based modeling can in fact be complementary. Schieritz and Grobler (2002) were among the first to discuss the merits of combining SD with ABM in modeling supply chains. While Rahmandad and Sterman (2006) have shown that both approaches can be used successfully in describing diffusion dynamics but that the SD approach is more parsimonious and less exacting on computational power. Yet, a combination of the two approaches to reinforce their relative strengths and avoid some weaknesses remains a promising area of research

8.3.5 SD and ABM models for the Air Traffic Control System (ATC)

The air traffic control system is critical for airline operations but, as we discussed in Chapter 5, we considered it only as a potential limitation to capacity expansion. The ATC system is complex enough to be considered an enterprise of enterprises by itself albeit less complex than the CA EoE. Its primary constituents include the traveling public, airlines, FAA, FAA employees, the governments and their budgeting and cooperation, etc.

We discuss the ATC system not only because it is part of the CA EoE but also to compare the relative merits of system dynamics and agent-based modeling (ABM). Galvin (2004) studied the ATC system and its potential for future expansion under the different strategic alternatives like the adoption of free-flight GPS –based systems faced by FAA using system dynamics as the methodology of choice. Niedringhaus (2004) on the other hand used ABM to investigate the evolution of the airline industry and the US

National Airspace System (NAS) for the same purposes (i.e. to evaluate the responsiveness and capacity expansion options of the ATC).

Galvin's model used aggregate flights and assumptions on how they would perform under different ATC schemes and focused rather on the revenue and manpower evolution that FAA would face as the schemes were implemented.

The Niedringhaus model created instead a very elaborate representation of the actual flights and origin-destination matrix for a preselected set of airports. Airlines that operated the aircraft in the Niedringhaus model would take competitive actions like fare raises, aircraft buying etc. The airline agents would in addition exhibit "personality" traits in terms of their individual strategic preferences for market-share and on-time performance which along with profits would create their objective function.

While the detail of the ABM model could seem pretty microscopic, this had a negative effect on the realism of the scenarios actually run. These range from two airport, four aircraft monopoly vs. duopoly scenarios to airports in the eastern U.S. and 1700 aircraft flying for a single day.

Even if the ABM model is not completed, the comparison of the two models implies a preoccupation with detail for ABM models out of which a bigger picture, it is hoped it, will emerge. System dynamicists instead draw on a larger picture canvas focusing on the more salient relationships and allowing only little role for agency in the model.

8.3.6 Econometric Models for Airlines: Game theory and Demand Modeling in Airline network choice and Merger Outcomes

Competition in a hub-dominated environment has been analyzed by Hansen (1990) as an n-player non-cooperative game with profit maximization as the objective function and adjustment of frequency as the sole available strategy.

Adler in a series of papers (Adler and Berechman (2001), Adler and Smilowitz (2005)) improved this model to include aircraft size and network type in the formulation. They used a combination of demand modeling (discrete choice models for passenger choice), logit models (for establishing market share), linear programming, and game theory to study optimal and expected behavior of airlines in developing their network. Optimal hub-spoke network design was studied in Adler and Berechman (2001), and Adler (2003). Airline decision variables were hub-choice, service frequency, aircraft size, and fare but the model complexity prevented the analysis of a large number of competitors. Adler and Smilowitz (2005) studied the effect of mergers on network choice in international markets.

Alderighi et al. (2002) did not take the hub system as a given but instead considered three strategic alternatives for airlines: point-to-point, hub-spoke, and multi-hub. They use a combination of econometrics and game theory, similar to the methodology used by Adler, to study a simpler market where consumer and airlines try to maximize their corresponding welfare. They find that a stable equilibrium for large size markets is an

asymmetric configuration where one competitor provides point-to-point service and the other uses a hub-spoke network which they consider a representative of the current competitive environment with legacy and low-cost carriers coexisting.

Armantier (2000) used game theory for a duopoly competition in a single hub and found that complete cost information exchanges are beneficial to the airlines without impacting consumer surplus. Like in the previous studies mentioned, some quite restrictive assumptions were used including no fixed costs, no network effects, no potential entrants which do not allow for full generalization of the results.

Bilotkach (2005) investigate the effects of consolidation through alliance on interline passenger fares based on whether they are granted antitrust immunity (i.e. the ability to coordinate fares – see also Chapter 3) or not. His model includes 4 airlines and therefore has the ability to investigate a competition between two alliances (two and two) and finds that alliances with antitrust immunity allows for fare decrease in spoke-hub-spoke traffic.

Bhadra (2005) used an econometric model to study the post-9/11 commercial aviation environment in the US and observed a strong change in the network structure from hub-spoke to point-to-point.

8.3.7 Game theory and Econometrics in the Competitive environment of Industries with focus on Airframe Manufacturers

Moving on to the competition between airframe manufacturers, a series of models were developed to address aspects of this system.

With regard to aircraft type choice, Bhadra (2003) represented the airlines' aircraft type choice decision process based on route characteristics using an econometrics model.

Krugman (1987) describes the competition between Boeing and Airbus using a matrix where the two Nash equilibria (both companies build a Super Jumbo or none builds one – see Figure 8-3) are inefficient solutions. As a result both players need to emphasize their commitment in building such an aircraft thus trying to make the opponent not to take up the task.

Airbus recognized the monopoly of 747 yet industry feasibility studies indicated that the market could not profitably sustain two super jumbo jets. When Airbus announced its intent to build a plane larger than the 747, Boeing responded with an announcement of an even bigger plane yet the specter of internal cannibalization, that is the reduction of sales of the B747 because of the introduction of a newer and larger aircraft by Boeing, did not make the threat credible – thus Esty and Ghemanwat (2002) use this as a showcase of a strategic but failed preemption.

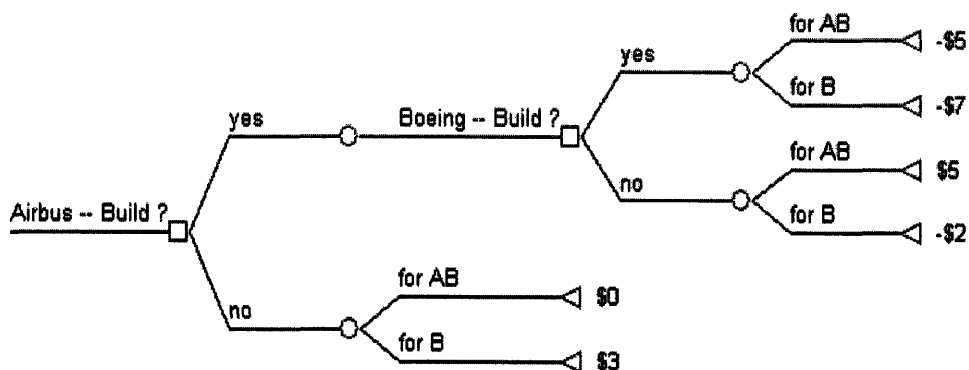


Figure 8-4 A game theoretic view of the B-AB competition for an LCA in the 500+ seat category
 (Note: Outcome values are illustrative, based on Krugman (1987))

Benkard (2004) created an empirical econometric model of aircraft pricing using data from the Lockheed Tristar (see also Chapter 4). He observed that due to the prominent learning curves and very high barriers to entry, aircraft prices can be well below static marginal costs during the initial production phases as manufacturers try to penetrate the market. He used a labor based cost function based on experience accumulation. On modeling the demand side, he chose to represent aircraft purchases as rentals rather than a static discrete choice. This approach was followed in SD models (see below and Chapter 9) and can be justified by the very active used aircraft market.⁸⁷

Benkard's model for aircraft choice is multinomial logit based on characteristics like number of seats, engines, range etc. It is based on Ericson and Pakes (1995) dynamic models of imperfect (oligopolist) competition that allows for heterogeneity across the competing firms due to entry, exit, and differences in investments. These models are computationally intensive to solve and constrained as to their assumptions and are usually approached with Monte-Carlo simulations. Using this technique, Weintraub et al. (2005) found that as industries increase in size the consolidation or fragmentation of the market depends on the increases of the returns to investment.

In trying to validate his model, Benkard was only able to do qualitative comparisons due to the lack of available historical data on aircraft costs. The model he used allowed for three industry structures: single-product firms, multi-product social planner, multi-product monopolist. The social planner structure resembles a cooperative multi-objective optimizing enterprise of enterprises which in Benkard's experiments provides the highest total surplus with the single-product firms being a close second. Based on these observations, he recommends that *aircraft industry policy should focus on ensuring that the manufacturers maintain high enough current output per product rather than production efficiencies.*⁸⁸ A completely competitive situation results in excess production,

⁸⁷ He observed that 10-20% of the aircraft fleet is traded every year with more than 60% of aircraft older than 10 years had more than one operator. Changes occur even seasonally on a global scale.

⁸⁸ In an earlier investigation, Benkard (2000) used the Lockheed Tristar data to establish the dynamics of learning and forgetting in manufacturing and found that in contrast to traditional learning curve theory, reductions in output actually push-up the marginal costs of production. To avoid this "depreciation of

multiple products and diminished learning effects while a completely monopolist one transfers much of the surplus to the manufacturers. Benkard also explores an alternative policy to the “*government-sanctioned monopoly*” where firms are punished if they exceed a certain percentage of market share which actually is found to have a negative effect on consumer surplus.

Neven and Seabright (1995) reached a similar conclusion as they also found that a monopolized industry due to the learning-curve effects may produce more total societal surplus than a duopolistic one based on their multi-stage game theory application on the aviation industry. They used a multi-stage game with three players representing Boeing, Airbus and McDonnell Douglas that was intended to inform government industrial policy. They find that in their model, competition and consumer surplus was not enhanced with the entrance of Airbus as it commensurately reduced MDD’s incentive to compete. As a result they estimated that Airbus had a negative impact on total world welfare but a positive one for European welfare. They posit that government-supported entrance forces competitors to adjust in a way that they would not otherwise and they provide as an example the update of the 737 in the face of the A320 entrance – they speculate that Boeing might have opted for a completely new design if left unchallenged.

Neven and Seabright summarize aircraft development into six generic stages of two market segments: narrow body and wide body aircraft. Trying to identify optimal development strategies, they solve the problem backwards by considering entry and exit decisions for each stage. In order for the system formulation to be tractable, they assume that manufacturers make a fixed choice on production capacity when they make the choice to produce an aircraft or not which remains for the 25 years of the production duration. They also assume that aircraft pricing is not variable in order to gain market share in the initial introduction or over time in any form of price discrimination or defense industry spill-overs. They do not consider the possibility that competition force process or technology innovation. Finally, they consider that the capability to overcome the barriers to entry for each segment as given – a generous assumption as there are economies of scope across segment and network effects on the side of the operators. Given these limitations, their findings and methodology are still valuable but indicate a need for more realistic dynamic modeling. System dynamics offers a way to do so in aggregate terms as shown in the next section.

In a later study, Irwin and Pavcnik (2004) used econometrics and demand modeling to calculate the impact of reduction in subsidies after the 1992 trade agreement and of the effect that the entry of the A380 would have in the widebody aircraft market. They found that prices of aircraft did increase coinciding with the withdrawal of subsidies and that the A380 would reduce the market share of the B747 by 15% but have greater impact on Airbus’s own widebody sales⁸⁹.

experience” he recommended retention of labor even if temporary underutilized as knowledge hemorrhaging and retraining are the probable causes of forgetting. See also Section 4.3.2.

⁸⁹ Their expectations on the latter matter have been shown inaccurate. The A380 pretty much eliminated the market for the older B747 and if it were not for the significant A380 production delays, there was no indication that any new orders for the 747 would have been placed.

8.3.8 System Dynamics in the Airline Industry and Airframe Manufacturing

System dynamics has a long history of applications in corporate and policy planning. Expectedly, there are a number of applications related to commercial aviation. In this section we will review the most important of them along with representative examples of SD applications in other industries.

Liehr et al. (2001)

Liehr et al. (2001) used a system dynamics model with the explicit purpose of analyzing cycle-generating structures in the airline industry and identifying corresponding “*cycle-management*” strategic alternatives. Sponsored by Lufthansa, their effort was focused on what a single airline company should do to outperform the industry based on an understanding and forecast of cycles.

The basic model used is shown in Figure 8-5 and consists of a negative feedback loop with two delays – a structure prone to oscillations.

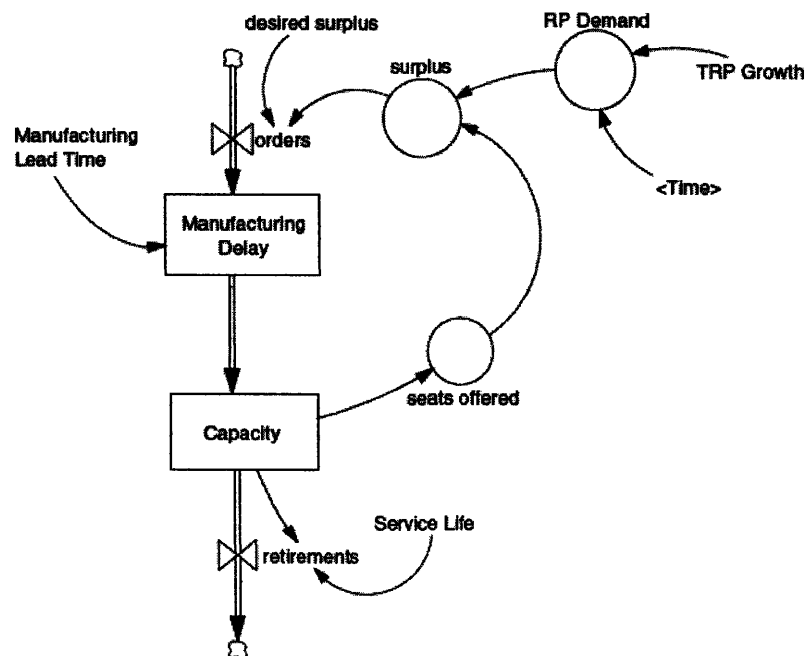


Figure 8-5 Abstract micro-structure of the airline market that can generate business cycles (Source: Liehr et al. (2001))

Based on this basic structure, they developed a model with three modules: the airline and aircraft industries combined, a microstructure of Lufthansa, and a competition module that allocates demand to Lufthansa and the rest of the industry. They intentionally chose a ‘parsimonious’ model structure to “prime policymakers for debate” rather than a more complex and accurate model that would have limited buy-in as it would be treated as a black box by management.

Using their model, they found that counter to prevailing managerial opinion, a large part of the cycle is due to endogenous dynamics as opposed to external events. In this, aviation is similar to other cyclical industries like paper, real estate, commodities and shipbuilding. Based on their findings, they recommended:

- Creation of an organizationally independent business unit to manage capacity as a prerequisite in any meaningful cycle management strategy.
- Strengthening of alliances as key in introducing wider capacity controls in the industry. Network planning in the alliance and equalization across regions would also add stability. Fleet flexibility based on leasing and retirement policies is another way of managing capacity.
 - The retirement policy would require a larger percentage (10-15%) of older aircraft with low fixed costs to be retained in the fleet to allow easier capacity management when needed and reduce the pressure on utilization.
 - For this strategy to work, countercyclical ordering with higher than desired orders during downcycles and less than desired orders during upcycle would be needed. For the leasing strategy to be effective, requires a similar ability from the part of leasing firms to even-out their orders over time.

Lyneis (1999 and 2000)

A second example of application of SD in commercial aviation comes from Lyneis (1999, and 2000). He advocates the use of SD models to support business strategy not only as tool of great explanatory power as used by Liehr et al and described earlier by Morecroft (1985) but also as an accurate forecasting tool. The reasons for this is that forecasting in decision-making is inevitable and SD models can be better than most in providing not only a numerical result but also an understanding of the dynamics to the management and a platform to test strategies in a wide variety of scenarios.

In the consultancy role Lyneis (1999) aims to use SD models to:

- Provide effective understanding of the client's problem
- Educate the client for the dynamics of the system by active participation in the creation of smaller "insight" models to avoid the "black box syndrome"
- Reaching out to others in the company not directly involved with the modeling
- Institute a learning and planning culture that can use the model over the long-term

He uses an example from the commercial aircraft industry to illustrate this with the client being a large commercial jet aircraft manufacturer and the problem faced by the client is the highly cyclical behavior of aircraft orders. The questions asked by the client were:

Is the current state (1987-1991) another peak?

- Is adding capacity necessary?
- When should we introduce a next generation aircraft?
- What is the effect on orders generated by:
 - European market liberalization,
 - growth in freight,
 - future oil prices and economic condition?
- What causes cycles and to what extent are they due to external environment?

Lyneis's basic model, as shown in Figure 8-6, features the same negative feedback loop as Liehr et al.

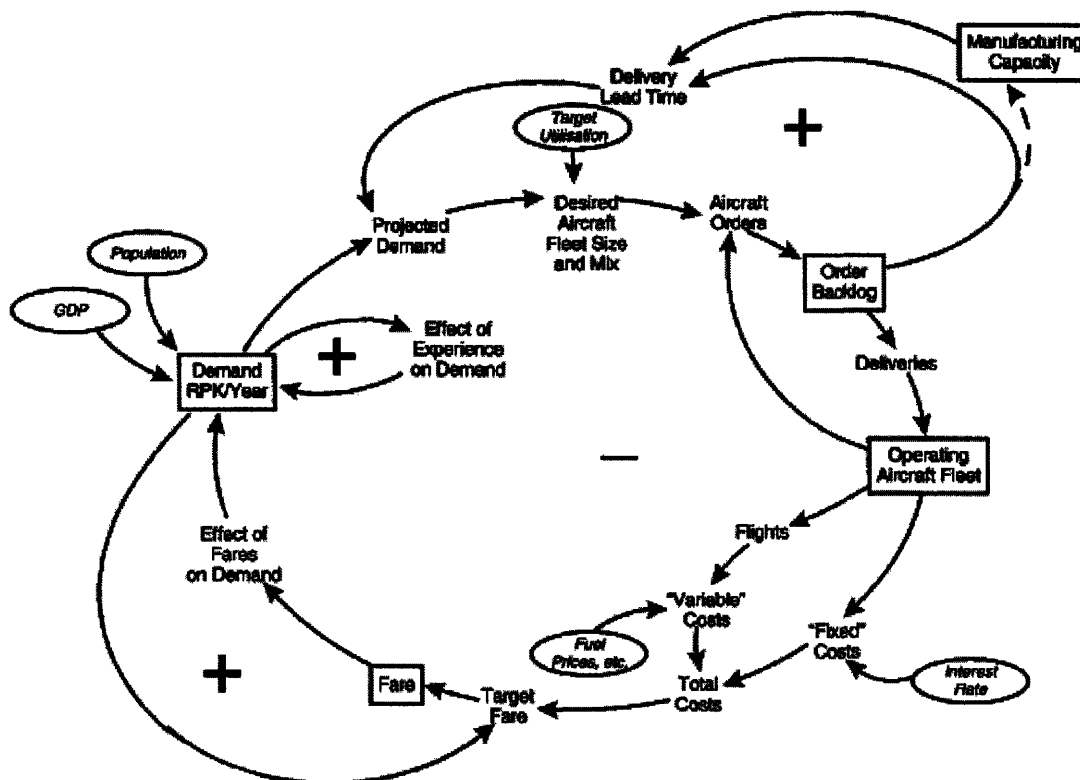


Figure 8-6 Basic dynamics in the commercial aircraft industry (Source: Lyneis 2000)

Although intuitively useful, this model could not answer the specific questions posed by the client and therefore additional detail was added in a structure shown in Figure 8-7 by disaggregating demand by domestic and international, by region, and by adding modules for leasing firms and manufacturers.

Using the more detailed model, Lyneis (2000) observed that the reasons for cycles revolve around the inability of the individual airlines to perceive and act on the information of the industry as a whole.

More specifically he attributes the cycles to the following:

- The significant delays in the major negative feedback loop amplify the variation in economic conditions by preventing airlines in total to account for the aircraft that are in backlog.
- This error is compounded by
 - the use of extrapolation forecasting by airlines
 - competition for market share in the upcycle create a situation where the total expected market share by the airlines exceeds significantly the actual market.

- Secondary aircraft markets amplify the cycles by allowing capacity to stay in the system when the new aircraft are delivered.
- Financial dynamics amplify the cycles by instigating investment in upcycle and discouraging it during a downcycle.

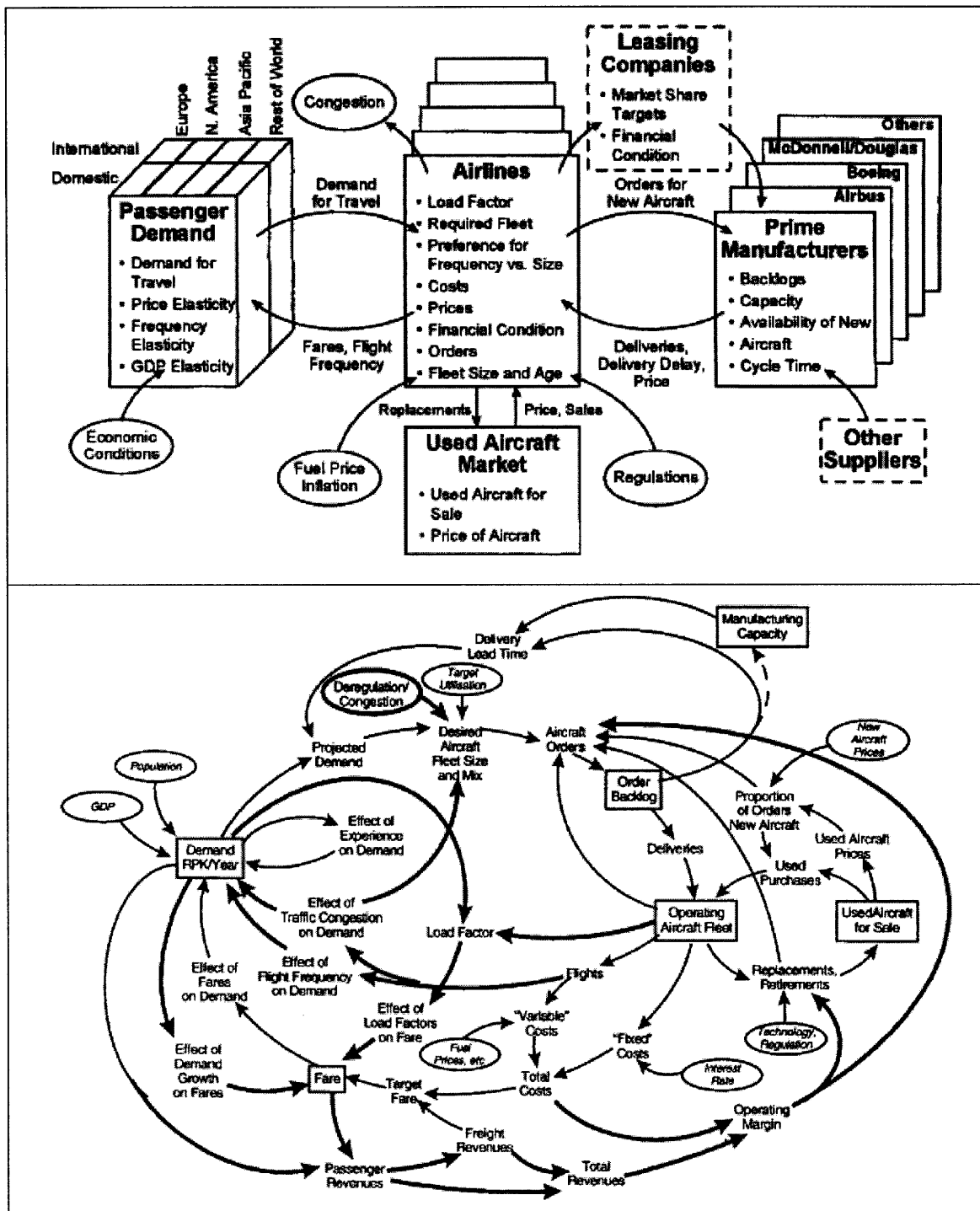


Figure 8-7 Additional detail for the SD commercial aircraft model (Source: Lyneis 2000)

While Lyneis does specify recommendations based on the above observations (his aim is to show the possibility and advantages of using SD models as forecasting tools), he briefly mentions their recommendation to an aircraft part supplier not to cut their production as much as they used to during the downcycle as they were provided with a more detailed and accurate mid-range forecast.

Skinner et al. (1998)

Skinner et al. (Butler 1999 Chapter 3, pg. 27) present a third research project that used SD to model the dynamics of the airline industry cycle with the objective of showing that management of the cycle is possible. They postulate that an airline that can somehow manage the cycle will have a better price-to-earnings ratio by increasing investor confidence. As more carriers adapted their strategies the whole industry could change limiting the losses during the downcycle.

The expert consensus at the time (a period of sustained profitability for most airlines in the US) was that industry changed towards a better managed model in two ways:

- Management focus shifted from market share oriented to long term profitability with a consequent restraint in capacity, and
- External capacity constraints due to longer backlogs and regulatory mandated retirement of older, non-compliant aircraft.

In addition, they reference⁹⁰ two aspects of the industry that may smooth future cycles:

- Long term contracts with aircraft deliveries spread over time
- Reductions on lead times by the manufacturers

While they concede that changes have been made and restraint was arguably evidenced, they argue that these changes may make the industry less reactive to short-term profits and other fluctuations but it has not changed the fundamental way the industry operates: i.e. with high fixed costs, barriers to exit, and long lead times all lead to cyclical industry performance.

Using this model and different scenarios of demand growth, they correctly anticipated the existence of a downcycle in the following years given the high number of orders in the period 1995-1998. They focus on devising “cycle management strategies” for a single firm through cycle anticipation, corresponding growth and competitive behavior, and adding flexibility in areas like aircraft mix, options ordering, and labor. Among the strategic alternatives they propose are:

- Wet leases
- Fleet age stratification
- Fractional ownership
- Profit-sharing programs
- Code-sharing and alliances to coordinate changes in capacity

They only test fleet management strategic alternatives using their model: retirement adjuster (steady order influx, capacity is adjusted by retirements), order adjuster (steady

⁹⁰ Boeing’s 1998 Market Outlook.

retirements, capacity is adjusted by orders), dual adjuster (capacity is adjusted by both the orders and the retirements). Their effectiveness follows the order of presentation and suggests that the dual adjuster leads to overreaction and that stable ordering with good fleet stratification is the more efficient strategy.

Weil (1996)

The fourth SD application (first chronologically) on the airline industry is given in Weil (1996) and its basic structure is shown in Figure 8-8 which is based on a general model of market commoditization. The basic feedback loops are similar to those in the Liehr et al. and Lyneis models.

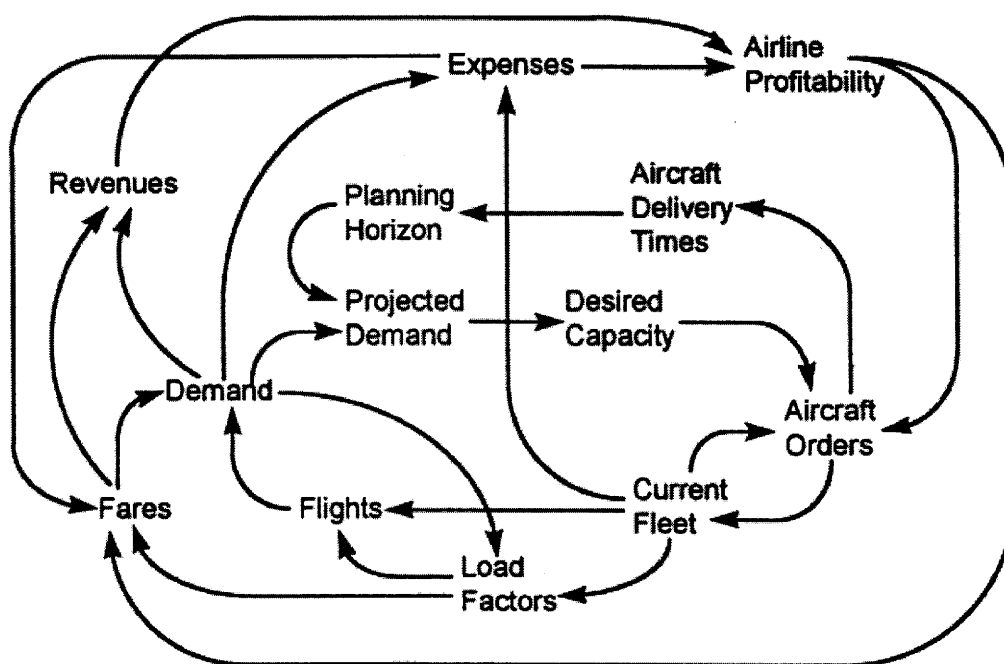


Figure 8-8 Commoditization model of the airline industry (Source: Weil 1996)

Weil concurs that the boom-bust cycles in the commercial aircraft industry are driven by the structure of the industry rather than external factors. With this model Weil aimed to respond to the following questions:

- What factors caused the peak of aircraft orders in 1988-1990 and the resulting excess capacity?
- Why did airline profits collapse?
- What was the role of market liberalization in this?
- Is the damage permanent, to what extent, and what are the mid-term recovery prospects?

Based on the generic industry model, Weil attributed the excess capacity to the following set of causes:

- Over-estimation of demand growth
- Amplification of planning and forecast errors
- Large and increasing number of players
- Lack of adequate financial constraints
- Market liberalization

The above causes do not act independently but in concert. Firstly, as the market matures, the price elasticity of the market increases as it expands and attracts more price-sensitive consumers. As the number of airlines increase – an aftereffect of deregulation – the potential for making errors are increased. This phenomenon extends to the leasing firms that also exhibit aggressive market share targets. Another aspect of new entrants is their relative reduced sensitivity to losses as these are ‘expected’ until they are established thus resulting in the projected demand overshoot. The combined effect of the excess orders from new entrants and legacy carriers is delayed because of the amplified delays in aircraft delivery. In ‘rational’ markets these problems would generate an aversion in investment to new entrants but this can be delayed or entirely absent when financial markets are in search for investment opportunities. This along with subsidization can delay exit of firms and the “normal industrial ecology” of consolidation and shake-out becomes less effective and creates an asymmetry of capacity creation versus destruction.

As a result of the above observations, Weil rightly predicted that the cycles “*will grow increasingly severe and irregular*” as commoditization spreads to other regional markets and that the long-term in the airline margins will be declining.

8.4 Choosing a methodology: combining strengths

8.4.1 Enterprise Modeling Alternative Comparisons

Having reviewed application of enterprise models in this and previous chapters, we summarize in this section their primary strengths and weaknesses.

Qualitative Empirical Narratives

<i>Strengths:</i>
Easy to understand, detailed, can be an interesting read.
<i>Weaknesses:</i>
No pattern necessarily emerges from the narration. Difficult to support normative predictions from past behavior. Causality is not rigorously demonstrated. While the human mind comprehends the details of each narrative moment, piecing them together is not easy especially when delays and complex causal loops exist; usually the narrators identify what they consider primary interaction.
<i>Uses:</i>

- familiarizing non-experts with the system,
- extracting input data,
- identifying plausible hypotheses for cause and effect relationships, and
- identifying major stakeholders / possible scenarios for modeling.

Theoretical Frameworks

Strengths:

Provides a structured way of perceiving commonalities across systems with seemingly disparate characteristics.

Weaknesses:

**In pursuit of generality, it may end being simplistic.
Needs more complex models to validate hypothesis.**

Uses:

- Identifying patterns.
- Constructing easier to internalize yet useful mental models.

Econometric Models

Strengths:

**Rigorous methodology.
Relatively quick to implement when the data are collected.
Data rich.**

Weaknesses:

**Needs significant amount of data for estimation and validation.
Little explanatory value.
Prone to bias intentional or unintentional.**

Uses:

- Excellent as input feed for specific non-critical functions of more complex models.

Game theory

Strengths:

Strategic tool. Simple to understand in its basic format.

Weaknesses:

Outcome valuation is arbitrary. Model structure is fairly abstract "simplifying away" potentially important parameters (e.g. the customers).

Uses:

- Decision-making tool when outcomes are evaluated and backed-up by other models.

System Dynamics Modeling

Strengths:

Explanatory power. Reflects to and refines mental models. Can be used both qualitatively (causal loop diagrams) and quantitatively. Inputs can simulate different scenarios. Emergence exists by shifting dominance across causal loops.

Weaknesses:

Rigidity of structure. Any room for system change or emergent needs to be hardwired in advance. Views system in aggregate so the impacts of individual behavior cannot be outlined easily.

Uses:

- Overview of complete enterprises or enterprise of enterprises.

Agent-based Modeling

<i>Strengths:</i>
Bottom-up creation of structure. Flexibility in allowing emergence. Individual agent behavior can be monitored and how it impacts the system. Ability to run in non-continuous timeframe. Intuitive appeal since socio-technical systems are influenced by discrete decisions (which SD aggregates in a continuum).
<i>Weaknesses:</i>
Explanatory power not as strong as SD as it relies in emergent behavior based on agent schemata.
<i>Uses:</i>
→ Need to verify hypotheses on agent behavior. Of interest when individual behavior may affect the system in emergent fashion.

The **qualitative/empirical narratives method** is very valuable in the initial understanding of the system and for collecting nuanced information out of disparate data sources. Having the information in this format, though, does not help in evaluating specific normative hypothesis regarding the system. In the best case, a mental model is built in the minds of the readers/analysts using this method but, if the model entails more than two or three causal/feedback loops, any attempts to follow it for more than one or two time steps would probably tax the reasoning capabilities of an average person.

Theoretical frameworks are based on simpler notions or comparisons that intend to identify common pattern rooted in the heart of different systems. Unlike the narratives, they offer an organizational lens to the researcher who then needs to perform the additional effort of finding whether the framework is actually conforming to the real system. In our case, Piepenbrock (2005) (see also Chapter 5) created an attractive framework that offers valuable insights which additional quantitative models can implement in quantitative fashion.

Statistical parametric (econometric) models are not ideal for our purpose because of their limited explanatory power. Lyneis (1999) compared the ability of econometric models to forecast the cyclicalities in demand for aircraft to an SD model. He tested the most promising econometric model⁹¹ across several proposed using retrodiction⁹² with the same inputs for the two methods and demonstrated how the ability to forecast breaks down after a few cycles even for the best fit regression model as compared to the SD model.

On the other hand, regressions are useful for modeling parts of the system which are not of direct interest to the researcher or otherwise would entail too much additional complexity in the modeling effort. Several researchers followed a hybrid use of statistical models and SD like Liehr et al. (2000) and Dikos (2004). Another example of synergy can be Bhadra's work discussed previously; his equations may be used in a more complex model to derive whether a wide-body or narrow body better fits a certain O-D

⁹¹ Incidentally this model uses the GDP lagged 2 years and the change in fuel price as explanatory variables.

⁹² Retrodiction is a modeling technique that uses a model to forecast past performance using limited historical data.

pair's characteristics. On the other hand, if the same result can be obtained by an algorithmic process (i.e. by examining the relative costs/seat mile, expected load factors, and type of destination airport) at low computational cost then this should be preferred and the results cross-checked for validity to the parametric equations.

In effect the question of methodology for quantitatively modeling the commercial aviation industry retaining explanatory power boils down to the two remaining methodologies: **SD** and **ABM**. As we saw in Section 8.3.8, at least five research projects adopted SD as the method of choice to study the cycle dynamics in commercial aviation.

This stated goal and the methodology used imply an unspoken assumption: the individual agents participating in the system (airlines in the case of Liehr et al. and aircraft manufacturers in the case of Lyneis) *do not greatly* influence the total system's behavior. If this assumption does not hold then system dynamics, with its aggregate system view may fail to recognize the importance of the change in behavior of an individual stakeholder or class of stakeholders. Supporting this notion, Lean Enterprise thinking submits that the environment *can* be changed by the actions of individual firms (Womack and Jones 1996).

8.4.2 Matching Project and Method

Before we proceed to argue the case for our purposes, it would be useful to review the characteristics of the SD and ABM modeling methodologies side by side in Table 8-2.

Table 8-2 Side-by-Side Comparison of system dynamics and agent-based modeling (Source: Scholl (2001) modified)

	System Dynamics	Agent-Based Modeling
Perspective	Top-down	Bottom-up
Main Building block	Causal loops	Agent entities
Unit of Analysis	System structure	Rules of agent behavior
Level of Modeling	Aggregate system behavior	Individual agent behavior
System Structure	Pre-determined	Evolvable
Time Handling	Continuous	Continuous or discrete

The main drawback that Schieritz and Grobler (1999) identify with SD when used to model supply chains is the rigidity of the structure that requires the hardwiring of every possible interaction. This becomes quite an undertaking if the number of possible partners goes above 2 or 3 for each stage of the chain. As a result, they propose use of ABM, where the agents' decision-making process ("schemata") is modeled to the classical SD archetype. This way the agents are allowed to switch back and forth between

suppliers based on their relative attractiveness; as the simulation progresses, a form of stable extended-enterprise emerges depending on the simulation parameters.

The issue of choice between two or more suppliers is very important in our case where the aircraft manufacturers offer similar, almost commoditized product lines and, as we have seen in Section 2 and will discuss in more detail later, decisions are affected by parameters that vary from spur-of-the-moment CEO decisions to heavy political influencing. Another consideration from our perspective is not only how the system as a whole performs but also how the individual stakeholders can affect it.

For example, airlines tend to have different characteristics with a more prominent one being the division between low-cost carriers (LCC) and legacy carriers. While LCCs tend to own a very homogeneous fleet, legacy carriers are operating many types of equipment. The fleet choice then becomes an individual problem that is hard to represent in aggregate with fidelity. Moreover, as Piepenbrock argues, the manufacturers have different organizational structures and modes of behavior which are again hard to replicate on an aggregate basis. Knowing whether the behavior of a few customers (airlines) or suppliers (manufacturers) can influence the system (e.g. dampen the cyclicity in the industry) is one of our stated objectives. For this reason we believe that some combination of agent-based methodology with system dynamics decision making is the more appropriate tool for our purposes.

From the system dynamics models presented in Section 9.3.8, it becomes apparent that airlines although differentiated do not have an adequate market power to affect the system. General transition trends e.g. increasing market shares of LCCs can be modeled successfully in aggregate. Airframe manufacturers, on the other hand, are concentrated and their decisions (agency) can significantly impact the system. This leads us towards a structure where the airline industry is represented in aggregate while the manufacturing part of the value chain is disaggregated into individual agents.

This does not mean that the other methodologies are less useful. On the contrary, as explained above and outlined in Table 8-3, they can be used for their respective strengths supporting, at different points, the model development.

To summarize, we expect that an ABM / SD hybrid model will provide the more useful insights when viewing the commercial aviation industry from an enterprise perspective. Eventually the model should help us in understanding:

- i. the nature of the boom/bust cycle in the industry
- ii. the impact of differentiated individual behavior of different agents both from the airline and the manufacturer side
- iii. the long term system evolution under different scenarios (although not intended for predictive use)

Table 8-3 Different system modeling methods and ways to use them during development

	Qualitative	Quantitative	Project Use
Narrative-based	√		Forming model structure. Forming agent rules.
Framework-based	√		Testing hypotheses generated by the Piepenbrock framework.
Econometrics		√	Using as inputs for certain functions (e.g. pricing estimates)
Game Theory	√	√	Forming agent schemata.
System Dynamics	√	√	Hybridize! Create dynamics structures
Agent-based		√	Use agents to differentiate in the behavior of primary actors. Primary system modeling methodology.

8.5 Chapter 8 Summary

Chapter 8 provided a review of the available modeling methodologies that could be utilized in developing appropriate and useful models in the context of Enterprise of Enterprises. From a theoretical review of the ideal properties of an EoE-focused model, we transitioned into reviewing specific examples of enterprise-related models but centered our attention on the models that had been developed for the commercial aviation enterprises.

In reviewing models for EoE, we found that there is no one single best modeling approach for the objectives of an EoE. Instead, a combined approach that draws from qualitative and quantitative research methods is advised. On the quantitative modeling side, system dynamics had several advantages but for our purposes, a model that combines agency attributes, that is it differentiates between the strategic choices of the two manufacturers would be desirable. In the following chapter we outline the structure of the proposed model that fits this description and discuss the validation and verification process used to support it.

Chapter 9 System Dynamics Model of the CA EoE

In Chapter 8, we saw that a number of researchers used system dynamics as the modeling methodology of choice for several enterprise-level and industry-wide applications. For commercial aviation specifically, a series of models using approximately similar structures were developed to study aspects of this industry.

In this chapter, we describe the basic structure and development process of the model we used for our investigation. Section 9.1 presents the basic model structure tying it back to our modeling objectives and Section 9.2 describes the verification and calibration procedure. The complete model is provided in html and executable formats at <http://lean.mit.edu/> in the Publications section.

9.1 CA EoE Model Presentation

9.1.1 Modeling objectives

As mentioned in Chapter 8, Forrester and Sterman underline the necessity of building a model around certain goals and judging it by how effectively these goals are met. Heeding their advice, this section presents the goals of the modeling effort in terms of the questions that we seek to answer. In order to identify the desirable characteristics of our model and the minimum necessary level of fidelity we will work backward from the primary objective to secondary requirements.

Referring back to the three questions introduced in Chapter 1, our objective was to answer the following:

- Q1. How is cyclicity manifested in commercial aviation? What are the impacts from cyclicity in commercial aviation?
- Q2. What are the salient causal mechanisms that induce the cyclical behavior in commercial aviation?
- Q3. What are implementable strategic alternatives for dampening that cyclicity and what are their benefits?

Q1 introduces the need for comparative measures in order to assess the relative benefits of strategic alternatives with regard to the effect of cycles to the various constituents of the CA EoE.

In order to develop acceptable performance measures for the CA EoE constituents we use the formulation first presented in Section 5.3 (see Table 5-3) and transcribe it quantitatively as shown in Table 9-1.

