

total exports of goods and services as well. In 1960, real service exports accounted for 19.4 percent of goods and services exports; by 1991 they represented 27.0 percent of the total. Real net exports of services are projected to rise from \$55.7 billion in 1992 to \$8.4 billion in 2002 and \$207.9 billion in 2016. The United States will become an increasingly open economy with international trade playing a larger role in relation to real GDP.

AVIATION INFRASTRUCTURE AND DEMAND AS COMPLEX ADAPTIVE SYSTEMS

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Has the air transportation market reached saturation, or does it still have a way to go? What are the implications of the status of this market for the planning and design of air transportation infrastructure? The status of the market for air travel, and more fundamentally, how to think about the status of the market for air travel, are matters of great importance to the aviation community. Questions about market saturation are also important for other infrastructure systems.

The following remarks address these questions by reasoning from first principles about the nature of demand for derived goods and services like transportation and from exploring their implications for air transportation. They apply primarily to the aviation infrastructure sector, although they have some relevance to aircraft acquisition and carrier operations.

In reflecting on the significance of the degree of saturation for aviation infrastructure planning, it is essential to recognize how heavily planning relies on the predictability of the market. Predictability is a fundamental assumption of planning and design facilities. While this may seem obvious, it is well worth emphasizing. Of course, we predict demand when we invest in facilities that are going to last 25 or 30 years. But, it is important to recognize that predictability is an assumption, and as such, it may be correct or incorrect. Furthermore, it is an assumption that is fundamental to the business of aviation infrastructure planning. Not only do we assume predictability, we assume it over fairly long horizons. It is not uncommon to see forecasts to 2020 or 2025. Such predictions are very important inputs into decision making about the construction of airports, air traffic control systems, and other facilities and systems.

The specific nature of this assumption is that because facilities last 25 or 30 years, it must be useful to forecast their condition over the same time horizon. Furthermore, this assumption implies that, while we know the forecasts will be wrong (it is the nature of the business, after all) it is still useful to have them. That is, the forecasts are better than no information at all.

But it is an heroic assumption, nonetheless. Why do we make it? Because it is an essential rationale for those who believe in building long-term infrastructure. We are accustomed to providing for long term infrastructure, and we accept the concomitant assumptions. There may also be a little engineering conceit. Engineering materials will last for 25 or 30 years, after all. The world must be predictable enough for us to predict the conditions they will face over that horizon. Concrete and steel are fairly predictable materials under particular conditions; ought we not be able to predict the social and economic conditions that will affect them?

We have gotten very accustomed to this idea in making aviation infrastructure plans, and making infrastructure plans in other sectors. We might call it "the myth of predictability — the myth of assuming that the world is as predictable as the engineering materials we build with.

My second point follows directly from the first. The assumption of predictability is not very well grounded. Indeed, it is substantially at odds with the kinds of activities that generate air transportation demand. Part of the reason we believe in predictability is an extension of the Newtonian model of the universe. We can predict the location of the planets in the solar system. Social and economic forces ought to be equally as predictable.

But the Newtonian concept of the universe is now being widely questioned. The planets do move fairly predictably over the generations of man. But in astronomical time they are subject to highly unpredictable forces, such as the "Big Bang." We cannot trace back the trajectory of the universe very far in astronomical time, nor can we necessarily predict exactly where it is going to be a few astronomical generations from now.

Questions about the predictability of the universe in astronomical time are paralleled by questions about the predictability of systems and processes that are much closer to home: the economy, the stock market, technological innovation and progress. The widely used assumption of long periods of fairly predictable behavior punctuated by occasional "structural changes" is now in question. A structural change such as the entry of women into the labor force in the 1960s is coming to be seen not as an aberration, but as an inherent aspect of

the behavior of social and economic processes. Forecasts in the late 1950s of employment for the Washington, D.C., area in the 1980s were significantly below actual. Yet population forecasts at the same time were actually fairly accurate. What changed was one of those "fundamental constants" of forecasting, the labor force participation rate of women, which changed due to other economic forces that we were not really able to anticipate. A structural shift occurred, which we can explain in hindsight but which we did not anticipate at the time.