Table 9-1 CA EoE Constituent Value Functions

	Value function	Symbols
Passengers	$P_{VF} = \begin{cases} \max \sum_t \sum_i Q_{it} \\ \min \sum_t \sum_i D_{it} F_{it} (1+r_p)^t, \quad r_p = 0 \\ \min \frac{\sum_i D_{it}}{\sum_i Q_{it}}, \forall t \end{cases}$	
Carriers	$Car_{VF} = \begin{cases} \max \left(\sum_t \underbrace{(F_{it} D_{it} - C_{it} Q_{it})}_{EVA} \cdot (1+r_i)^t \right) \\ \min(std(EVA)) \\ \min(t, EVA < 0) \end{cases}$	t: unit of time i: carrier j: airframe manufacturer r: discount rate Q: Available Seat Kilometers (ASK) D: Realized demand in Revenue Passenger Kilometer (RPK) F: Yield (Revenue / RPK) C: Unit cost (Expenses/ASK)
Airframe Manuf.	$Mfg_{VF} = \begin{cases} \max \left(\sum_t (P_{jt} - CP_{jt}) QP_{jt} \cdot (1+r_j)^t \right) \\ \min(std(QP_{jt})) \end{cases}$	including cost of capital P _j : Manufacturer revenue per aircraft QP _j : Aircraft delivered CP _j : Production costs per aircraft including cost of capital
Government	$Gov_{VF} = \begin{cases} \sum_i Q_{it} > q_t, \forall \text{ domestic } i \\ \text{and} \\ \sum_j QP_{jt} > qp_t, \forall \text{ domestic } j \end{cases}$	
Capital Markets	$Cap_{VF} = \begin{cases} \max \left(\sum_t (F_{it} D_{it} - C_{it} Q_{it}) \cdot (1+r_m)^t + \sum_t (P_{jt} - CP_{jt}) QP_{jt} \cdot (1+r_m)^t \right) \\ \text{or} \\ \max((F_i D_i - C_i Q_i) + (P_j - CP_j) QP_j), \forall t \end{cases}$	

The value function formulations in Table 9-1, reflect the following intuitions:

- *Passengers and shippers* desire for the lowest fare prices but also higher levels of service. We use load factors as a proxy for service for reasons explained in Ch. 2.
- *Carriers* are interested in the highest profitability levels possible but also in a reduction in the volatility of returns and the time they are unprofitable. These desires also cover the expectations of their employees with the assumptions stated in Ch. 5 that the employees benefit from working in a stable and profitable industry.
- *Airframe manufacturers* are also interested in the long-term profitability and their employees in the reduction of the volatility of production rates.

- *Capital markets* (as a whole or assuming universal ownership) would be interested in higher total return from the CA EoE in its entirety or in a more short term perspective, to maximize return at any given time.
- Finally, *governments* would share the incentives of capital markets but also see their domestic industries meet some output targets. Employment targets are implicitly accounted for, as production and employment levels are closely correlated in both the airline and the aircraft manufacturing industry

It should be noted that the value functions for the constituents and stakeholders are independent of the modeling methodology chosen. They are given as an optimization objective functions but they

In order to adequately respond to Q2, the several causal mechanisms we identified in Ch. 7 will need to be present in the simulation model that we develop. Having these mechanisms in place means that the strategic alternatives designed to address them can be tested against each other and for potential synergies.

Additionally, based on the generic characteristics of a good model listed in Section 8.1, we would expect that our model is *predictive* and allows the spectrum of strategic alternatives that will be considered to span from continuation of the status-quo to alternatives that directly change the structure and hierarchy of the fundamental relationships in the system. Furthermore the model should be *complete* and *perceptible*, as the final recommendations would be intended for use by decision-makers in the private and governmental constituent enterprises. Therefore, it is important to use intuitive causal relationships that would be communicated with ease and understood by managers and executives to assist their acceptance.

In short, the desired model should

- (i) *exhibit cyclical behavior,*
- (ii) *adequately simulates the most important potential causal mechanisms that we have identified in Chapter 7*
- (iii) *allows for extensive experimentation with strategic alternatives that can structurally change the system, and*
- (iv) *uses intuitive relationships and has explanatory power to facilitate communication with the end users.*

Having these mechanisms in place can help us identify quantitatively what the apparent primary causes of the cycle are by deconstructing the relative contribution of each cause. Further the model should identify promising strategies, and facilitate the communication of results to decision-makers.

In theory an econometric model might be able to provide similar quality of information assuming that the tight correlations, time-lags, and of the explanatory variables can be sorted out successfully. However, an econometric model relies on observed data from the existing environment and assumes that the prevailing relationships of the explanatory variables persist into the future. It does not account for changing fundamental structures

and does not exhibit the causal mechanisms of the behavior it depicts. As a result it fails to meet characteristics (iii) and (iv) described above.

System dynamics instead provides a platform for analyzing the relative impact of causal relationships with the additional benefits of (i) allowing the testing of structurally different scenarios compared to the existing observations and (ii) providing a more intuitive causal relationship in the form of causal loop diagrams that can be used for communicating the fundamental model assumptions and gain stakeholder buy-in when required (see also Mostashari 2005).

9.1.2 System Dynamics CA EoE Model

In order to meet the requirements for completeness and parsimony, we had to strike a balance between what aspects of the EoE would be included in the model and how accurately they were represented. In this section, we present the model boundaries and general structure in Subsection 9.1.2.1 and the rest of the subsections are present specific key subclasses of the model.

9.1.2.1 General Model Structure

Following the structure used by Weil (1996) and Lyneis (2000), our SD model, on a general level, depicts the structure of the CA value chain with the core model constituted by three basic classes:

- Demand generation
- Airline competitive environment
- Airframe supply competitive environment

In addition to this basic structure that functions endogenously for the most part, exogenous influences like fuel prices, economic growth rates that are correlated to demand growth rates, and government regulations are modeled. In the model we use real prices instead of nominal ones so that no adjustments for inflations should be necessary as the model is executed over a period of decades. In the rest of this section, we will review specific parts of the model.

Figure 9-1, graphically presents the model boundaries using the representation of the CA EoE from Ch. 5, while Figure 9-2 shows the model structure, and Figure 9-3 the primary causal loops in a diagram using SD notation.

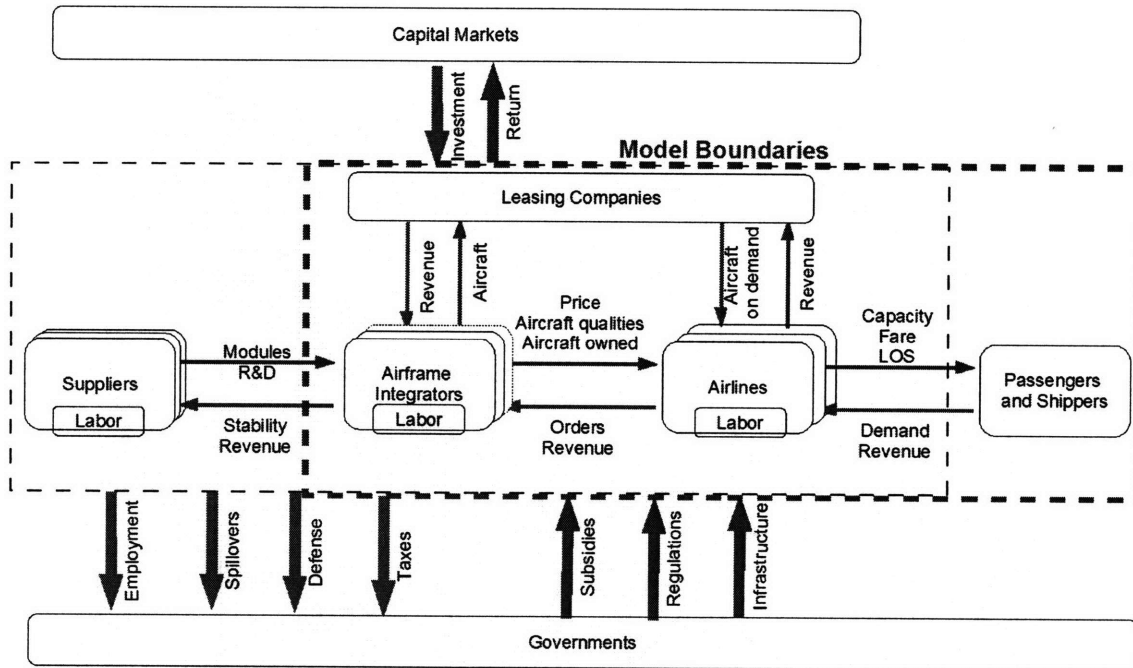


Figure 9-1 Graphical representation of the model boundaries within the CA EoE

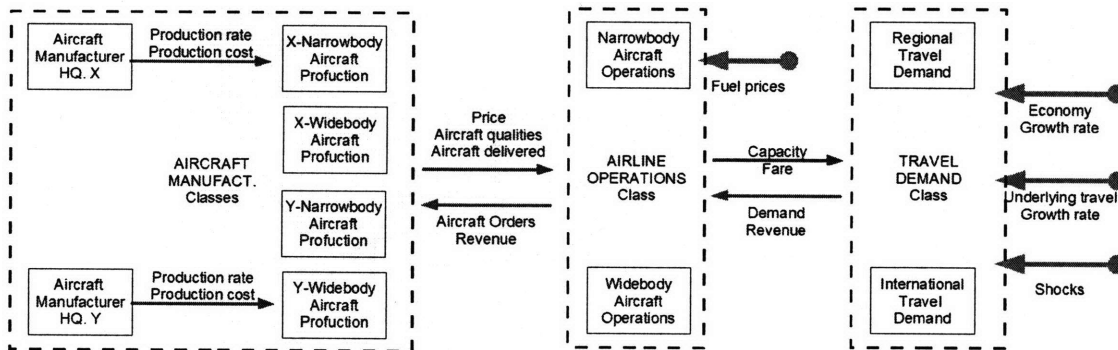


Figure 9-2 CA EoE Model Structure

In the subsections that follow, we present in greater detail each class, the interface variables and exogenous parameters, and the basic dynamics present.

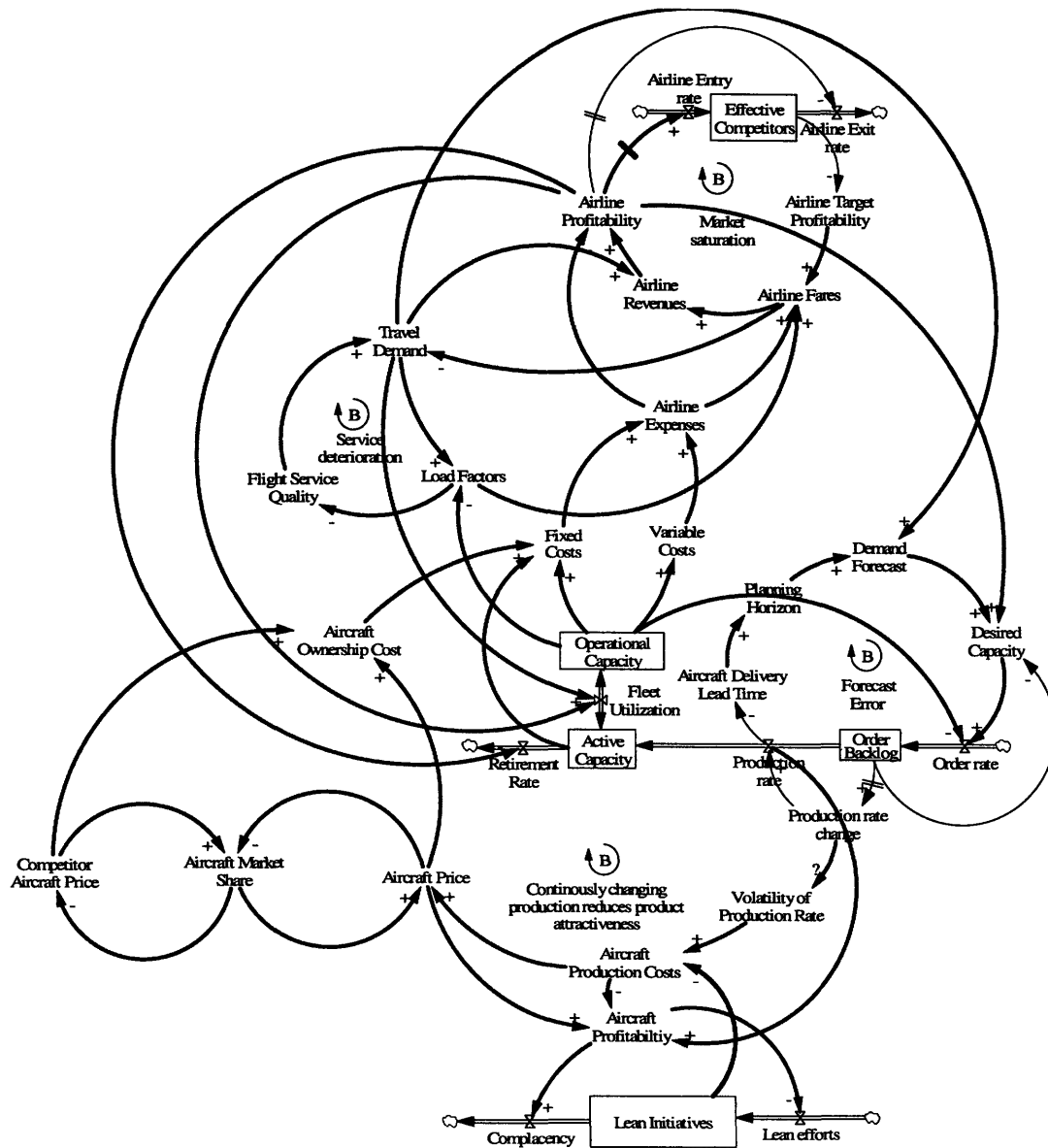


Figure 9-3 High-level causal loop diagram showing the major interactions of the CA EoE SD Model

9.1.2.2 Travel Demand Class

In the model, demand for air travel is considered to be global passenger demand. Air travel via commercial airlines uses the following general types of aircraft: widebody LCA, narrowbody LCA, and regional jets with approximately 100 seats or less. As we saw in Chapters 3 and 4, the norm is that widebody aircraft are used for long-range O-D markets and mid-range popular routes, narrowbodies for mid-range thin markets and short-range dense ones, and regional jets for short-range thin feeder routes. This distinction is in practice muddled with the development of long-range narrowbodies and high capacity RJs. As a result, we chose to distinguish between narrowbody / RJ demand and demand serviced primarily by widebody aircraft.

Demand is expressed in revenue passenger kilometer (RPK). Demand is dependent on GDP growth rate, average fare price in \$/RPK⁹³, and service quality which is in turn dependent on aircraft load factors and average delays. The consideration of price elasticity permits different types of responses to price changes to be modeled, a feature that allows us to emulate differences in the mix of passenger types given that business travelers are known on average to be more price-inelastic compared to leisure travelers (Ch. 2). Finally, demand is affected by external factors; conditions that reduce demand in ways not captured in their full effect by strictly economic factors like terrorist attacks, armed conflicts, or pandemics.

Of course, airlines do provide freight services using the cargo space of their aircraft. Freight revenues (along with other ancillary revenues described in Ch. 3) are part of total airline revenues.

The parameters that influence demand are shown in Fig. 9-4 using SD notation for labeling the interactions. For example, as discussed above, demand levels are negatively impacted by an increase in fare price or service quality and this is what the negative sign indicates next to the arrow. In these level diagrams we do not show the broader feedback loops that actually define model behavior but only the direct lower level causal relationships. In other words, the level of demand itself affects the level of fare price and the load factors and the delays encountered but we will discuss these higher order interactions as we progressively build the complete model.

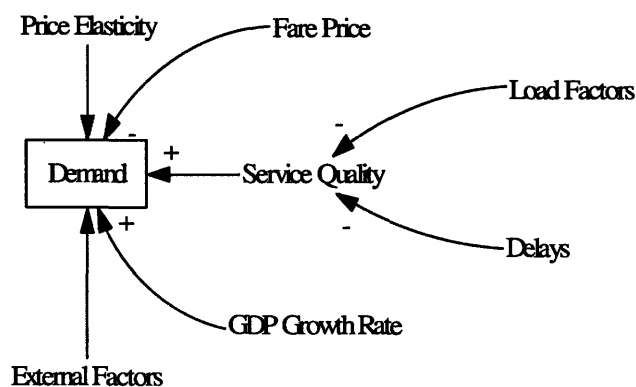


Figure 9-4 Structure of Demand Class

⁹³ For calibration, we used the total airline revenues divided by the total passenger miles to generate the fare price in \$/RPK. This means that we consider that passengers pay higher ticket prices that include freight and other ancillary revenues. By doing so, we avoid constructing an additional demand function for freight which in practice is tightly correlated to passenger demand while maintaining the correct level of total airline revenues. This design decision was justified because (i) passenger aircraft capacity and freight aircraft capacity for passenger airlines are directly correlated, (ii) the demand for freight services and the relevant revenues are a comparatively small portion of the total airline revenues (15%<), (iii) our objective was to correctly model the airline business cycle and the effect of a separate freight demand would be the same as that of a combined passenger/freight demand function so in the interest of parsimony we did not disaggregate it (also followed by Weil(1996) and Liehr(2002)). For other purposes, such disaggregation does not require substantial modifications.

Table 9-2 Input and Output Variables and Exogenous Parameters of Demand Class

	Units	Description	Type*
Input Variables			
Fare price	\$/RPK	The fare price as charged by the airline class	E
Service quality	Dimensionless	High load factors imply low service quality and vice versa (TF**)	E
GDP growth rate	Dimensionless	Rate of economic growth (TF**)	X
Price Elasticity	Dimensionless	Change of rate of demand growth based on the fare price change rate. (Range -0.4 to -1)	X
External factors	Dimensionless	Changes in demand for air travel not captured by economic activity (e.g. wars, pandemics, terrorism, etc) (TF**)	X
Output Variables			
Demand	RPK	The current level of demand for air travel	E

* E: Endogenous, X: eXogenous

** TF: Table Function. For details see App. I.

The key demand equation is further analyzed in Table 9-3.

Table 9-3 Demand Growth Rate Equation Analyzed

demand_growth_rate =	
(intercept +	Captures non modeled changes like population growth.
GDP_growth_rate * GDP_elasticity +	Captures the effect of economic activity. GDP_elasticity is a variable that moderates the impact of negative GDP growth rates because we observed historically that recessions have relatively less impact to demand growth rate compared to periods of economic growth
fare_price_change * price_elasticity (f(time and passenger mix)) *	Captures the effect of altering the price of airline tickets. Instead of using the absolute value of the fare, we use the relative change and a value of elasticity appropriate for the mix of passengers that may change over time
service_efct_on_demand (f (load_factor + fleet age))*	The effect that the level of service have on demand. Level of service is dependent on load factors, congestion, and average fleet age
external_efct_on_demand (f(time))	External effects

9.1.2.3 Airline Industry class

The airline industry is modeled in aggregate terms. The reason for this design decision is that on a global scale the airline industry is highly fragmented numbering approximately 50 significant airlines and many more smaller ones. As a result, the effect of their individual actions with regard to the global scale of the industry cycle is relatively small and response functions can be devised to successfully represent their aggregate impact as demonstrated by Weil (1996), Lyneis (2000, and Liehr (2002) (see Ch. 8). The key to

modeling the industry as a whole is the ability to present the prevalent type of competitive behavior which is in turn is also dependent on the level of consolidation.

Mirroring the functions in the real world, the airline industry in our model performs the following functions:

- Forecasts future demand,
- Orders aircraft to meet desired capacity
- Manages the utilization and retirements of existing capacity based on demand
- Sets and adjusts fare prices

We discuss each function below.

Demand Forecast Module

Demand forecast is done by extrapolation of the trend in past years. The forecast horizon is variable and equals to the average delivery time of new aircraft on the premise that this is the time that needs to be forecasted. This premise is parallel to the actual practice in which airlines are considered to normally have a two to three year long-term planning horizon.

The number of historic years used to calculate the trend and the moving average smoothing factor are also variable. The choice of their value represents long vs. short institutional memory with longer histories and higher smoothing factors characterizing a more consolidated industry while the opposite better represents a fragmented industry with a number of new entrants. The input and output variables for the demand forecast module with their corresponding equations are given in Table 9-4.

Table 9-4 Input and Output Variables and Exogenous Parameters of Demand Forecast Module of the Airline Class

	Units	Description	Type*
Input Variables			
Demand	RPK	The current level of demand for air travel	E
Forecast horizon	Years	Current delivery lead time for aircraft.	E
Extrapolation History	Years	Historic demand used as data to extrapolate demand growth trend. (Range: 1-6)	X
Target load factor	Dimensionless	Desired level of load factor. Depends on the competitive environment and operational advances like yield management and electronic distribution that allow increased load factors. (TF)	X
Output Variables			
Projected Demand	RPK	Forecast of the demand expected for the end of the forecast horizon	E
Desired Capacity	ASK	= Projected Demand / Target load factor	E

* E: Endogenous, X: exogenous, TF: Table Function

Capacity Ordering Module

Aircraft capacity is modeled in available seat-kilometers. New capacity is ordered based on forecasted demand adjusted by the desired load factor and from which the levels of existing capacity, planned retirements, and only a portion of the existing backlog are subtracted. The fact that the backlog is not subtracted represents the phenomenon of supply chain discounting referred to in Chapters 6 and 7. Lower levels of discounting may be used as a sign of industry consolidation but the current industry behavior is modeled quite well if supply chain discounting is 100%.

This desired additional capacity is adjusted by the relative profitability of the industry where profitable periods trigger relative overinvestment and unprofitable ones underinvestment [*profit_efct_on_orders*].

Orders are then allocated to the two manufacturers based on the relative profitability that their aircraft achieve, which in turn depends on manufacturer relative pricing, fuel consumption and non-fuel operating costs. Another criterion for allocating capacity is the relative difference in the lead times between manufacturers. Finally, the existence of inertia in ordering due to the operational efficiency advantage that an incumbent manufacturer has (see discussion on the vendor lock-in effect Ch. 4) can skew this allocation in favor of the dominant manufacturer and are represented by a network-effect adjustment variable. The input and output variables for the capacity ordering module with their corresponding equations are given in Table 9-5.

Capacity Management Module

Once aircraft capacity is received by the airline industry it ages but remains active until it is retired. This means that the secondary market for aircraft is not modeled as those aircraft that are sold by some airlines are retained and used by others until they are retired or sold to be converted to dedicated freighters (a class of aircraft that is outside our model's boundary). This choice is supported by Strandenes' (2002) characterization of the second hand market in shipping as secondary with no significant impact on transportation supply.

The decision to retire aircraft is based on the retirement age variable that starts with an initial value of 25 years (average aircraft life expectancy) and adapts based on profitability [*profit_efct_on_retirements*]. Similar to the policy described by Skinner et al. (1998) the retirement age adjusts upwards during profitable times and downwards during downcycles where capacity is typically shed. Retirement age can also be forced exogenously in order to simulate government regulation that forces older aircraft that do not meet the current standards on noise or emissions to retire. This effect is not drastic because: (i) regulations are introduced progressively and account for the social costs of replacing relatively new non-compliant aircraft, (ii) manufacturers and airlines try to anticipate the regulations by offering aircraft that meet them before they are actually enacted, and (iii) non-compliant aircraft are resold to regions that have not adopted the new standards.

Table 9-5 Input and Output Variables and Exogenous Parameters of Ordering Module of the Airline Class

	Units	Description	Type*
Input Variables			
Desired Capacity	ASK	Level of capacity as provided by the Forecast module	E
Current Active Capacity	ASK	Level of existing current capacity at average utilization	E
Order Backlog	ASK	Level of capacity that is in backlog or in production by the manufacturers	E
Supply chain visibility	Dimensionless	Percentage of the backlog "perceived" by the industry. (Range: 0%-100%)	X
Order smooth	Years	Aggressiveness in the order placement. They can be spread over more periods as means to reduce the risk of forecasting error. (Range 1-4)	X
Capacity Retirement rate	ASK/year	Current rate at which the capacity is being retired	E
Profit efct on orders	Dimensionless	Models "irrational exuberance" by increasing levels of orders in profitable periods and reducing them in unprofitable ones. (TF)	E
Service efct on orders	Dimensionless	When service levels deteriorate increases the pressure to order aircraft even if unprofitable. (TF)	E
Cancellation ratio	Dimensionless	Order rates are allowed to be negative to represent cancellations as permitted by the cancellation ratio. (0%-50%)	X
Relative profit efct	Dimensionless	Relative advantage of aircraft from the competing manufacturer in terms of ownership costs, fuel efficiency, and operating costs. (TF)	E
Relative lead time efct.	Dimensionless	Relative advantage of aircraft from the competing manufacturer in terms of delivery lead time. (TF)	E
Vendor lock-in efct	Dimensionless	Relative advantage of aircraft from the competing manufacturer in terms of legacy operational efficiency (can also reflect commonality). (TF)	E
Output Variables			
Order rate	ASK/year	$= (\text{DesiredCapacity} - \text{CurrentCapacity} - \text{OrderBacklog} * \text{SCvisibility}) / \text{OrderSmooth} - \text{CapacityRetirementRate}$	E
Order rate to Mf X	ASK/year	$= \text{OrderRate} * \text{Rel.Profit.Efct} * \text{Rel.LeadTime.Efct} * \text{Vendor.Lock-in.Efct} * \text{ProfitEfctOnOrders(X)} * \text{ServiceEfctOnOrders}$	E
Order rate to Mf Y	ASK/year	$(\text{OrderRate} - \text{OrderRateMfX}) * \text{ProfitEfctOnOrders(Y)} * \text{ServiceEfctOnOrders}$	E

* E: Endogenous, X: eXogenous

Capacity is measured in available seat-kilometers which depends on aircraft utilization (hours flown) along with the number of aircraft. This implies that there is limited flexibility to increase or decrease available capacity at any given time simply by increasing or decreasing the hours of aircraft usage before actually having to retire it. Using this parameter addresses the distinction between operating and active capacity as discussed in Ch. 4 and allows us to reconcile, for calibration purposes, the capacity data as reported by the airlines that include only flights actually flown and not those that would be possible for a given fleet size. As aircraft are expensive assets, airlines try to utilize them to their maximum potential and as a result the range of utilization flexibility is rather small in practice.

Total operational capacity can be constrained by the capacity of the infrastructure, if such an influence is desired, by modeling the effect that such a constraint has on service. The input and output variables for the capacity management module with their corresponding equations are given in Table 9-6.

Table 9-6 Input and Output Variables and Exogenous Parameters of the Capacity Management Module of the Airline Class

	Units	Description	Type*
Input Variables			
Current Active Capacity	ASK	Level of existing current capacity at average utilization	E
Operational Capacity Adjustment	Dimensionless	Flexibility to increase or decrease active capacity depending on competitive conditions and extent of flexible leases. (TF)	X
Normal retirement age	Years	Average aircraft lifecycle in airline operations. It can be lowered to simulate regulatory interventions. (Range 20-30)	X
Profit effect on retirements	Years	Aircraft are retained longer during profitable periods and retired earlier during unprofitable ones. (TF)	X
Output Variables			
Operational capacity	ASK/year	= CurrentCapacity * OperationalCapacityAdjustment	E
Capacity Retirement rate	ASK/year	= CurrentCapacity / (NormalRetirementAge * ProfitEffectOnRetirements)	E

* E: Endogenous, X: exogenous

Finance Module: Costs

The costs incurred by airlines are divided into:

- Capital costs (aircraft ownership/leasing costs)
- Operating Costs
 - Fuel costs
 - Non-fuel operating costs (includes all other costs e.g., crew, administrative, airport fees etc)

This allocation partially matches the ones used in the industry (Ch. 3) as it separates capital ownership costs and fuel costs (of direct interest to our purposes) and lumps together other expenses like crew costs, administrative, maintenance etc. The reasoning for this is that changes and innovations on other operating costs may give a temporary competitive advantage to a given airline but they are quickly adopted industry-wide. In fact, as we shall see when mapping conceptual strategic alternatives to the model (Ch. 11) we investigate the effect of flexibility in crew compensation – what is known as profit-sharing programs – by adjusting a percentage of the operating costs.

Fuel costs and other operating costs are given in \$/RPK and are defined exogenously using a historic price database and prices based on scenarios for the future years. Prices for fuel use the actual fluctuations in real jet fuel prices. Operating costs monitor the process advances of LCCs that allow for significantly reduced cost of operations per seat mile when adjusted for distance.

Table 9-7 Input and Output Variables and Exogenous Parameters of the Cost Module of the Airline Class

	Units	Description	Type*
Input Variables			
Aircraft Ownership Cost	\$/ASK	The price of ownership for aircraft capacity as annual lease. It is based on the "aircraft price" at which it is sold by manufacturers and depreciates as capacity ages	E
Capacity depreciation	Dimensionless	The reduction in the "rent" cost of capacity of an aircraft as it ages. Set at 12% per year of age from original price.	X
Fleet fuel efficiency	\$/ASK	Specific fuel consumption per ASK at the time of aircraft sale. Specified by manufacturers. (TF)	X
Operating cost	\$/RPK	Cost of operations. Depends on the ability of airlines to improve their operating efficiency. (TF)	X
Output Variables			
Ownership Expenses	\$	= AircraftOwnershipCost * CurrentActiveCapacity	E
Fuel Expenses	\$	= FleetFuelEfficiency * CurrentOperationalCapacity	E
Operating Expenses	\$	= Operating Costs * CurrentDemand	E
Total Expenses	\$	= OwnershipExpenses + FuelExpenses + OperatingExpenses	E
Unit Costs	\$/RPK	= TotalExpenses / Demand	E

* E: Endogenous, X: exogenous

Capacity costs are endogenously generated based on the prices charged by the manufacturers allocated over the lifetime of the aircraft (in effect a rental charge). The total expenses are calculated by multiplying this charge with the total active capacity. In order to simulate the added flexibility of leasing, we use a ratio of capacity that is paid per RPK (actual demand) to represent the economics of a leased fleet. The input and

output variables for the capacity cost module with their corresponding equations are given in Table 9-7.

Finance Module: Revenues, Airline competition and Fare Price Setting

The airline industry's revenues are calculated similarly to costs: i.e. by multiplying the total demand by the current fare price. The estimation of the current fare price is the critical aspect here as it is an endogenous process influenced by a number of parameters and instrumental for the representation of the competitive status of the airline industry.

It starts with a fairly basic cost plus model in which the per passenger mile costs calculated previously are adjusted by the profitability expectations [target_profitability], the load factor expectations [loading_efct_on_price] and the reality of current profit margins [profit_efct_on_price].

The target profitability is defined exogenously to represent the different stages in the competitive situation in the industry. As we discussed in Ch. 3, a large number of new entrants tend to compress profit margins with the expectations of increasing their market share and future profitability while a more consolidated industry has the ability to reach for higher profit margins.

The model allows for two ways of adjusting target profitability: either by exogenously defining the level of competition as represented by the [target-profitability] variable using a table function or by internally adjusting the level of competition based on the relative profitability of the airline industry. In this case, competitor entrance increases the level of competitive behavior simulated by a stock [effective_competitors] while their exit decreases it. The value of [effective_competitors] is then translated to [target_profitability] using a table function. The endogenous market dynamics are also shown graphically in Fig. 9-5.

Table 9-8 Input and Output Variables and Exogenous Parameters of the Revenue and Competition Module of the Airline Class

	Units	Description	Type*
Input Variables			
Unit Costs	\$/RPK	Costs per unit of demand	E
Loading Effect on Price	Dimensionless	Effect that load factors have on fare price (TF)	X
Profit Effect on Price	Dimensionless	Effect that profitability has on fare price (TF)	X
Target Profitability	Dimensionless	Desired level of profitability. Depends on competitive status of the airline industry.	X or E
Output Variables			
Fare Price	\$ / RPK	$= [\text{UnitCosts} / (1 + \text{TargetProfitability})] * \text{LoadingEfctOnPrice} * \text{ProfitEfctOnPrice}$	E
Revenues	\$	Demand * FarePrice	E
Profits	\$	Revenues - Expenses	E

* E: Endogenous, X: exogenous

The target load factor is also defined and it allows for operational improvements made through the extensive use of yield management practices and optimization algorithms and of a competitive environment that suppresses prices with the widespread entry of low-cost carriers that can push their load factors upwards (see Ch. 3). When the target load factor is not met, the price will tend to increase and correct this imbalance and vice versa.

This tendency needs to be balanced in order to prevent the airline industry module from falling into protracted loss inducing periods. Profitability effect on price plays that balancing role by pushing the price upwards when the industry is unprofitable. The input and output variables for the revenue and competition module with their corresponding equations are given in Table 9-8.

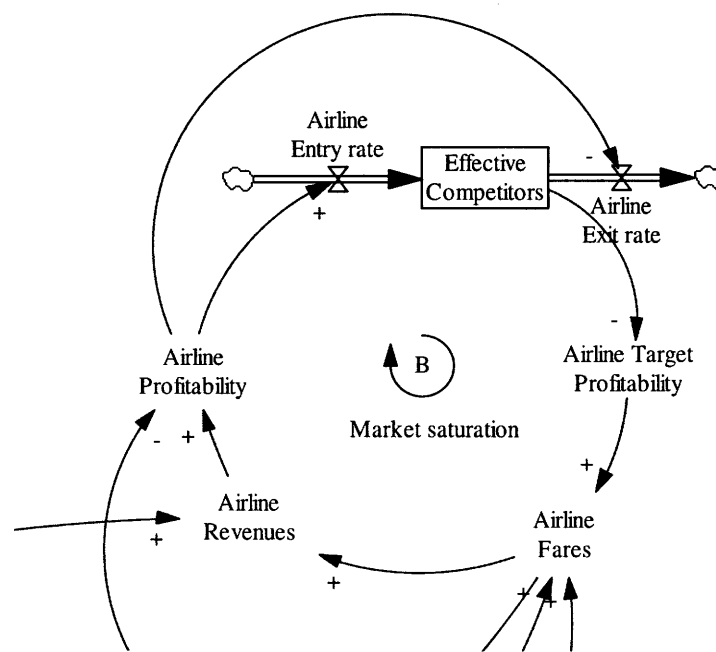


Figure 9-5: Airline entry and exit dependent on profitability

9.1.3 Airframe Manufacturers Class

As noted previously, airframe manufacturers are modeled as a duopoly with manufacturers competing using different strategies. Domination of the market by one manufacturer can be modeled but the emergence of a third player can only be modeled exogenously by reallocating the revenues and costs of the equivalent market share from the two modeled manufacturers.

Each manufacturer:

- Plans for and allocates production capacity based on demand to the production lines of each market segment (narrowbody and widebody)
- Produces and delivers the ordered aircraft
- Sets the price at which the aircraft are sold and their technical characteristics (fuel consumption)

Production Module

Production capacity adjusts to the demand fluctuations but in a delayed fashion and come at a cost that simulates the inertia of the supply chain and the investment or additional employee compensation⁹⁴ required to ramp productions rates up or down respectively. Constant production rates allow for reduction in base unit costs do simulate the learning curve. When production rates have to increase drastically to catch up with demand, expenses include employee hiring and training, building of new facilities, and coordination of suppliers which cumulatively increase production unit costs (as discussed in Ch. 4). Similarly, when capacity is drastically reduced, there are costs involved that resemble “forgetting”; production unit costs are pushed upwards due to the fire cycle from the need to provide severance packages to the loss experience.

Table 9-9 Input and Output Variables and Exogenous Parameters of the Production Module of the Airframe Manufacturer Class

	Units	Description	Type*
Input Variables			
Order rate of MF	ASK/year	The level of orders received by a manufacturer	E
Target Backlog	Years	Years of backlog targeted by a manufacturer	X
Production Smooth	Dimensionless	Aggressiveness in the change of production. Production adjustments can be spread over more periods as means to reduce the risk of forecasting error. (Range 1-6)	X
Base Unit Cost	\$/ASK	Base costs of aircraft production. Increasing due to complexity and technology. (TF)	X
Lean Efforts	Dimensionless	Number of lean efforts attempted	X
Cost of Production Adjustments	Dimensionless	Rewards steady production rates but penalizes drastic increases and reductions. (TF)	X
Output Variables			
Order Backlog	ASK	= OrderRate - ProductionRate	E
Desired Production Rate	ASK/year	= OrderBacklog / TargetBacklog	E
LeanAdjustment	Dimensionless	= LeanEffortSuccess - LeanEffortForgetting	
Production Rate	ASK / year	= ProductionRate + (DesiredProductionRate - ProductionRate) / ProductionSmooth	E
Production Unit Cost	\$ / ASK	= BaseUnitCost * CostOfProductionAdjustment (ProductionRateChange / ProfuctionRate) * LeanAdjustment	E

* E: Endogenous, X: eXogenous

Production itself requires a given minimum time once the order is received. When orders are received at higher rates than the production then an order backlog accumulates. Production rates are adjusted in order to maintain that order backlog at the desired level.

⁹⁴ From overtime and hiring.

Another way available to manufacturers to reduce their production unit costs is lean manufacturing (see Ch. 4). There are three aspects of lean manufacturing that are available as options:

- Reduced production lead times (production time needed from the start of an aircraft construction to its delivery)
- Reduced production rate change costs (ability to switch production lines easily and adjust capacity based on demand)
- Reduced base unit production costs. The latter are balanced by the level of lean initiatives as shown in Table 9-9 and Figure 9-6. The feedback of increasing complacency when profitability targets are met can be adjusted.

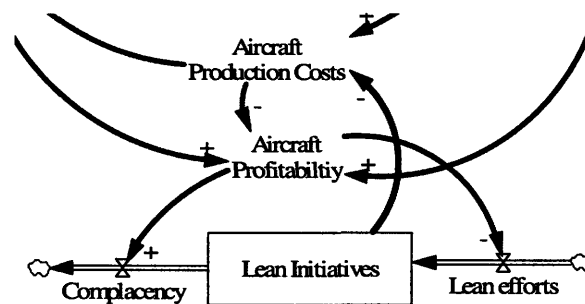


Figure 9-6 Lean Initiatives for the Airframe Manufacturers Production Module

While lean manufacturing had been proven successful when applied to mass production – applying it to the specialized production of LCA requires strong leadership to guide through a period of adaptation and experimentation. State-of-the-art lean manufacturing involves just-in-time (JIT) pull production with substantially lower unit costs compared to traditional mass production. While applying it to aircraft manufacturing is a huge challenge, we considered it as an option for production management. It depends on the level of commitment for applying it and directly impacts production unit costs. The input and output variables for the production module with their corresponding equations are given in Table 9-9.

Finance Module

Similar to airlines, manufacturers base their prices on a cost plus model which is in turn modulated by several factors. The base costs are defined exogenously to reflect the increase in R&D and manufacturing costs due to the increasing complexity and advanced material technology is required to achieve the performance of modern LCA. This base cost curve is considered common for both manufacturers. Using this and a level of target profitability the “list price” is calculated. The list price is then discounted to the “real price” in order to meet market share and/or production targets that are defined by the competitive strategy of each manufacturer. Revenues are then calculated based on the capacity delivered in real prices.

The real costs of production depend upon the rate of production rate adjustments (that are intended to include the learning/forgetting dynamic of the hiring/firing cycle). made as well as can be exogenously defined to simulate differences that like large scale technical

missteps if necessary (e.g., the recent Airbus A380 wiring problems that ballooned the R&D budget by an additional estimated \$2B).

Table 9-10 Input and Output Variables and Exogenous Parameters of the Finance Module of the Airframe Manufacturer Class

	Units	Description	Type*
Input Variables			
Production Unit Costs	\$/ASK	Real production unit costs that vary based on production rate changes and the learning effect.	E
Base unit costs	\$/ASK	Base costs of aircraft production. Define the "list" price. Increasing due to complexity and technology. (TF)	X
Target Market Share	Dimensionless	Desired share of annual airline aircraft orders.	X
Market Share	Dimensionless	= OrderRateMfX / OrderRateMfY	E
Market share Effect on Price	Dimensionless	Level of price discount based on the difference between current order market share and target market share. If market share is low, then prices are lowered and vice versa. (TF)	X
Target Backlog	Years	Years of backlog targeted by a manufacturer	X
Demand Effect On Price	Dimensionless	Level of price discount based on the difference between current production rates and backlog. If backlog is depleting fast, then prices are raised and vice versa. (TF)	
Profitability Effect on Price	Dimensionless	The effect that profitability exerts on price levels. Low profitability tends to increase the real price but the effect is relatively weak given that manufacturers can rely on subsidies and other business unit diversification (defense) for support. (TF).	X
Target Profitability	Dimensionless	Desired level of profitability for manufacturers. Set at 10%.	X
Output Variables			
Price	\$/ASK	= [BaseUnitCost / (1 + TargetProfitability)] * DemandEfctOnPrice * MarketShareEfctOnPrice	E
Revenues	\$	=ProductionRate * Price	E
Expenses	\$	= ProductionRate * ProductionUnitCosts	E
Profits	\$	Revenues - Expenses	E

* E: Endogenous, X: eXogenous

The competitive strategies for the manufacturers are focused on producing the right product, at the right price, at the right time. As we saw in Ch. 4, an aircraft from one manufacturer can be more competitive than the equivalent offering of the other based on:

- (i) list and discounted price tag,
- (ii) performance,
- (iii) lifecycle operating costs,
- (iv) availability, or
- (v) politics.

In the way that we executed this model we assumed that only prices (i) differ on average between rival fleets. It is possible to execute strategies where the difference is performance, which was tried by McConnell (2007) using a very similar model. Prices (and profitability) are impacted by production rates and lean efforts. The specific strategic alternatives that we considered in our experiments are discussed in Section 10.4. The input and output variables for the production module with their corresponding equations are given in Table 9-10.

9.2 Calibration Verification and Validation in the Literature and application in CA EoE Model

9.2.1 Calibration Verification Validation of System Dynamic Models (Literature Review)

As we saw in Section 8.1, Law and Kelton identified three steps in completing a model: validation, verification and accreditation, and we noted that the SD view of these phases is that it is not a two state process (Sterman 2004): that is, a model does not become valid from invalid but it is rather an iterative process that increases the confidence in the validity of the model.

Having said that, there are two schools of thought with regard to SD modeling:

- *Classical (Educational)*: this approach favors purposefully simple and intuitive model structures that can create fairly complex outcomes. Accreditation (that is buy-in from the users) is an educational process of the user in the behavior of the simple structures and their ability to convey fundamental aspects of the problem despite imperfect tracking of the key parameters. The outcome of the model although not accurate, is robust enough to be used for policy making purposes (Radzicki (2004), Graham (1980)). The parameter estimation in this approach is made outside the model – established entirely empirically. These models are quite robust to parameter fluctuation and therefore exact estimation is not necessary.
- *Statistical (Forecasting)*: By contrast, practitioners of this approach strive to generate very detailed and complex models in order to achieve both more accurate forecasting value and buy-in by correctly tracking key parameters of the system. This approach was partly propelled as a response to criticism of major SD models like the World Dynamics model (Forrester 1971) (e.g., Nordhaus (1973)) and involved statistical and econometric tools for parameter estimation and validation. Peterson (1980) (p. 226) discusses statistical tools for calculating parameter values and specifically the FIMLOF (full information maximum likelihood via optimal filtering) method.

Hand calibration is a middle road between the two schools that combines some of their strengths and can be used when data are hard to obtain. Lyneis and Pugh (1996) (p1-2) (referenced by Radzicki (2004)) rebut criticisms of hand calibration by conducting an experiment to compare the relative effectiveness of the two methods. With regards to

ease of replication and rigorousness, they found that “[h]and calibration works, and is less of an art and more replicable than might be expected. Moreover, it produces results which are as close to the true values as automated calibration, and typically are close enough to make no significant difference to the outcome of policy interventions.”

As discussed in the next section, in our model we used a combination of the above approaches by using econometrics where applicable along with hand calibration of variables based on intuition of the basic system behavior. For our purposes the attractiveness of hand calibration for some variables was motivated by the difficulty in obtaining historic values.

Sterman (2004, pp. 859-861 and remaining chapter) summarizes a large number of assessment tests for SD models proposed from various sources and expands on their use. In the next section we apply the tests that are pertinent to our modeling needs to support the model validation process.

9.2.2 CA EoE Model Verification

As we saw in Section 8.1, verification is an iterative process. The first part of verification was constructing the model based on the mental model of how the various enterprises as model subsystems interact that was facilitated by the EoE framework. A part of the model (the airline and demand modules) employed structures utilized by previous researchers (Weil (1996) and Lyneis (2000)) which gives added weight to the conceptual acceptance of the structures used.

Boundary adequacy and *structure assessment* are test areas proposed by Sterman (2004) that are pertinent to verification. These were addressed in the discussion of Section 9.1.2 using boundary tables.

As part of the development process, the model was run multiple times in different computers and using different integration methods and time steps without significant changes in outputs but some integration methods failed to execute due to incompatibility with some of the functions used. The current choice of integration methods and time-step was made for computational speed.

Finally, the equations used were checked for dimensional consistency and each subsystem was checked for performing according to expectations.

9.2.3 CA EoE Model parameter calibration

The second step of the modeling process was the definition of values for the numerous parameters of the model as it was being built. This was approached sequentially:

- establishing correlation,
- defining a basic reasonable value, and
- adjusting it to match the selected key parameters with the historical data used for calibration.

When dealing with entire subsystems (modules) and in an effort to match the historical data we used the following procedure:

- Initial estimation of parameters of the module,
- Separating the module and feeding historical data,
- Calibrating to historic data
- Reconnecting the module to the complete model

The key parameters used for calibration were:⁹⁵

- Airline total demand, operating capacity, and load factors
- Airline revenues, costs, and profit margins
- Airline orders and manufacturer backlog (aircraft delivery lead times are captured with backlog)

Due to the strong feedback loops involved, this was an iterative process. It consisted of isolating components and establishing that they perform as expected independently using the relevant historic data as inputs and then reconnecting all the modules to verify that the rest of the model performed as expected.

The values of all the parameters are given in the electronic attachment of the model (available in html and executable format at <http://lean.mit.edu/> in the Publications section) but in this section we will present an example of how the calibration process proceeded, discuss the values of key parameters, and present the graphics used for the final verification. In the example all variable calibration methods are discussed from econometric, to data fit, to intuitive estimation and existing literature.

Initialization

We calibrated the model using 1984 as the starting year. By 1984 the following structural aspects of the industry were in the process of being established:

- airline deregulation in the US market was well under way,
- LCCs were introduced and growing (Southwest, People Express etc)
- Yield management systems started to grow
- Airbus had carved a niche for itself in widebody aircraft and was about to introduce its narrowbody family.

In these ways, the structure of the industry approximated the current environment and for this reason mid-eighties is a good starting point for the system dynamic model as it gives ample historical data for further calibration and does not have to account for big differences in industry structure.

Example of the Calibration Process: calibrating the demand subsystem class

From the discussion in Ch. 2 we have seen that we expect demand for air travel to depend on:

- economic output,
- population growth,

⁹⁵ Load factors, airline profit margins, and manufacturer backlog are second order effects

- fare price
- external events, and
- service quality

And this is the structure we used as discussed in Section 10.1.2.1 with the exception of population growth which we captured by using a constant in the growth rate equation.

Box 9-1 Testing demand and its input factors with regression

Simple model of demand:

$$Dr = b1 * GDP_r + b2 * YIE + b3 * Wd + a$$

Dr: Demand annual growth rate

GDP_r: GDP annual growth rate

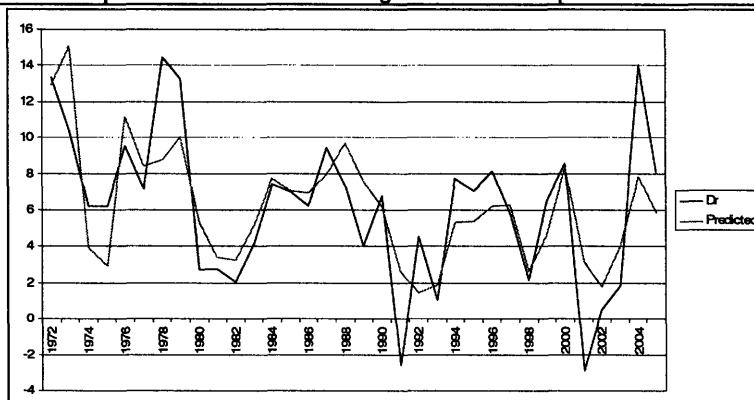
YIE: Average airline yield in \$/RPK

Wd: Dummy indicating external effects on aviation (1 for the years 1973 (Yom-kippur war and terrorist attacks involving aircraft, 1988 (Lockerbie largest terrorist attack involving aircraft), 1990-1 (First Gulf war), 2001-2 (9/11 terrorist attacks, War in Afghanistan))

The results from an ordinary least squares (OLS) regression using data spanning 1971-2004 are shown below:

	Coefficients	Standard Error	t Stat	P-value
Intercept	2.33648	3.387256	0.689786	0.495631
GDP _r *	2.212452	0.524759	4.216126	0.00021
YIE	-29.6423	24.13605	-1.22814	0.228945
Wd	-1.2232	1.493174	-0.8192	0.419135
Adjusted R ² : 0.53				

Only the GDP effect is shown to be statistically significant (at the 5% level) but the yield and the external effect factors have the right signs while the intercept is positive indicating a constant increasing trend. The predicted with the above equation vs. actual demand growth rates are plotted below.



Testing for economic output and fare price and leaving the population growth to be considered in the intercept, we run a simple OLS to verify this model, the results of which are shown in Box 9-1. These results are indicative that the factors we identified are correct. We did not test for the effect of service levels as their effect would only be seen

in spillover demand of which we do not have direct aggregate data. Nevertheless we would still like to have that feedback mechanism influencing the demand because first it is intuitive and second potentially useful when it comes to extreme levels of congestion which are not experienced by the historic system.

Having tested the relevance of the factors we considered with regard to estimating the demand growth, we test and see what values would resemble the historic data as output. To do this, we use, when available, historical data as inputs and calibrate the value of the parameters in the function at hand.

To make this process clearer, we return to our example. The equation of the demand growth rate variable is structured as shown in Table 9-3.

In this function the variables that are endogenous and generated in other parts of the model are `fare_price_change` and `load_factors`. These we can substitute with historical values and subsequently adjust the other variables so as to match the known historical demand as an output.

In order to initialize the unknown parameters we use best guess estimations from available data:

- For example as starting point value for the intercept we used 0.023 based on the coefficient from the regression in Box 9-1.
- For the price elasticity values we use estimates in the literature that were presented in Chapter 2 (see Figure 2-7) based on two meta-studies that compiled price elasticity estimations for air travel. We choose a number close to the average between business and leisure passengers for the elasticity of international and short-haul travel which gives us -0.45 for widebody and -0.9 for narrowbody.
- For the external `efct_on_demand` we construct a table that attempts to capture events that would not be adequately captured in the economic metric (see Fig. 9-6 and also Box 9-1). Notice that the effects span two years and precede the event because a smoothing function is applied to avoid the appearance of jugged lines in the output diagrams which is cosmetic rather than functional as the model is robust to abrupt trend changes.
- Finally, the `service_efct_on_demand` is a variable that associates the potential negative effect that increased load factors and overly aging fleets with their associated negative safety implications have on demand. This factor can also capture the effect that external constraints on capacity (i.e. infrastructure) would have as they would force the use of higher load factors given that additional flights could not be added in a congested system despite the desire to do so. This is constructed based on the intuition that people find the inconvenience of congested aircraft, delays, and overbooking as deterrent to travel and choose either to not travel for long-range flights or chose an alternative mode for shorter range ones. Based on this the concave shape of the variable, shown in Fig. 9-7, makes intuitive sense as the level of discomfort increases disproportionately to the load factor (i.e. a passenger in a 55% loaded plane would find little if any difference to a 65% one but the difference would become significant for an 80%

loaded one. In constructing this shape, we also took into account the fact that it is an average value which implies that the number of 95% load factor flights is much higher in a system with average load factors of 80% as opposed to one with 65%).⁹⁶

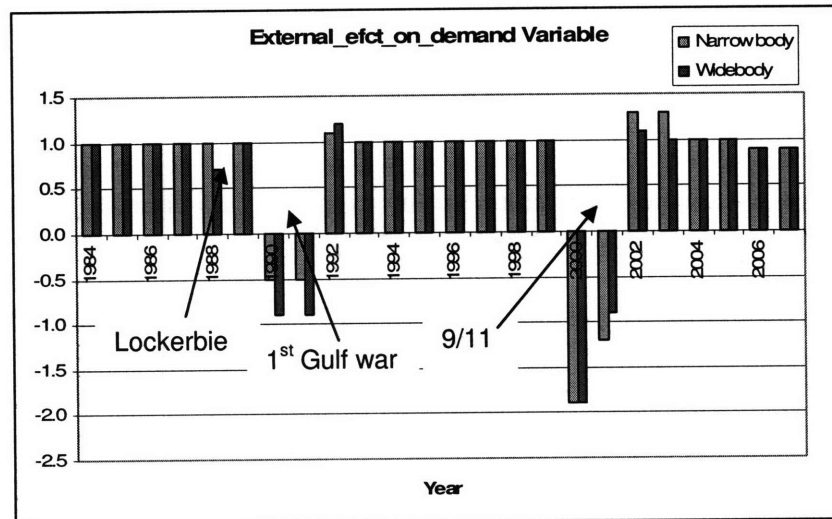


Figure 9-7 Values for the external_efct_on_demand variable in the demand modules

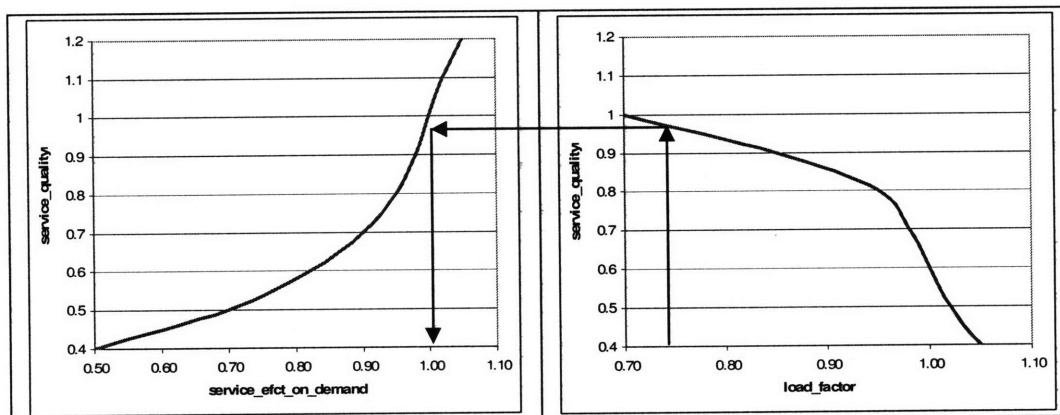


Figure 9-8 Calculation of the service_efct_of_demand variable based on load_factor assuming that the average fleet age is 10 years

Using these values as initial estimates and historical data as inputs, we performed multiple runs micro-adjusting them to achieve a close match between historical and modeled output.

This process was repeated for the other modules and several more times after connecting them together to adjust the endogenous dynamics and the differences that the slight changes in the values created. The resulting graphs were compared to historical data among other calibration techniques as discussed in the next section.

⁹⁶ These values were initialized based on Weil (1996) model and later slightly adjusted to reflect differences between widebody and narrow body trip types.

9.2.4 Validation of the CA EoE Model

Having discussed verification and calibration, this sector presents the validation procedures for the CA EoE model. Below are some assessment tests/questions suggested by Sterman (2004) (pg. 852) that have not been discussed previously and are relatively straight forward:

- *Structure assessment*
 - *Does the model adhere to physical laws?* the model contains no stocks like aircraft ordered or the aircraft production backlog that are allowed to have negative value. Similarly, load factors are not allowed to exceed 100%.
- *Parameter assessment –*
 - *Are there “fudge” factors?* The model does not have any parameters with no real world counterpart. There are cases where that relationship may not be straightforward like functions where the exact values are unknown (e.g. the load factor – service quality relationship in Fig. 9-8b) or the value of parameters that exist but represent non-measurable quantities (e.g. target profitability for airlines and airframe manufacturers). But in these cases there *is* a relationship represented which if not taken into account would be implicitly disregarded.
 - *Are the parameters consistent with the knowledge of the system?* The calibration process described in Section 10.2.3 explored this by isolating each model subsystem.
- *Extreme conditions and sensitivity*
 - *Does the model respond plausibly when subjected to extreme policies, shocks and parameters?* A large number of experiments were conducted using a varying number of sometimes extreme policies. The areas where the model is robust to these events and where it is not are addressed in Chapter 10.
- *Behavior reproduction*
 - *Does the model reproduce the behavior of interest in the system? Endogenously?*
 - *Does the model generate the problems that motivated the study?*
 - *Does it match the frequency and phase of variables match historic data?*

These questions need a more extensive treatment and are answered in the following Sub-section 10.2.4.1.

9.2.4.1 Behavior reproduction tests

This is a series of statistical and observation tests in which the parameters used for calibration as presented in the beginning of Section 10.2.3 are presented against the model results. In order to test how well the model is able to reproduce future events, we use a test run that was constructed utilizing historical data until 1995 and all the variables that explicitly use historical data to be calibrated were “forecasted” for the period 1995-2005.

Operating capacity, demand, and Load Factors

Using data from the global airline industry collected by the Airline Transport Association ATA as historical basis, we constructed the demand and capacity time series and compared with the corresponding model outputs as shown in Figure 9-9.

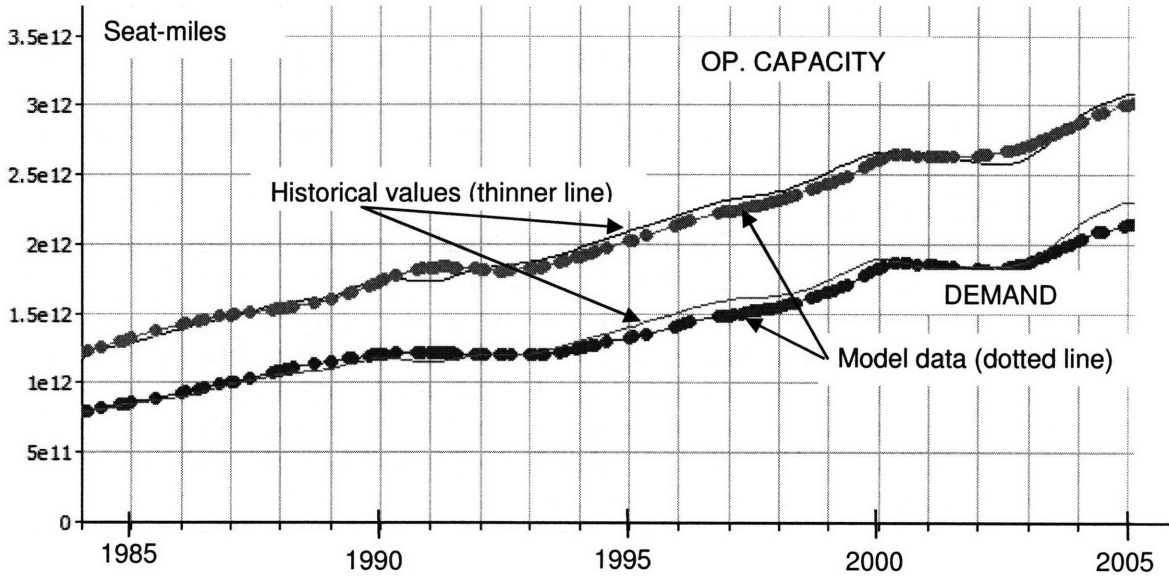


Figure 9-9 Calibrated demand and total capacity (in RPM and ASM) model data compared to the historical values for global airlines (Source for historical data: ATA 2006)

A second order effect that describes the relationship between capacity and demand are load factors which are tracked in Figure 9-10.

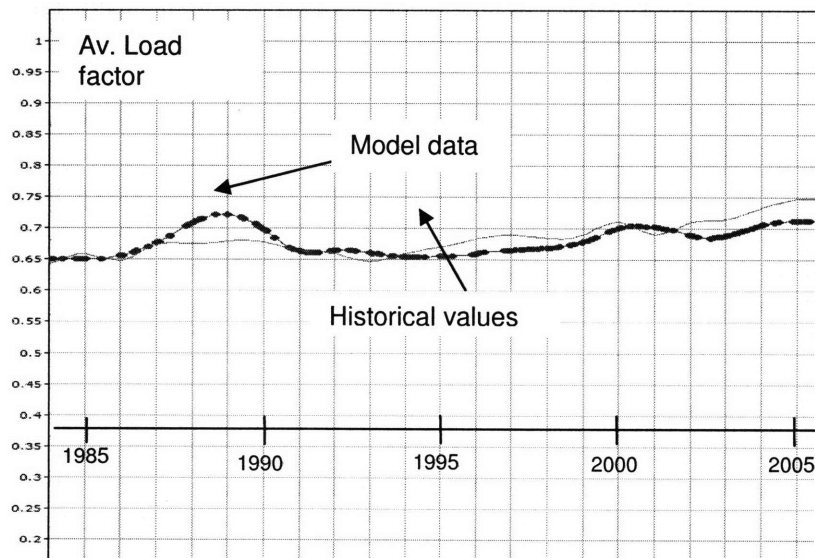


Figure 9-10 Historical and model data comparison: Load Factors

Airline Revenues Costs and Profit Margins

Costs and revenues are another important aspect of the model's ability to depict reality and are shown in Figures 9-11 and 9-12.

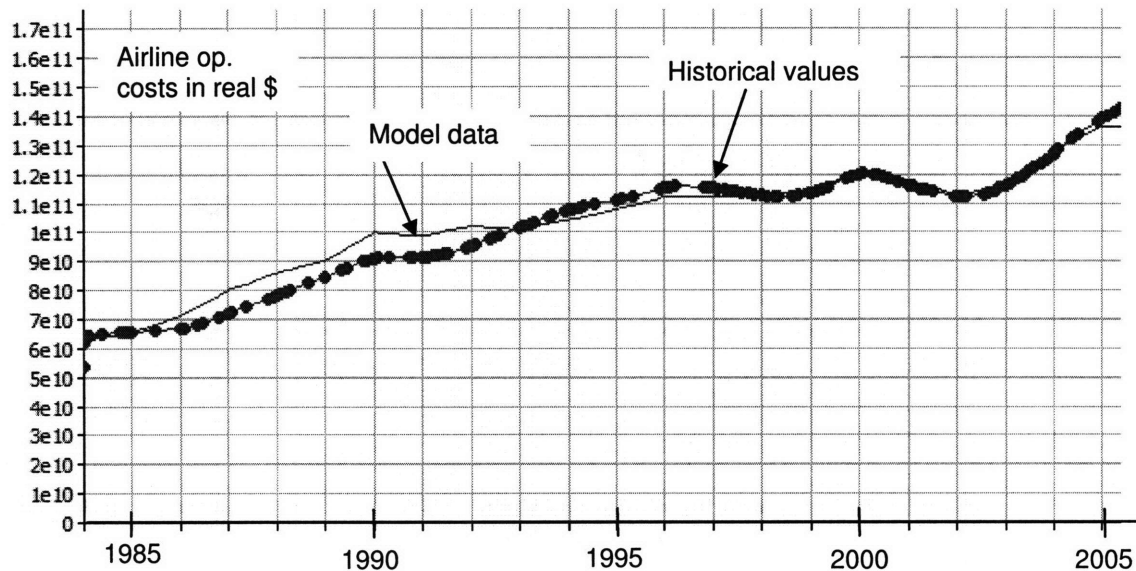


Figure 9-11 Historical and model data comparison: Airline costs (Source for historical data: ATA 2006)

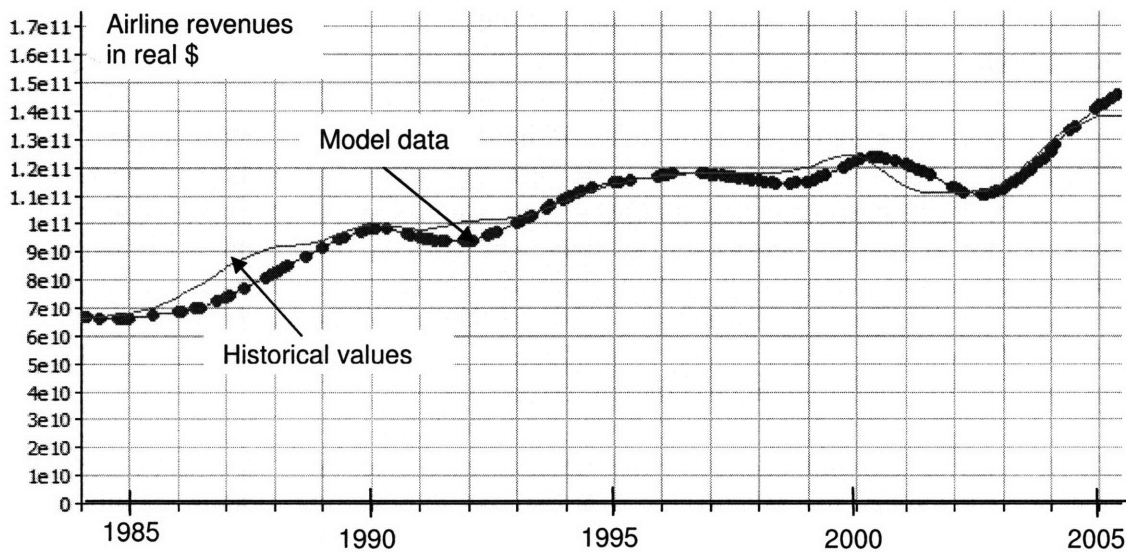


Figure 9-12 Historical and model data comparison: Airline revenues (Source for historical data: ATA 2006)

The second order effect that compares how the relationship between the two economic measures is the profit margin shown in Fig. 9-13.

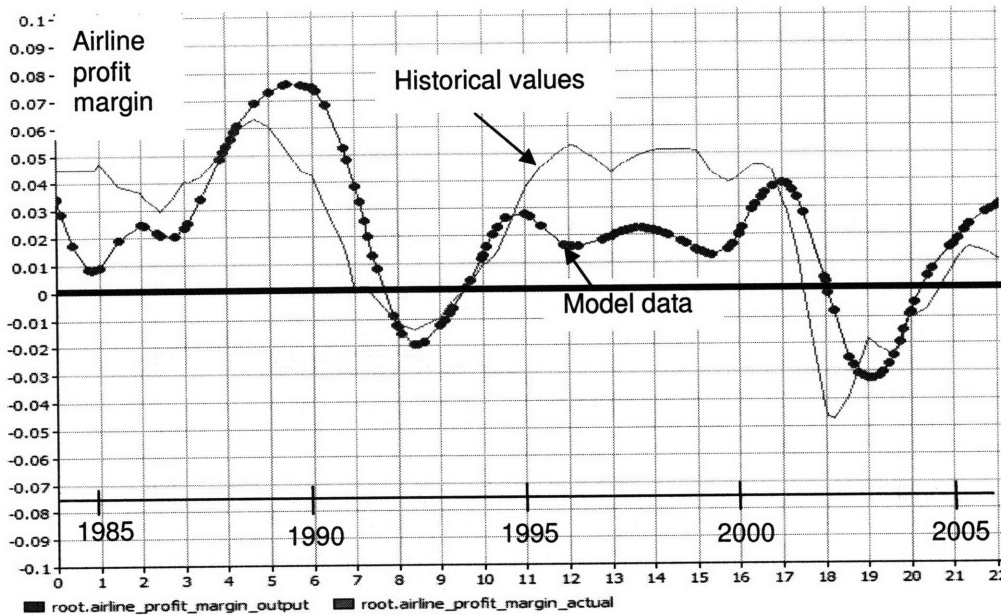


Figure 9-13 Airline Profit Margins of the Calibrated Model vs. Historical data (Source for historical data: ATA 2006)

Airframe Manufacturers Orders and Backlogs

On the boundary between airframe manufacturers and airlines are the orders of aircraft and the amount of backlog orders that the manufacturers carry which reflect their production rates.

As we discussed in Chapter 4, there are considerable differences between the two manufacturers in the real world that include different production policies (including backlog), production costs, implementation of lean manufacturing, pricing policies and different points in market penetration (Airbus was still an incumbent in 1984 just introducing the A320 narrowbody product line). Not only these differences exist, but their implications were also identified as potentially important for the cyclicity in the CA EoE as discussed in Chapter 7 (e.g., a production policy that favors longer backlogs may exacerbate the ‘supply chain discounting’ effect).

For these reasons we simulated the two manufacturers in order to capture these differences. The orders for Manufacturer A (MF.A) representing Boeing (combined Boeing and MDD for the 1984-1997 pre-merger period) are captured in Fig. 9-14 while the orders for Manufacturer B (MF.B) representing Airbus are shown in Fig. 9-15. While the orders track the historical record, there are differences that can be attributed to the following two reasons:

- As discussed in Section 9.1.3, our simplifying assumption was that manufacturers competed only on price while their product lines were technically similar,
- As discussed in Box 4-3, aircraft ordering can be highly politicized – especially in the international front – and as a result these effects cannot be captured.

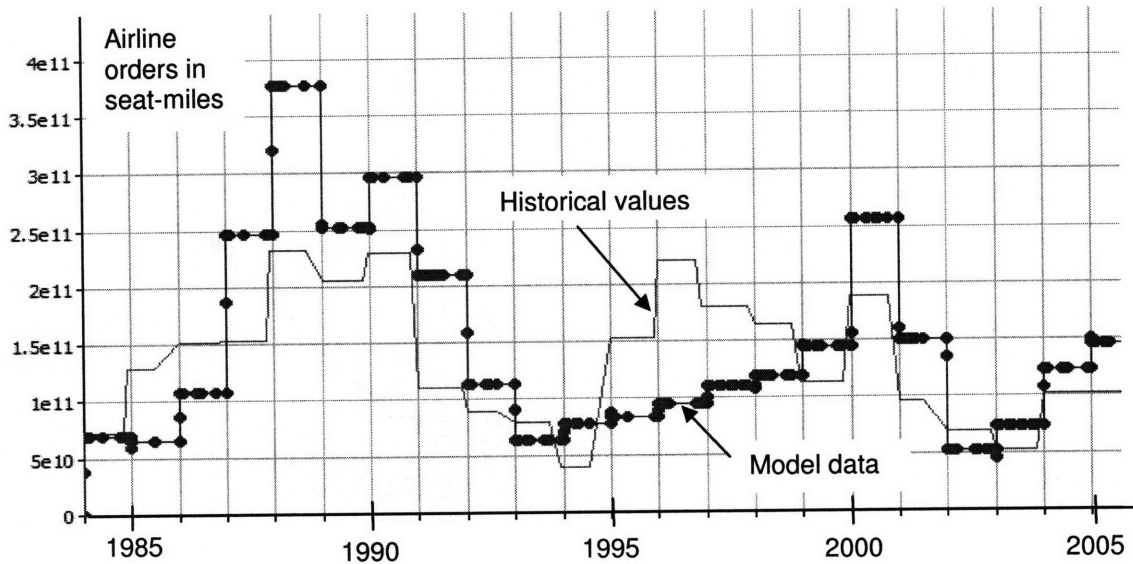


Figure 9-14 MF.A airline capacity orders (in ASM) for the calibrated model and historical data (Source for historical data: Boeing orderbook and author's calculation)

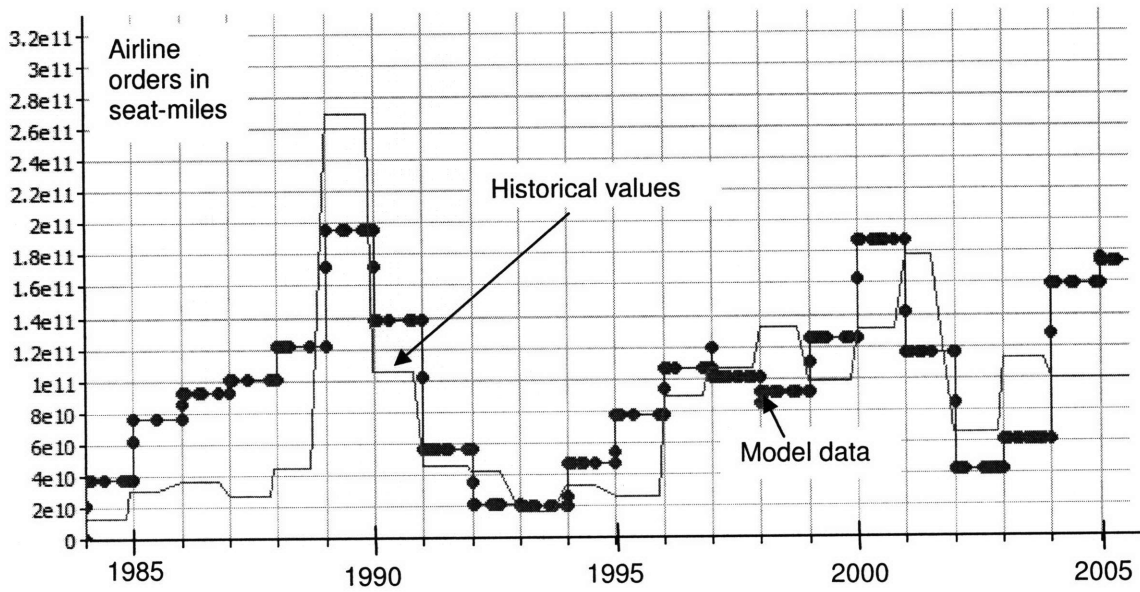


Figure 9-15 MF.B airline capacity orders (in ASM) for the calibrated model and historical data (Source for historical data: Airbus orderbook and author's calculation)

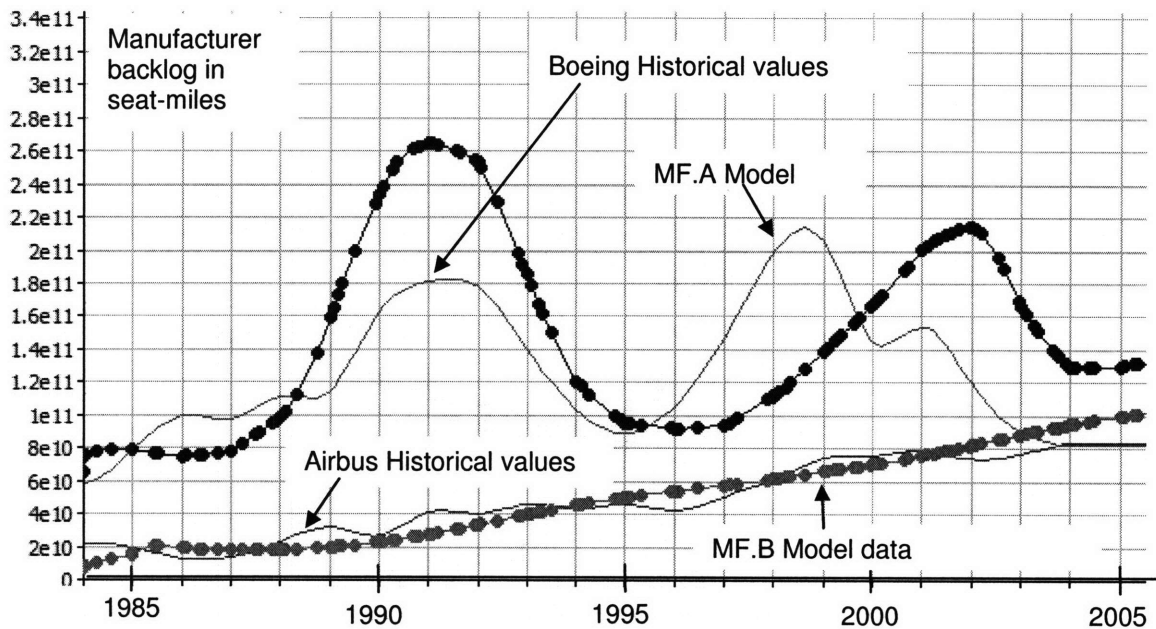


Figure 9-16 Historical and model data comparison: Airframe Manufacturers Deliveries (Source for historical data: Boeing and Airbus websites and author's calculations)

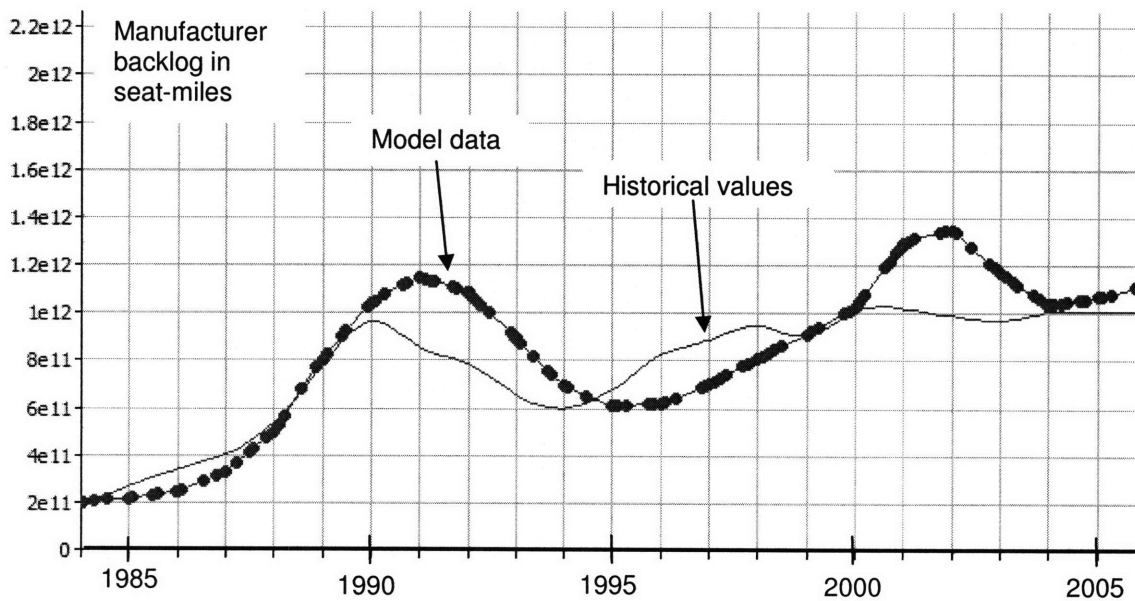


Figure 9-17 Historical and model data comparison: Airframe Manufacturers Backlog (Source for historical data: Boeing and Airbus websites and author's calculations)

Finally, Figures 9-16 and 9-17 show the comparisons of model data with historical delivery rates for the manufacturers individually and aggregate and total aircraft order backlogs. Order backlogs are second order effects and still match quite well with the data.

For the delivery rates, while the Airbus data series matches the model quite well, between the two manufacturers, for Boeing, the higher level of orders that it receives in the model in years 1986-1991 (as shown in Figure 9-14) result in the higher level of deliveries in the period 1989-1994 (delayed by the manufacturing lead time).

From a visual inspection of the figures displayed in this section, one can see that the model tracks the real world data reasonably well. In order to test this relationship statistically, we perform the following tests.

Statistical Testing

Statistical tests conducted support that the model results are not statistically significantly different compared to the real world data as summarized in Table 9-11.

Table 9-11 Statistical results of the historic vs. model comparisons

Variable	Mean d	Mean m	Sqrt (MSE)	R sq.	Theil statistics			P(T<=t) two- tail	Statistically significant difference at 0.05
					U _m	U _s	U _c		
Capacity (in trillion op. ASM)	2.03	2.03	0.077	0.981	0.001	0.153	0.845	0.986	No
Demand (in trillion RPM)	1.39	1.39	0.061	0.975	0.004	0.007	0.989	0.976	No
Load factors	0.68	0.68	0.02	0.430	0.019	0.002	0.979	0.718	No
Airline costs in (\$B)	101	98.9	5	0.959	0.172	0.246	0.582	0.730	No
Airline revenues	103	101.1	5.2	0.949	0.152	0.185	0.663	0.735	No
Airline profit margins	0.026	0.027	0.018	0.663	0.003	0.000	0.997	0.916	No
Aircraft orders (in trillion ASM)	0.21	0.19	0.067	0.628	0.081	0.095	0.824	0.531	No
Aircraft backlog (in trillion ASM)	0.61	0.63	0.164	0.636	0.019	0.111	0.871	0.771	No

The t-test statistical test in Table 9-11, starts with the hypothesis that the model results are statistically not significantly different than the data distribution which in all cases cannot be rejected. We notice that the errors are increased compared to second order variables (like profit margins and backlogs) which is to be expected.

We also notice from the fact that the U_c Theil statistic is greater than U_m and U_s that there is a phase shift between the model results and the historical data but does not give information as to the relative magnitude. By inspection, this phase shift is less than one year which is a small time frame for the time-scales that we are considering. On the same topic, Sterman (2004)(pp. 877) notes that the system type we are considering -- a combination of supply chains and commodity markets -- "*selectively amplify certain frequencies in the random shocks that constantly perturb them. Since no model can capture all the random variations in the environment, model dynamics can diverge from the data even if the model is perfectly specified.*" (emphasis in the original).

9.2.4.2 Ex-post forecasting

As a final part of the calibration procedure we tested the model as forecasting tool using data until 1995 for the calibration of its external variable inputs (external effects on demand, fuel prices, GDP growth rates) and extrapolated “reasonable forecasts” of these assuming that were unaware of their real values.

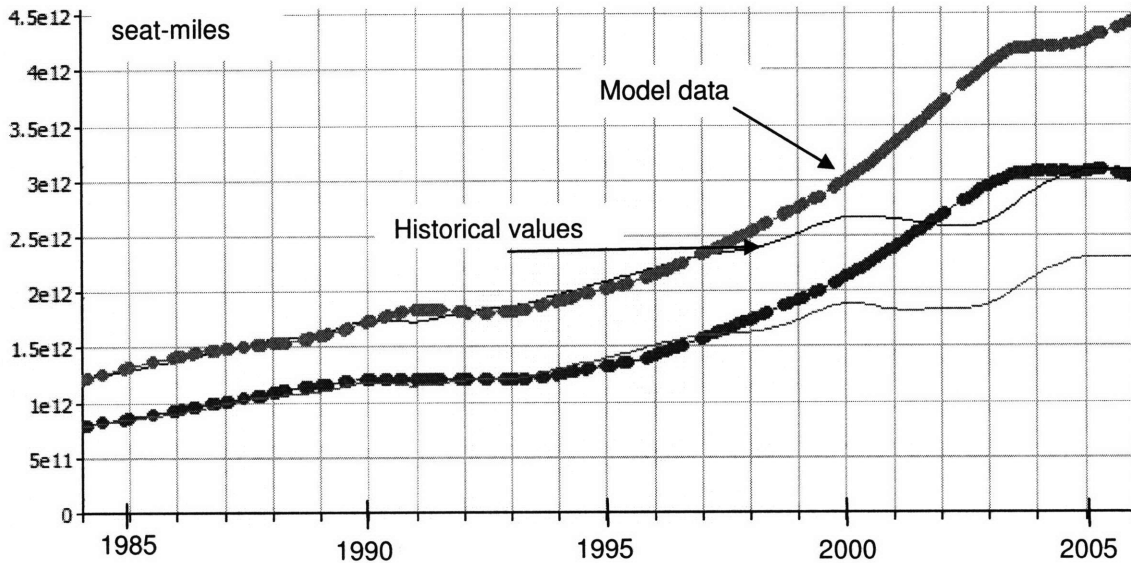


Figure 9-18 Ex-post forecast for capacity and demand with calibration data “known” until 1995.

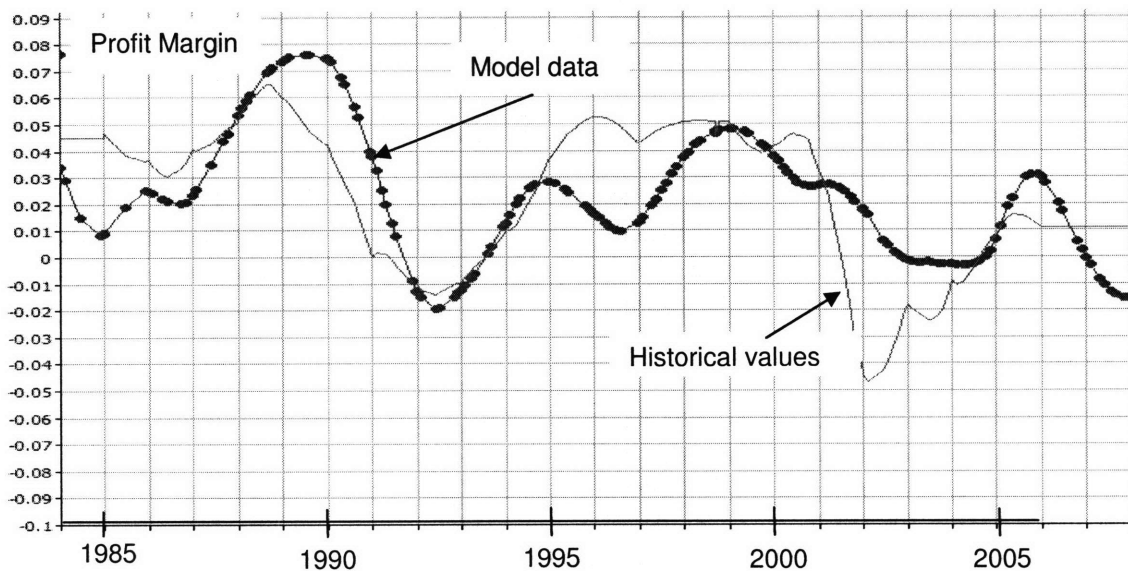


Figure 9-19 Ex-post forecast for airline profit margins with calibration data “known” until 1995.

The model proved quite robust under that test missing of course the level of demand drop caused by the combination of economic slowdown, the 9/11 terrorist attacks and their aftermath but overall tracking close to our expectations as shown in Fig. 9-16. More

importantly, the model captured an endogenous cycle in profitability showing a significant dip in airline profit margins as shown in Figure 9-17.

9.3 Chapter 9 Summary

In this chapter, we presented the basic structure of the system dynamics CA EoE model that we built to perform quantitative experimentation on the CA EoE. We also described the calibration, verification, and validation processes that were employed to ensure that the model is a useful simulation of reality for our purposes and shown that the logical structure as well as the outputs compared to historical data match well by visual inspection and statistical comparisons.

In Chapter 10 we use this model to compare and contrast the specific effects of the set of strategic alternatives that we identified in Chapter 7 with regards to their relative effectiveness in dampening the CA EoE cyclicity and providing benefits to the stakeholders involved.