The emerging theory of "complex adaptive systems" does not pretend to be able to identify particular structural shifts in advance. Rather, it underscores the dubiousness of assumptions that social and economic processes will follow a fairly smooth trajectory over the medium to long term. The market can be fairly predictable over the short term, and remarks elsewhere in these proceedings provide some understanding of what is likely over the next three to five years. But the longer the horizon, the greater the likelihood of intervening structural change that moves events in a direction that we are not able to anticipate. Thus, the market is highly unpredictable in many respects.

The aviation sector has undergone major structural changes wrought by technological innovations, like the

DC-3 and the jet aircraft. These had a tremendous effect, and yet their occurrence and consequences were not predictable. The Arab-Israeli peace accord that was signed on the day of this conference has the potential to make enormous impacts on the international aviation market, but it, too, was not predictable. The entry and exit of powerful industry figures, like Frank Lorenzo, are highly unpredictable. What is more predictable in many respects is the behavior of the governmental systems and processes that are in charge of the planning, design, and development of aviation infrastructure.

To demonstrate this unpredictability, consider the development of U.S. domestic enplanements per capita starting from the 1920s through the early 1990s. This measure provides some perspective on market saturation since it focuses on the activity of the individual consumer of air transportation. Annual domestic enplanements per capita have grown from virtually zero in the 1920s to about 2 at present. (See Figure 24.)

What do these data suggest about market saturation? They appear to follow a logistic, or S-shaped, curve, which is frequently employed for explaining deployment processes. Figure 25 shows the realization of an S-curve based on the assumption that the process is symmetrical over time. Saturation appears to occur sometime in 2020 or 2030 at about 2.3 enplanements per capita.

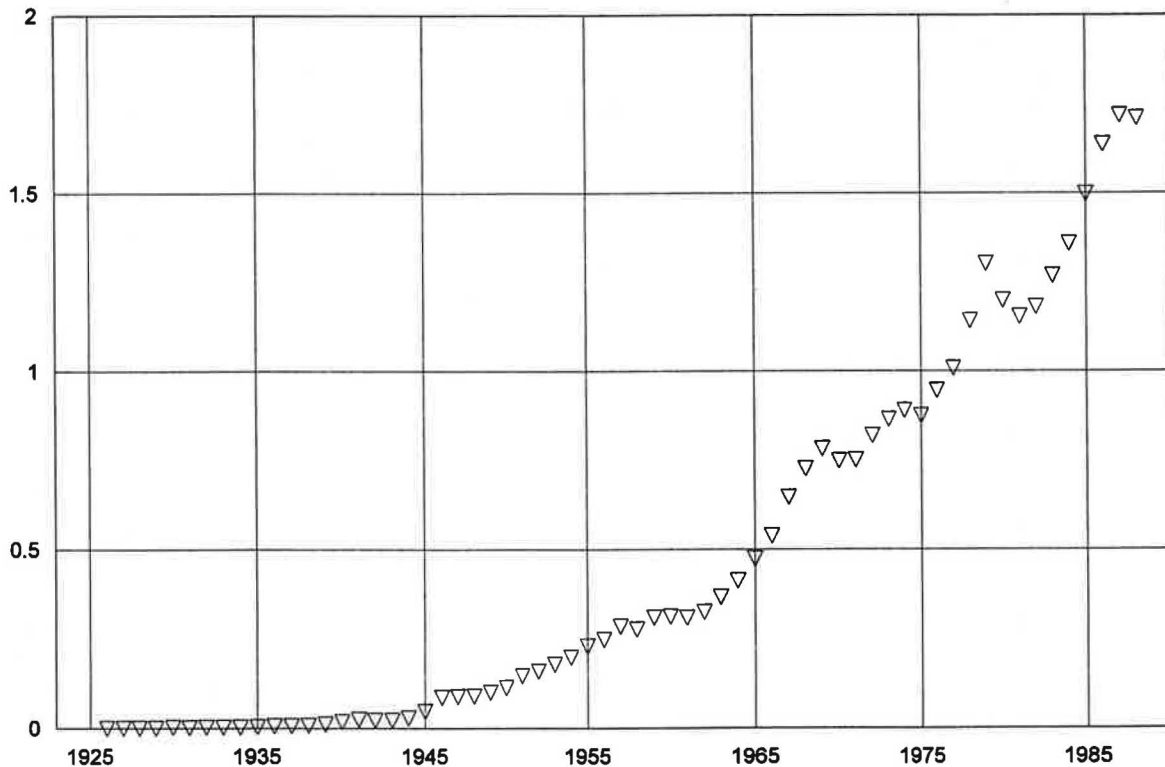


FIGURE 24 Enplanements per capita, 1926-1990.