Chapter 10 Scenarios and strategies for the CA EoE: Design and Execution of Experiments

In Chapter 9, we described how we structured, calibrated, and validated a system dynamics model of the CA EoE. This chapter is using the model to evaluate different strategic alternatives with regard to their effectiveness in dampening the cyclicity evidenced in the CA EoE. The approach that we take in analyzing the CA EoE is summarized for clarity in Figure 10 1.

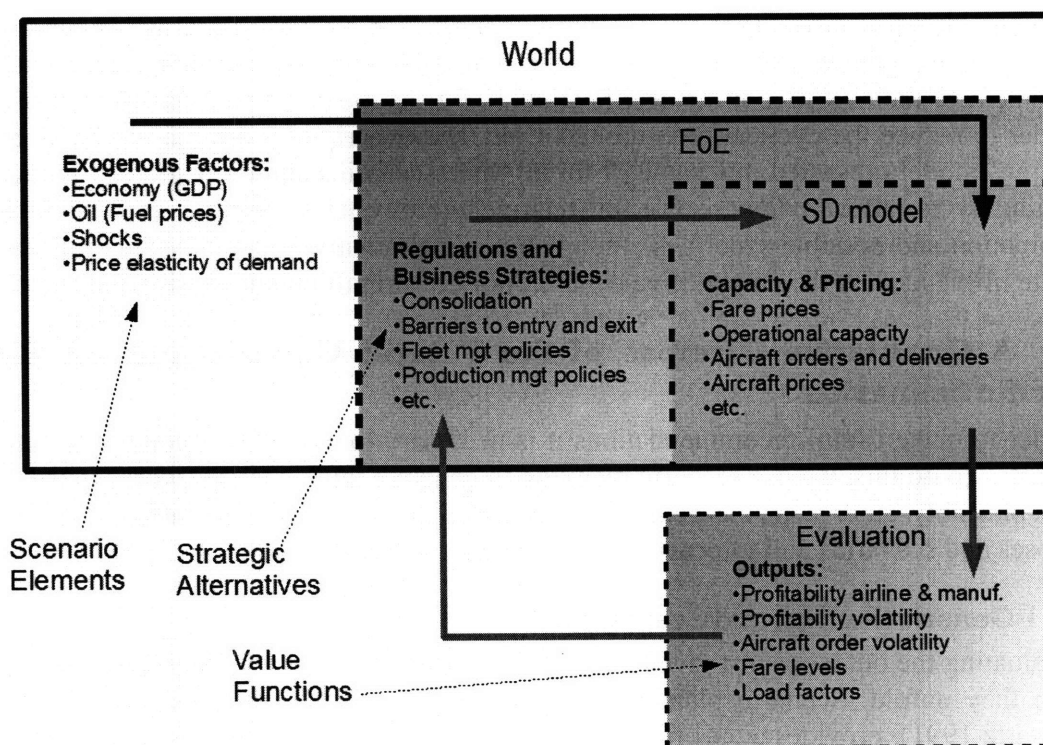


Figure 10-1 Levels of Analysis for Experimentation using the SD Model of the CA EoE

From a high level perspective, there are four levels of analysis in our approach as shown in Fig. 10-1:

- *World level:* it is exogenous to actions taken by the constituents. It provides the elements of the different scenarios.
- *EoE level:* actions taken by EoE constituents are considered endogenous to this level but are exogenously defined for the SD model. E.g., the decisions and lobbying needed to convince the government constituents to allow higher levels of consolidation in the industry are exogenous to the SD model but they are considered as a strategic alternative that has a direct impact on the EoE and this impact can be evaluated by using the SD model.

- *SD model level*: the model level can compute the results from different combinations of scenarios (World level inputs) and strategic alternatives (EoE level inputs).
- *Evaluation level*: The outputs from the model are then evaluated based on a (subjective) representation of the value functions of the CA EoE constituent (shown in Table 9-1). Those strategies that are symbiotic (or come close to being) are selected and they are considered with regard to their implementability. The identification of strategies can be iterative.

The rest of the chapter is devoted to discussing how this analysis was conducted in detail and presenting its results. Specifically, we look into the possible futures of the CA EoE system using ideas from scenario planning in Section 10.1, defining the external factor parameters for the next 20 years for each scenario. In Section 10.2, we distinguish between the exogenous and endogenous causes of cyclicalities and provide a quantitative assessment of their relative influence. Section 10.3 tests the strategies that we identified in order to reduce the cyclicalities in the CA EoE. The experiments are run on the system dynamics model presented in Chapter 9 for all three scenarios and each strategy is tested individually to allow comparisons for relative effectiveness. Section 10.4, explores combination and possible synergies among strategic alternatives and how they influence and are influenced by the competitive dynamics of the aircraft manufacturing industry.

10.1 A Qualitative Glimpse of the Future: Generic and CA EoE Specific Scenarios

In order to make useful recommendations it is necessary to extend the model into future forecasts. To do this, we use scenario planning to generate three possible world states that could plausibly emerge in the next 20 years based on scenarios generated for generic purposes and scenarios and forecasts that are specific to the CA EoE.

10.1.1 Generic Background Scenarios

In evaluating the outcomes for given strategies we need to somehow specify the future in which they unfold. Scenario planning, as pioneered by Shell and others in the 1970s (Schwartz 1991), provides a tool for ‘imagining’ different possible futures in a structured fashion.

Our scenarios aim to create believable settings for the conditions faced in the future by the commercial aviation EoE rather than foreseeing all possible variations including extreme ones. Therefore we will vary the basic “environmental” parameters of the model (demand growth rates along with GDP growth rates, demand elasticity, fuel prices, potential infrastructure limitations, technology inputs and their variance) to generate the basic scenarios.

Scenario 1 (S1): Global Village

This scenario is generally following the trends we have witnessed until now without drastic changes. The background is a globalized interconnected economy. Developing giants like China and India steadily increase their economic output per capita while world

population keeps increasing but at a declining rate, with most of the increases occurring in the developing world. Moderate to high economic growth tightens the global ties and makes travel for both pleasure and business a desired activity. Both regional and international travel is highly prized. Airport infrastructure is built on an as needed basis but with some delays involved given the negative externalities created in the areas surrounding busy airports and the resulting opposition. Some regional travel is substituted by 2015 and onwards by the creation of high speed rail networks in the US and China and expansion of the existing ones in the EU and Japan.

Large environmental catastrophes and widespread diseases are avoided through coordinated planning and any armed conflicts that arise are confined to regional levels. Global warming is kept under control by using a mix of alternative energy and technical fixes, with SO₂ sprayed artificially as an “atmospheric sunscreen” being one of them (reference). As a result, the demand for fossil fuels lessens but not by much thus making the peak in “peak oil” a fairly protracted plateau with occasional high variability in fuel prices but generally stable levels. While variation in the level of economic output is still present, large crises in the form of the 1930s Great Depression are averted.

Scenario 2 (S2): Islands of Sufficiency

After significant turmoil in the first half of 2010s, the populations in North America, Europe and Asia took an inward turn towards self sufficiency. Economic booms (and crises) became a thing of the past, as sustainable growth levels hovered close to 1% for the developed world and did not exceed 5% for the developing world. As a result of this introverted focus, technologies of the “small is beautiful” kind such as micro manufacturing (reference) gained ground and proved sufficient in providing for most of the moderated material needs of societies. Artificial reality environments based on information technology served the need for interaction across cultures and oceans far better than expensive and security obstacle-riddled air travel.

As a result the demand for long range wide body aircraft diminishes significantly and it is primarily the dedicated business travelers who make up the lists for smaller but long range jets similar to the Boeing Business Jet (BBJ) based on the 737 platform and its rivals. As a result of a significant reduction in the demand pressure, fuel prices plateau and expansion of airport capacity ceases.

Scenario 3 (S3): Growth and Overshoot

Global economic output starts increasing at a slightly accelerating pace. Climate change remains off the political agenda and as a result fuel prices are subject to significant fluctuations. Their average levels are controlled by the infusion of new oil discoveries and coal to oil conversion processes. The positive economic outlook fuels demand for air travel and the infrastructure capacity needed is struggling to catch up due to the delays involved in supplying it.

After several years of apparent prosperity, the fundamental economic instability of big trade imbalances, and asset price bubbles is compounded by extreme weather events and consequent large losses of agricultural production. Inflation in the prices of primary goods like food and clothing becomes very high and only the most affluent can afford to travel. Furthermore, severe measures to quickly curb these problems follow the political turmoil that in some nations is little less than a revolution.

10.1.2 CA EoE Scenarios Relative to Generic Scenario Planning

There is a vast number of scenarios generated for use under different contexts. In order to provide some sense of how the scenarios that we propose match with larger scope scenario exercises we reference two such works. The first is the Intergovernmental Panel on Climate Change (IPCC 2001), a seminal study on the potential global impacts of climate change and the other was from scenario planning master Shell (2002).

IPCC used seven scenarios that broadly fell in four quadrants. Scenario family A1 was based on increasing economic and population growth rates and increasingly connected economies that lead to cultural and political convergence. In A2 the world fragments and regional development becomes competitive and slower. B1 retains the global convergence aspect of A1 but emphasizes cooperation to reduce environmental and societal problems. Finally, B2 aims for similar objectives but the means of doing so are based on self-sufficiency. Compared to the IPCC scenarios presented here, the three scenarios that we are using for testing our strategic alternatives (S1, S2, S3) can be relatively placed to conform to IPCC's scenario matrix as shown in Table 10.1 and Figure 10-1.

Table 10-1 Scenarios used by IPCC (Source: IPCC 2001)

A1FI, A1T, and A1B		
<p>The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity-building, and increased cultural and social interactions, with a</p>	<p>substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all</p>	<p>sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).</p>
A2	B1	B2
<p>The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.</p>	<p>The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.</p>	<p>The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.</p>

As opposed to IPCC's multiple scenarios, Shell's practice is to create only two characteristic scenarios. For their 2002 exercise these were named Business Class and Prism respectively. These are interesting as they project the volatility of both regional growth rates and fuel prices. Although notably, the oil price projections are significantly

lower than actually materialized the long term volatility projections resemble those of S2 for the Prism Shell scenario and S1 for the Business Class Shell scenario.

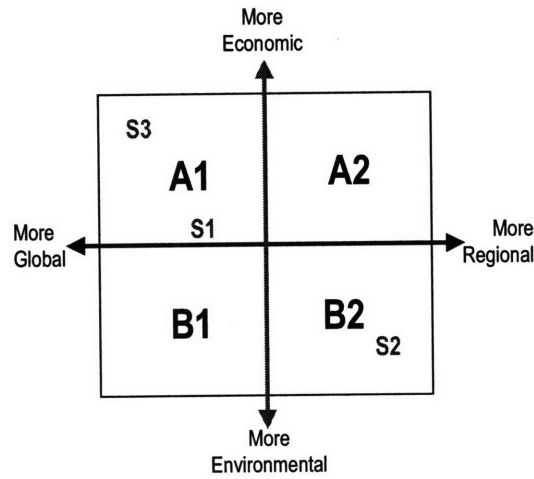


Figure 10-2 IPCC Scenarios and the Relative Placement of S1, S2, S3

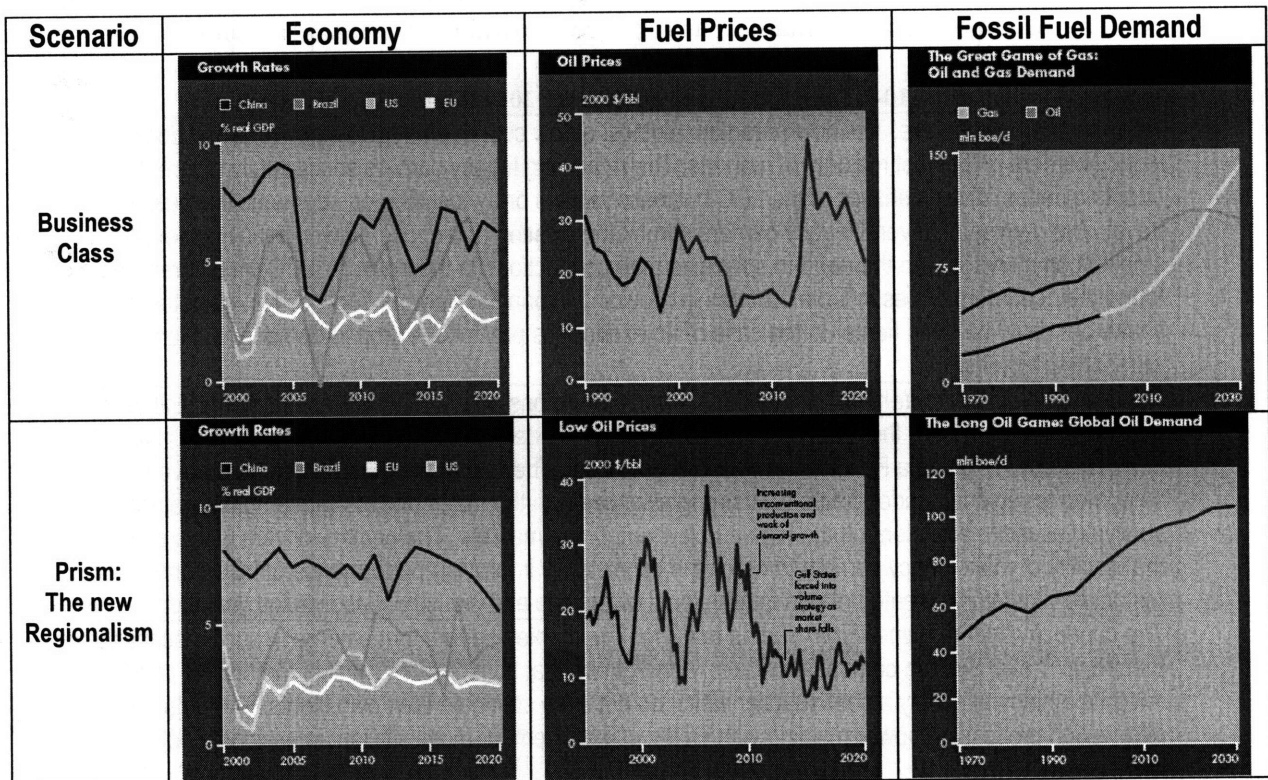


Figure 10-3 Shell Scenario Parameter Projections (Source: Shell 2002)

The scenarios we presented in the two previous sections referred to the external environment of the commercial aviation industry. Of course the industry itself will react to these changes dynamically along with endogenous evolution. Therefore it is useful to

consider the potential range of these changes and we start doing so by reviewing the literature on future scenarios for airlines and trends in aircraft manufacturing.

10.1.3 Commercial Aviation Specific Scenario Planning

Taneja (2002) describes some “radical” scenarios in Chapter 6 of his book *Airline Survival Kit* (pg. 175 on). In terms of aircraft, he posits that the clever combination of existing types of aircraft can enable additional markets by by-passing busy international hubs. He considers the possibility of successful ascendance of fractional ownership and air taxi business jets to provide a significant fraction of business travel with the advantages of ubiquitous access and convenient boarding. At the low end of the market, leisure travel can be captured by low cost carriers both for national and international trips. These two events can put legacy airlines in a difficult position thus driving the least efficient of them out of business unless subsidies or adaptation takes place.

He also envisions the potential effect of community-sponsored airlines, effectively local governments subsidizing airline service to their communities although that may be harder for poorer areas which would be presumable the ones underserved. As part of the changing business environment, he also suggests the possibility of using airport staff for most airline needs. This approach could even be extended to aircraft and crews, making airlines core competence that of business aggregators and network designers (similar to Nike in the athletic apparel market) as opposed to owners of the production capital.

Table 10-2 Four Aviation Scenarios for 2010 (Source Taneja (2004))

<p><i>Triumph of the new wave:</i> The new paradigm airlines, or low cost carries (LCCs), have all but dominated the legacy carriers in the vast majority of markets. The remaining legacy carriers successfully differentiated by adopting certain characteristics of the LCC business models or by focusing on segments like business travel. The demise of several legacy carriers shrunk the existing hub-spoke networks leaving several smaller communities with the need to subsidize their connections to the network. LCCs in different regions found their counterparts as reliable partners in providing expanded network service. Taneja notes that the shake-out could be even fiercer in the case of an exogenous precipitous drop in demand (e.g. pandemic or widespread terrorism).</p>
<p><i>Survival of the late adopters:</i> In this scenario, Taneja envisions an era of global airline giants. Either through consolidation or attrition, the number of remaining major carriers globally is reduced to three in N.America, four in Europe, six in Asia Pacific, and one in Middle East. The rest of the surviving carriers have been delegated to regional/feeder status with strong alliances with the major players with a number of them surviving as niche providers on the high and low end of the markets. The primary drivers in this scenario are the inability of most legacy carriers to reach the consistently improving performance of LCCs and a less restrictive regulatory climate both on international ownership and industry consolidation limitations.</p>
<p><i>The connectivity paradigm – From surfing to flying:</i> The market leaders that emerge in such a scenario are Electronic Travel System companies. Travel aggregators that consolidated most of the market power relegate airlines to simply a seat supplier which do not even schedule their own flights. The databases and information processing power residing with ETS's makes them far more efficient in assigning optimal travel itineraries.</p>
<p><i>Emerging Markets – the New Frontier:</i> The growth in travel demand by emerging economies like China, India, Brazil and Indonesia, relocates the focus of the industry to these countries. Led by “enlightened” regulatory policies from their governments the entrepreneurial spirit of these countries allows the lower income populations to use travel services tailored to their needs.</p>

The same author, in his book *Simpli-flying*, published two years later (Taneja 2004, pg. 161), provides four more structured scenarios for the year 2010 as summarized in Table 10-2.

A more formalized scenario planning approach to the aviation industry was implemented by Farr and his team (Farr et al. 2005). They created a software tool that allows practitioners to set their scenario expectations for where the industry is heading and it then generates forecasts on specific parameters based on those predictions. The list of parameters that they are considering aligns with the ones that we are using.













Finally, another set of scenarios that are specifically related to the CA EoE were presented by Jarry (2003). He identified two scenarios: one of isolation and regional rather than global travel which is similar to our “islands of sufficiency” scenario and a second scenario named “the little planet” which is more optimistic and similar to our “global village” scenario. As for the aircraft evolution, he does not see any dramatic changes in the form of propulsion, speed, and capacity of the aircraft in the next one hundred years. Although, these types of predictions have frequently been erroneous failing to foresee scientific breakthroughs and the pace of innovation, they should be sufficient for our outlook for a mere 20 years – after all the A380s and Boeing 787s built today will almost certainly be in use in that timeframe.

The manufacturers themselves have been forecasting future demand pretty consistently for the same period of time (see Boeing 2006 Outlook and Airbus Global Market Forecast 2006) although they do differ on how this demand will be divided between different types of aircraft primarily in the widebody category.

10.1.4 Translation of Scenarios to Model Parameters: extending the current state

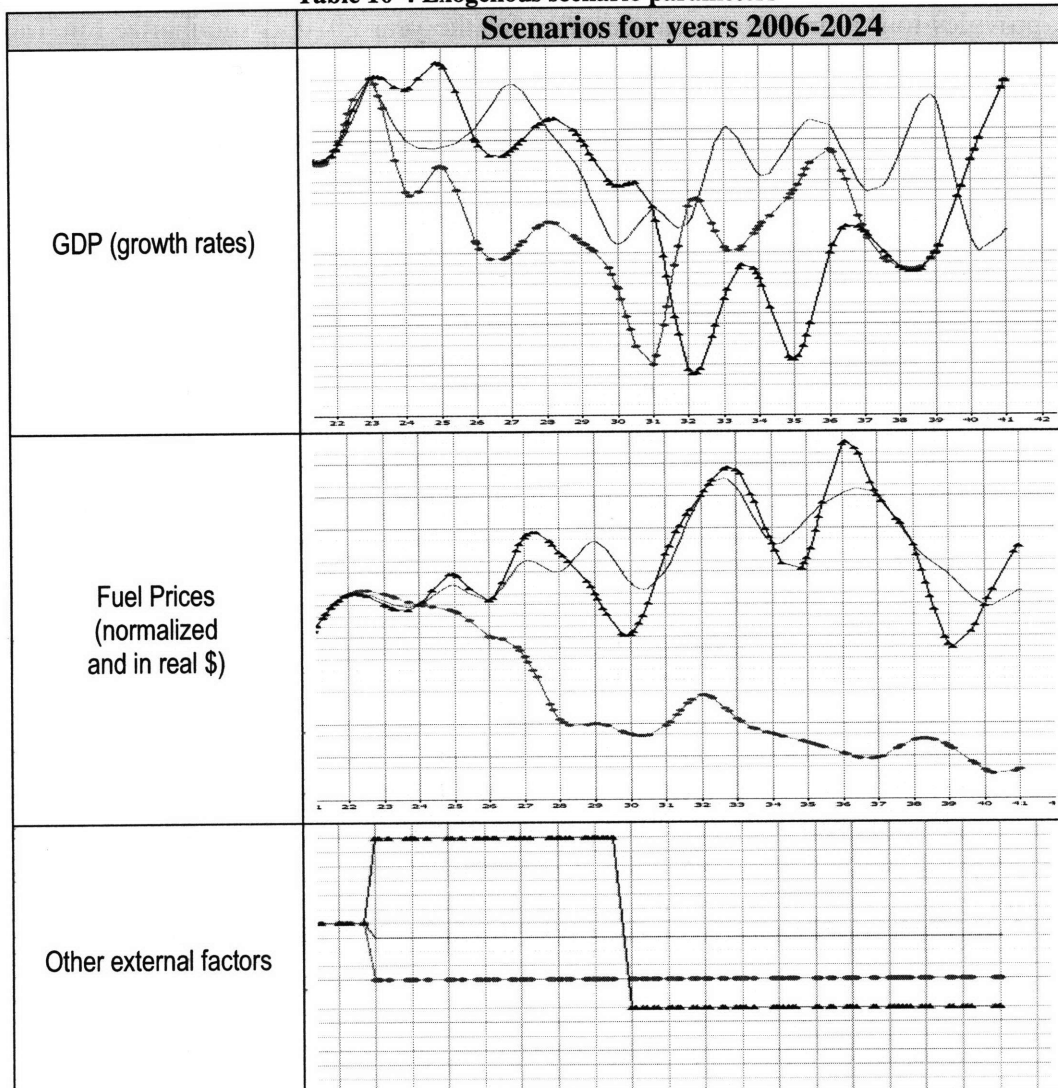
Table 10-3 summarizes the effects on the external factors of the above scenarios.

Table 10-3: Overview of Scenarios Primary Variables

Scenario	GDP		Demand		Elasticity			Fuel		Infrastr.
	Growth	Variance	Narrowb.	Wideb.	Business	Leisure	Goods	Growth	Variance	
S1. Global Village		M			L	L	L		M	Some delay
S2. Islands of Sufficiency		L			M	L	M		L	Ample
S3. Growth and Overshoot		H			L and M	L and H	M		H	Delay

These scenarios are translated into corresponding parameter inputs for our CA EoE SD model as shown in Table 10-4.

Table 10-4 Exogenous scenario parameters



S1: red line, S2: green line dotted with circles, S3: blue line dotted with triangles

Having presented the potential futures that we will use in running the model, we now proceed in conducting some sensitivity analysis with regard to the relative effects of exogenous factors in Section 10.2 and of different strategic alternatives in Section 10.3.

10.2 Relative Importance of Exogenous and Endogenous Factors as Mechanisms for Cyclicity

In Chapter 7 we identified certain mechanisms as possible causes of cyclical behavior in economic and supply chain systems. In this section, we review those mechanisms testing their relative effect by using the CA EoE model. We start by comparing the relative impact on cyclicity of the external factors in 10.2.1 and proceed in investigating endogenous mechanisms in Section 10.2.2 and on. For this section, comparisons are

made with the baseline of the calibrated model for the S1 scenario unless otherwise specified.

We describe each mechanism providing a background, the reasoning for how it would work, and their actual simulated impact. At this stage we only consider mechanisms that can be construed as strategic alternatives with regard to a single objective: reducing variability in the airline industry sector. In Section 10.3, the value functions of different stakeholders as presented Table 9-1 will be discussed extensively.

10.2.1 External Factors

In the CA EoE system there are several external factors based on regional differences, competing modes, and regulations but in the model these have been abstracted to

- global economic growth,
- disruptive events with disproportional effect on air travel compared to their economic impact, and
- fuel prices

While there is a correlation between fuel prices and economic growth, these are used in different areas of the model. While economic growth rate is influencing the demand for air travel, fuel prices only go into the calculation of the expenses of the airlines. Another potential caveat is the ability of airlines to hedge fuel prices through future contracts⁹⁷ but that is currently diminishing.

In order to see the effect of each, we run the model using scenario S1 and isolating each external factor. Figures 10-4 and 10-5 show the differences in the oscillatory behavior for airline profit levels and aircraft order rates respectively.

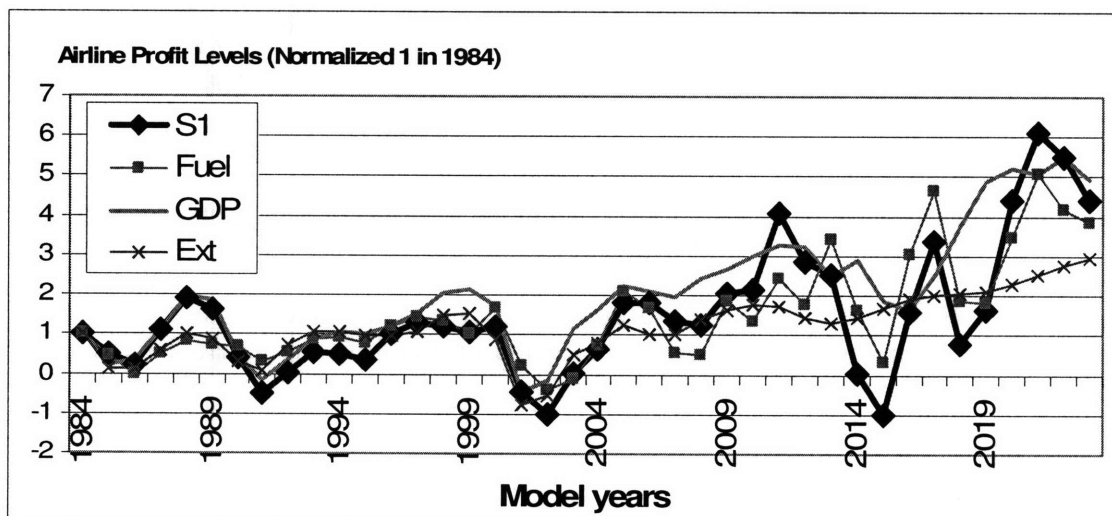


Figure 10-4: Comparison of Normalized Airline Profit Levels when all external factors are active (S1) and when only one is active for each run

⁹⁷ As we saw in Ch. 3, there is no futures market for avgas but rather the markets for crude and heating oil that are highly correlated to the price of av gas and therefore are used for hedging.

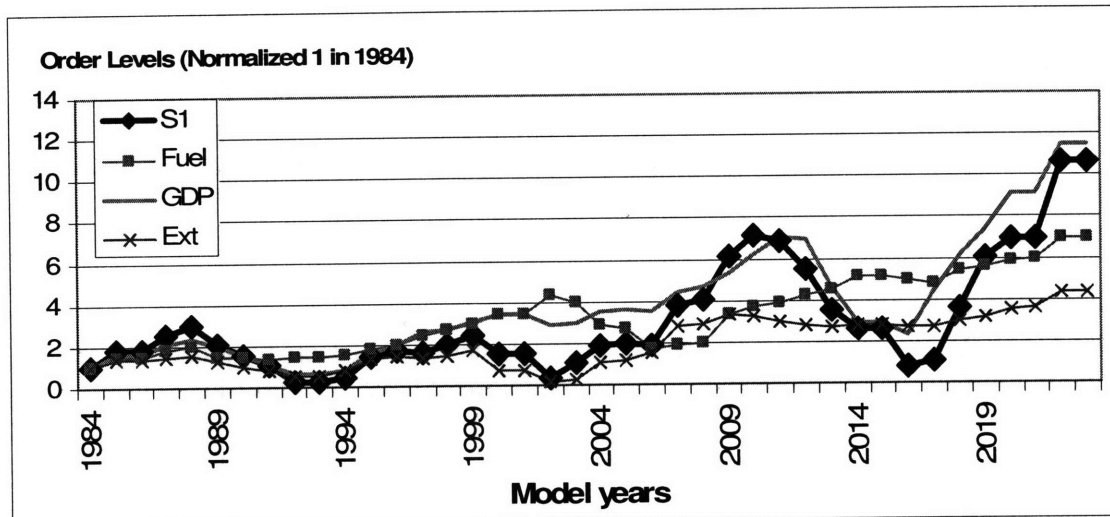


Figure 10-5 Comparison of Normalized Airline Profit Levels when all external factors are active (S1) and when only one is active for each run

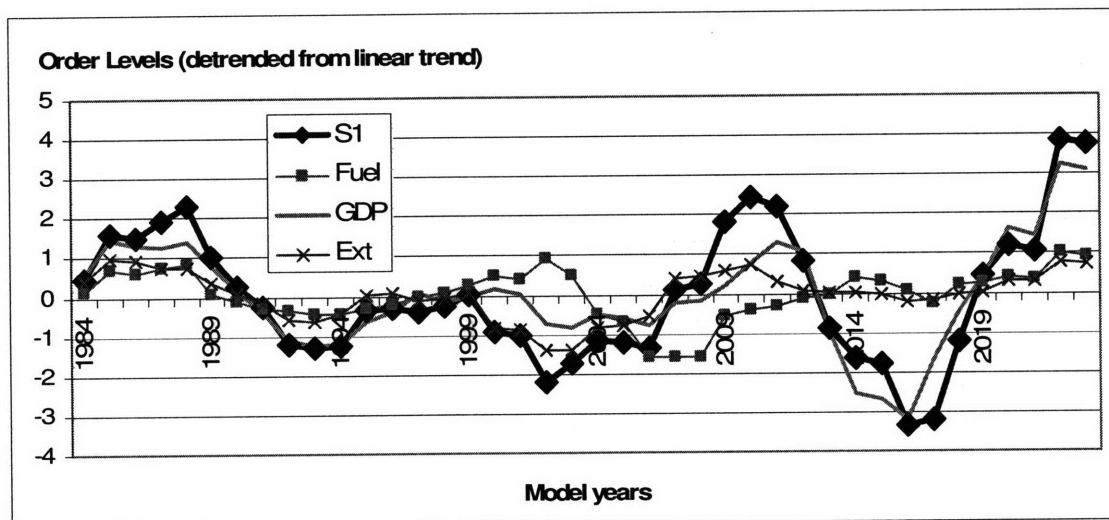


Figure 10-6 Comparison of Detrended Airline Profit Levels when all external factors are active (S1) and when only one is active for each run

Inspection of Figures 10-4, 10-5, 10-6 and Table 10-5 which shows the coefficient of variation⁹⁸ for each case indicates that for airline profitability the external factors that influence its tendency to oscillate are in order:

1. Fuel price volatility,
2. GDP growth rate variations and
3. External factors.

⁹⁸ Coefficient of variation is a dimensionless measure of volatility and is calculated by dividing the standard deviation of a population over its mean:

$$CV = \frac{\sigma}{\mu}$$

This means that profitability in the short term is much more dependent on the unpredictable fuel changes than that of demand (GDP and external factors both influence demand directly). The opposite is true for aircraft orders which are more influenced by changes in demand rather than the short term cost changes of the fuel input.

Table 10-5 Coefficient of Variation List for External Factor Experiments

Experiment	Airline Profitability	Aircraft Orders
S1 (all exogenous factors active)	1.10	0.86
Fuel (fuel active)	0.88	0.53
GDP (GDP active)	0.74	0.71
Ext (external factors active)	0.67	0.58

These results indicate that the exogenous factors are not critical in generating cyclical behavior in the system. *These results show that even in the improbable case that exogenous factors stabilized, the internal dynamics of the CA EoE can force it into cyclical behavior even with small exogenous perturbations.* The mechanisms that contribute to this endogenous behavior are discussed in Section 10.3.7.

Even the most optimistic strategist does not expect that the structured randomness of economic and fuel cycles factors will actually disappear. As a result, we look into the endogenous parameters of the CA EoE to investigate areas where flexibility or resilience to the unavoidable destabilizing effect of external factors can be found.

10.2.2 Effects of Competitive Environment in the Airline Industry

In Ch. 3 we saw that deregulation opened the door to industry restructuring with waves of new entrants and bankruptcies of some legacy carriers. Competition bred different business models and pushed fares and unit costs downwards but in most cases it implied reduced profit margins. This effect of the competitive environment is correlated to industry concentration although as we saw in Ch. 2, each O-D pair is a market in itself which in general is only imperfectly contestable.

Waves of new entrants can be attracted by high profit margins during an upcycle, and are enabled by availability of capital from willing investors, and affordable and available equipment either from the secondary market or from operating leases. A common characteristic of new entrants besides high leverage is the willingness to defer profitability for several years until sufficient levels of market share, name recognition, or consumer loyalty is reached.

This effect of industry concentration on profitability can be captured in the model by two equally effective ways: (i) exogenously defined target profitability levels and (ii) endogenous dynamic of market entry and exit (see Ch. 9). This subsection investigates the effect that these endogenous industry fluctuations have on the observed oscillatory behavior with two experiments (shown in Table 10-6).

The differences are captured in Figures 10-7 and 10-8 by comparing a flat target profitability curve that corresponds (on this aspect only) to a more concentrated industry with the calibrated target profitability curve that simulates two waves of new entrants and hence two periods of reduced target profitability. In order to make the comparison more clear we removed the influence of all external factors in these experiments.

Table 10-6 Experiments related to the effect of competitive environment

Exp. #	Characteristics	Coef. of Variation	
		Airline Profit	Orders
S1	Baseline	1.10	0.86
10.2.2.A	Continuously concentrated industry and no external factors	0.56	0.53
10.2.2.B	Industry with interspersed waves of entry and consolidation (calibrated endogenous) and no external factors	0.64	0.53

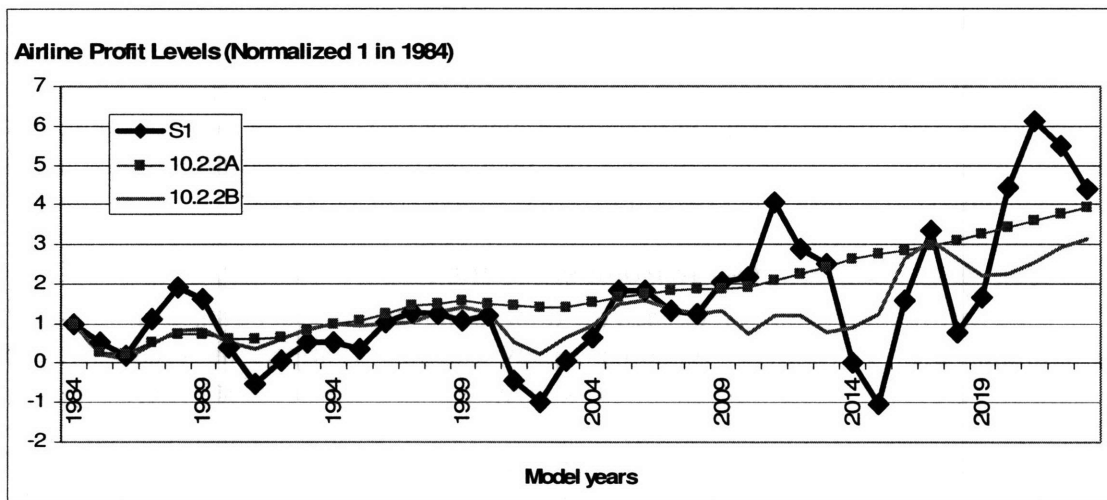


Figure 10-7 Normalized Airline profits Comparison

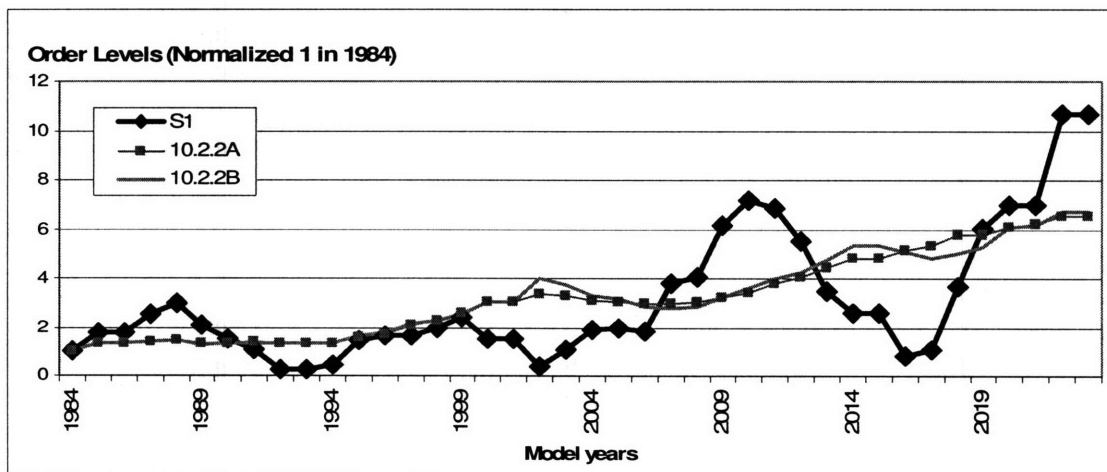


Figure 10-8 Normalized Orders Comparison

The effect of new entrants in fueling a profit cycle is pronounced whereas the effect on order levels is much less so since we assumed that for these experiments industry consolidation will only affect profit seeking and not the order process. These results are robust even when we make industry concentration endogenous.

For completeness, it is also important to note the effect of the aircraft manufacturers' competitive behavior in the above, which is demonstrated in Section 10.4.

From the above we can also see that the cycle in orders is influenced more heavily by the forecasting process and variations in demand that are generated by the exogenous factors rather than the cycle in airline profitability. *This result indicates that it is possible to retain a competitive yet less oscillatory market.*

10.3 Countercyclical Strategic Alternatives

In the previous section we demonstrated that (i) exogenous factors trigger cyclical behavior in the CA EoE but with varying relative significance and that (ii) the CA EoE has endogenous dynamics that create cyclical behavior even when exogenous factors are stabilized. We demonstrated (ii) by comparing between a continuous consolidated environment (akin to the regulated period in airline history) vs. an open competitive environment with entrants and exits (but with higher barriers to exit). Even with stable exogenous factors the later environment was shown to generate business cycles.

Given that the variability in the exogenous factors is by definition not controllable, we focus our attention on strategic alternatives that are aimed to counteract the cyclicity in areas endogenous to the CA EoE. Based on the strategic alternatives that were developed qualitatively in Chapter 7 we investigate the following areas:

- Levels of flexibility in airline operations:
 - Fixed vs. variable costs
 - *Fixed to Variable Costs: Profit Sharing and Outsourcing* (Section 10.3.2). Investigates the transfer of fixed operating costs to variable via profit-sharing agreements and service outsourcing as a way to defer costs in a downcycle.
 - *Leasing Variation: Ownership fixed costs to flexible costs* (Section 10.3.1.1). Investigates the effect of more flexible ownership costs offered by leasing.
 - Aircraft fleet management
 - *Flexibility in Aircraft Fleet Utilization* (Section 10.3.1). Investigates how different aircraft utilization strategies affect cyclicity.
 - *Aircraft retirement patterns: Retirement Adjuster* (Section 10.3.3.1). Investigates how a change in the aircraft retirement patterns affects the CA EoE.

- Aircraft ordering patterns
 - *Supply chain visibility* (Section 10.3.3.4). Investigates reductions in ‘supply chain discounting’.
 - *Demand Forecasting* (Section 10.3.3.2). Investigates changes in forecasting: how smoother forecasts affect the cycle.
 - *Adjusting the Effect of Profitability on Order Patterns* (Section 10.3.3.3). Presents the effects of moderating ordering ‘exuberance’ in profitable for airlines periods.
- Changes in the airline competitive environment
 - *Competitive environment and yield management* (Section 10.3.4.1). Illustrates how industry consolidation and consequent increase in fare prices affect cyclicalities.
 - *Effect of Airline Entry and Exit* (Section 10.3.4.2). Studies the effect of changing barriers to entry and exit on pricing and how this impacts the cyclicalities in CA EoE.
- The competitive environment of aircraft manufacturers:
 - *Effects of Aircraft pricing* (Section 10.3.5.1). Investigates the effect of coordinated (i.e. assuming manufacturer cooperation) changes in aircraft pricing.
 - *Production rate adjustments* (Section 10.3.5.2). Investigates the effect of coordinated (i.e. assuming manufacturer cooperation) changes in aircraft production rates.
 - *Competitive strategies of aircraft manufacturers* (Section 10.4). Removes the coordination constraint and investigates how the competition between manufacturers impacts the CA EoE.

10.3.1 Flexibility in Aircraft Fleet Utilization

Demand for air travel can be heavily seasonal and is also subject to external events⁹⁹. While yield management is intended to even out some of these demand variations (see Ch. 3), there still are times where demand is not matched with supply and therefore supply needs to be readjusted. This is especially the case when there is overcapacity in the market in which case the available responses for any airline are four: (i) reduce active capacity by retirement of aircraft (secondary market sales may correct an imbalance if other regional markets experience undercapacity but in general retain the capacity in the market), (ii) reallocate the current active capacity to non-impacted routes (if there are available markets), (iii) reduce operational capacity (use the existing active capacity at lower utilization levels), and (iv) do nothing and simply compete aggressively on pricing.

Airlines do a combination of the above to obtain an outcome as close to their strategic objectives as possible. Airlines that have the option to reallocate capacity or have low enough operating costs to operate profitably with lower utilization rates have an obvious advantage over airlines that have to reduce active capacity by cutting down on frequency

⁹⁹ See Chapter 2.

or even mothballing aircraft for periods of time as in this case they continue to incur the aircraft capital costs and at least part of the fixed operating expenses like base crew salaries and gate leases.

Assuming that reallocation is not possible (choice ii), then retirement (choice i) is an option if there are aircraft in the right age bracket. Reduction of operational capacity by reducing the utilization of active capacity (choice iii) is a viable option limited by the requirements of network coverage (a carrier cannot stay in a market with frequencies that are too low) and the fact that aircraft are expensive assets whose underutilization reflects on the balance sheet. Moreover, in a downcycle, prices of aircraft in secondary markets are also significantly reduced¹⁰⁰ thus making any thoughts of selling less palatable and a choice of the last resort. The same perspective is true for the majority of the leased aircraft, for which the leasing terms are long enough as not to be useful in times of significantly reduced demand¹⁰¹.

On an industry-wide basis, the more operational capacity is maintained on the market, all else being equal, the less profitable average operations are. Therefore, the first strategy for addressing this dynamic is to consider the effect that greater flexibility for establishing operational capacity based on observed demand. In practical terms, the policies that would allow this strategic alternative (i.e. increased fleet management flexibility) include:

- Operating leases (wet or dry) for individual carriers,
- Buy-back agreements from the manufacturers (aircraft put options),
- Active time arbitrage for aircraft (buy low in downcycle with the expectation to sell high during an upcycle),
- Greater industry consolidation in a manner that creates a competitive environment that is not dictating maximum fleet utilization.