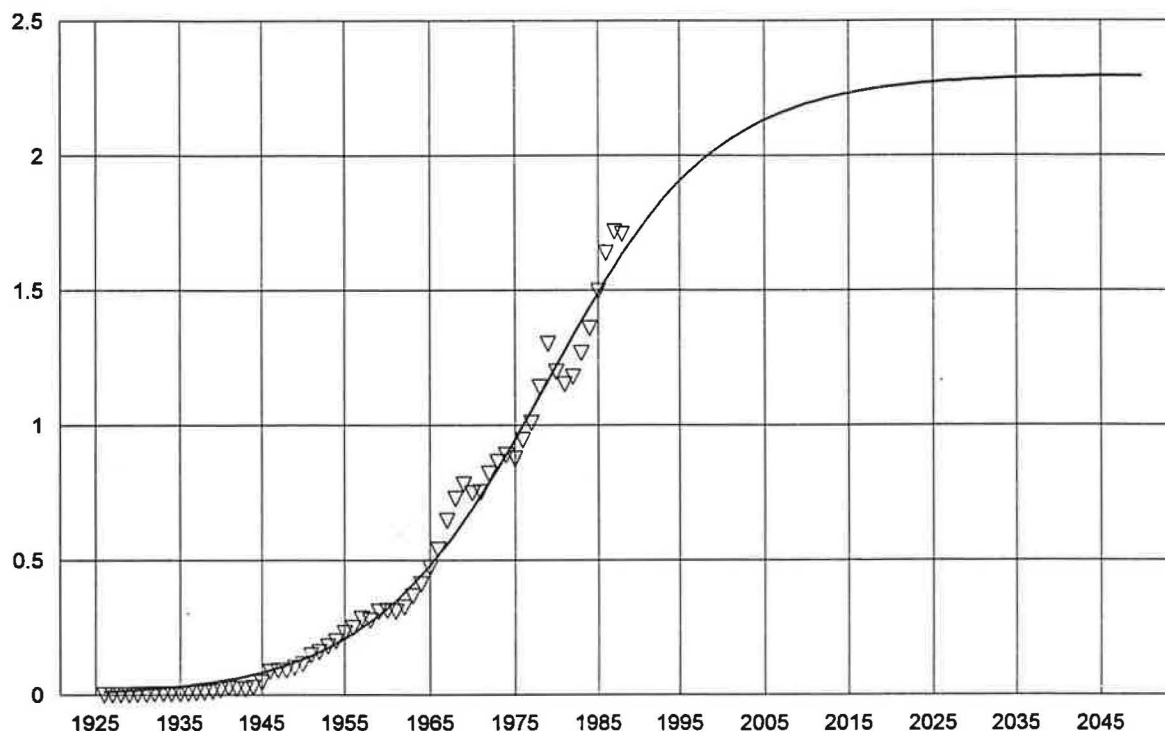


FIGURE 25 Enplanements per capita, 1925-2050, as a single S-curve.

Yet the same data suggest a very different future if we assume that they are not the realization of a single air transportation deployment process but rather a series of three successive processes corresponding to structural changes in the aviation sector. (Figure 26) The left S-curve in Figure 26 reaches saturation at about 0.4 enplanements per capita in the late 1950s, roughly corresponding to the end of the DC-3 era. The middle S-curve is realized over a much shorter period — the twenty years from the mid-1950s to the mid-1970s, roughly corresponding to the Boeing 707 era. The S-curve on the right suggests the beginning of a powerful and very broad scale deployment, perhaps motivated by the restructuring induced by deregulation in the late 1980s or the deployment of wide-body aircraft, leading to enplanements per capita on the order of 3 by the end of the century, with much rapid growth to follow. Yet the exact parameters of the right-hand S-curve are much more uncertain because much less of the process has occurred.

The point is not that Figures 25 and 26 are right or wrong. The point is that the nature of this market and the nature of the saturation and market penetration processes are highly unpredictable, and highly sensitive to events that are difficult to anticipate in any planning sense. A similar analysis for airborne hours per capita

-- another consumer oriented measure --demonstrates the same phenomenon.¹

What sources of structural change are at large that might affect future demand for aviation? We have already mentioned the recent Israeli Peace Accord and its potential effect on international demand. On a very different front, a recent business feature in *The New York Times* examined the changing nature of the work force at General Electric. Many of the upper level managers have been eliminated, and the ten or fifteen percent of the remaining upper level managers are working in cinder block cages out on the shop floor.² The nature of upper level management has changed significantly, and may be undergoing a structural shift. That has been a very rich market for the aviation sector for many years. What are the implications? We cannot really know at this point.

Telecommunications and its effect on transportation may also induce structural shifts. To what extent will it substitute for transportation; to what extent will it reinforce demand for transportation? After all, the first telephone call induced a trip, "Watson, please come here." Yet we do not know the extent to which telecommunications will reinforce or substitute for transportation in the future. Furthermore, major structural shifts are occurring elsewhere in the economy

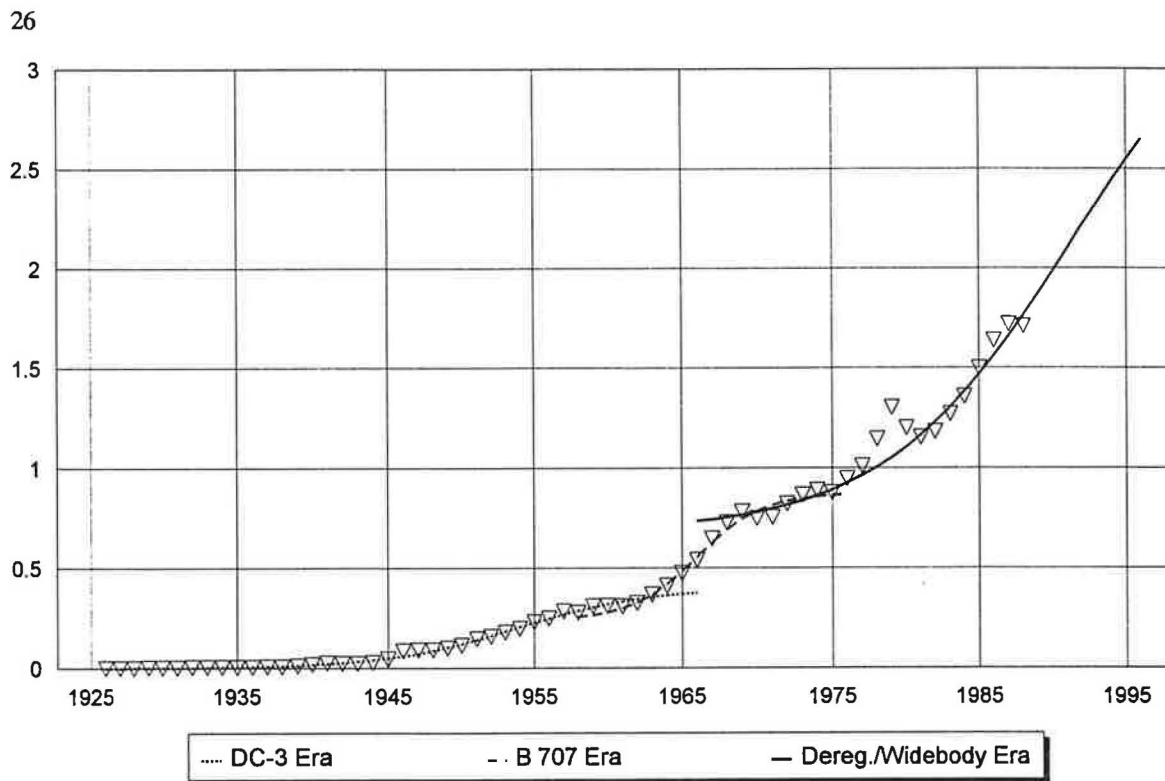


FIGURE 26 Enplanements per capita, 1925-1995, as three S-curves.

and in the work force that could have a significant effect on demand.