Experimental Results

We conduct a set of experiments comparing the baseline (moderate flexibility) for each scenario that we identified with two experimental runs. Specifically the representative alternatives are:

- Little flexibility (airlines are highly competitive in their market share and have only a 10% leeway to park/underutilize their available equipment)
- Moderate flexibility (the baseline situation where on average airlines have a 20% leeway in fluctuating their capacity.¹⁰² with some like American Airlines having up to 40% seasonal swings and Southwest having less than 5% seasonal swings).
- High flexibility (In this option, the flexibility accorded to airlines is up to 40% on an industry-wide basis).

¹⁰⁰ See Ch. 4.

¹⁰¹ See Udvar-Hazy's opinion as CEO of ILFC, a large leasing firm, in Section 3.4.9.2.

¹⁰² These estimates of fleet management flexibility are based on the range of seasonal flexibility that is observed in airlines currently. For example American Airlines has a seasonal fluctuation in its capacity of about 40% while Southwest a more modest 5%.

Table 10-7 Flexibility in Aircraft Management

Scenario	S1			S2			S3		
	Baseline	Less Flex	More Flex	Baseline	Less Flex	More Flex	Baseline	Less Flex	More Flex
Airlines									
NPV (*)	100.00	73.87	184.43	79.29	53.57	140.58	59.97	22.05	131.95
Change	0.0%	-26.1%	84.4%	0.0%	-32.4%	77.3%	0.0%	-63.2%	120.0%
Coef. Var.	1.36	1.91	0.95	1.04	1.85	0.75	18.76	7.93	3.09
Change	0.0%	40.2%	-30.6%	0.0%	78.9%	-27.3%	0.0%	-57.8%	-83.5%
Median Cap. Utilization	73.8%	81.4%	61.2%	72.8%	80.7%	57.4%	72.6%	80.1%	63.0%
Manufacturers									
NPV (*)	100.00	93.77	123.45	66.70	62.29	86.03	117.07	114.79	137.40
Change	0.0%	-6.2%	23.5%	0.0%	-6.6%	29.0%	0.0%	-1.9%	17.4%
Coef. Var. (Profit)	1.47	1.42	1.22	1.02	1.27	0.85	2.15	2.48	1.83
Total orders (*)	100.00	90.51	121.89	52.18	46.46	64.61	97.71	99.47	109.26
Change	0.0%	-9.5%	21.9%	0.0%	-11.0%	23.8%	0.0%	1.8%	11.8%
Coef. Var. (orders)	0.83	0.90	0.79	0.43	0.59	0.38	1.26	1.34	1.10
Change	0.0%	8.5%	-5.4%	0.0%	36.6%	-12.6%	0.0%	6.5%	-12.4%
Passengers									
Average Fare (*)	100.00	98.88	102.97	92.83	91.63	95.93	101.20	100.97	103.43
Median Fare (*)	100.00	96.99	103.85	89.55	86.81	93.96	101.47	104.41	104.41
Change	0.0%	-3.0%	3.8%	0.0%	-3.1%	4.9%	0.0%	2.9%	2.9%
Average LF	69.5%	67.5%	73.3%	69.7%	68.5%	72.7%	67.3%	64.6%	70.5%
Change	0.0%	-2.8%	5.4%	0.0%	-1.7%	4.3%	0.0%	-3.9%	4.8%

Note on significance: Given the uncertainties involved in model building, changes of less than 3% are not considered significant differences. In the first place our model fidelity in some variables diverges from the real-world values by 5%. For this reason, and in order to maintain a healthy margin against a false positive we consider changes between 3% and 15% as indicative, while 15% or above are considered strong.

Interpretation and Discussion

For S1 a reduction in flexibility has a negative effect on airline NPV (-26.1%), the reductions in the other two scenarios are more pronounced especially for S3, which sees a reduction of 32%. The same holds true for manufacturers (6% reduction of profitability in S1). Conversely, increasing flexibility provides a strong boost in the returns for the two types of enterprise constituents. The improvement is more pronounced, ranging from 84.4% for the airline NPV in S1 to 120% in S3. This boost occurs because fleet flexibility allows the airlines not to compete based on available capacity (i.e. park aircraft more easily) and also as a result of this, allows airlines to order with less risk. *This happens even as the idle capacity is continued to be paid for by the airlines.* The effect on cyclicalities are consistent with the above; for S1, the airline profitability cyclicalities is increased by 40% when less flexibility is allowed and decreased by 30% for more flexibility.

We also note that the greatest benefits for airlines accrue under the more volatile Scenario 3 where the reduction in volatility of airline profitability and total order rates is the most pronounced.

In other words, it benefits the CA EoE with an improvement between 20% to 50% in the net present value of airline profitability and up to 30% of improvement in the airframe manufacturers profitability to have an operational capacity limiting scheme, i.e. to be able to reduce available operational capacity while still competing as aggressively as before in the other dimensions using the remaining capacity. Such a reduction though becomes a coordination and policing problem, going back to the prisoner's dilemma / variation of tragedy of the commons discussed in Ch. 5.

10.3.1.1 Leasing Variation: Ownership fixed costs to Variable Costs

Capacity flexibility in the previous set of experiments was achieved with the airlines bearing the costs of the underutilized aircraft under the baseline leasing structure (starting from less than 5% of the fleet and reaching up to 30% of it). In this experiment, we wanted to explore what happens if the number of leased aircraft which transfers an amount of the risk to the leasing firms varies. We used the following alternatives:

- Less leasing: Leased aircraft limited to 15% of the fleet.¹⁰³
- Moderate leasing (baseline): leased aircraft reach 35% of the fleet.
- More leasing: leased aircraft exceed 50% of the fleet

Experimental Results

The results from these experiments are shown in Table 10-8.

Table 10-8 Ownership Fixed to Variable Costs

Scenario	S1			S2			S3		
	Baseline	Less Leasing	More Leasing	Baseline	Less Leasing	More Leasing	Baseline	Less Leasing	More Leasing
Airlines									
NPV (*)	100.00	100.24	101.76	79.29	79.73	79.49	59.97	59.10	62.85
Change	0.0%	0.2%	1.8%	0.0%	0.6%	0.3%	0.0%	-1.5%	4.8%
Coef. Var.	1.36	1.35	1.34	1.04	1.03	1.04	18.76	22.02	12.55
Change	0.0%	-0.8%	-1.8%	0.0%	-1.0%	0.2%	0.0%	17.4%	-33.1%
Median Cap. Utilization	73.8%	73.6%	73.9%	72.8%	73.2%	73.0%	72.6%	72.6%	72.6%
Manufacturers									
NPV (*)	100.00	101.28	107.03	66.70	65.47	69.20	117.07	117.50	119.61
Change	0.0%	1.0%	7.0%	0.0%	-1.8%	3.7%	0.0%	0.4%	2.2%
Coef. Var. (Profit)	1.47	1.38	1.23	1.02	1.10	0.95	2.15	2.14	2.04
Total orders (*)	100.00	97.81	106.04	52.18	51.19	53.39	97.71	97.97	96.26
Change	0.0%	-2.2%	6.0%	0.0%	-1.9%	2.3%	0.0%	0.3%	-1.5%
Coef. Var. (orders)	0.83	0.86	0.80	0.43	0.44	0.42	1.26	1.25	1.22
Change	0.0%	3.8%	-3.4%	0.0%	2.4%	-1.4%	0.0%	-0.8%	-3.5%
Passengers									
Average Fare (*)	100.00	101.27	96.26	92.83	93.99	89.30	101.20	102.91	96.26
Median Fare (*)	100.00	101.60	93.61	89.55	90.74	85.44	101.47	105.61	93.53
Change	0.00	0.02	-0.06	0.00	0.01	-0.05	0.00	0.04	-0.08
Average LF	69.5%	69.4%	69.8%	69.7%	69.7%	69.7%	67.3%	67.1%	67.8%
Change	0.0%	-0.2%	0.4%	0.0%	0.0%	0.1%	0.0%	-0.2%	0.7%

The effect of leasing as a way of transitioning ownership costs from fixed to variable for the industry as whole is shown to be very limited (less than 1% while our margin of significance is 3%) on the airline side on total profitability and its volatility. Where it plays a minor role is in increasing the effect of price differentials in aircraft when volatility is high, but this effect is hardly noticeable.

Interpretation and Discussion

As a result of the above experiments we can deduce that leasing is effective in the grand scheme of reducing the airline profitability cycle only if it is combined with greater flexibility in fleet utilization and not in and of itself. The reduction in aircraft ownership costs it can provide during a downcycle is not sufficient and in practice countered by the greater overall cost of lease financing, since as it has to include the profitability of the lessor.

¹⁰³ These are estimates intended for a sensitivity testing. They cover the existing situation ~30% of LCA are under some form of lease as well as the upside (50%) and the low end (15%) possibilities.

10.3.2 Fixed to Variable Costs: Profit Sharing and Outsourcing

A common complaint of airlines in dire straits revolves around their fixed operating costs from crew salaries and also airport operations. Crews need to be retained for the next upswing in demand as their training and experience is expensive to duplicate. While average crew real salaries have not increased faster than inflation (see Ch.3), legacy airlines have to resort to bankruptcy protection in order to force further concessions from their employees.

One way to potentially address this issue is to apply flexible industry-wide profit sharing agreements and to outsource non-core operators. By implementing them, airlines will have the flexibility to manage their operating costs during downturns but also the obligation to better compensate their employees when their profitability targets are exceeded and pay a premium to the airport-service firms for the flexibility to cancel their contracts.

We investigate the effect of these alternatives with the following experiments:

- 15% cost deferment: Operating costs can be reduced up to 15% and the premium for services is up to 5%.¹⁰⁴
- 25% cost deferment: Operating costs can be reduced up to 15% and the premium for services is up to 8% of regular operating costs.

Experimental Results

The results from these experiments are shown in Table 10-9.

Table 10-9 Comparative Results for the Cost Deferment / Profit Sharing Strategic Alternative

Scenario	S1			S2			S3		
	Baseline	15% Cost deferment	25% Cost deferment	Baseline	15% Cost deferment	25% Cost deferment	Baseline	15% Cost deferment	25% Cost deferment
Airlines									
NPV (*)	100.00	112.33	115.13	79.29	86.17	87.39	59.97	68.39	71.80
Change	0.0%	12.3%	15.1%	0.0%	8.7%	10.2%	0.0%	14.0%	19.7%
Coef. Var.	1.36	1.23	1.18	1.04	0.96	0.99	18.76	11.45	10.10
Change	0.0%	-9.7%	-13.4%	0.0%	-7.8%	-4.5%	0.0%	-39.0%	-46.2%
Median Cap. Utilization	73.8%	75.1%	76.5%	72.8%	74.1%	73.7%	72.6%	75.0%	76.6%
Manufacturers									
NPV (*)	100.00	121.62	129.47	66.70	81.52	87.92	117.07	136.94	143.72
Change	0.0%	20.2%	29.5%	0.0%	22.2%	31.8%	0.0%	17.0%	22.8%
Coef. Var. (Profit)	1.47	1.42	1.42	1.02	1.00	1.00	2.15	2.12	1.98
Total orders (*)	100.00	108.84	112.31	52.18	54.77	57.30	97.71	98.83	100.79
Change	0.0%	8.8%	12.3%	0.0%	5.0%	9.8%	0.0%	1.1%	3.2%
Coef. Var. (orders)	0.83	0.81	0.80	0.43	0.38	0.37	1.26	1.22	1.18
Change	0.0%	-2.5%	-4.0%	0.0%	-10.9%	-13.6%	0.0%	-3.7%	-6.6%
Passengers									
Average Fare (*)	100.00	95.94	93.45	92.83	88.95	86.50	101.20	96.80	94.18
Median Fare (*)	100.00	94.65	91.62	89.55	85.35	81.96	101.47	95.62	92.39
Change	0.0%	-5.3%	-8.4%	0.0%	-4.7%	-8.5%	0.0%	-5.8%	-8.9%
Average LF	69.5%	70.3%	70.4%	69.7%	70.1%	70.1%	67.3%	68.2%	68.5%
Change	0.0%	1.1%	1.3%	0.0%	0.6%	0.6%	0.0%	1.4%	1.9%

¹⁰⁴ These estimates are hypothetical and represent savings from both outsourcing of non-core services and/or profit sharing that amount to about 5% of total operating costs.

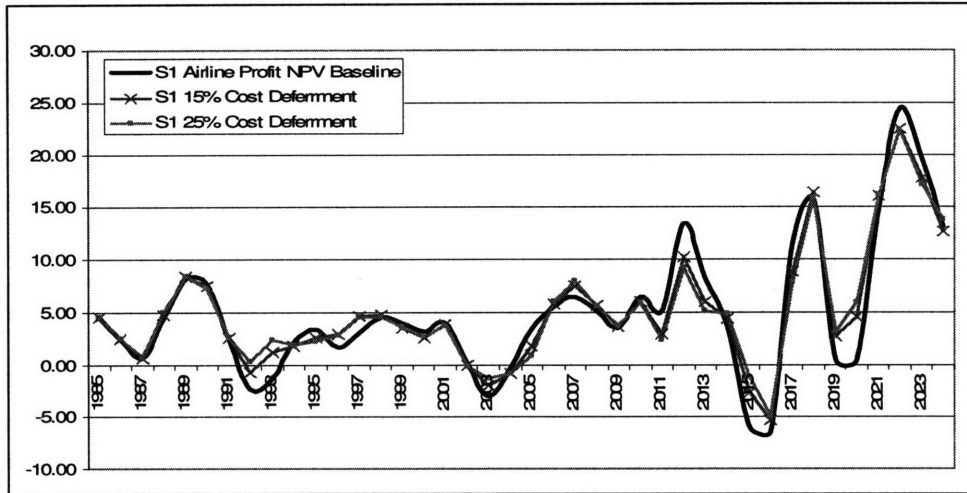


Figure 10-9 Comparative Airline NPV Diagram for the Cost Deferment/ Profit Sharing Strategic Alternative (Scenario S1)

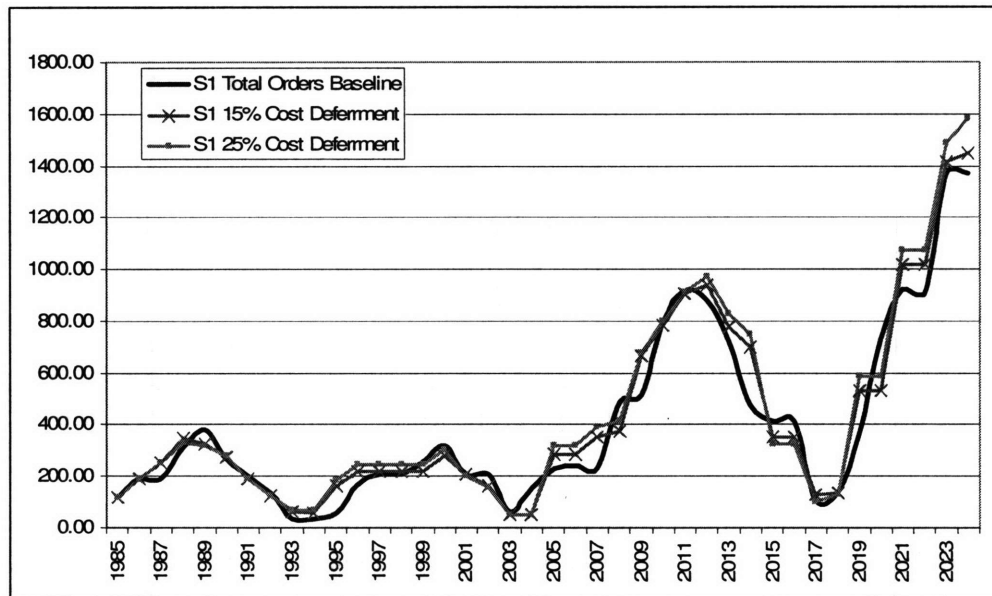


Figure 10-10 Comparative Total Orders Diagram for the Cost Deferment/ Profit Sharing Strategic Alternative (Scenario S1)

Interpretation and Discussion

In theory, this strategic alternative should facilitate stability in the airline profitability cycles, and the model experiments shown in Table 10-9 and Figure 10-9. Cost deferments increase airline profitability from 15% (S1 25% deferment) to almost 20% (S3 25% deferment) and provide a reduction in cyclicity as well. Peaks and troughs are shaved moderating the ordering behavior. More importantly, as costs “seem” to be reduced in the troughs, this allows the downward push of prices to continue and increase overall demand. The primary beneficiary of this are the airline customers that perceive significantly reduced average fares (up to 8% for S1) and subsequently respond by increasing the demand.

This in turn supports the demand for more aircraft capacity (see Fig. 10-10 also) with total orders increased from up to 12% but with only small reductions in the order variation. Interestingly, manufacturers gain from the surge in orders which increases their NPV return by up to 32% (\$2 25% deferment).

In the upcycle, the reduced profitability (in Fig. 10-9 for 2012 the profit is reduced by about 30%) would also induce slightly less competitor entrance.

As our experiments have pushed the level of costs that can be reduced to a relative extreme (15% and 25% of operating expenses excluding fuel and maintenance), it is to be expected that in practice any effect would be smaller. More importantly, implementation would require strong discipline from the management and employee side to provide increases when called for and accept the benefit reduction from the labor side. If either of these fails then the effectiveness of the strategy is jeopardized as shown to be the case historically (Petzinger). Schemes that have better chances of success may include stock options rather than profit sharing (e.g. Southwest). Another disadvantage of this strategy is that it requires industry-wide implementation to have the effect showed above – a far from easy proposition, but on the other hand, it can be implemented by individual airlines (it does not require cooperation) and to an extent it does, as the spread of outsourcing of non-core airport services shows.

10.3.3 Changing Fleet Management Practices as Strategic Alternatives to Counter Cyclicity

In the previous experiments, the order functions of the airline industry were only indirectly influenced by the strategic alternatives that were examined. This set of experiments is investigating the impact of direct changes in fleet management. We start by applying the retirement adjuster strategy proposed by Skinner et al. (1999)(see Ch. 9).

10.3.3.1 Aircraft retirement patterns: Retirement Adjuster

The retirement adjuster strategy is based on a fairly simple concept: retire older aircraft when profitability is low and retain them longer when profits are strong which by implication means that available capacity is limited and retaining capacity eases the strain.

Our baseline model is structured so that airlines do follow this strategy (see Ch. 9). In this section we investigate its relative effectiveness. The three samples of this strategic alternative are:

- Baseline: for negative profitability the normal retirement rate can be increased up to double the normal and decreased down to 90% of the normal for positive profitability.
- Stronger retirement adjuster: for negative profitability the normal retirement rate can be increased up to triple the normal and decreased down to 70% of the normal for positive profitability. The 'normal' retirement age of the aircraft is also increased by 2 years to 27 years.

- Weaker retirement adjuster: for negative profitability the normal retirement rate can be increased up to 20% above the normal and decreased down to 95% of the normal for positive profitability. The 'normal' retirement age of the aircraft is also reduced by 2 years to 23 years.

Experimental Results

The results from this set of experiments are shown in Table 10-10.

Table 10-10 Comparative Results for the Retirement Adjuster Strategy

Scenario	S1			S2			S3		
	Baseline	Stronger Retirement Adjuster	Weaker Retirement Adjuster	Baseline	Stronger Retirement Adjuster	Weaker Retirement Adjuster	Baseline	Stronger Retirement Adjuster	Weaker Retirement Adjuster
Airlines									
NPV (*)	100.00	102.00	95.87	79.29	80.42	75.79	59.97	61.03	55.82
Change	0.0%	2.0%	-4.1%	0.0%	1.4%	-4.4%	0.0%	1.8%	-7.3%
Coef. Var.	1.36	1.35	1.34	1.04	1.05	1.07	18.76	17.97	24.80
Change	0.0%	-0.5%	-1.5%	0.0%	1.5%	3.0%	0.0%	-4.2%	32.2%
Median Cap. Utilization	73.8%	73.8%	73.2%	72.8%	72.8%	72.3%	72.6%	72.5%	72.5%
Manufacturers									
NPV (*)	100.00	102.67	100.28	66.70	68.69	64.60	117.07	117.89	115.94
Change	0.0%	2.1%	0.3%	0.0%	3.0%	-3.2%	0.0%	0.7%	-1.0%
Coef. Var. (Profit)	1.47	1.45	1.33	1.02	1.01	1.02	2.15	2.27	1.98
Total orders (*)	100.00	100.82	95.10	52.18	52.64	49.69	97.71	98.48	94.28
Change	0.0%	0.8%	-4.9%	0.0%	0.9%	-4.8%	0.0%	0.8%	-3.5%
Coef. Var. (orders)	0.83	0.84	0.85	0.43	0.45	0.46	1.26	1.24	1.25
Change	0.0%	1.6%	2.1%	0.0%	3.5%	6.4%	0.0%	-1.9%	-0.7%
Passengers									
Average Fare (*)	100.00	100.26	99.48	92.83	93.14	92.28	101.20	101.39	100.67
Median Fare (*)	100.00	100.19	99.38	89.55	89.76	88.75	101.47	101.52	100.91
Change	0.0%	0.2%	-0.6%	0.0%	0.2%	-0.9%	0.0%	0.0%	-0.5%
Average LF	69.5%	69.5%	69.4%	69.7%	69.7%	69.5%	67.3%	67.4%	67.1%
Change	0.0%	0.0%	-0.2%	0.0%	0.0%	-0.2%	0.0%	0.1%	-0.2%

Interpretation and Discussion

The overall effect of strengthening or weakening the baseline retirement adjuster strategy is minor and below our threshold of significance except for weakening the retirement adjuster effect which has a 5% negative impact on airline profitability in the more volatile Scenario 3. Similarly, although a stronger retirement adjuster strategy does seem to positively influence the profitability of airlines (up to 2% increase in S1), it has no measurable impact on the cycle and the same is true for the weaker adjuster strategy.

Part of the benefits from the strategy are offset by the poorer fleet-wide fuel efficiency and greater maintenance costs that this strategy requires as a complication of the retention of an older fleet. It should also be noted that in a very volatile environment like the one simulated by Scenario S3 the value of this strategy is slightly greater as it prevents larger losses.

This is not to say that our findings directly contradict the findings of Skinner et al (1999) and the similar recommendations of Liehr et al. (2002). It may well be true that an individual airline could benefit from having a reserve fleet of older aircraft used in less dense routes for which the ownership costs are minimal as at this age the aircraft would be amortized (although that is not true for their maintenance and operating costs, primarily fuel consumption). We just find that as an industry-wide strategy, its influence on the cycle is comparatively less pronounced. Finally, there are two downsides in relying on an industry-wide retirement adjuster strategy that are not captured by the

model: (i) the potential for increasing the industry's emissions due to the retention of older aircraft and (ii) the fact that capacity is sticky and the tendency by competing airlines to be reluctant to withdraw capacity unilaterally even if it is cheaper to do so.

10.3.3.2 Demand Forecasting

Another way to affect capacity is to change the order patterns of airlines. We saw that airlines, like most enterprises, extrapolate from the present to define and project their future needs. In aggregate, their projections are based on a relatively short past period which we adjust in order to examine the effects that this would have on the overall industry performance using the following experiments:

- Baseline: 3 years historic demand used to smooth the projections
- Smoother forecast: 6 years history used to smooth projections
- Less smooth forecast: 1.5 year of historic demand used to smooth projections

Experimental Results

The results from the relative experiments are summarized in Table 10-11 and presented graphically in Figures 10-11 and 10-12.

Table 10-11 Comparative Results for Forecasting Adjustment Strategy

Scenario	S1			S2			S3		
	Baseline	Longer History (smoother forecast)	Shorter History (less smooth forecast)	Baseline	Longer History (smoother forecast)	Shorter History (less smooth forecast)	Baseline	Longer History (smoother forecast)	Shorter History (less smooth forecast)
Airlines									
NPV (*)	100.00	117.23	98.74	79.29	92.17	76.85	59.97	82.29	57.13
Change	0.0%	17.2%	-1.3%	0.0%	16.2%	-3.1%	0.0%	37.2%	-4.7%
Coef. Var.	1.36	1.36	1.38	1.04	1.30	0.90	18.76	12.31	13.24
Change	0.0%	0.2%	1.7%	0.0%	25.2%	-12.8%	0.0%	-34.4%	-29.4%
Median Cap. Utilization	73.8%	74.9%	74.1%	72.8%	72.8%	73.5%	72.6%	75.6%	72.8%
Manufacturers									
NPV (*)	100.00	107.27	100.29	66.70	75.68	68.47	117.07	133.43	121.76
Change	0.0%	7.2%	0.3%	0.0%	13.5%	2.6%	0.0%	14.0%	4.0%
Coef. Var. (Profit)	1.47	1.16	1.45	1.02	0.83	1.13	2.15	1.71	1.99
Total orders (*)	100.00	100.08	103.07	52.18	54.09	51.37	97.71	110.44	94.57
Change	0.0%	0.1%	3.1%	0.0%	3.7%	-1.6%	0.0%	13.0%	-3.2%
Coef. Var. (orders)	0.83	0.77	0.90	0.43	0.40	0.48	1.26	1.21	1.26
Change	0.0%	-7.0%	7.9%	0.0%	-6.9%	12.7%	0.0%	-4.0%	0.0%
Passengers									
Average Fare (*)	100.00	100.26	100.04	92.83	93.26	92.86	101.20	101.55	101.08
Median Fare (*)	100.00	99.71	99.93	89.55	89.54	89.99	101.47	103.03	100.71
Change	0.0%	-0.3%	-0.1%	0.0%	0.0%	0.5%	0.0%	1.5%	-0.7%
Average LF	69.5%	70.0%	69.5%	69.7%	69.9%	69.6%	67.3%	68.1%	67.2%
Change	0.0%	0.7%	0.0%	0.0%	0.3%	-0.2%	0.0%	1.2%	-0.2%

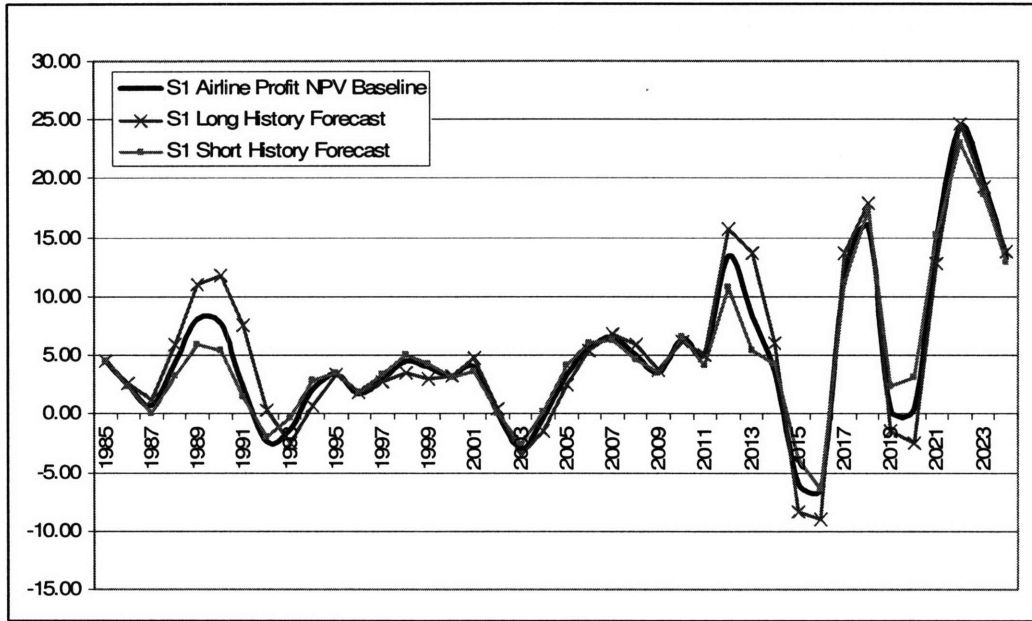


Figure 10-11 Comparative Airline NPV Diagram for the Forecast Adjustment Strategic Alternative (Scenario S1)

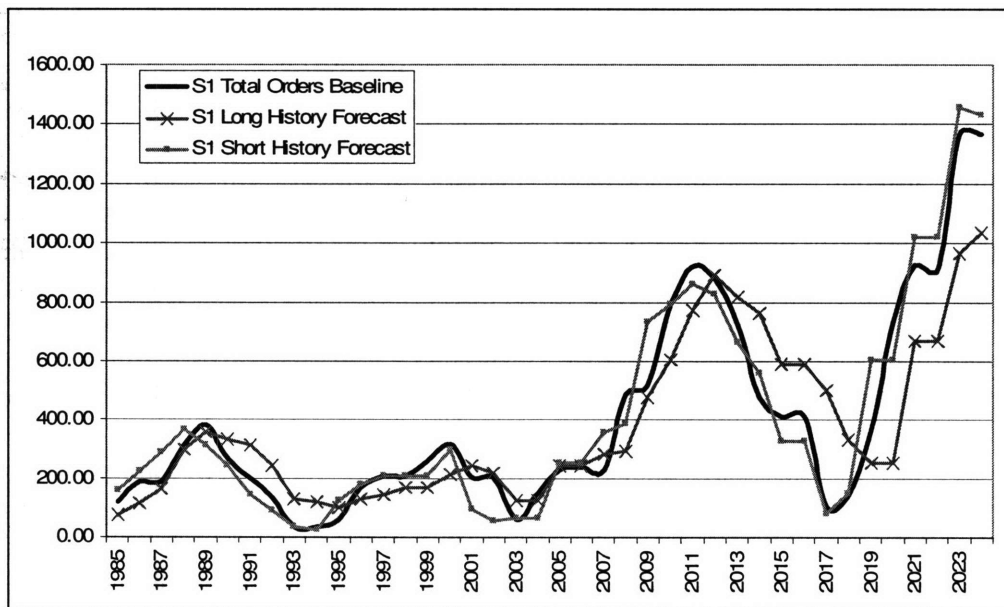


Figure 10-12 Comparative Total Orders Diagram for the Forecast Adjustment Strategic Alternative (Scenario S1)

Interpretation and Discussion

A look at the results would indicate that the long history adjustment of the forecast improves the profitability for both the airlines (up to 17% for S1 and S2 and 34% for S3) and the manufacturers (up to 14% NPV improvement for S3) while not dramatically increasing the prices for passengers (less than 1% increase in average fare). The manufacturers receive a more stable order pattern (see Fig. 10-12) and that is the key explanation for their profitability as cumulatively they receive fewer orders. All this

comes at the cost of slightly increased cyclical behavior for the airline profitability both at the bottom and the peak of the cycle which is indicative of a lag in the desired level of capacity and the capacity actually ordered (expected as the forecast trend becomes less sensitive to short-term variation). Interestingly in the volatile scenario (S3) both of the alternatives do better than the baseline in dampening the cycle although only the smoother forecasts does improve overall profitability.

The picture is reversed when the short-term history forecast is used: cyclical behavior in the airline profitability is slightly reduced from the base case but this means that the cost of acquiring the aircraft is increased due to the increased variation in orders and, more importantly, the capacity that is available at any given time is increased by following the often spurious short-term small upward moves.

Overall, lengthening the historic forecast period smooths order patterns and increases overall profitability primarily by restricting supply of aircraft in upturns but with the disadvantage of persistence in ordering in the downtrends. As a result, the smoother order pattern in one echelon of the CA EoE value chain (manufacturers) does little, in this case, to resolve cyclical behavior for the airline industry, although the end outcome is significantly positive. *That is, there are strategic alternatives that although they increase cyclical behavior in the long run, they provide benefits to the bottom line for the CA EoE constituents*

10.3.3.3 Adjusting the Effect of Profitability on Order Patterns

Similar in concept to adjusting the forecast history for smoothing the aircraft order pattern, we consider the effect that profitability exerts on aircraft orders. The effect of profitability simulates the disproportionate increase of orders during profitable periods and their reduction during unprofitable ones. As discussed in Ch. 3, the increase in orders during the upcycle can be attributed to the availability of capital, exuberant expectations of demand growth and market share capture by any given airlines, and the increased number of entrants during these periods – entrants that need aircraft to operate.

To explore what the impact is of changes in this aspect of the ordering behavior of airlines we conducted the following experiments:

- **Baseline:** In low profitability times, the calculated (forecasted) amount of orders is reduced by up to 20% and inflated up to 20% when profitability targets are met or exceeded.
- **Unreactive to profit:** In low profitability times, the calculated amount of orders is reduced up to only 5% and inflated up to 5% when profitability targets are met or exceeded.
- **Reactive to profit -moderated:** In low profitability, the calculated amount of orders is reduced by up to 40% and inflated up to 5% when profitability targets are met or exceeded.
- **Reactive to profit:** In low profitability, the calculated amount of orders is reduced by up to 70% and inflated up to 40% when profitability targets are met or exceeded.

Experimental Results

The results from the relative experiments are summarized in Table 10-12 and presented graphically in Figures 10-13 and 10-14.

Table 10-12 Comparative Results for Profitability Effect on Order

Scenario	S1				S2				S3			
	Baseline	Unreactive to Profit Ordering	Mod. Reactive to Profit Ordering	Reactive to Profit Ordering	Baseline	Unreactive to Profit Ordering	Mod. Reactive to Profit Ordering	Reactive to Profit Ordering	Baseline	Unreactive to Profit Ordering	Mod. Reactive to Profit Ordering	Reactive to Profit Ordering
Airlines												
NPV (*)	100.00	58.43	151.37	152.38	79.29	38.63	119.00	119.00	59.97	6.27	102.95	113.84
Change	0.0%	-41.6%	51.4%	52.4%	0.0%	-51.3%	50.1%	50.1%	0.0%	-89.5%	71.7%	89.8%
Coef. Var.	1.36	2.59	1.19	1.21	1.04	3.53	0.70	0.70	18.76	-5.01	12.40	6.75
Change	0.0%	90.6%	-12.9%	-10.9%	0.0%	240.1%	-32.9%	-32.5%	0.0%	-126.7%	-33.9%	-64.0%
Median Cap. Utilization	73.8%	70.3%	83.4%	84.0%	72.8%	70.1%	88.8%	89.2%	72.6%	69.8%	83.4%	82.9%
Manufacturers												
NPV (*)	100.00	112.98	97.67	94.39	66.70	72.34	53.70	52.20	117.07	128.19	129.21	114.47
Change	0.0%	13.0%	-3.3%	-5.4%	0.0%	8.5%	-19.5%	-21.7%	0.0%	9.5%	10.4%	-2.2%
Coef. Var. (Profit)	1.47	1.47	1.51	1.32	1.02	1.13	0.98	0.95	2.15	2.14	2.46	2.45
Total orders (*)	100.00	107.79	90.34	90.70	52.18	55.16	42.39	42.90	97.71	107.16	119.78	108.25
Change	0.0%	7.8%	-9.7%	-9.3%	0.0%	5.7%	-18.8%	-17.8%	0.0%	9.7%	22.6%	10.8%
Coef. Var. (orders)	0.83	0.89	0.95	0.88	0.43	0.50	0.48	0.46	1.26	1.27	1.68	1.56
Change	0.0%	6.7%	14.1%	5.5%	0.0%	15.5%	12.3%	7.2%	0.0%	0.4%	33.0%	23.4%
Passengers												
Average Fare (*)	100.00	100.61	99.63	99.42	92.83	93.11	91.52	91.49	101.20	101.93	102.19	101.18
Change	0.0%	0.7%	-0.7%	-1.4%	0.0%	-3.3%	-2.6%	-2.4%	0.0%	2.0%	4.4%	0.8%
Median Fare (*)	100.00	100.65	99.30	98.61	89.55	89.28	87.27	87.42	101.47	103.51	105.96	102.25
Change	0.0%	0.7%	-0.7%	-1.4%	0.0%	-3.3%	-2.6%	-2.4%	0.0%	2.0%	4.4%	0.8%
Average LF	69.5%	68.0%	71.9%	72.1%	69.7%	68.3%	71.7%	71.8%	67.3%	65.4%	70.0%	70.8%
Change	0.0%	-2.1%	3.5%	3.7%	0.0%	-2.0%	2.9%	3.1%	0.0%	-2.8%	4.0%	5.3%

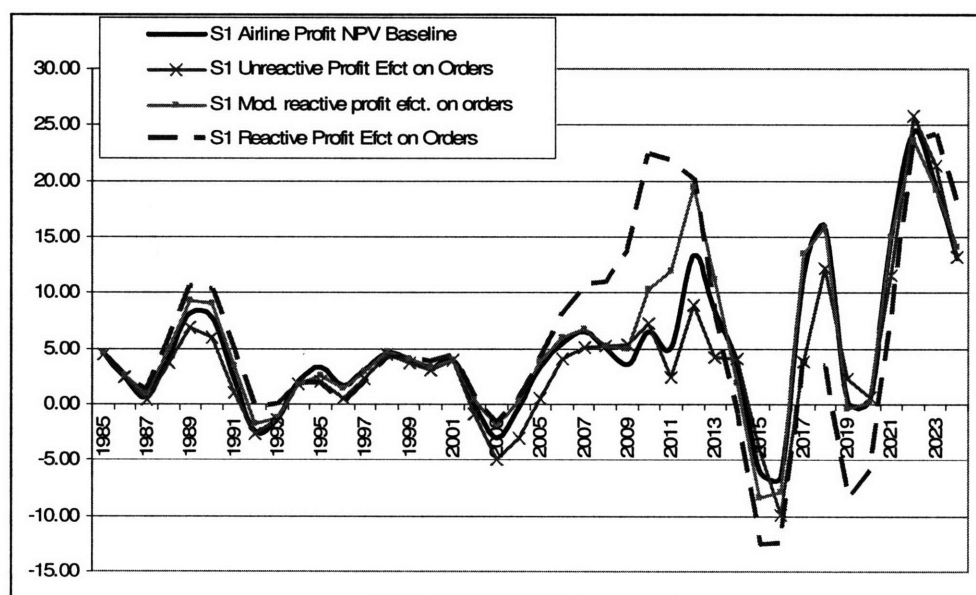


Figure 10-13 Comparative Airline NPV Diagram for the Profit Effect Adjustment Strategic Alternative (Scenario S1)

Interpretation and Discussion

Observation of the results show that as a general rule, disregarding the profitability indications¹⁰⁵ leads to deteriorated performance. Profitability drops significantly (50% for S1 and S2 and almost 90% for the more volatile S3) when airlines rely solely on forecasts for their ordering. In other words, following the market signals rather than the forecasts, in the competitive CA EoE, is a more rewarding way of operating. This is a

¹⁰⁵ Profitability is a reliable signal for over- or undercapacity in competitive markets by model design and following basic economic tenets.

‘surprising’ outcome in some ways as in theory decoupling ordering from the effects of ‘exuberance’ would be expected to moderate the cycle which is shown not to be the case.

The strategy of being moderately reactive performs better than the other two alternatives in all of the scenarios, as it allows for a less varying order stream for manufacturers. In this case, the strength of the strategy stems from a not-excessive limitation of orders during the downcycle which pushes profitability enough in the upcycle to retain order levels equal to the baseline.

From the implementation perspective, the industry appears to use the signal from changing profitability sensibly although reducing the “exuberance” side of the ordering cycle is shown to be beneficial for both the airline and the manufacturer industries with limited negative impact on the customers.

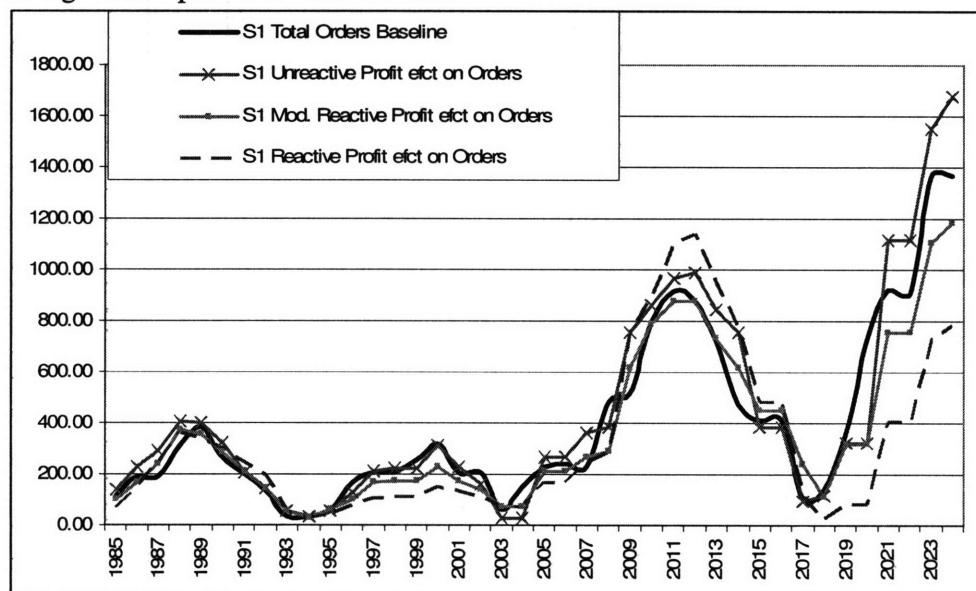


Figure 10-14 Comparative Aircraft Orders Diagram for the Forecast Adjustment Strategic Alternative (Scenario S1)

10.3.3.4 Supply Chain Visibility

The third strategic alternative related to ordering patterns investigates the effect of taking into account the backlog in aircraft orders and reducing the ‘supply chain discounting’ effect noted in Ch. 6 and 7 generally and implemented in the SD CA EoE as described in Ch.9. The SD literature discussed in Chapter 8 also demonstrated the importance of backlog visibility in supply chains. Even an idealized supply chain made of individuals is prone to disregarding the backlog orders as was repeatedly shown by the ‘beer game’ demonstrations (see Sterman 1989 and Ch. 6).

In the much more complex airline industry, competitive behavior that leads to market overestimation (exuberance), order gaming (phantom orders), and the desire to remain competitive have the effect of a cumulative industry behavior to heavily discount the aircraft in order backlog when placing their current orders. The ‘supply chain visibility’

strategic alternative balances this trend by taking into account a percentage of the actual current backlog of airframe manufacturers when ordering new aircraft.

To investigate the importance of this effect we run the following experiments:

- Baseline: (0% supply chain visibility which is equivalent to 100% supply chain discounting)
- 50% visibility of the supply chain
- 75% visibility of the supply chain

Experimental Results

The results from the relative experiments are summarized in Table 10-13 and presented graphically in Figures 10-15 and 10-16.