So that is the second point. The market is not very predictable. It behaves in unpredictable ways, and the assumption of predictability is ill-founded.

The third point is that points one and two, above, really matter. Assuming predictability is not a close approximation to what actually happens out in the real world. Accepting the myth of predictability leads us to build aviation infrastructure that is not necessarily well suited to the emerging form of markets. Buying into the myth of predictability has consequences. It is not just a little bit of random error.

We should not spend scarce resources today to build infrastructure that is supposed to come into service 20 years from now when we have near-term demand that is going begging for the lack of resources to serve it. What happens when you build infrastructure on the basis of this myth of predictability? First, technological obsolescence can set in. I think there is probably general agreement that, while we would rather have it than not have it at all, the current generation of the air traffic control system has lasted far too long. We should not be building an air traffic control system that lasts 30 years in this environment. We should have an air traffic control system that can evolve and take advantage of the

technological opportunities that are constantly being presented. A statically designed system, while it may be easier to procure and manage, is not necessarily the right kind of system for the technological marketplace and the technological capacity of the economy and the society.

Another effect, in addition to technological obsolescence, is underutilized facilities. Robert Crandall of American Airlines mounted an ambitious growth strategy of building new hubs in the 1980s. Two of those hubs, Nashville and Raleigh, are now closed. In one sense, this is just another failed business strategy -- history is littered with them. What is so different about American Airlines? In another sense, however, Crandall, along with officials in Nashville and Raleigh, assumed that the post-deregulation restructuring of the aviation industry had largely occurred and that the aviation market was settling down into a smooth trajectory that allowed them to forecast demand and build facilities accordingly. In fact, events have proved them wrong.

But more important than technological obsolescence and underutilized facilities is a third effect of accepting the myth of predictability: deploying infrastructure on the basis of the assumption of predictability distorts market development. Deploying one infrastructure

facility precludes the use of the same resources for deploying another facility elsewhere (or using the funds for an entirely unrelated purpose). And because households and firms try to take advantage of facilities that are built, the planned capacity for, say, 20 years is used up in only a few. Hence, the assumption of predictability ends up powerfully influencing the direction of economic development.

The result is that, rather than households and firms deciding how best to utilize social and economic resources, government officials (engineers like myself) powerfully influence the direction of social and economic development. Government officials and government conclusions about social and economic trends, based on this myth of predictability, actually take precedence over freely agreed upon, voluntary transactions in the economy.

So that is my third point, that making this assumption has serious consequences, and some of which may not be salutary.

My final point is that there is a better approach. The infrastructure planning profession will not go out of business if it acknowledges that long-term predictability is a myth. To be sure, forecasts are extremely useful in understanding what is happening now, or what has happened in the last few years in the economy. But the profession must turn its energies to the planning and design of flexible, adaptable facilities and systems.

Flexibility and adaptability are sort of like apple pie. The key question is how to operationalize flexibility and adaptability in an organizational and political setting involving the construction of facilities that have long term impacts? What does it actually mean? What is flexible infrastructure planning?

First, flexible planning emphasizes consumers, that is, households and firms. (See Table 1.) It does not emphasize things that make life comfortable for suppliers. That is a very important point. The assumption that consumers accept high aviation worker wages, for example, is currently being challenged by the "no frills" carriers. Planning that makes life comfortable for suppliers is probably not flexible planning because it is easy for professionals to tell themselves that, well, the world just has to be a particular way, and that this is what consumers really want. Ask consumers, ask households, and ask firms what they want. Offer them something that they can pay for or walk away from. Give them choices.

Second, flexible planning focuses on projects with a very rapid payoff. Avoid projects that will not pay off until the 25th or 30th year. It is simply impossible to predict out that far, and hence it is not a good use of resources. Instead, focus on the near term, and focus on

TABLE 1 FLEXIBLE INFRASTRUCTURE PLANNING

Emphasize consumers (households, firms), not suppliers.
Focus on projects with rapid payoffs
Preserve options for future development
Defer irreversible actions as long as possible

projects that can pay off quickly, thereby liberating resources to build better-attuned, better targeted facilities 10 or 15 years from now when these are worn out.

Third, flexible planning attempts to preserve options for future development. Take actions now that leave options open.