Table 10-13 Comparative Results for the Supply Chain Visibility Strategic Alternative

Scenario	S1			S2			S3		
	Baseline	50% SC Visibility	75% SC Visibility	Baseline	50% SC Visibility	75% SC Visibility	Baseline	50% SC Visibility	75% SC Visibility
Airlines									
NPV (*)	100.00	238.53	314.37	79.29	176.65	236.96	59.97	206.70	273.45
Change	0.0%	138.5%	214.4%	0.0%	122.8%	198.9%	0.0%	244.6%	355.9%
Coef. Var.	1.36	1.11	0.99	1.04	0.73	0.63	18.76	1.22	0.88
Change	0.0%	-18.3%	-27.1%	0.0%	-30.1%	-39.5%	0.0%	-93.5%	-95.3%
Median Cap. Utilization	73.8%	99.4%	100.0%	72.8%	99.4%	100.0%	72.6%	97.8%	99.8%
Manufacturers									
NPV (*)	100.00	63.29	54.43	66.70	39.64	36.50	117.07	70.93	63.43
Change	0.0%	-36.7%	-45.6%	0.0%	-40.6%	-45.3%	0.0%	-39.4%	-45.8%
Coef. Var. (Profit)	1.47	2.08	2.41	1.02	2.25	2.52	2.15	3.75	2.97
Total orders (*)	100.00	67.75	62.71	52.18	32.86	31.51	97.71	59.16	48.58
Change	0.0%	-32.2%	-37.3%	0.0%	-37.0%	-39.6%	0.0%	-39.5%	-50.3%
Coef. Var. (orders)	0.83	1.03	1.07	0.43	0.73	0.82	1.26	1.38	1.26
Change	0.0%	24.5%	28.4%	0.0%	69.7%	91.0%	0.0%	9.4%	-0.2%
Passengers									
Average Fare (*)	100.00	97.69	98.26	92.83	90.27	90.75	101.20	98.41	98.41
Median Fare (*)	100.00	97.13	96.64	89.55	86.89	88.03	101.47	99.24	98.65
Change	0.0%	-2.9%	-3.4%	0.0%	-3.0%	-1.7%	0.0%	-2.2%	-2.8%
Average LF	69.5%	75.8%	78.9%	69.7%	74.8%	77.7%	67.3%	75.6%	78.3%
Change	0.0%	9.0%	13.5%	0.0%	7.3%	11.5%	0.0%	12.3%	16.4%

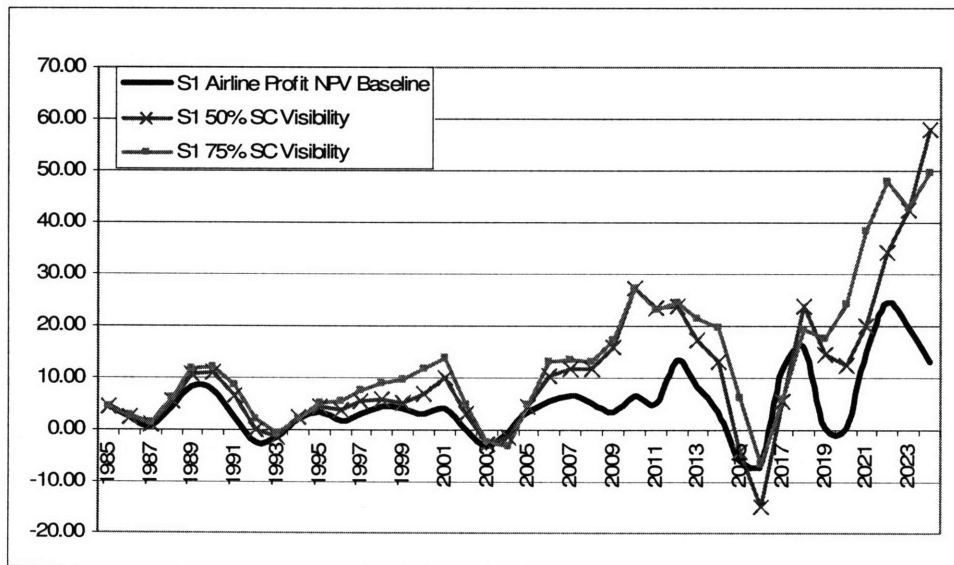


Figure 10-15 Comparative Airline NPV Diagram for the Supply Chain Visibility Strategic Alternative (Scenario S1)

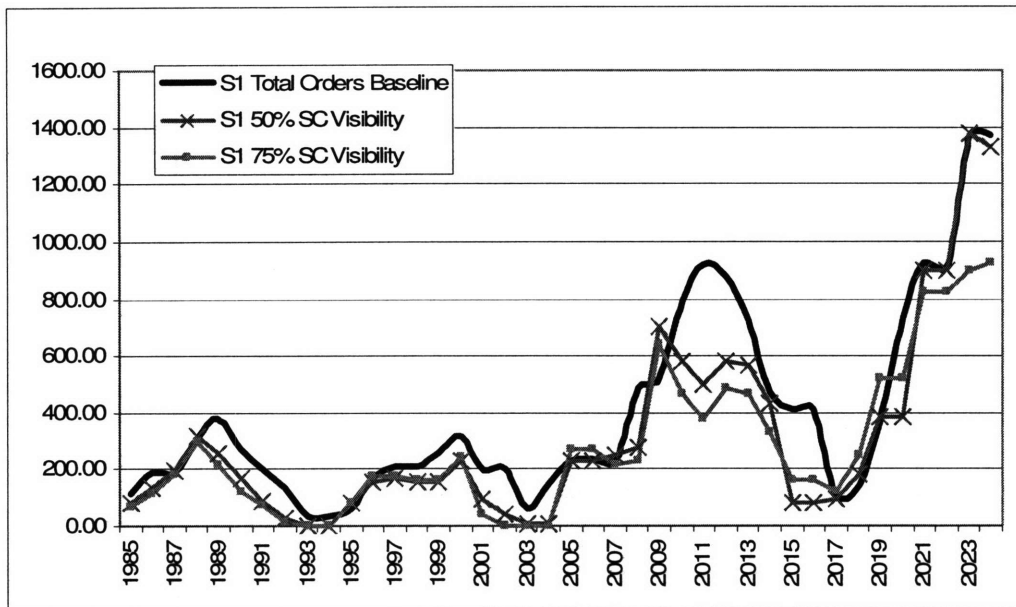


Figure 10-16 Comparative Total Orders Diagram for the Supply Chain Visibility Strategic Alternative (Scenario S1)

Interpretation and discussion

The effect that supply chain visibility has is indeed quite dramatic as the NPV of airline profitability in effect doubles (140% change for 50% SC visibility in S1 and up to 240% change in S2). The impact is higher the more volatile the environment is, as indicated by a comparison between S3 and S2. This does come at a price for the manufacturers for which the total order rates and profitability plummet while the variability of orders is increased significantly (CV increases by 25% for S1 50% visibility and 70% for S2 for the same strategic alternative). While passengers face higher load factors (thus lower service levels and as a result, need lower prices to be induced to travel) the total levels of both demand and the average and median fare remains close to the baseline.

This seemingly very effective strategy is a traditional remedy for the bullwhip effect in the supply chain management literature (see Chapters 6 and 7). *We find that it does not work exactly as expected for the whole value chain as some of the “excess” capacity that is ordered acts as a buffer for the errors in forecasting.* The removal of that buffer makes ordering more erratic (increasing order CV by up to 90% for the S2 75% visibility) and hurts the profitability of manufacturers who because of their competitive situation have to carry this additional cost. Yet, the potential for implementation is quite low in a fragmented industry environment. *It would require a consolidation of the ordering process and a compensation scheme for manufacturers who would otherwise have the incentive to continue supplying larger volume of aircraft to any party interested in buying them as their volatility of orders is in fact increased.*

10.3.4 Changes in the Airline Competitive Environment

We have seen in Chapter 7 that an increase in the number of new entrants induced by lower barriers to entry and the difficulty to shed capacity due to barriers to exit can lead

to overcapacity and consequent severe price competition. Anti-trust regulations can prevent industry consolidation and as a result the decision to merge or not resides with the airlines but the ability to do so involves both government and capital market stakeholders (financing).

In this section we focus on the pricing effects of consolidation as the effects on order rates and fleet management were discussed previously.

10.3.4.1 Competitive Environment and Yield Management

This set of experiments looks at how different competitive environments influence the CA EoE by employing variable yield management. As we discussed in Ch. 3, using yield management, airlines adjust their prices so as to achieve the desired load factors. In a competitive environment, airlines are willing to lower their prices much more than if they operate as a monopoly (which is true even for contestable markets). To see how this influences cyclicity we conduct the following experiments

- Baseline: The desired fare level (calculated by a cost plus target profit model) can be increased or decreased by up to 20% to adjust to the external demand.
- More competitive: The desired fare level can be increased only up to 8% and reduced by 45%.
- More consolidated: The desired fare level can be increased up to 35% and reduced by 10%.

Experimental Results

The results from the relative experiments are summarized in Table 10-14.

Table 10-14 Comparative Summary Results for the Effect of Competitive Environment and Consolidation in Pricing

Scenario	S1			S2			S3		
	Baseline	More Competitive	More Consolidated	Baseline	More Competitive	More Consolidated	Baseline	More Competitive	More Consolidated
Airlines									
NPV (*)	100.00	36.92	243.82	79.29	24.30	193.76	59.97	-57.47	224.83
Change	0.0%	-63.1%	143.8%	0.0%	-69.4%	144.4%	0.0%	-195.8%	274.9%
Coef. Var.	1.36	4.16	0.76	1.04	4.20	0.43	18.76	-2.90	0.79
Change	0.0%	205.4%	-44.5%	0.0%	304.8%	-58.1%	0.0%	-115.5%	-95.8%
Median Cap. Utilization	73.8%	73.6%	73.8%	72.8%	73.2%	72.4%	72.6%	72.2%	73.6%
Manufacturers									
NPV (*)	100.00	99.17	106.88	66.70	64.60	70.11	117.07	116.47	120.45
Change	0.0%	-0.9%	6.9%	0.0%	-3.2%	5.1%	0.0%	-0.5%	2.9%
Coef. Var. (Profit)	1.47	1.38	1.36	1.02	1.09	0.96	2.15	1.92	2.05
Total orders (*)	100.00	98.70	107.26	52.18	51.17	54.01	97.71	92.48	101.06
Change	0.0%	-1.3%	7.3%	0.0%	-1.9%	3.5%	0.0%	-5.3%	3.4%
Coef. Var. (orders)	0.83	0.77	0.86	0.43	0.41	0.45	1.26	1.20	1.22
Change	0.0%	-7.4%	3.7%	0.0%	-4.4%	4.0%	0.0%	-5.2%	-3.7%
Passengers									
Average Fare (*)	100.00	97.52	104.35	92.83	90.53	96.87	101.20	96.95	106.18
Median Fare (*)	100.00	96.84	104.84	89.55	86.19	92.84	101.47	93.86	109.16
Change	0.0%	-3.2%	4.8%	0.0%	-3.8%	3.7%	0.0%	-7.5%	7.6%
Average LF	69.5%	72.9%	67.1%	69.7%	72.7%	67.2%	67.3%	70.9%	64.8%
Change	0.0%	4.9%	-3.4%	0.0%	4.4%	-3.5%	0.0%	5.3%	-3.8%

Interpretation and Discussion

It is not surprising to note that the consolidated industry has lower load factors but significantly higher NPV for airlines (more than doubled at 144% for S1 and S2 and 274% for S3). The coefficient of variation in their profitability is also reduced (by almost 50% from 1.30 to 0.7 for S1) but that is not translated in a reduction for the variation in

total orders (slight increase from 0.83 to 0.86 for S1). Even so, airframe manufacturers increase their revenues as well (by 7% for S1), because the higher profitability increases the number of total orders.

It should be noted though that this strategic alternative does not include changes in the ordering patterns which would most probably be a direct consequence of consolidation in the industry (but not necessarily so in the case of simple pricing collusion). It is expected that a consolidated airline industry would manage their fleet with less variation (but this would not be the case with a colluding industry). Even in this case, the airframe manufacturers may not benefit much as they would face customers with stronger purchasing power.

Overall, pricing power in a consolidated industry is quite a strong mechanism for reducing variability but returning to the regulated environment that would allow such behavior is not a feasible standalone political option. The argument for greater consolidation needs to be tied to increases in service levels. From the model results this is shown to be a plausible claim as the increase in the fare price to the end consumer (fare increases by up to 7% for S3) is balanced by an increase in service levels (load factors as our proxy for them are reduced by little less than 4% across the board). More importantly, the inverse – i.e. more competition – provides some benefit in price reductions compared to the baseline (between 3 and 7%) but it also amplifies cyclicity in profitability substantially (tripling the C.V from 1.36 to 4.16 in S1). Yet interestingly, this profitability do not translate into additional order swings.

10.3.4.2 Effect of Firm Entry and Exit on Pricing

One effect of changing the barriers to entry and exit is to adjust ordering practices, the magnitude of which as we saw in Section 10.4.3 can be quite substantial. In this section we isolate the effect of entry and exit to pricing; a large number of new entrants lowers the profitability expectations in the whole industry (therefore the base pricing) as they attempt to establish. The reverse is true for a consolidated industry. We investigate this effect of entry and exit with the following experiments:

- Higher entry rates and lower exit rates: More competitive environment by doubling the baseline entry rates and halving the exit rates.
- Lower entry rates and higher exit rates: Less competitive environment by halving the baseline entry rates and doubling the exit rates.

Experimental Results

The results from the relative experiments are summarized in Table 10-15.

Interpretation and Discussion

As in the previous section, the results coincide with the expectations of economic theory: i.e. consolidation allows prices to rise and stabilizes the output of the industry and the welfare of the final consumer is degraded. What is interesting in this set of results is that the relative impact of changing entry and exit rates from the consequent pricing changes is small but not insignificant (7% benefit to airline profitability and a 10% reduction in CV for S1 that can be up to 24% airline profitability increase and 60% reduction in CV

for the more volatile S3 scenario). These effects do not come at the expense of the consumer as there is no significant change in the median fare.

Table 10-15 Comparative Summary Results for the Effect of Adjusting Barriers to Entry and Exit on Fare Pricing

Scenario	S1			S2			S3		
	Baseline	Lower Entry Higher Exit Rates	Higher Entry Lower Exit Rates	Baseline	Lower Entry Higher Exit Rates	Higher Entry Lower Exit Rates	Baseline	Lower Entry Higher Exit Rates	Higher Entry Lower Exit Rates
Airlines									
NPV (*)	100.00	113.30	95.57	81.50	89.99	77.17	62.01	76.95	55.91
Change	0.0%	7.2%	-9.6%	0.0%	10.4%	-5.3%	0.0%	24.1%	-9.8%
Coef. Var.	1.31	1.17	1.31	1.00	0.92	1.04	1.721	6.94	37.20
Change	0.0%	-10.8%	0.0%	0.0%	-8.2%	4.1%	0.0%	-59.7%	116.2%
Median Cap. Utilization	73.9%	74.1%	73.8%	72.6%	72.7%	72.6%	73.0%	73.1%	73.0%
Manufacturers									
NPV (*)	100.00	102.24	105.49	68.74	67.82	67.99	126.33	121.92	125.83
Change	0.0%	2.2%	5.5%	0.0%	-1.3%	-1.1%	0.0%	-3.5%	-0.4%
Coef. Var. (Profit)	1.50	1.42	1.33	1.00	1.01	0.98	1.77	1.92	1.76
Total orders (*)	100.00	99.92	100.96	52.96	51.22	51.37	99.79	98.23	98.76
Change	0.0%	-0.6%	0.5%	0.0%	-3.3%	-3.0%	0.0%	-1.6%	-1.0%
Coef. Var. (orders)	0.86	0.88	0.87	0.42	0.45	0.45	1.24	1.23	1.23
Change	0.0%	2.5%	1.4%	0.0%	6.9%	8.5%	0.0%	-1.0%	-0.6%
Passengers									
Average Fare (*)	100.00	100.31	99.82	92.85	93.06	92.64	101.20	101.56	101.00
Median Fare (*)	100.00	99.97	100.05	88.92	89.10	88.76	101.40	102.06	101.21
Change	0.0%	0.1%	0.2%	0.0%	0.2%	-0.2%	0.0%	0.6%	-0.2%
Average LF	69.5%	69.6%	69.6%	69.8%	69.7%	69.8%	67.3%	67.3%	67.3%
Change	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

10.3.5 Aircraft Manufacturer-specific strategic alternatives

As noted in the previous set of experiments, the aircraft capacity aspect of the CA EoE is a most critical one. Therefore, the action of aircraft manufacturers, as influenced by their competitive environment, are expected to influence the whole CA EoE. In the set of experiments presented in this section, we investigate the effect of pricing policies and manufacturer competition along with the effect of production rates and planning.

10.3.5.1 Airframe Manufacturers: Effects of Aircraft Pricing

Aircraft pricing (which included additional incentives for an aircraft like financing, buyback agreements and performance guarantees) is a key component of aircraft manufacturing competition. Testing its influence on the cycles of the CA EoE we run experiments in which the price of aircraft was altered based on current demand. For this exercise we forced the two manufacturers to follow the same pricing policy (a constraint that will be relaxed when discussing the airframe manufacturers' strategies in Section 10.4).

These experiments test the relative impact of discounting from list price for aircraft. In Ch. 4, Figure 4-9, we saw that these discounts can be as much as 50% for mass orders although price increases are not as substantial, assuming that the average selling price is 80% of the list price would allow for increases to reach the actual list prices when aircraft supply is tight.

The experiments that were conducted to explore the relative impact over this range of discounts are the following:

- Baseline pricing: Adjusted upwards or downwards by up to 20% in an effort to manage demand towards the current production rate.¹⁰⁶
- Manufacturer collusion: Pricing is adjusted only 10% downwards and up to 40% upwards. Manufacturers do not compete on gaining market share either.
- Manufacturer signal pricing: Strong swings of pricing both ways: 50% downwards and 40% upwards.
- Manufacturer intense competition: Pricing downward adjustment of up to 50% discounts from the desired (list price) when demand is low. Aggressive discounting for capturing market share was also included in this run.

Experimental Results

The results from the relative experiments are summarized in Table 10-16 and Figure 10-18.

Table 10-16 Comparative Summary Results for the Aircraft Pricing Strategic Alternatives

Scenario	S1				S2				S3			
	Baseline	MF. Price Collusion	MF. Signal Pricing	MF. Intense Competition	Baseline	MF. Price Collusion	MF. Signal Pricing	MF. Intense Competition	Baseline	MF. Price Collusion	MF. Signal Pricing	MF. Intense Competition
Airlines												
NPV (*)	100.00	94.28	82.37	94.82	79.29	78.23	60.07	70.83	59.97	36.40	62.00	56.87
Change	0.0%	-5.7%	-17.6%	-5.2%	0.0%	-1.3%	-24.2%	-10.7%	0.0%	-39.3%	3.4%	-5.2%
Coef. Var.	1.36	1.52	1.61	1.40	1.04	1.15	1.57	1.34	18.76	-12.04	7.89	14.75
Change	0.0%	11.4%	18.2%	2.7%	0.0%	10.9%	51.6%	29.1%	0.0%	-164.2%	-57.9%	-21.4%
Median Cap. Utilization	73.8%	73.1%	72.1%	72.7%	72.8%	73.4%	72.9%	72.2%	72.6%	71.2%	73.7%	72.0%
Manufacturers												
NPV (*)	100.00	254.10	179.59	-7.48	66.70	177.97	94.80	-19.51	117.07	283.77	172.47	-10.71
Change	0.0%	154.0%	79.6%	-92.5%	0.0%	166.8%	42.1%	-129.2%	0.0%	142.4%	47.3%	-109.2%
Coef. Var. (Profit)	1.47	1.35	1.81	98.95	1.02	0.87	2.25	4.50	2.15	1.83	3.15	12.99
Total orders (*)	100.00	93.93	100.92	104.53	52.18	49.22	51.59	52.84	97.71	98.95	93.13	99.36
Change	0.0%	-6.1%	0.9%	4.5%	0.0%	-5.7%	-1.1%	1.3%	0.0%	1.3%	-4.7%	1.7%
Coef. Var. (orders)	0.83	0.95	0.80	0.83	0.43	0.49	0.49	0.46	1.26	1.30	1.19	1.26
Change	0.0%	14.0%	-4.3%	-0.3%	0.0%	13.8%	14.2%	6.9%	0.0%	2.7%	-5.4%	0.2%
Passengers												
Average Fare (*)	100.00	104.86	100.74	96.35	92.83	96.82	92.77	89.18	101.20	106.21	100.15	96.81
Change	0.0%	4.9%	0.3%	-4.7%	0.0%	3.8%	-2.3%	-4.7%	0.0%	7.8%	-0.2%	-5.5%
Median Fare (*)	100.00	104.93	100.28	95.26	89.55	92.94	87.47	85.33	101.47	109.42	101.23	95.87
Change	0.0%	4.9%	0.3%	-4.7%	0.0%	3.8%	-2.3%	-4.7%	0.0%	7.8%	-0.2%	-5.5%
Average LF	69.5%	68.6%	69.1%	69.5%	69.7%	69.4%	69.0%	69.4%	67.3%	66.0%	68.4%	67.4%
Change	0.0%	-1.3%	-0.5%	0.0%	0.0%	-0.4%	-0.9%	-0.4%	0.0%	-1.9%	1.6%	0.1%

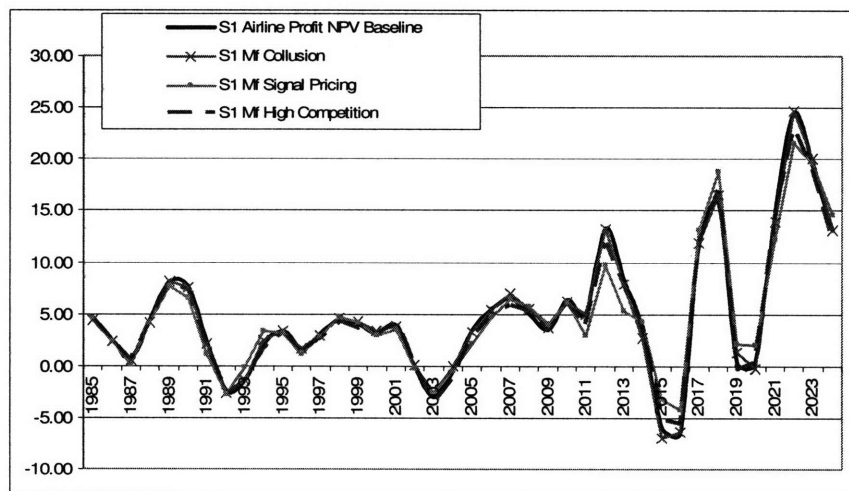


Figure 10-17 Comparative Diagram of Airline NPV for Aircraft Pricing

¹⁰⁶ As discussed in Ch. 9, if demand for aircraft persists, the production rates are raised but this comes at a cost and is a delayed response.

Interpretation and Discussion

The dramatic changes in aircraft pricing based on supply/demand equilibration that are showcased by the three stylized experiments appear to have little effect on the airline competitive behavior (airlines see a reduction of slightly more than 17% in signal manufacturer competition for S1 and up to 24% for S2). Cutthroat pricing expectedly results in significant losses for the manufacturers (ranging from -60% for S1 to -130% for S2) and would have repercussions in aircraft R&D that are not modeled here.

The signal pricing, on the other hand, in which price swings to extreme in both directions improves the manufacturers' profitability substantially (30-40% across scenarios) Ordering and owning more expensive aircraft during an upcycle does not seem to induce substantially less orders anymore that lower prices in the downcycle induce more orders.

These results are based on the indirect effect of changing the ownership costs of aircraft which are transferred to consumers despite the competitiveness of the airline industry. Also, the psychological inducement of a steep aircraft discount which is known to play a role in aircraft buying is not modeled here; this may increase the actual impact of these strategies on a case by case basis. *Overall, swings in aircraft pricing provide little benefit to the airline industry and in fact intense competition with the consequent reduction in ownership costs are simply passed on to consumers.*

10.3.5.2 Airframe Manufacturers: Production Rate Adjustments

Besides pricing, production scheduling is another lever available to airframe manufacturers with a potential of significant impact on the CA EoE. Production rate changes simply respond differently to the changes in aircraft demand and only impact it by second order effects (e.g., without supply chain visibility, a decrease in production rate responsiveness increases 'invisible' backlogs and as a consequence the swings in demand will be exacerbated). Given the history of previous experiments we expect that the leverage of this alternative would be significant and the results indeed do not disappoint.

We conduct experiments in which both manufacturers follow the same strategies that are categorized into slower production rate adjustments and faster production rate adjustments. The following stylized experiments were conducted:

- *Slow production rate change*: MF.A is mimicking MF.B in their production rate and backlog choices. The change of production rates is slowed to one third of the rate of change in baseline for MF.B and the backlog increased to from two to six years.
- *Slow production rate change and 25% SC visibility*: We explore the synergies provided by a slower production rate and a more informed ordering strategy that is no misled by the large backlog accumulation.
- *Fixed production scheduling*: Production adjustment are entirely decoupled from orders and pegged to long-term air transport demand trends.

- *Quick production rate change*: MF.B adopts the manufacturing practices of MF.A with faster production rate changes and shorter backlogs. The change of production rates is increased to double the rate of change in baseline.
- *Just-in-time (JIT) delivery*: both manufacturers transition to very fast production rate changes and backlogs of around a year or less. Linear production scheduling: Production rate changes are disabled entirely and replaced by a fixed production schedule that is using a linear regression of the projected demand growth rates for the entire simulated period. In order to make this option feasible is to utilize lean manufacturing methods that reduce the costs of production rate changes.
- *Just-in-time (JIT) delivery and 25% SC visibility*: This experiment retains the manufacturing process of the previous one but it also investigates the potential synergy offered by a reduction in the supply chain discounting by 25%.

Experimental Results

The results from the relative experiments are summarized in Tables 10-17 and 10-18 and Figure 10-19.

Table 10-17: Comparative Summary Results for Aircraft Production Rate Adjustment Strategic Alternatives (Slower or decoupled production)

Scenario	S1				S2				S3			
	Baseline	Both slow prod. rate change	Both slow prod rate change + 25%SC visibility	Fixed Production	Baseline	Both slow prod. rate change	Both slow prod rate change + 25%SC visibility	Fixed Production	Baseline	Both slow prod. rate change	Both slow prod rate change + 25%SC visibility	Fixed Production
Airlines												
NPV (*)	100.00	121.28	210.85	213.10	79.29	78.53	143.28	85.77	59.97	93.86	200.96	76.56
Change	0.0%	21.3%	110.9%	113.1%	0.0%	-0.9%	80.7%	8.2%	0.0%	56.5%	235.1%	27.7%
Coef. Var.	1.36	1.34	0.97	1.06	1.04	1.95	0.72	2.71	18.76	3.86	1.50	5.83
Change	0.0%	-1.4%	-28.5%	-21.9%	0.0%	88.5%	-30.9%	161.1%	0.0%	-79.4%	-92.0%	-68.9%
Median Cap. Utilization	73.8%	77.6%	97.4%	92.6%	72.8%	76.5%	92.8%	84.6%	72.6%	81.6%	97.4%	76.0%
Manufacturers												
NPV (*)	100.00	173.67	118.55	270.83	66.70	97.32	51.14	192.81	117.07	200.63	137.62	128.64
Change	0.0%	73.7%	18.6%	171.0%	0.0%	45.9%	-23.3%	189.1%	0.0%	71.4%	17.6%	9.9%
Coef. Var. (Profit)	1.47	0.79	0.94	0.64	1.02	0.65	0.92	0.43	2.15	1.28	1.57	2.26
Total orders (*)	100.00	129.92	83.27	166.25	52.18	57.97	39.54	58.58	97.71	114.67	77.15	102.09
Change	0.0%	29.9%	-16.7%	66.2%	0.0%	11.1%	-24.2%	12.3%	0.0%	17.4%	-21.0%	4.5%
Coef. Var. (orders)	0.83	0.79	0.90	0.83	0.43	0.52	0.63	0.49	1.26	1.36	1.73	1.24
Change	0.0%	-4.4%	8.5%	0.4%	0.0%	20.0%	47.5%	13.9%	0.0%	8.0%	37.5%	-1.7%
Passengers												
Average Fare (*)	100.00	100.36	98.30	100.80	92.83	92.73	90.99	94.63	101.20	101.08	99.28	100.44
Median Fare (*)	100.00	99.33	98.23	100.72	89.55	92.23	87.53	91.62	101.47	101.54	98.76	99.37
Change	0.0%	-0.7%	-1.8%	0.7%	0.0%	3.0%	-2.3%	2.3%	0.0%	0.1%	-2.7%	-2.1%
Average LF	69.5%	70.6%	74.2%	73.9%	69.7%	69.4%	72.4%	69.8%	67.3%	69.2%	75.0%	68.5%
Change	0.0%	1.5%	6.7%	6.3%	0.0%	-0.4%	4.0%	0.2%	0.0%	2.9%	11.4%	1.8%

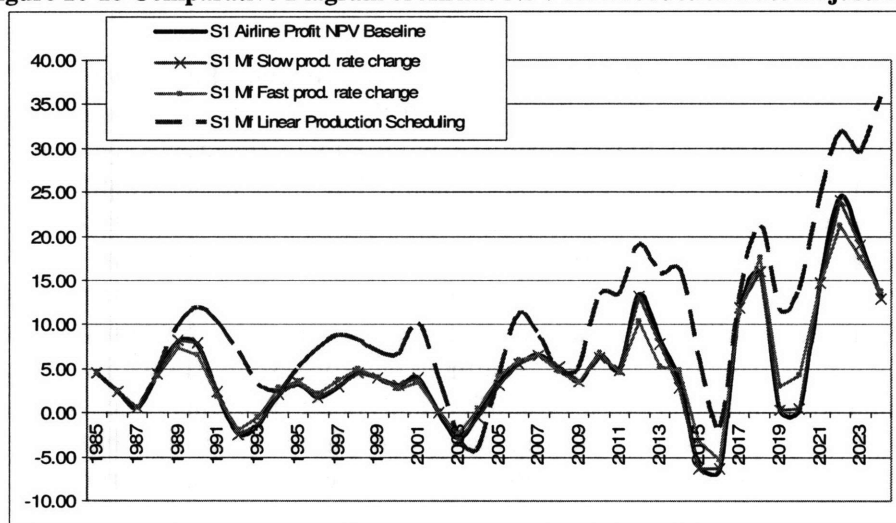
Interpretation and Discussion

As anticipated, this strategic alternative shows significant potential for affecting the CA EoE. Simply slowing down the production rate changes to one third of the baseline, increases manufacturers' welfare by 74% for S1 while increasing airline profitability by 20% for S1. For the less volatile S2 scenario, the manufacturers still see benefits from the strategy (46% increase in profitability) but the airlines' profitability is not affected. This strategy also exhibits synergies with the SC visibility strategic alternative; airline profitability jumps by 110% for S1 and even more for S3 which is more volatile. Not only that, but in both cases the median fare sees small decreases that can be attributed to the efficiency gains in production by the manufacturers. *Overall, these two strategies show indications of a symbiotic win-win-win combination assuming that they are implementable which will be discussed later in this section.*

Table 10-18 Comparative Summary Results for Aircraft Production Rate Adjustment Strategic Alternatives (Quicker or JIT aircraft delivery)

Scenario	S1				S2				S3			
	Baseline	Both quick	Both JIT	Both JIT + 25% SC visibility	Baseline	Both quick	Both JIT	Both JIT + 25% SC visibility	Baseline	Both quick	Both JIT	Both JIT + 25% SC visibility
Airlines												
NPV (*)	100.00	116.44	146.76	187.62	79.29	89.05	99.55	121.69	59.97	98.29	131.99	138.30
Change	0.0%	16.4%	46.8%	87.6%	0.0%	12.3%	25.6%	53.5%	0.0%	63.9%	120.1%	130.6%
Coef. Var.	1.36	1.26	1.19	1.29	1.04	0.74	0.69	0.74	1.76	2.47	1.41	1.60
Change	0.0%	-7.5%	-12.8%	-5.5%	0.0%	-29.1%	-33.5%	-28.7%	0.0%	-86.9%	-92.5%	-91.5%
Median Cap. Utilization	73.8%	81.1%	92.2%	96.1%	72.8%	79.3%	89.6%	95.6%	72.6%	77.1%	88.7%	85.8%
Manufacturers												
NPV (*)	100.00	84.52	68.65	64.78	66.70	59.84	44.84	38.44	117.07	85.06	69.38	66.76
Change	0.0%	-15.5%	-31.3%	-35.2%	0.0%	-10.3%	-32.8%	-42.4%	0.0%	-27.3%	-40.7%	-43.0%
Coef. Var. (Profit)	1.47	1.35	1.65	1.83	1.02	0.93	1.17	1.81	2.15	1.86	1.17	1.63
Total orders (*)	100.00	84.18	77.40	69.45	52.18	46.23	41.21	37.68	97.71	71.36	62.73	63.15
Change	0.0%	-15.8%	-22.6%	-30.6%	0.0%	-11.4%	-21.0%	-27.8%	0.0%	-27.0%	-35.8%	-35.4%
Coef. Var. (orders)	0.83	0.82	0.95	0.96	0.43	0.38	0.44	0.55	1.26	0.99	0.77	1.16
Change	0.0%	-1.0%	14.3%	15.4%	0.0%	-10.7%	1.4%	26.8%	0.0%	-21.7%	-39.1%	-8.0%
Passengers												
Average Fare (*)	100.00	98.34	97.76	97.42	92.83	91.70	90.84	90.16	101.20	98.82	97.74	98.41
Median Fare (*)	100.00	96.58	94.15	95.14	89.55	87.70	87.16	87.29	101.47	98.13	95.61	97.93
Change	0.0%	-3.4%	-5.9%	-4.9%	0.0%	-2.1%	-2.7%	-2.5%	0.0%	-3.3%	-5.8%	-3.5%
Average LF	69.5%	70.6%	71.7%	73.1%	69.7%	70.5%	71.0%	72.1%	67.3%	70.0%	71.5%	71.9%
Change	0.0%	1.6%	3.2%	5.2%	0.0%	1.2%	1.9%	3.4%	0.0%	4.0%	6.2%	6.9%

Figure 10-18 Comparative Diagram of Airline NPV for Production Rate Adjustments



A fixed production schedule adopted by both manufacturers provides a marginal improvement in airline profitability over the Slow + SC visibility strategic alternative raising airline profitability by 113% for S1 (3% more) but the manufacturers see their profitability skyrocket by 171% as all production rate changes fall within the range of sustaining the learning curve effect. Interestingly but not unexpectedly, with an entirely rigid aircraft delivery date that is not reactive to changes in demand, in the low volatility scenario (S2), the linear production rate strategy is in fact increasing the volatility of the performance of the airlines as it adapts slower than forecasting. Besides this, the downsides to this alternative include an increase in the cost of travel for the consumer (up to 2% for the S2 case) but, importantly, a substantial increase in the average load factors and equipment utilization which imply a deterioration of service levels.

On the other hand, the JIT delivery set of experiments, and to a lesser extent the faster production rate changes alone, does show a net positive impact to airlines for the more volatile scenarios (S1 and S3) but at a significant cost for the manufacturers that have to adjust their production rates almost instantly even when lean production is in place.

10.3.6 Strategic Alternative Review and Comparative Discussion

Using the results above, we can specify the strategic alternatives that would be expected to have the better performance in moderating the CA EoE oscillatory behavior based on the relative impact of the mechanisms that were investigated. Table 10-19 summarizes the results from the key experiments conducted in this section while Figure 10-19 shows the strategic alternatives that are within the ‘symbiotic quadrant’ for airlines and manufacturers.

Exogenous factors do provide a continuous noise input that changes the equilibrium of the system and their absence would go a long way towards stabilizing the system. In practice though, this is not a workable proposition and it is the system itself that amplifies these input variations and propagates the cycle by almost doubling the volatility. (Section 10.2.1)

Focusing on the things that the CA EoE constituents have control over, we found that the competitive environment does affect amplitude of the cycles and, in absence of external factor noise, the changes in the competitive environment do create cyclical behavior affected by the waves of entry and consolidation but with lesser amplification. This means that it is possible to retain the benefits of competitive behavior without the level of cyclical variation currently observed. Our working hypothesis, that control over cyclicity would have positive impacts on the CA EoE constituent enterprises is also shown to be correct as all the alternatives that improve the value for “universal owners” reduce cyclicity as perceived by the constituent enterprises and shown by reductions in the coefficient of variations in profitability and order patterns. The only seeming exception (MF fixed production rate) increases cyclicity for airlines but it practically eliminates it for manufacturers (total decoupling of production from orders).

Transforming some of the short-term fixed costs for airlines to variable through profit sharing in its current form has a small but significant positive effect in moderating the cycle but it does increase profitability for the airline industry (at the expense of employees mostly).

Affecting the supply of capacity instead can have dramatic impact in the reduction of the cycle. Increasing the flexibility of capacity or moderating the order rates so that they take into account the backlog of the entire industry go a tremendous way towards reducing cyclicity.

Intervention by manufacturers alone, on the other hand, in the form of managing their backlogs and production rates more efficiently (lean production) can moderately help compared to the existing situation (especially since the conventional approach to orders is that due to airline related delays, any deliveries in less than a year’s time are bound to be underutilized. Deterioration of service and backlog explosion though amplifies the cycles to the extreme. Similarly, pricing discipline by the manufacturers and strong signaling has little noticeable effects.

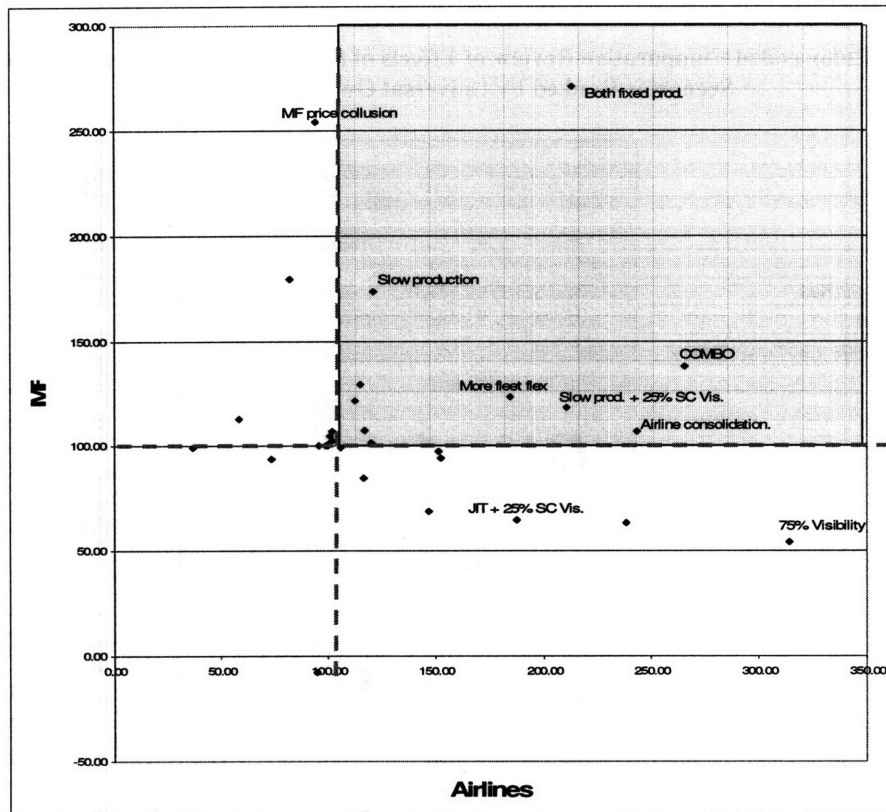


Figure 10-19 Relative Plot of Strategic Alternatives Performance for Airlines and Manufacturers based on S1 (shaded 'sybiotic' quadrant)

From the experiments in this section we can draw the following general conclusions:

- Control of capacity is key in controlling the performance of the CA EoE
- Reductions in volatility in the CA EoE are positively related to improved performance (with the exception of when airline performance is decoupled from ordering as in the MF fixed production experiments)
- After airline industry consolidation/collusion, the more powerful strategic alternative is decoupling aircraft production from ordering (i.e., adoption by MF.A of the MF.B production strategy of higher backlogs and slower production rate changes)
- Implementation of a JIT delivery strategy has comparatively less impact than the previous strategic alternative and its success relies on the technological ability to adjust production rates. It has the advantage that it does not require any cooperation/collusion between constituents vertically or laterally.

In the next two subsections we will review and explain these findings in terms of their dynamic behavior in Section 10.3.7 and in terms of their theoretic implications in Section 10.3.8.

Table 10-19 Color-coded Comparative Review of Effects of Strategic Alternatives Averaged Over Scenarios Ranked by Universal Owner Returns

	Airline		Manufacturers		Passengers		Univ. Owner
	NPV Change	CV change	NPV Change	Order CV Change	Fare Change	LF change	Change
75% SC visibility	256.4%	-54.0%	-45.6%	-41.8%	-2.6%	13.8%	113.0%
More consolidated airlines	187.7%	-66.1%	5.0%	6.2%	5.4%	-3.6%	98.8%
MF fixed prod. Rate	49.6%	23.4%	123.3%	N/A	0.3%	2.8%	80.4%
Slow prod rate change + 25%SC visibility	142.2%	-50.5%	4.3%	-5.3%	-2.2%	7.4%	75.9%
50% SC visibility	168.7%	-47.3%	-38.9%	-31.5%	-2.7%	9.5%	69.8%
MF Collusion	-15.5%	-47.3%	154.4%	-16.1%	5.5%	-1.2%	62.1%
More flexibility	93.9%	-47.1%	23.3%	23.0%	3.9%	4.8%	59.8%
Slow prod rate change	25.6%	2.6%	63.7%	43.5%	0.8%	1.3%	42.5%
Reactive to profit ordering	57.7%	-26.5%	-3.8%	-2.4%	0.4%	3.5%	30.1%
Mod reactive to profit ordering	64.1%	-35.8%	-9.9%	-6.5%	-1.0%	4.0%	29.7%
MF JIT+ lean + 25% SC visibility	90.6%	-41.9%	-40.2%	-25.4%	-3.6%	5.2%	29.4%
25% cost deferrment	15.0%	-21.4%	28.0%	30.7%	-8.6%	1.3%	20.4%
Mf signal pricing: sensitive	-12.8%	4.0%	56.3%	-3.4%	-0.8%	0.1%	18.1%
Longer history (smoother forecast)	23.6%	-3.0%	11.6%	7.6%	0.4%	0.7%	17.2%
MF JIT+ lean	64.1%	-46.3%	-35.0%	-17.1%	-4.8%	3.8%	15.6%
15% cost deferrment	11.7%	-18.8%	20.3%	21.0%	-5.3%	1.0%	15.3%
Lower entry higher exit	25.2%	-29.5%	2.0%	3.4%	-0.1%	0.0%	14.0%
MF Quick prod. Rate	30.9%	-41.1%	-17.7%	-4.1%	-2.9%	2.3%	6.0%
Baseline with active firm entry and exit	7.9%	-5.1%	3.0%	2.0%	-0.4%	0.0%	5.7%
More leasing	2.3%	-11.6%	4.3%	5.3%	-6.3%	0.4%	3.0%
Higher entry lower exit	0.8%	31.7%	4.3%	2.3%	-0.5%	0.1%	2.7%
Stronger retirement adjuster	1.7%	-1.1%	2.1%	3.7%	0.2%	0.1%	1.8%
Less leasing	-0.2%	5.2%	-0.1%	1.9%	2.3%	-0.1%	0.0%
Shorter history (less smooth forecast)	-3.0%	-13.5%	2.3%	0.0%	-0.1%	-0.1%	-0.4%
Weaker retirement adjuster	-5.3%	11.2%	-1.3%	-2.7%	-0.7%	-0.2%	-3.2%
Less flexibility	-40.6%	20.4%	-4.9%	-2.8%	-1.1%	-2.8%	-22.6%
Unreactive to profit ordering	-60.8%	68.0%	10.3%	11.5%	0.8%	-2.3%	-26.3%
More competitive	-109.4%	131.6%	-1.5%	-0.6%	-4.8%	4.9%	-54.3%
MF intense competition: high comp	-7.0%	3.5%	-115.3%	-2.8%	-5.0%	-0.1%	-55.2%

Green: indicative positive impact for the constituent enterprise
Orange indicative negative impact for the constituent enterprise

10.3.7 The Endogenous CA EoE cyclicity amplification mechanisms

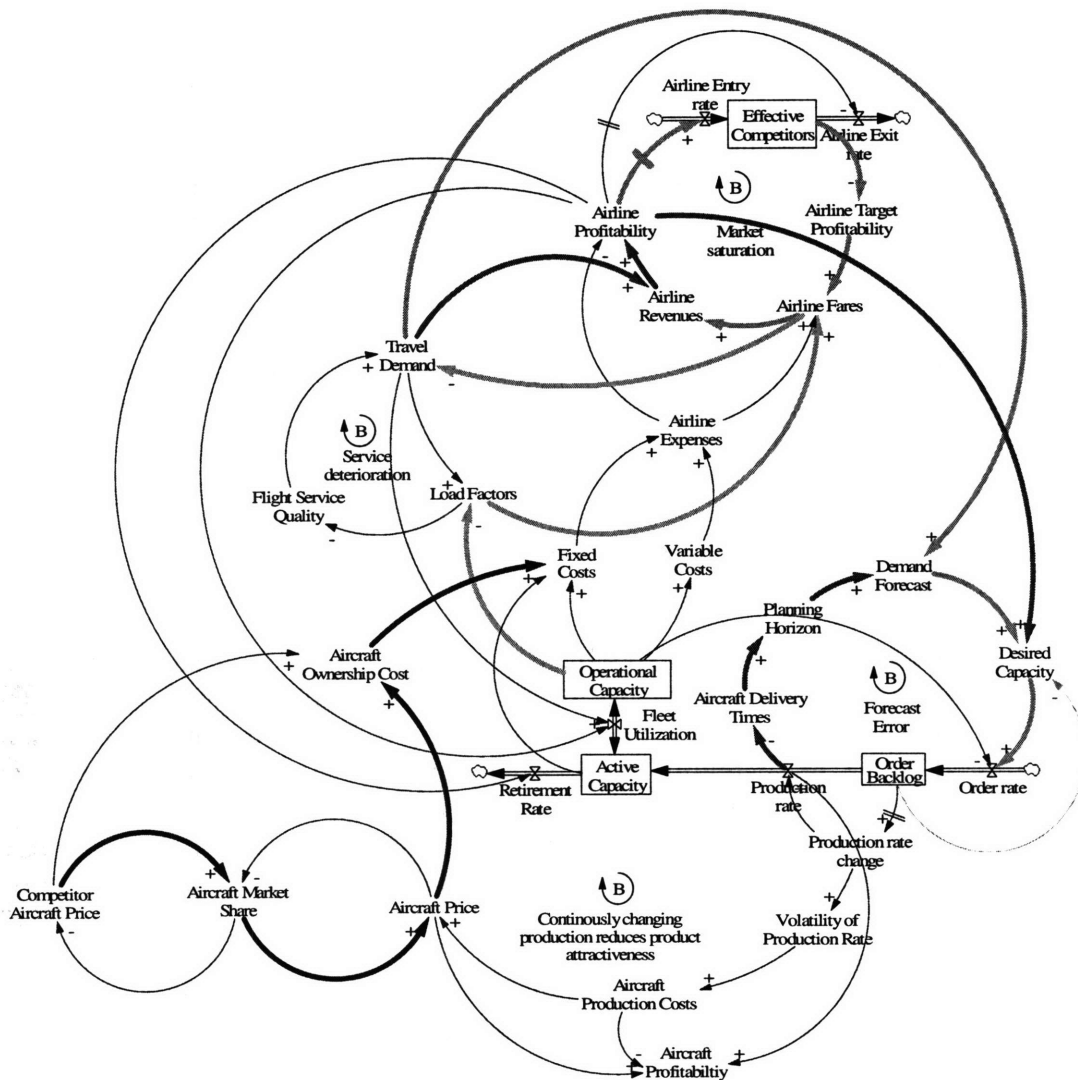


Figure 10-20 Endogenous Amplification mechanisms for the CA EoE (Relevant Sections 10.3.7.1 and 10.3.7.2)

From the cyclicity inducing mechanisms in the CA EoE described in Ch. 7, we showed that some are more prominent than others.

We summarize each mechanism and our findings in the subsections below and with the help of Figure 10-20.

10.3.7.1 Mechanism 1: Low Barriers to Entry, High Barriers to Exit

Indicated with the green bold arrows in Fig. 10-20, this amplification mechanism is based on the delay of entry: an unanticipated increase in travel demand for which capacity is not adequate, improves the profitability of existing carriers which in turn attracts new entrants. The new entrants intensify competition to gain market share and drop the

“target_profitability” for the industry which in turn suppresses airline fares and profitability. If exit is slower than entrance, then this slump in profitability can be protracted even if it does not coincide with a demand trough.

As described in Section 10.3.4.2, we found that changing the *rates* of entry and *exit* has relatively less impact to the industry compared to changing the *intensity* of competition. In this case, as Section 10.3.4.1 discussed, the deeper the competition (i.e. price war) the more intense the cycle becomes (volatility in the system is increased by 25% when tickets can be discounted up to 45% of the normal profit price as opposed to 20% of the baseline).

The latter refers particularly to the ‘intensity’ of the [Load_Factors] → [Airline_Fares] link that represents the yield management system. When fare prices are more sensitive to load factors amplifies the effect of the mechanism discussed in the next section.

10.3.7.2 Mechanism 2: Aircraft Order Delivery Lead Time Effect

This is the classic bullwhip mechanism. In Fig. 10-20 is shown in bold orange arrows.

An unanticipated increase in demand boosts the forecast for future demand which in turn is translated in aircraft orders. A side mechanism that amplifies these orders is the investment exuberance which fuels the increase in the orders based on an increase in profitability ([Airline_profitability] → [Desired_capacity] shown in brown arrows). Depending on the manufacturers production capacities and policies, the orders can take anywhere from two to six years to materialize as capacity. In the meantime, capacity is lacking, load factors remain high, and so is profitability which continues to press the order rates upwards.

Once these cumulative orders start to materialize, load factors are suddenly lowered and profitability along with them. Orders suffer disproportionately, thus preparing the ground for the next iteration of this mechanism.

In section 10.3.3.2, we saw that ‘smoothing’ the historic data points used for ordering, improves profitability but, also, slightly increases cyclicity. This happens because the overall inertia of the system is increased that way and the effects of additional profits when the airline orders are slow to respond to an upward demand trend actually exacerbate the mechanism described here.

The “moderately reactive to profit ordering” strategic alternative discussed in Section 10.3.3.3 was more effective, and more consistent, in increasing returns for airlines and reducing cyclicity. It exploits the ([Airline_profitability] → [Desired_capacity] link by making airlines to order less aircraft in downturns but also capping the exuberance in upturns. As discussed in Section 10.3.3, this mechanism is effective but only on an industry wide basis as it would penalize any single airline that would try to follow it.

A balancing link to this mechanism is the one shown as the dotted thin orange arrow link: [Order_Backlog] → [Desired_Capacity]. It provides the ability to countervail the accumulation of orders by reducing the ‘supply chain discounting’ effect. As discussed in Section 10.3.3.4, increasing supply chain visibility to 75% suppressed the cyclicity of the airline profitability but with slightly degrading effect for the manufacturers both in increased volatility of orders and also in reduced volume of orders (and hence revenue). Aside from this, implementation of this strategy requires consolidation of the fleet management function; a role to be taken either by the manufacturers or by leasing firms.

An additional effect that increases the impact of this mechanism is the lengthening of the planning horizon as manufacturer backlogs increase (shown with the red bold arrows in Fig. 10-20). Of course, the reverse effect is observed when faster delivery times are implemented (see JIT in Section 10.3.5.2). As such, JIT delivery is an interesting alternative assuming that the technical problems of a JIT assembly for an airframe can be overcome.

10.3.7.3 Mechanism 3: Competitive Manufacturing and Aircraft Price Decoupling from Production Costs

The third main mechanism that creates an internal cycle amplification dynamic is shown in Figure 10-21 marked by the bold green arrows. It is based on the decoupling of short-term manufacturer profitability and real aircraft prices.

In this case, an increase in travel demand which we saw eventually results in an increase in orders causes the manufacturers to ramp-up production. If the increase in orders is small, then production costs are decreased based on the learning effect and in fact prices can be lowered even further, thus stimulating further demand. If the increase in orders is high enough and the manufacturer’s response strategy is to maintain a low order backlog, then unit production costs increase. Yet, this is not an increase that is ‘felt’ by the airlines that would in turn respond by lowering their new orders. Given the competitive dynamics shown in ‘red’ arrows in Figure 10-21, the manufacturer *will not* raise prices. This is especially the case if the two manufacturers follow different production strategies; if one manufacturer continues to ascend the learning curve as it avoids costly production volatility while the other caters to customer demand faster, then the prices of aircraft remain low despite the increase in production costs in the more responsive manufacturer.

The implications of this endogenous amplification mechanism are further explored in Section 10.4.

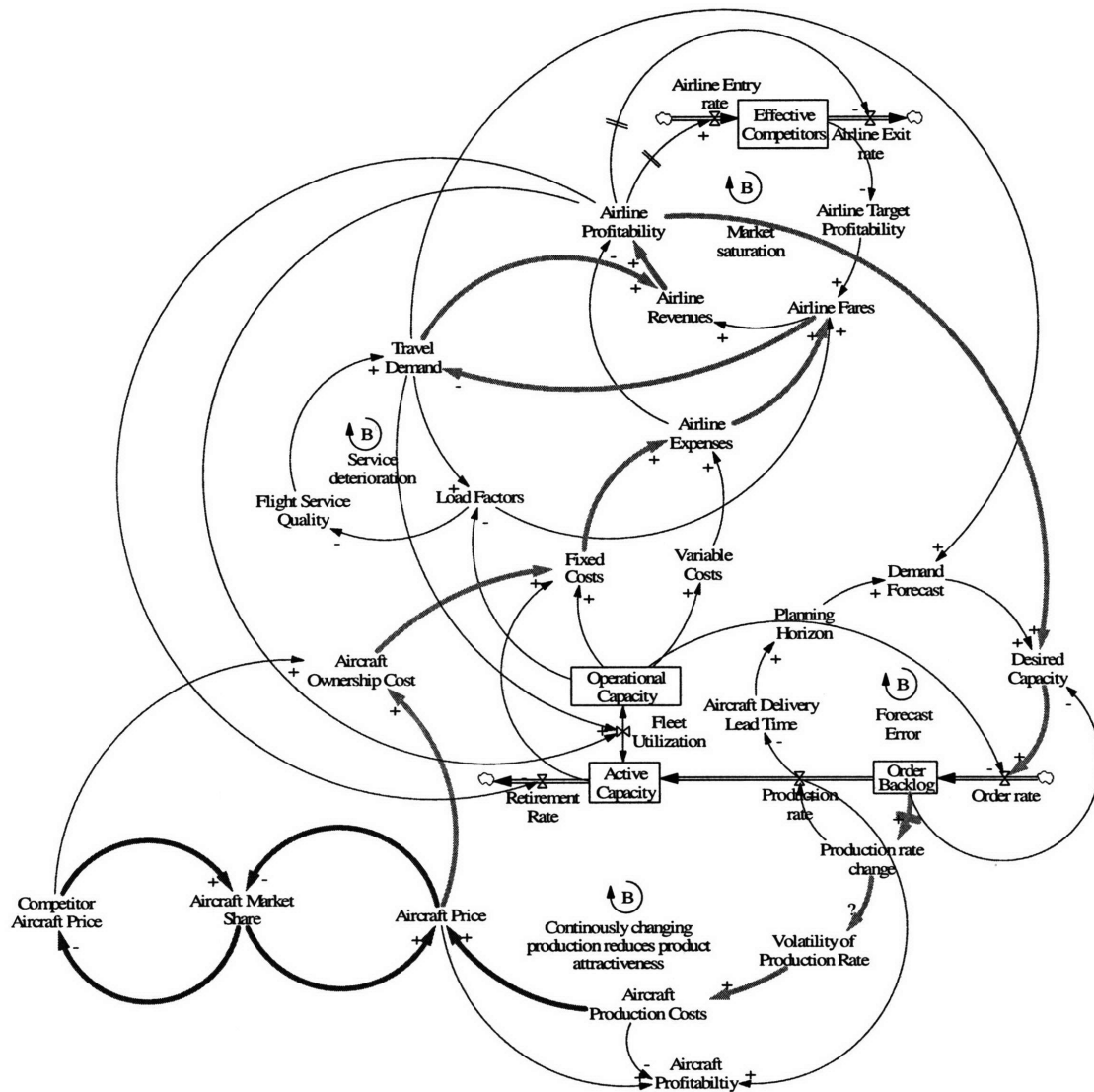


Figure 10-21 Endogenous CA EoE Amplification Mechanism (Relevant Section 10.3.7.3)

10.3.8 Symbiotic Strategies from the Systems Perspective of the CA EoE

Going back to the indications in Ch. 5, the strategic alternatives available for the constituents of an EoE can be broadly categorized into strategic alternatives that ‘couple’ or ‘decouple’ (thinking of this as a range of possibilities with shades of gray rather than black and wide) a given constituent enterprise with the ones directly related to them.

While changing the state of coupling between two directly related constituents affects their interaction, it also has side effects that can ripple across the EoE.

In this section, we review some of the key strategic alternatives discussed above from the perspective of EoE and summarize their characteristics of:

- Authority delegation to another enterprise (usually to risk and resource poolers), and
- Level of coupling between enterprises

and how this affected the manifestations of cyclicity in the CA EoE.

10.3.8.1 Changing the competitive airline environment (collusion)

A consolidation of the airline industry (or widespread price collusion) can be represented as an increase in the direct coupling between airlines as shown in Fig. 10-22.

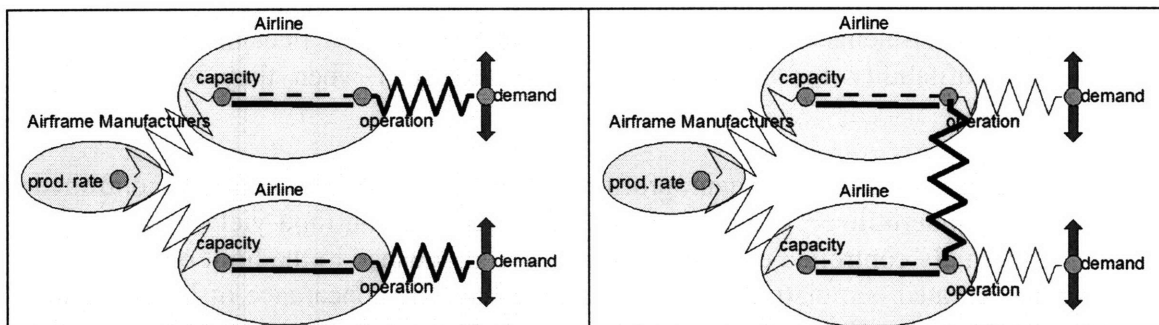


Figure 10-22 EoE View: Increasing effective mass of airlines by coupling through consolidation or collusion¹⁰⁷

The coupling between airlines and their demand is reduced as the monopoly pricing power of airlines is increased. Thinking in mechanical terms, this implies an increase in the effective mass of airlines relative to the mass of the oscillating bodies representing demand, as shown in Figure 10-22.

10.3.8.2 Fleet Management

The advent of leasing firms allowed for a decoupling of asset ownership and operation. As such it removed a controlled relationship that was traditionally held within the enterprise (airlines as owners/operators) to a relationship with a newly formed enterprise entity (leasing firms and the firms associated with their asset management) that depends on a relationship with differing degrees of coupling; this relationship can have shades from tightly coupled (own leases) to entirely decoupled (wet leases). By moving an internally controlled function to an external enterprise, we expect that some of the cyclicity faced by the airline will be transmitted to the leasing firms and partly dissipate because of their ability to hedge on a larger scale. The mechanical analogy that clarifies this idea is shown in Figure 10-23.

¹⁰⁷ A refresher note on the EoE view figures notation from Ch. 5: Capital first letter and oval represents enterprises. Double line one dotted the other continuous indicate control from an enterprise. Lower case first letter and small circle denote capacity or function. Small oval represents pooled capacity or function. Spring indicates interface/coupler.

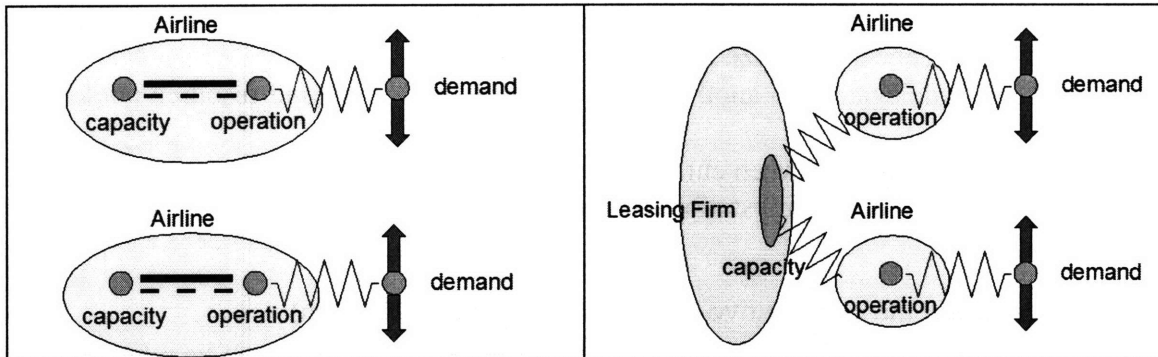


Figure 10-23 EoE View: Internally controlled ownership function over aircraft capacity transforming into an interface coupler between enterprises (Leasing Firm and airlines)

Based on the experiments in 10.3.1, increasing the flexibility in fleet management for airlines the profitability for the airlines is increased even when they bear the full ownership costs.

Before deregulation, the significant profit margins allowed the internally controlled capacity to be underutilized without penalty. With deregulation (and yield management systems), internally controlled capacity was increasingly pushed to the limit of utilization even when it created cumulative losses in the industry. The appearance of leasing firms as independent enterprises that could pool the risk of aircraft ownership across many airlines allowed for the decoupling between aircraft owners and operators with benefits accruing to both.

The stability provided by this decoupling depends upon the following caveats:

- (i) demand faced by the client airlines of lessors be uncorrelated, and
- (ii) ordering of capacity by leasing firms to be based on aggregated demand forecasts and to be the majority (ideally the only) source of orders
- (iii) the length of the contract between operators and owners to be substantially less than the period of oscillation.

Alas, none of the three is fully applicable:

- As we saw in Ch. 2, the demand faced by airlines even across continents is correlated given the tight interconnections of a globalized economy and while such division may be used for seasonal variations, macroeconomic business cycle variations usually cascade globally to some extent.
- As we saw, in Ch. 3, leasing firms base their orders to a very large extent on the orders they receive from airlines. To make the overcapacity problem worse, when leasing firms order speculatively, their orders are *in addition* to the orders already placed by airlines on their own.
- The majority of operating leases have durations of 3-5 years which is very close to the period of the business cycle (5-7 years) and therefore allows little recourse for airlines to break these contracts and therefore airlines are *effectively owners of the aircraft assets for the duration of the cycle*.

In addition to the above, the appearance of leasing firms further reduced the barriers to entry in the airline industry thus increasing the number of effective competitors and the effects of exuberance in ordering.

Sidenote for the retirement adjuster strategy (from Section 10.3.1.1)

The retirement adjuster strategy does not delegate control of a function to another entity that can pool risk and resources. On the other hand, it does allow for a partial decoupling of capacity and operations within the airline as it makes the cost of retirement at any of the remaining older aircraft at any given time practically zero. In any case the benefits from such a strategy are measurable but small.

10.3.8.3 Fixed to Variable Operating Costs

This strategy has strong similarities from the EoE perspective to the leasing strategy as it involves the delegation of control to a coupling interface with other constituents but with the difference for the CA EoE system that it does not involve aircraft capacity. The similarities are underscored by the mechanical representation of Figure 10-24.

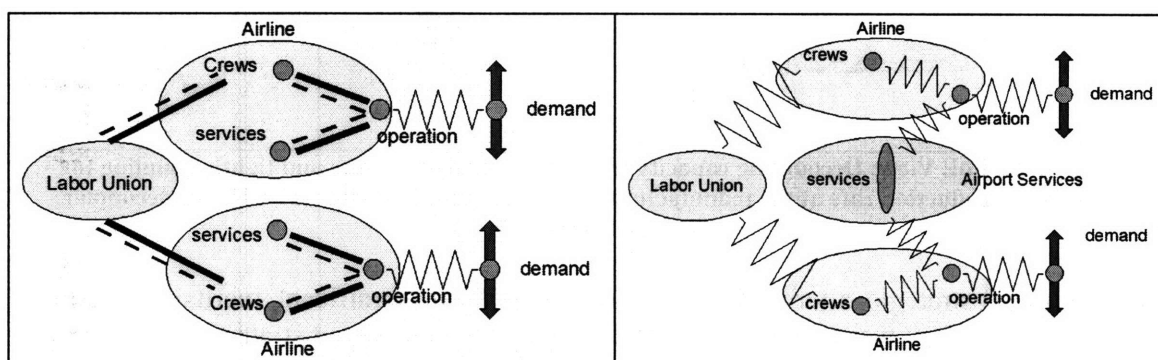


Figure 10-24 EoE View: Internally controlled service function transforming into an interface coupler between enterprises (Airport services). Similarly the unions 'relax' their control of the crews to allow for the profit-sharing agreement (the labor union enterprise is delegating control to crews and thus is now loosely coupled to the Airlines).

From the experiments in Section 10.3.2, we found that such relaxation has a measurable effect but is not as significant as changes of capacity.

10.3.8.4 Airframe manufacturers: Dual effective strategy?

As we saw from the experiments and discussion in the previous sections, capacity is key for controlling the cycles in the CA EoE. Yet the promising strategic alternatives that involve control of volatility can take two distinct paths. One strategy that was shown to work was the traditional lead time reduction recipe for controlling the bullwhip effect (see Table 10-19 and related discussion): if aircraft can be delivered with little lead time and backlogs are not allowed to build up, then the ineffective and delayed corrections of supply is reduced and significant cyclicity-inducing strain is taken off the CA EoE value chain.

These two different strategies are presented in diagram form in Figures 10-25 and 10-26.

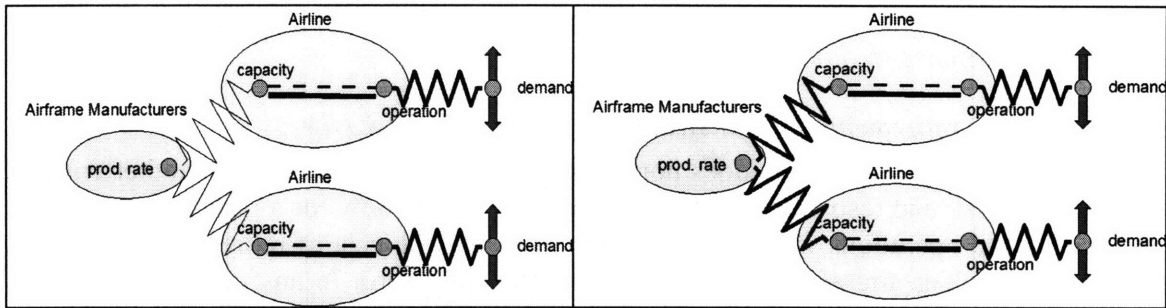


Figure 10-25 EoE View: Tightly coupling production rate at the manufacturers to airline capacity while retaining the control structure of airlines over capacity. (the SM-CH.2 or JIT strategy from Ch. 5)

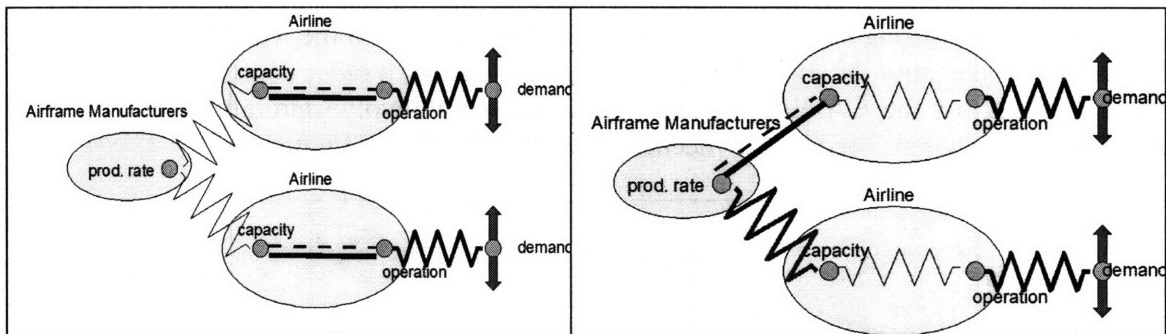


Figure 10-26, EoE View: Decoupling capacity from the control of airlines and tightly coupling (or controlling) production rate at the manufacturers to airline capacity. (the SM-CH.3 or decoupler strategy from Ch. 5)

Both of these strategic alternatives were shown to have significant merits in Section 10.3.5.2; in fact they were the most dramatic among the considered strategic alternatives. Their implementation and how to resolve strategic differences between the competing manufacturing enterprises present additional challenges and require further experimentation and the use of a game theoretic context. Furthermore, there is the potential to generate synergies between strategic alternatives. The experiments related to these aspects are described in detail in the next section.

10.4 Competitive Behavior of Manufacturers: Bundles of Strategic Alternatives and their Impact on CA EoE

In the previous section we explored the ‘design and policy space’ of the CA EoE by conducting experimental runs by implementing only a single strategic alternative with varying intensity of implementation. This helped us demonstrate that, barring airline collusion or consolidation and the pricing power available to airlines this way, the primary system leverage lies with various strategic alternatives to control capacity availability.

Some, like JIT production, do not require any degree of behavior that might be considered anticompetitive, although they may require strengthening of the extended

Table 10-21 Experimental Results for Scenario S1

	Base.	Exp1	Exp2	Exp3	Exp4	Exp5	Exp6	Exp7	Exp8	Exp9	Exp10	Exp11	Exp12	Exp13	Exp14	Exp15
Airlines																
NPV (Normalized)	100.00	100.25	103.00	102.62	100.64	100.57	100.13	101.84	101.20	112.43	155.93	100.74	111.14	99.91	120.45	117.68
Coef. Var. (Profit)	1.34	1.63	1.60	1.63	1.68	1.66	1.72	1.51	1.64	1.43	1.19	1.38	1.31	1.38	1.37	1.42
Median Cap. Utilization	0.74	0.76	0.76	0.75	0.75	0.75	0.75	0.76	0.75	0.83	0.94	0.74	0.79	0.74	0.78	0.77
Manufacturers																
NPV (Normalized)	100.00	85.34	112.89	113.43	85.39	83.53	86.32	28.69	106.99	66.85	76.37	121.34	80.52	99.67	169.96	173.53
Coef. Var. (Profit)	1.47	2.11	1.10	1.10	1.92	1.98	1.84	48.64	1.21	2.60	1.25	0.87	1.21	1.40	0.79	0.71
Total orders (Normalized)	100.00	99.21	102.40	102.45	99.60	99.66	103.11	102.85	100.99	97.35	65.00	99.42	85.78	98.96	129.83	133.03
Coef. Var. (orders)	0.82	0.89	0.91	0.90	0.91	0.91	0.94	0.86	0.93	0.97	0.82	0.84	0.83	0.86	0.79	0.81
Mf. A																
NPV (Normalized)	82.62	64.91	109.51	122.39	69.17	64.09	78.24	1.50	109.03	40.11	60.55	121.32	74.40	87.00	154.55	181.41
Coef. Var. (Profit)	1.47	2.11	1.10	1.10	1.92	1.98	1.84	48.64	1.21	2.60	1.25	0.87	1.21	1.40	0.79	0.71
Total orders (Normalized)	155.81	152.54	158.11	160.08	155.71	155.25	169.49	153.24	159.57	145.24	87.15	151.06	120.03	152.99	179.15	191.02
Coef. Var. (orders)	0.85	0.94	0.94	0.93	0.96	0.96	1.01	0.88	1.01	1.09	0.80	0.86	0.80	0.89	0.75	0.75
Mf. B																
NPV (Normalized)	100.00	90.95	96.66	84.75	86.77	88.45	79.40	50.90	86.36	81.97	78.92	100.27	72.65	95.02	155.84	135.51
Coef. Var. (Profit)	0.80	0.83	0.84	0.88	0.83	0.84	0.89	1.01	0.88	0.82	0.98	0.81	1.29	0.78	0.95	0.87
Total orders (Normalized)	100.00	101.24	103.83	102.00	99.06	99.69	94.27	109.85	98.76	103.79	79.13	103.25	99.40	100.16	152.96	149.28
Coef. Var. (orders)	0.83	1.01	0.98	1.02	1.02	1.03	0.99	1.01	1.00	1.01	0.91	0.88	0.95	0.86	0.92	0.92
Passengers																
Average Fare (Normalized)	100.00	99.84	99.88	99.99	99.79	99.80	99.85	98.47	99.99	98.80	96.94	100.26	98.55	100.17	100.40	97.36
Median Fare (Normalized)	100.00	97.46	97.63	97.82	97.31	97.37	97.60	96.12	97.78	96.12	94.00	100.51	97.36	100.29	99.56	94.45
Average LF	0.70	0.69	0.69	0.69	0.69	0.69	0.69	0.70	0.69	0.70	0.72	0.69	0.70	0.69	0.71	0.71

Table 10-22 Processed Experimental Results (color coded)

	Exp1	Exp2	Exp3	Exp4	Exp5	Exp6	Exp7	Exp8	Exp9	Exp10	Exp11	Exp12	Exp13	Exp14	Exp15
Airlines															
NPV Change	0.2%	3.0%	2.6%	0.6%	0.6%	0.1%	1.8%	1.2%	12.4%	55.9%	0.7%	11.1%	-0.1%	20.5%	17.7%
Coef. Var. Change	21.6%	19.1%	21.7%	25.1%	24.0%	28.6%	12.6%	22.2%	6.4%	-11.4%	3.0%	-2.1%	3.2%	2.5%	5.7%
Mf. A															
NPV Change	-21.4%	32.5%	48.1%	-16.3%	-22.4%	-5.3%	-98.2%	32.0%	-51.5%	-26.7%	46.8%	-10.0%	5.3%	87.1%	119.6%
Total order change	-2.1%	1.5%	2.7%	-0.1%	-0.4%	8.8%	-1.6%	2.4%	-6.8%	-44.1%	-3.0%	-23.0%	-1.8%	15.0%	22.6%
Order coef. Of Var. change	10.5%	10.6%	9.7%	13.2%	13.4%	19.7%	4.3%	18.9%	28.7%	-6.1%	1.7%	-6.2%	5.2%	-11.9%	-11.2%
Mf. B															
NPV Change	-9.1%	-3.3%	-15.2%	-13.2%	-11.6%	-20.6%	-49.1%	-13.6%	-18.0%	-21.1%	0.3%	-27.3%	-5.0%	55.8%	35.5%
Total order change	1.2%	3.8%	2.0%	-0.9%	-0.3%	-5.7%	9.9%	-1.2%	3.8%	-20.9%	3.2%	-0.6%	0.2%	53.0%	49.3%
Order coef. Of Var. change	21.3%	18.1%	22.4%	23.0%	23.6%	19.4%	21.1%	19.7%	21.8%	9.2%	5.5%	13.8%	4.1%	10.3%	10.1%
Pax															
Fare change	-0.2%	-0.1%	0.0%	-0.2%	-0.2%	-0.1%	-1.5%	0.0%	-1.2%	-3.1%	0.3%	-1.5%	0.2%	0.4%	-2.6%
LF change	-0.2%	-0.1%	-0.2%	-0.3%	-0.3%	-0.5%	0.3%	-0.2%	0.9%	3.9%	0.0%	1.3%	-0.1%	1.6%	1.4%
Total Return															
Universal owner view	93	108	108	93	92	93	65	104	90	116	111	96	100	145	146
Rank															
Universal owner view	12	6	5	11	13	10	15	7	14	3	4	9	8	2	1

Green: significant positive impact for the constituent enterprise

Orange significant negative impact for the constituent enterprise

Baseline

With the experiments in this section we tried to account for competitive behavior between manufacturers. The baseline which we compared against had the following characteristics:

Manufacturer A (modeled after Boeing)

Mf. A is dominant in both the narrow and wide body markets at the beginning of the simulation, year 1984. Mf. A adapts its production rate faster than Mf.B retaining a target backlog of ~3 years. Mf.A has the advantage of the vendor lock-in effect but a disadvantage in average production costs that it attempts to counter with lean production initiatives.

Manufacturer B (modeled after Airbus)

Mf. B is following a different philosophy in production. By not adjusting their production rates immediately, their backlog is allowed to build up to an average of ~6years. This inertia to production rate change makes Mf. B less prone to costs from adapting to the

cycle. It may mean that they lose part of the orders from customers that have to wait longer but only a 15% order spill is allowed (possibly more than what has been historically observed).

Summary of experiments

Exp.1: *Manufacturer A (MF.A) speeds up production to achieve JIT delivery.*

No benefit in airline profitability, increases in volatility and deterioration for the manufacturers indicate that this is a weak move.

Exp.2: *MF.A speeds up production (JIT delivery) and hones the skills for lean manufacturing reducing production costs.*

It improves MF.A's position (+32%) and slightly improves airlines' position (+3%) although MF.B is at a small disadvantage (-3.3%).

Exp. 3: *MF.A speeds up production (JIT delivery) and hones the skills for lean manufacturing reducing production costs AND manages to reduce the costs of production changes. MF.B continues to change production rates at a slower rate but also utilizes lean production.*

MF.A is better able to use this type of change to its advantage but a price war between manufacturers and the inability of MF.B to match the level of lean that MF.A has creates a losing proposition.

Exp. 4: *MF. A attempts vertical integration while using JIT.*

Vertical integration implies the ability to implement the supply chain visibility strategic alternative (discussed in Section 10.3.3.4) to only the subset of airlines that are clients of a single manufacturer (MF.A in this case). Both manufacturers are negatively impacted but airlines and customers see no significant difference.

Exp. 5: *MF. B attempts vertical integration.*

Both manufacturers are disadvantaged while airlines see little benefit. The fact that MF.A is operating in JIT mode does not offer the opportunity for improvement through supply chain visibility compared to when the delivery lead times were longer.

Exp. 6: *MF.B attempts vertical integration augmented by lean manufacturing*

As in Exp.5, both manufacturers lose.

Exp. 7: *Both manufacturers attempt vertical integration combined with lean mfg. and they both compete aggressively*

Airlines are practically unaffected (+1.8%) but both manufacturers are negatively impacted (-98% for MF.A and -48% for MF.B).

Exp. 8: *Same as Exp. 7 with the difference of normal competitive behavior on behalf of the manufacturers, less supply chain visibility (15% down from 50%) and the ability to implement lean manufacturing augmented.*

Airlines are practically unaffected but MF.A registers gains (+32%) while MF.B is negatively impacted.

Exp. 9: *While MF.B stabilizes production to fixed scheduling, MF.A pursues a JIT strategy.*

The airlines benefit from such commitment but both manufacturers lose although MF.A is at greater disadvantage (-51%).

Exp. 10. *Both manufacturers pursue JIT deliveries and master lean mfg.*

This is a winning proposition for the airlines but both manufacturers are disadvantaged.

Exp. 11: *Manufacturer production rates follow the baseline but they both pursue lean with MF.A still better adapted to do so.*

Mf. B appears to be unaffected from this move while Mf. A sees the bulk of the gains (+47%) and the airlines are also unaffected.

Exp. 12: *MF.B increases production rate changes to match that of Mf.A while Mf. A implements lean manufacturing.*

The airlines gain from the reduction in lead times but both manufacturers lose compared to the baseline.

Exp. 13: *MF.B combines vertical integration and lean manufacturing (Variant of Exp.6).*

Mf. A gains at the expense of Mf. B while airlines are only marginally benefited. Single manufacturer implementation of supply chain visibility penalizes the manufacturer that initiates it.

Exp. 14: *MF.A and MF.B follow slow to adapt production.*

This experiment simply replicates the run of Section 10.3.5.2 that showcases the effect of stabilized production rates for both manufacturers. **All constituent enterprises benefit from such a choice** while the final customers, passengers and shippers, are only slightly (below our significance threshold) disadvantaged.

Exp. 15: *MF.A and MF.B follow slow to adapt production enhanced by lean manufacturing and supply chain visibility.*

This experiment enhances the slow to adapt production by combining lean manufacturing and a level of supply chain visibility with it. Only Manufacturer A sees extra benefits with this arrangement as it can quickly diminish the original cost advantage of MF.B and take better advantage of their higher lock-in effects. The other stakeholders also benefit but to a lesser extent compared to Exp. 14.

In order to more effectively compare these alternatives with a larger number of bundled alternatives that allow different combinations we run optimization experiments. The optimization algorithm followed a taboo search approach and aimed to maximize the combined profitability of airlines and airframe manufacturers. The results from one such experiment that involved a set of 200 model replications is shown in Figure 10-27. While the experiments did not include the fixed production option, when compared to them, the fixed production alternative is shown to be a non-dominated strategic alternative.

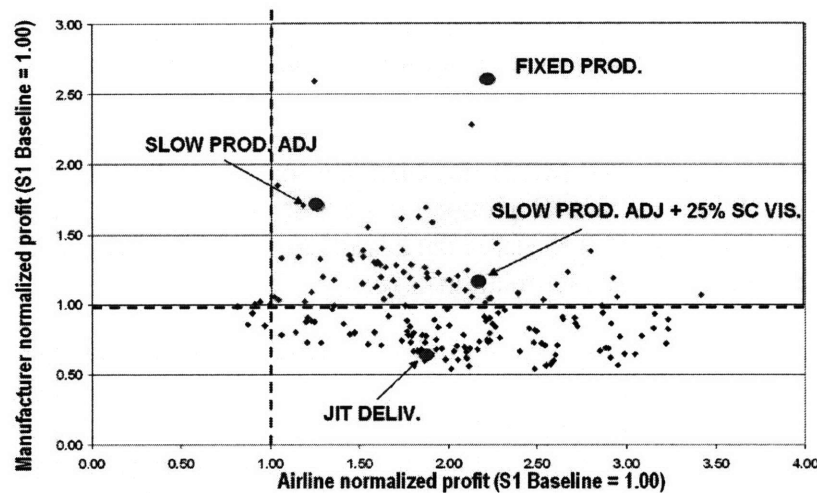


Figure 10-27 Optimization experiment results (200 model replications)

Interpretation and Discussion of Experiments

One implication that comes out of these experiments is that the production strategy followed by Mf. B that involves slow production rate adjustments confers a competitive advantage. As a result, it would be against the interest of Mf. B to change their strategy.

A second implication is that there are no significant benefits if a single manufacturer could move to a JIT delivery production system (assuming that such a move would be technically feasible) but airlines would see benefits if both manufacturers did that. Not only that, but there are no apparent synergistic benefits if the two manufacturers pursue drastically different strategies (i.e. one with JIT delivery from a backlog of 3 years and the other continuing a long lead-time delivery strategy).

A third implication (from Exp. 6,7 and 8) is that when manufacturers pursue a vertical integration strategy with some of their airline clients, the airline industry benefits only if a no manufacturer follows JIT delivery. In either case, the manufacturers that initiates it would require some form of revenue redistribution in order not to be penalized.

By testing the two different strategies followed by the manufacturers, we wanted to investigate the potential for synergistic value chain behavior. That is, whether the two manufacturers faithfully pursued different strategies would create more value for the chain than if they followed identical strategies.

Manufacturer B follows a strategy that can be characterized as long-term mistrust to the market signals. They loath to adjust capacity fast enough so as to respond to the signals from their customers and instead focus on the long-term coordination with their own suppliers and employees. While Ren et al. (2006) imply that the customers have an information advantage for their markets, given the need to forecast and adjust to competitor behavior, their long-term expectations may be far from system optimal. In this case, it is shown that a more efficient outcome is generated by practically *ignoring* the airline signals and rather building on the long-term demand trend. This outcome is also

reinforced by the ability of the airlines to use the competitiveness between the manufacturers to their advantage thus rendering any long-term punishment of airlines for breaching their contract ineffective.

The success of this strategy for Mf. B, is dependent on the ability of Mf. A to deliver their aircraft in JIT-fashion at low production costs. Given the difficulty of such an achievement, the ability of Mf.B to retain the advantage has higher probability of success even with non-trust based customer relationships.

Aircraft manufacturers face a prisoner's dilemma kind of problem in their decision to adjust capacities independent of orders to optimize for long-term performance. That is they have an incentive for adjusting production rates fast enough so that they can cater to airline demand and avoid losing orders due to delays. On the other hand, they would both be better off if they adjusted production rates slowly. Unfortunately, if both did follow the same slow adjustment strategy it may induce the entrance of a third LCA competitor – an unlikely for the immediate future but possible long-term effect. The key to compete effectively even with large backlogs may lie with the uncertainty of orders in the backlog; as airlines place phantom orders, these may be exchanged or auctioned if and when they are cancelled. This is a strategy that Airbus seems to follow, i.e., delivery times of significantly less than the backlog would allow are offered to buyers with the expectation that some of the original firm orders will be actually freed up by cancellations from the clients that actually placed them.

While it is true that neither of the two manufacturers will face bankruptcy in the near future as they are supported by large consortiums with multiple interests and of course governments have a vested interest in their operation, it is highly unlikely that their management would be willing to go to such a step as they are measured and judged by short-term economic performance.