Fourth, flexible planning defers irreversible actions as long as possible. Once you have poured concrete, it is impossible to recover its value if you later decide it was a bad idea. If you defer pouring concrete for a year, you can always reverse that decision. You have lost a year's worth of benefits, but you may have gained a lot better information about where the economy is going and what is actually available.

And finally, flexible planning relies on good intelligence and market research. Focus on understanding what is happening in the current environment, and what has just happened, so that you can make intelligent short-term forecasts about where to invest resources.

Is flexible planning not excessively short-term, focusing on the near term and devoid of any long-term view? No. Flexible planning focuses on the most important long-term question: what kind of infrastructure will provide future generations as many options as possible from which they can choose those that will work in future conditions of production, consumption and distribution of goods and services. We cannot know today what will be useful for the production, consumption and distribution of services in 2020 or in 2025. A look back at the production, consumption and distribution processes of 30 years ago reveals miraculous differences that no one could have predicted. Thus, infrastructure planners should focus not on figuring out what kind of infrastructure future generations will need. Rather, we should focus on how to enrich and empower future generations by giving them as many resources and as many options as possible.

In summary, this paper has laid out four major points. First, the assumption of predictability is pervasive in infrastructure planning and design. Second, it is not an accurate or a supportable assumption given the nature of the economy and the society in which we live. Third, assuming predictability can lead to facility obsolescence, poor utilization, and excessive government influence on the direction of economic development. And finally, a flexible approach that is consumer-focused, oriented toward quick payoffs, avoids irreversible actions where possible, and utilizes good market research is a much more appropriate way to plan aviation infrastructure.

References

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TELECOMMUNICATIONS AND BUSINESS TRAVEL: THE REVOLUTION HAS BEGUN

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President, The Arvai Group

It is a great pleasure to speak to a group concerned with the future of transportation about a topic which we believe too little attention has been paid -- future advances in telecommunications substituting for business travel.

In the novel, *Jurassic Park*, a character named Dr. Ian Malcom, espousing "chaos theory", clairvoyantly states that "nature always finds a way" to make a stable situation unstable. Today, I would like to modify that notion and apply it to the business community -- "new technology and entrepreneurs will always find a way."

Many of you in the audience might say "Here we go again, another forecast of videoconferencing reducing air travel demand. We went through this in the 1980s, and it didn't happen. What is so different today?" Our research indicates that those pipe dreams of the 1980s are becoming possible as we approach 2000.

We believe that the business world will soon undergo a *revolutionary* change, as important as the introduction of the personal computer. These changes in the way we communicate, driven by technology, will affect how we work, how we communicate with others, and how often we will need to travel on business.

The results of our recent research into the impact of advanced telecommunications technology on business travel indicate that a significant substitution effect will take place as desktop videoconferencing becomes affordable and commonplace. (Figure 27)

- ◆ Telecommunications Will Compete with Air Travel through Desktop Videoconferencing
- ◆ It will Enhance Productivity and Substitute for Some Business Meetings
- ◆ Several Forces Will Drive a Fundamental Shift in the Market Dynamics of the Air Travel Industry

FIGURE 27 The revolution has begun.

What is desktop videoconferencing? Our vision of desktop videoconferencing is full motion video communications between individuals utilizing their personal computers as videoconferencing units from their desktops.

Imagine your office in 2005. Your PC will likely have a large, multi-window, flat-panel display, which could be mounted on your wall. It will be connected to the phone network, and through standard interfaces with your combination scanner, fax and printer, you can send and receive documents from almost any user anywhere through standard protocols developed in the late 1990s. You will also have a micro-camera to transmit video and audio of your conversations and the capability to connect into multiple videoconferences from your desktop.

You still even have full-motion video voice-mail systems; and when these connections are made, you will be able to judge the reactions, body language, and expressions of the other party, something that is impossible with plain old telephone service today. AT&T's commercial showing a mother tucking in her baby by remote videoconferencing indicates that we are not far away.

Desktop videoconferencing can be effective for many situations and could substitute for direct contact. Sales people with established relationships will use desktop videoconferencing to substitute for some (not all) in-person sales calls. Rather than call on the company once every two months, a salesperson could videoconference monthly and visit quarterly or semi-annually, providing double the contact at a lower price.