Airlines on their side face prisoner dilemma choices on a smaller scale and tend to overorder as a result of that but they are too disaggregated for any change to be meaningful. The potential of alliances to turn into mega-carriers may be paradigm changing but their ability to navigate anti-trust regulations is still unclear. Even if mega-carriers are established, it is not unreasonable to expect the same competitive conditions to exist between mega-carriers (i.e. a push towards overordering to preempt the competition).

Several isolated measures taken by the manufacturers (like shorter lead times, and strong pricing incentives) could have potential in reducing the amplitude of the cycle but not sufficiently so.

The potential for a manufacturer to enter into a unisourcing service provision agreement with one or more alliances/mega-carriers is shown to have negative implications for the manufacturer if it provides increased supply chain transparency. If a manufacturer does this without support from a leasing firm they would be entering the leasing business and be viewed as competitors in that business. In such an agreement, the equipment provider

will have the responsibility to support their partners/clients in their needs on a long-term basis. While this is an effective strategy for reducing cyclicalities in the airline industry and increasing airline's returns in all of these cases the acting manufacturer face losses in profitability.

Overall, the best symbiotic strategy that can be initiated by the manufacturers is slowing down their production adjustment rates as repeated in Exp14. This strategy can be managed effectively by allowing the manufacturers to base their quoted delivery schedule on the (high) probabilities of cancellation in a given airline. This strategy may start to become more difficult as airlines start to stabilize *because* of the limitations on production capacity and therefore stop cancelling their orders. At this point (perhaps a decade or more in the future) pricing of the delivery slots through auctioning and increasing the penalties for cancellations may work. This is the point at which the vulnerability from a third entrant in the LCA market is also the greatest. As our model does not include this event our ability to design strategies for this eventuality is limited but it can be implemented in future model expansions. The benefits of this strategic alternative are quite high and even bundles of strategic alternatives cannot easily outperform it.

10.5 Chapter 10 Summary

In Chapter 10, we used the system dynamics model of the CA EoE developed in Chapter 9 to experiment with and compare the set of strategic alternatives aimed at reducing cyclicalities and increasing the welfare of the CA EoE constituents as measured by their proxy value functions (see Table 9-1). The basis for these alternatives was first presented in Chapter 7 but they were quantified in order to be testable in this chapter (Sections 10.3 and 10.4).

We identified three primary mechanisms by which the structure of the CA EoE sustains and amplifies the exogenous cyclicalities-inducing factors. Aside from consolidating the airline industry and giving monopoly pricing power to the remaining airlines, capacity management appeared to be the best family of strategic alternatives.

Available aircraft capacity is controlled not only by airlines but also by the actions of airframe manufacturers and leasing firms. The consolidated airframe manufacturing and leasing industries were identified as prime candidates for affecting change in the CA EoE since Ch. 5, and in this case we showed that their coordinated action can indeed create substantial benefits across the CA EoE and dampen the prevalent cyclical variation. From the two main strategic alternative options available, JIT delivery of aircraft and its antecedent long-term fixed schedule (or slowly changing) production rate, the first faces significant technical challenges in maintaining the manufacturers' returns and even then it is still inferior compared to the second alternative which may face surmountable institutional challenges to its implementation.

Given the different philosophies in manufacturing presented by Boeing and Airbus faster vs. slower production rate adaptation, we hoped to find them complementing each other.

The experimental results showed that the coexistence of the two strategies will only benefit the airline industry if it is combined with some form of vertical integration that reduces the supply chain discounting effect. If this is the case though, the manufacturer who actually implements such a system will be disadvantaged. These complications can be avoided if both manufacturers adopt a slower production rate adjustment which can be a win-win for the airlines and the manufacturers and does not require any collusive action from either side.

In the following, and final, chapter we will review our findings in the broader context of the thesis, summarize our work and identify avenues for future research.

Chapter 11 Conclusions, Contributions, Future Work

In this concluding chapter, we will present our findings concisely and tie them back to our research questions and hypotheses. We will also summarize the contributions that this work makes and identify areas where targeted additional work on modeling could further illuminate our understanding of enterprise of enterprises in general and refine our recommendations for the commercial aviation enterprise of enterprises (CA EoE) in particular.

Our research was motivated by the negative repercussions stemming from the volatile boom-bust cycle of the airline industry. Historically, the increase in volatility of airline profitability became significant in the post-deregulation period (after 1978 for the US with the rest of the world following gradually). While increased competition and a commoditizing product made air travel available and affordable to a larger segment of the world population, the accompanying increased volatility of returns, amplified in a bullwhip fashion in the value chain of the EoE (see Figure 1-2 for a view of the CA EoE) value chain and Figure 1-3 for a visualization of the volatility), caused increased friction with employees and an unstable environment for the complex and expensive task of aircraft development and production.

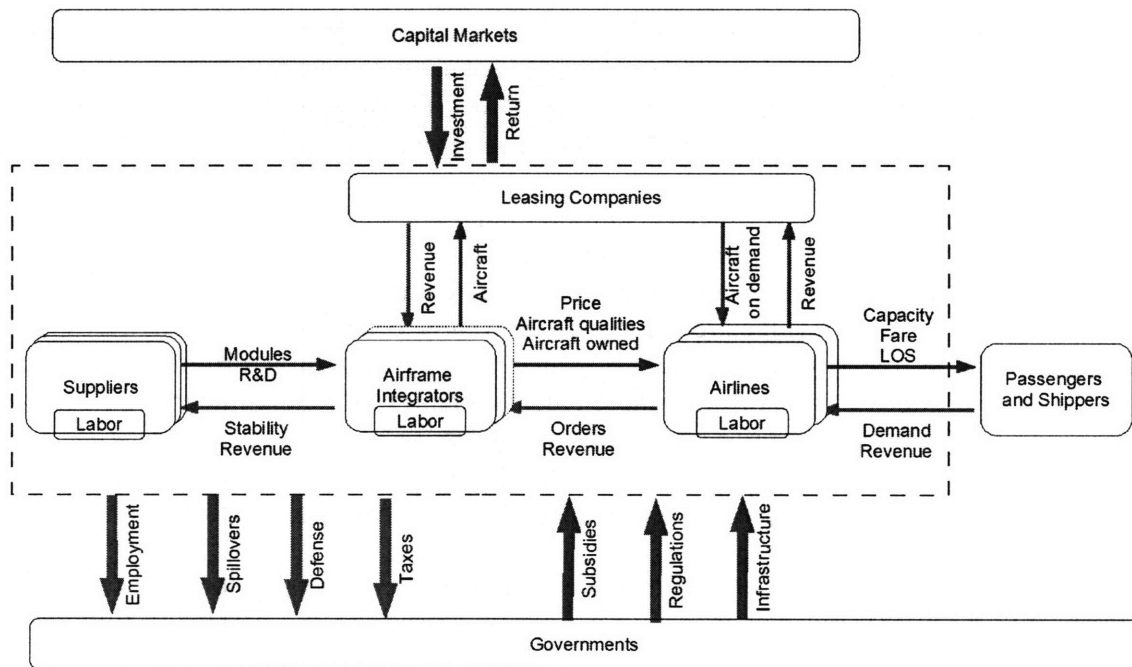


Figure 11-1 A View of the Commercial Aviation Enterprise of Enterprises (from Ch. 5)

When looked from a systems perspective, the fundamental input to the system – demand for air travel – seems remarkably stable with negative growth rates occurring only in two years out of a sixty year history. Yet aircraft manufacturers are recipients of large order variations from the airlines in classic bullwhip effect fashion. From the same vantage

point, the commercial aviation system is not a classic supply chain bullwhip-forming environment. Some of its key characteristics are:

- The market for air travel is discrete, broken into O-D pairs. Contestability assertions aside, airlines, in practice, price with higher than competitive rates unless actually challenged on the specific route they serve, even when there are a number of competitors in the region.
- Two fundamentally different network systems are employed successfully: hub-and-spoke and point-to-point, each with each own set of advantages and disadvantages.
- The growth rate of demand for air travel is strongly correlated to the economic growth rate. Historical demand growth rates have decelerated but remained positive with only two exceptions (1991 with a recession and a war coinciding and 2001 after the 9/11 terrorist attacks).
- There are few, if any, product inventories involved in the sense that an aircraft seat-mile is a perishable good. Labor and capital are the areas that oscillate with periods of over- and under- investment.
- Airline costs are highly dependent on energy costs, labor costs, and capital ownership costs. Yet some airlines follow business strategies that allow them to manage these better than others (some low costs carriers or LCCs have managed cyclicalities better than most legacy carriers).
- The three major market segments, business travelers, leisure travelers, and freight shippers, exhibit substantially different elasticities of demand and level of service expectations. The characteristics of its segment are not static but evolve over time.
- The value chain echelons are characterized by different types of markets:
 - Airlines compete in markets that range from monopolies to almost perfect competition.
 - Infrastructure providers (airports and air traffic control systems) are regulated oligopolies in varying degrees.
 - Aircraft (and engine) manufacturers are competitive oligopolies.
 - Aircraft manufacturers for LCA currently consist of a duopoly. Despite this the two enterprises, Boeing and Airbus, exhibit different strategic outlooks with Airbus, a more recent entrant, being more integrated with its extended enterprise and Boeing being less so.
- Aircraft are increasingly expensive to develop but their production is still subject to strong learning economies, airline lock-in effects, and economies of scale.

This summary reinforces the notion that the commercial aviation sector *is* a complex system. Not only that, but that there is *no single authority*, in the current institutional situation, to enforce coordinated behavior.

These observations raised the following question:

How prone is the commercial aviation value chain to the cycles (endogenous factors) and how important are the factors outside its influence (exogenous factors)?

The natural, and more important, corollary to this question is:

Are there ways to retain the benefits of competition while reducing the resulting inefficiencies and social costs related to volatility in commercial aviation and can they be implemented by the enterprise constituents of the sector?

Which, based on the relatively centralized hour-glass like view of the CA EoE with the narrow point residing with the aircraft manufacturers (see Figure 1-1), leads to the final question:

Could the structure of the commercial aviation value chain and the characteristics of its enterprises be leveraged to affect non-zero sum positive change in the absence of centralized authority?

Answering these questions was the motivating force behind the research journey that is summarized in this chapter. In Section 11.1 we review our methodology and research structure. Section 11.2 summarizes the answers and conclusions that we reached based on our research and outlines our specific contributions. Finally, Section 11.3 discusses the areas in which promising future research can be conducted to further the answers to our research questions.

11.1 Research Structure and Methodology

In order to answer the research questions outlined previously, we needed to understand the nature and interactions of a system comprised of multiple enterprises with diverse interests, objectives and business strategies facing uncertainty in their decisions. Extending the system of systems (SoS) research, we considered all of commercial aviation as an enterprise: a purposeful undertaking that provides air transport services and is composed by a number of constituent enterprises. This enterprise of enterprises (EoE), formalizing the definition of the term first used by Nightingale (2004), has constituents that are managerially and operationally independent yet they all exist in part to provide this greater societal function (its Keynesian “social purpose”). Their relationships (*interfaces*), or levels of coupling, are not ones of authority but of codependence.

This lack of a directing authority turns the problem of coordination towards a specific goal, in our case the reduction of observed volatility and the accompanying improved efficiency into an almost impossible task reminiscent of the *tragedy of the commons* or an expansive *prisoner’s dilemma game* found in economics literature.

Yet, parsing the commercial aviation (CA) EoE into its constituent enterprises and abstracting their ‘local’ *value functions* and the *interfaces* that connect these enterprises helped in identifying the key leverage points and in structuring a model to simulate the behavior of the CA EoE. This provided a platform to quantitatively evaluate the performance of different strategic alternatives.

Based on the prerequisites for operationalizing this approach, our research methodology was structured so as to cover the following salient areas:

- Develop a fundamental understanding of the industry-specific characteristics of the CA EoE and specify how costly cyclicity is manifested in the different constituent enterprises (Chapters 2, 3 and 4).
- Internalize, adapt and extend the SoS concepts to address the particular features and needs of EoE analysis. Outline the application of the EoE conceptual framework in commercial aviation (Chapter 5).
- Review the literature on the characteristics and causes of business cycles and of the bullwhip effect in supply chains – phenomena closely related to the CA EoE cycle (Chapter 6). Using lessons from the literature, develop a narrative and working hypotheses on the mechanisms of the CA EoE cycle and corresponding strategic alternatives to reduce this cyclicity (Chapter 7).
- Define the desirable characteristics of an EoE model and scan the available modeling methodologies that are appropriate for enterprise modeling and the specific CA application (Chapter 8).
- Build and validate a simulation model of the CA EoE (Chapter 9) and use it to test different strategic alternatives and identify the ones that are more promising for implementation (Chapter 10).

To provide a more specific summary of the dissertation, the chapters' content is summarized below in greater detail.

In Chapters 2-4 we described the three primary echelons in the CA EoE value chain respectively: in Chapter 2 the drivers of demand for air travel, in Chapter 3 the diverse world of airlines and aircraft leasing firms, and in Chapter 4 the duopoly of two prime manufacturers – Boeing and Airbus – and how the industry and market for LCA transformed to its current stage. In each chapter the relevant features and accompanying costs of cyclicity were demonstrated.

<i>Complexity</i>	<i>Socio- Technical (systemic)</i>	Focus of: OR SE SA	EoE
	<i>Technical/ Mechanical</i>	Traditional Engineering	SoS
		<i>Unitary</i>	<i>Pluralist</i>
		Authority	

Figure 11-2 Classification of Systems (based on Jackson and Keys (1984) from Ch. 5)

In Chapter 5, we introduced the enterprise of enterprises framework as a useful way to characterize and analyze the interlinked commercial aviation industries and institutions. EoE was inspired by the system-of-systems (SoS) concept which was largely applied on technical/pluralist systems while EoE targets socio-technical/pluralist ones systems

(using the classification in Figure 11-2). The constituent enterprises in an EoE have operational and managerial independence, like an SoS, but the relationships are richer than an interface standard which has been the SoS researchers leverage point of choice for system change. Using the EoE framework and based on our understanding of the constituent enterprises and stakeholders in the system we identified potential points of leverage for affecting change in this system while accounting for the individual stakeholder value functions and area of influence.

Chapter 6 reviewed the literature on different manifestations of cyclical behavior, particularly in economics and supply chains. As a conclusion of this investigation, based on a narrative of mechanisms that can induce or influence cyclical behavior in the CA EoE, we drew a list of possible causes for the business cycle as exhibited in the CA EoE and the corresponding suggested countercyclical strategic alternatives in Chapter 7.

These potential strategic alternatives were vetted for effectiveness and implementability using the EoE structure, but actual quantitative testing of the most promising alternatives was necessary as a means of establishing their usefulness. The complexity and large scale of the system at hand forced the consideration of simulation modeling as tool for quantitatively testing and comparing our hypotheses. In Chapter 8 we reviewed the literature on modeling for enterprises of similar scale. The rich literature that used system dynamics as the methodology of choice to address similar problems for the airline industry was a strong indication that it was well adapted for our purposes as long as it could be extended to model differences in strategic choices between manufacturers (agent behavior).

Chapter 9 presents the details of the SD model as developed for the CA EoE based on a pre-existing model by Weil (1996). We discuss the calibration, validation and verification procedures in order to demonstrate that the model has adequate level of detail and can be useful for our purposes.

In Chapter 10 we start by developing the background for extending the simulation into the future by presenting three possible scenarios that exhibit different degrees of volatility and underlying demand growth rates. Each strategic alternative is tested individually for relative effectiveness and a connection between the strategic alternative and its theoretic impact is made using causal loop and EoE diagrams. Finally, combinations of strategic alternatives that are geared towards demonstrating the existence of potential synergies between alternatives and accounting for different competitive strategies are presented.

11.2 Conclusions

We present our conclusions from the research described above by respond to the initial research questions as formulated in Chapter 1.

11.2.1 How is cyclicity manifested in commercial aviation? What are the impacts from cyclicity in commercial aviation?

Year-to-year changes in the demand for air travel are highly correlated to economic conditions, regional and global, and travel-suppressing incidents like terrorist activity, active wars or the fear of pandemics. Yet these fluctuations are surprisingly small and the average trends of growth for the industry have been remarkably stable for decades (ref. Ch2).

Cycles with much greater variance are exhibited by the average profitability of airlines. American and international airlines exhibit comparable degree of variance which means that on average they experience cycles of similar intensity (Ch. 3).

Aircraft orders are highly correlated to the profitability fluctuations and exhibit even higher levels of variance than airline profitability changes (Ch. 4).

Faced with order variability of such magnitude, aircraft manufacturers, in a manner reminiscent of supply chain bullwhip fluctuation, respond by adjusting their production capacities. These adjustments usually are followed by significant hire and fire cycles (Ch. 4).

We showed that the cycles in the CA EoE are manifested primarily in:

- Airline profitability indicators
- Aircraft orders and deliveries
- Employment levels of airlines
- Employment levels of manufacturers

The impacts of the cyclicity in the above indicators on the different stakeholder groups and constituent enterprises in the CA EoE are numerous.

We identified a set of key stakeholders in the form of constituent enterprises and end users. Among the different types of stakeholders, some fare better than others in the cycle while individual enterprises are better suited to respond to the cycles compared to the average performance of their respective industries.

Passengers and shippers

The end users, i.e. passengers and shippers, increased their welfare substantially by the deregulation of the airline industry. At least a portion of this gain in welfare came as a result of direct or indirect subsidies to legacy carriers. For the most part though, the competitive environment fostered the adoption of the hub-and-spoke network by virtually all legacy carriers that allowed previously unheard of frequency levels and lowered unit costs. The competitive environment also allowed the emergence of low cost carriers and persistent declining trends in unit costs (CASM). These gains came at a cost; levels of service, reliability, and predictability of the fare prices deteriorated (fare variance increased) but are currently improving as the competitive environment seems to revert to equilibrium.

Airlines

We saw that the profitability of airlines is the prime cyclical indicator of the CA EoE. While an aggregate measure, most airlines in the industry face a synchronized cyclical trend although some airlines are better in managing to stay profitable even at the bottom of the cycle. For airline employees these cycles mean unanticipated income losses or unemployment and uncertainty for their future. In economic terms, the utilization of airline resources is inefficient (See Ch. 2).

While substantial, these costs would be manageable if the cycles did not propagate upstream in a bullwhip fashion as cyclical profitability is a lagging indicator for investment decisions.

Aircraft manufacturing supply chain

The inability of airlines to maintain consistent profitability for the majority of the airlines reinforces the cycle of intense overinvestment that is followed by a long period of underinvestment. As a result of this variation in orders, aircraft manufacturers and their suppliers systematically misestimate the amount of investment they should undertake. This leads to increased costs of inventory and “forgetting” and increased risks of investment in production capacity and aircraft (See Ch. 4). As orders fluctuate, manufacturers adjusting the production capacity to meet demand face heavy costs, both when they have to increase or decrease their production rates due to the capital and skilled labor intensive nature of their operations.

Capital Markets

The succession of profitable and unprofitable years strains the liquidity of airline carriers and manufacturers and increases the risks for investors. Perversely, the increased returns in the boom years and the high level of variance in returns may be desirable characteristics for fund managers that prefer short- over long-term return (see Ch. 5) even if they imply abysmal performance during the downcycle (small investors facing sever losses notwithstanding).

Other stakeholders

Airports have consistently generated better returns than airlines presumably due to their monopoly status. The few exceptions include airports that clamored for hub status without adequate local demand and excessive reliance on a single airline (see Ch. 5).

Aircraft leasing firms have also been consistently profitable. Their history as dominant aircraft owners is short and therefore the impact that a long downcycle would have on their returns has not been observed.

The D. Gross hypothesis: cycle benefits vs. costs

Gross (2007) argued that from a social welfare perspective, cyclical industries that leave a commercial infrastructure residue after the high growth period (bubble) halts have in fact a net positive effect on social welfare as the services that can provide allows for innovative entrepreneurial uses. This could be plausible for commercial aviation as the massive investment in aircraft and the competitive behavior of airlines showed the way

towards innovations to reduce unit costs and spurred booming industries from mass tourism to availability of relatively cheap air freight.

On the other hand, the resources needed for the manufacturing supply chain of commercial aircraft are not allocated efficiently over time and society bears a significant cost from the losses during downcycles that range from airline subsidies, to employee pension funds bail out and the hire/fire cycle in the industries involved.

More broadly, the approaching limit of resources (fuel and raw materials) faced by society in the not so distant future makes the expectation that the expansion of commercial aviation can continue unimpeded quite optimistic. In a cyclical environment, the ability to prepare for the coming crisis is severely limited with potentially catastrophic consequences.

To summarize, some of the direct impacts of cyclicity are the following:

- For owners and investors in the commercial aviation enterprises there are costs associated to uncertainty in the return of investment from the commercial aviation industries. Increased risk without commensurate increases in the economic returns.
- Inefficient allocation of capacity and productivity over the cycle. This is found in both the airframe manufacturing and the airline industry. In both instances as capacity lags behind demand and then races ahead the primary source of counterbalancing force in order reach equilibrium is employment levels.
- These cycles have impacts on the final service quality as experienced by passengers and freight shippers. There are fare price fluctuations along with variations in frequency and reliability that create a business environment that offers unreliable level of service.
- On the production side, frequent hire/fire cycles create labor management tensions and are costly both for the industries in the form of productivity losses and for the employees who have to bear unemployment externalities. Specifically for airframe manufacturers, that are characterized by strong learning economies, production rate volatility prevents full exploitation of the learning curve.
- In order to account and balance societal externalities, government assistance in various forms is used. These costs can be significant; for example the cost of the Air Transportation Stabilization Act to stabilize the US commercial aviation industry post-9/11 was estimated to be \$20B and an additional \$3.75B was requested for targeted employee retraining and transitory health coverage.

An important characteristic of the manifestations and impacts of cyclicity in the CA EoE is that they are correlated and reinforcing. As indicated above, the tendency of airlines and airframe manufacturers to fluctuate their capacity using employment creates lower productivity and additional costs. Interestingly, when these externality costs are addressed through government assistance and are directed to the enterprises rather than the employees, it has the perverse effect of retaining capacity in the system exacerbating overcapacity problems and deepening the impacts of the cycle to the other indicators.

In the last bullet for impacts, we referred to the Air Transportation Stabilization Act. While this type of assistance is far from unique and can be found in different settings, it can be argued that it was addressing a unique problem generated by an extreme event (the 9/11 terrorist attacks). As we explore in next question, the visible problems of the airline industry were preexisting conditions.

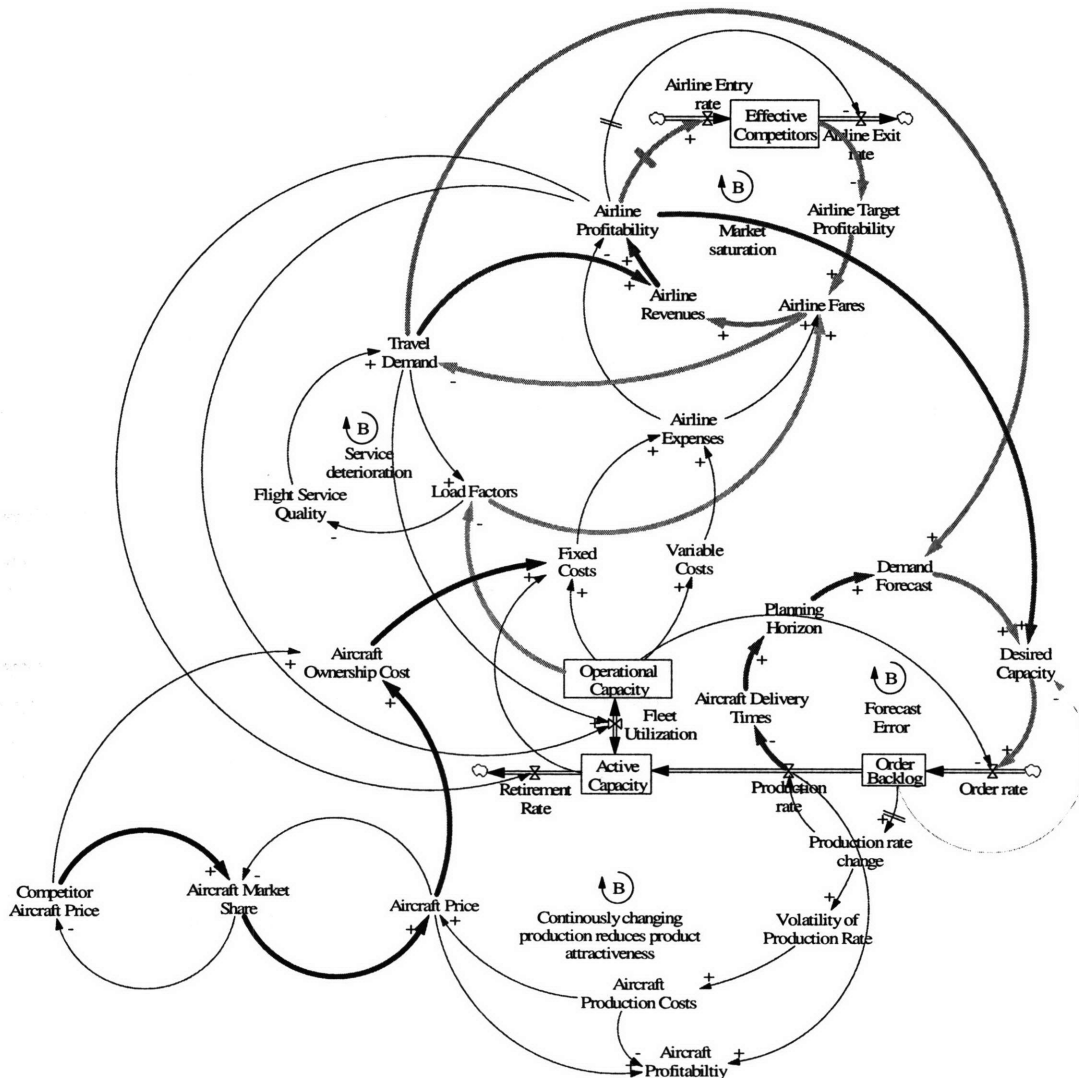


Figure 11-3 A sample of endogenous dynamics of the CA EoE (from Chapter 10)

11.2.2 What are the salient causal mechanisms that induce the cyclical behavior in commercial aviation?

Using sensitivity analysis and comparing the relative impact of external factors (GDP growth rate, fuel price volatility, and shocks) we found that the current structure of the CA EoE is prone to *endogenously generated cycles*. Even in the absence of external volatility, the CA EoE system will oscillate depending on the entry and exit dynamics for airlines. As for the relative impact of external factors, we found that they are ranked as

follows: fuel, GDP, shocks. Therefore, the justification of external shocks as special reasons for providing government assistance to the various enterprises does not seem to be supported.

The dynamic relationships that can cause the type of cyclical behavior referred to in Q.1 are numerous and reinforcing, as we discussed in detail in Ch. 7 and as shown in Figure 11-3.

The following is a summary list of the causal relationships that were identified:

- Macroeconomic induced volatility (wars and pandemics included) affect (i) the baseline demand by shifting the demand curve and (ii) the **elasticity** of demand for air travel.
- To clear the market, airlines change their prices. Because their supply is inelastic in the short-term due to capacity commitments, revenue management systems allow them to change the fares in order to maximize load factors since the marginal cost of serving an economy-class passenger is believed close to zero. In competitive markets, these adjustments may lead to price wars.
- Revenue management systems may create an illusion for airlines that are bent on meeting their load factor targets but at the expense of profitability with break-even load factors in cases becoming greater than 1. Having full planes provides a justification for further expansion of capacity forming a vicious circle of reduced profitability.
- Retaining capacity in an unprofitable market and needs for liquidity can intensify price wars into a death spiral.
- The lead time between order and delivery of new planes amplifies the cycle **if** the airlines do not anticipate the market growth and the actions of the other airlines on global scale correctly (i.e. in the presence of strong supply chain discounting). This is the case when a large number of discrete decision makers are involved. New entrants with financial backing that expect to defer profitability in the pursuit of market share also contribute to exaggerated ordering.
- Anticipating market growth is a hard task because of the uncertainty in the factors affecting demand and production costs (fuel) that establish the break-even point. Strategic behavior exacerbates this uncertainty because competing carriers may wish to secure the capacity in the face of competition. The fact that aircraft production capacity is limited creates the pressure to order capacity for the sake of having a position in the waitlist in a form of game ordering.
- Aircraft manufactures have their own competitive pressures and because of:
 - o Economies of scale and learning effects favor large production runs.
 - o Legacy and lock-in effects.
 - o Bandwagon effect.
 - o Production scaling.
 have the incentive to undercut their competitors and also offer undervalued aircraft options, delivery deferment, and cancellations.

11.2.3 What are implementable strategic alternatives for dampening that cyclical and what are their benefits?

We first look at the strategic alternatives available from a theoretical perspective and then we discuss the experimental findings.

EoE Architecting and Cyclical

From an architecture or systems theory point view, we found that the strategic alternatives that we generated to address cyclical in the CA EoE could be categorized under three archetypes of strategies for reducing cyclical in EoEs:

1. Delegation of control of functions or capacities to a 'pooler' enterprise that exerts greater and cumulative control over these functions of individual enterprises and therefore reduces redundancies and increases efficiencies (e.g. outsourcing of non-core function, aircraft leasing).
2. Tighter coupling of signal to response without any delegation of control exhibited as greater responsiveness or flexibility (e.g. pull production with just-in-time deliveries of aircraft).
3. Decoupling of signal to response through coordinated action in key echelons (e.g. fixed or slow to adjust production schedules based on long-term demand trends).

Effectiveness and Implementability of Strategic Alternatives

In the specific context of the CA EoE we found that control of capacity was *the* key leverage point in controlling cyclical.

For example, we found that if the owners of aircraft did not 'insist' in retaining the bulk of the fleet in operation during recessions the airlines collectively would gain up to 50% of their profitability *even if they would still carry the full cost of ownership*. The implementation of such a scheme fails for the same reason as the prisoner's dilemma game; in an uncoordinated, non-collusive environment with multiple competitors the Nash equilibrium is one where all competitors use all their available resources as their short-term incentives do not reward voluntary withdrawal.

The retirement adjuster strategy, as proposed by Skinner et al., attempts to address this by reducing the perceived cost of a withdrawal by maintaining a slightly older fleet on average in which the fully amortized aircraft would make the choice of retirement easier. Yet, we find that collectively the benefit from such a strategy is small and partially outweighed by the increased operating and maintenance costs.

Flexible leasing agreements that have durations of about a year or less and so are significantly less than the average period of the cycle (~8 years) as opposed to the current norm of 3 to 5 years, may be another promising way to allow for such reductions as long as the aircraft owners be it leasing firms or manufacturers can be compensated for the additional risk they are carrying.

The above were assuming that the current order and production patterns are maintained. It is exactly in this order/production pattern though were the key to controlling capacity

lies. As demonstrated by Sterman (1989) and others, the backlog in a given supply chain is heavily discounted by those making the ordering decision for a variety of reasons (like multiplicity of decision makers, order gaming, and 'irrational exuberance'). As delivery lead times become longer, so do the potential for forecasting errors and the effect of 'supply chain discounting' increase along with order volatility (bullwhip effect).

Airline industry consolidation or a vertical integration scheme between airline alliances and manufacturers that would reduce the supply chain discounting by 50% could double the airline industry's profitability but it would also reduce the volume of orders received by manufacturers and increase the volatility of those orders as there would be less slack in the system to meet unanticipated increases in demand.

A strategic alternative followed by manufacturers that involves pull-production with JIT deliveries could increase the return to airlines by 15% by having lead-times of less than one year without any changes in order patterns. Yet, the technical implementation of such a scheme could be infeasible for products like aircraft. Not only that, but the risks involved in not having substantial backlog would necessitate the ability to easily switch between production lines – a task that is again hard for these type of products. Is it impossible? The answer to this resides in the future.

Finally, the opposite of this strategy shows even greater potential. Given the complexities involved in aircraft production, rapid changing in production rates carries significant costs for the producer and for the labor force employed by them (aircraft production traditionally is labor and not capital constrained). As a result, a production strategy that involves steady growth pegged on long-term trends rather than actual orders would effectively decouple production from orders at the risk of order spill-over and of market share losses that threaten a loss of the edge in customer lock-in. Conversely, if the long-term production plan is overoptimistic, it may have the opposite effect of flooding the market with cheap aircraft and further reducing airline profitability.

We found that a coordinated move towards long-term production planning is positive for both the manufacturers that gain from production efficiencies (400%) and the airlines that benefit from a limited influx of new aircraft (gains of about 100%) while passengers are not heavily impacted (<5% average fare increase). As one of the manufacturers (Airbus) already follows a variant of this strategy (carrying much higher backlogs compared to Boeing – see Figure 4-23) compliance of the other would not be problematic. The problems stem from the strategic threat of potential entry by a third manufacturer.

Finally, we did not find any synergistic effect between two different manufacturer strategies: one following a JIT strategy and the other a fixed production schedule one. Depending on the ability to implement lean manufacturing cost effectively, the JIT manufacturer gains or loses moderately but at the expense of the slower production manufacturer.

We identified a set of strategic alternatives for the different constituents of the CA EoE (Ch. 7) and codified them so that they can be modeled by the system dynamics model we

developed for this purpose (Ch. 9). We summarize this codification below indicating in parenthesis the stakeholders directly involved:

- Reducing airline fixed costs:
 - Profit sharing agreements and outsourcing of non-core functions (Airlines/Unions)
 - Fleet flexibility (Airlines/Leasing firms/Manufacturers)
 - Leasing ratio (Airlines/Leasing firms)
- Controlling airline capacity:
 - Profit effect on orders (Airlines/Capital markets/Leasing firms)
 - Smoothing order patterns– long-term trend forecasts (Airlines/Leasing firms)
 - Collaborative order patterns (Airlines/Manufacturers and/or Leasing firms)
 - Vertical integration / supply chain visibility
 - Delivery patterns:
 - Production time (Manufacturers)
 - Target production backlog (Manufacturers)
 - Production rate flexibility (Manufacturers)
 - Capacity pricing (Manufacturers)
 - Effects of learning/forgetting dynamic and lean manufacturing on production costs
 - Market share targets and aggressiveness
- Controlling airline pricing:
 - Industry consolidation (Airlines/Capital markets/Governments)

Using the SD model developed, we identified that the dynamic with the greatest leverage over the airline profitability cycle is the apparent lack of transparency in the ordering process. Competitive pressures for gaming the system and the large number of decision-makers make orders that exceed optimal levels for stable profitability sometimes by far.

We demonstrated experimentally that reducing the lead times of delivery, improving forecasting by smoothing it over longer periods to better capture the trend, greater number of cancellations, or even allowing for greater pricing power of the airlines all have substantially lower impact on modulating the profitability cycle than simply ordering with full accounting of the aircraft in backlog. If this function is carried out by airlines though, the outcome for aircraft manufacturers is not Pareto-efficient as their profitability is reduced and the actual volatility of orders is increased. Instead we found that the most promising symbiotic alternative lies with the adoption of slow production rate adjustments by both manufacturers as shown in Figure 11-4. The strategic alternatives indicated in the symbiotic quadrant show that the aircraft production rate adjustments are key in improving returns (and cyclicity) in the system. It should be noted that passengers do not face deterioration of costs in this case as it is the increased production efficiency that contributes to the increased value rather than increases in fare prices.

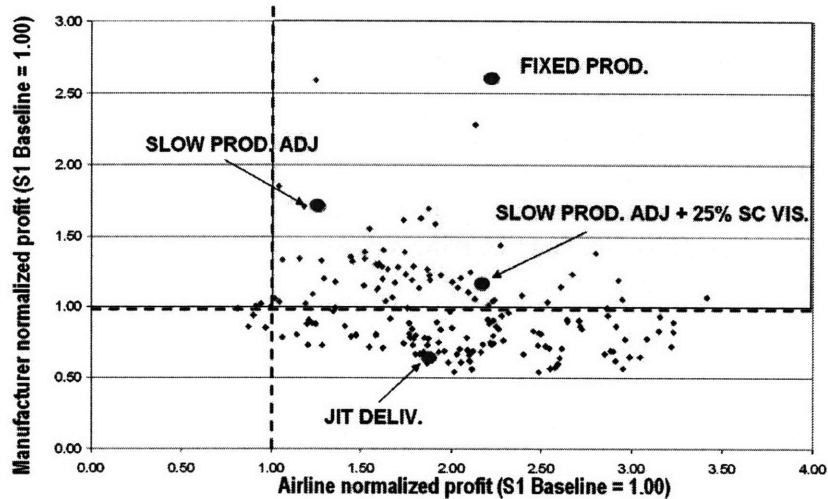


Figure 11-4 Relative performance (NPV of profitability) of bundles of strategic alternatives for Airlines and Aircraft Manufacturers

Based on the experimental quantitative results outlined above and the qualitative insights of the EoE analysis (Ch. 5), we identified the airframe manufacturers as the most promising link in the value chain for embarking on cycle modulating initiatives because they have both the consolidation level (duopoly), the incentives (large costs due to production rate fluctuations and increasing risk-sharing of the asset carrying cost with airlines) and the key leverage of controlling production capacity with perfect visibility of backlogs vis-a-vis realistic demand forecasts. Despite this alignment, the specific characteristic of the competitive dynamics in their industry described in the previous question also provide strong disincentives from modulating the cycle and incentives to fuel. As a result, there is a risk that the first mover in the airframe manufacturing industry to attempt to moderate the cycle may lose market share and fall into a death spiral or respond correctively to this losses and overcompensate.

The Womack and Jones hypothesis

Womack and Jones (1996)(see Ch. 6) postulated that as lean thinking is established in a critical mass majority of stakeholders in an industry, then business cycles would be eliminated or at least significantly reduced.

In the CA EoE value chain this hypothesis is only partially confirmed if we simply consider lean manufacturing principles. Even if both manufacturers (and their suppliers) create a responsive supply chain with minimal lead times between order placement and delivery and the ability to fluctuate production rates accordingly at low cost, the cyclical behavior is still very much present. Demand management techniques are necessary (possibly in the form of the virtual vertical integration described above) to really even out the cycles.

The Piepenbrock hypothesis

Piepenbrock (2005) suggested that integral firms can dominate in mature technologies and commoditizing markets while modular firms are better adapted to nurturing disruptive innovations in differentiated product markets.

Our model was not designed to investigate this hypothesis, but by showing the advantage of adoption of the slow production rate change as symbiotic strategy reinforces the first half of the hypothesis.

Will the cycle persist under different future scenarios with the current industry structure?

If no action is taken, the industry can be faced with its largest crisis if external factors turn sour. These possibilities were investigated using scenario analysis. Even with the increasing fuel efficiency of the fleet of new aircraft there is a very large number and increasing number of long-range wide-body aircraft in backlog (>550 787s, >200 A380s, >100 777s 2007 data) in addition to a large order backlog for narrow body aircraft like the 737NG and the A320 family. These orders, faithful to the historical pattern, come at a peak of airline profitability but may enter service in a period with very high fuel costs and depressed demand that has the potential of sending the industry into a large recession.

As the cycles are largely endogenously caused, changes in external factors, even if they stabilize, are not enough to restabilize the industry. This needs to happen through innovative rearchitecting and the bundles of strategic alternatives we propose (see previous question) can initiate such transformation.

11.3 Contributions

As a way of summarizing, we suggest that the contributions of this research are as described below:

In this research we contributed to the study of complex systems and business strategy. We did so by:

- (i) integrating disparate literature strands:
 - a. Comprehensive coverage of the literature on commercial aviation that spans air travel demand generation (Ch. 2), airlines and aircraft leasing firms (Ch. 3), and aircraft manufacturers (Ch. 4) along with regulatory and business strategy aspects of these industries.
 - b. Synthesis of the literature on business cycles as found in economics and supply chain (Ch. 6)
 - c. Providing an overview and comparison of strengths and weaknesses of the modeling approaches for enterprises (Ch. 8)
- (ii) introducing the Enterprise of Enterprises framework as appropriate for studying systems of interacting industries with multiple constituents that exhibit managerial and operational independence and relevant derivative 'architecting heuristics' (Ch. 5)
- (iii) identifying and categorizing the costs (and benefits) of business cycles in the CA EoE by stakeholder. Identifying and ranking by dominance the causes of the cyclicity in the CA EoE.
- (iv) creating a comprehensive, public-domain model of the CA EoE using system dynamics enriched by agent behavior for the airframe manufacturer class that expands previous models (Ch. 9)

- (v) developing symbiotic bundles of strategic alternatives aimed to moderate the cyclical behavior of the CA EoE and demonstrating their effectiveness and implementability across a series of future scenarios (Ch. 10).

11.4 Promising Areas of Future Work

Like most ongoing research endeavor on complex systems, this work is not definitive. It could benefit from improvements, additional testing, and expansions of the approach taken. In this section we outline some of the possible enhancements of this line of research.

Modeling improvements

As with any model, the balance between model fidelity and performance is not perfect. Our modeling approach could potentially benefit (or show that no additional improvement is made) by:

- Expanding the use of agents to include airlines
- Introducing seasonality and regional demand differences to enhance fidelity
- Using endogenous schemata for the decision of introducing new aircraft
- Modeling the possibility of new entrants in LCA manufacturing
- Calibrating the manufacturing processes with more accurate, proprietary, data (as opposed to using only data available in the public domain)
- Discretize aircraft to allow for a more intuitive representation of aircraft lifecycle
- Introduce freight markets in the model

In addition, the CA EoE system given the relatively small number of agents involved could be a proving ground for the nascent but promising field of agent-based models. Future research can investigate whether an agent-based only model would provide consistent dynamics with the ones observed in practice and with the system dynamics model. That would show that ABM can be applied in systems where the number of agents are low enough that the interactions cannot be fully represented statistically. If such a modeling approach is successfully validated, it would provide an excellent test-bed for verifying that alliances of enterprises following the proposed strategic alternatives would indeed have competitive advantage.

In addition to the above, a deeper exploration of the relative benefits of bundling of strategic alternatives by identifying those that display the highest level of synergistic behavior is also part of your intended future research.

Deeper qualitative work

For this research we relied on research conducted by researchers and journalists to capture and understand the effect of personal dynamics on the history and current condition of the CA EoE (i.e. the path-dependence of the CA EoE on the leadership and management choices of specific persons).

As a way to enhance the implementation potential of our proposed strategic alternatives, future researchers can investigate how they resonate with managers and decision makers

in the constituent enterprises. Using interviews and questionnaires of industry professionals would enhance the implementation aspect of the proposals.

Additional Applications

Finally, as we saw in Ch. 6, commercial aviation is not the only cyclical EoE. Therefore, it would be of great interest to apply the EoE framework and modeling methodology that we used to other cyclical industries like telecomm and shipping and investigate whether the lessons learned from this work can be generalized or whether the special characteristics of the other industries make for unique appropriate strategic alternatives.

Closing Words

Having reached the end of this research journey, we would like to thank the readers that were interested in our work. Our hope is that this contribution offers a small but solid addition to the understanding of complex socio-technical systems in general and of the highly competitive world of commercial aviation in particular.

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